Appendix C: Supplemental Technical Information – Emissions and Modeling

As discussed in PLAN Chapter 5 (Air Quality Overview), the Air District worked closely with the CSC to conduct an extensive technical assessment of air pollution sources and impacts in the PTCA area. This appendix builds on Chapter 5 by providing supplemental technical information related to emission inventory development, air quality modeling, and exposure assessment. This supplemental information covers four main topics:

1. **Technical Approach** – provides an overview of the methods and datasets used to develop the emissions inventory and conduct the modeling-based exposure assessment.
2. **Additional Modeling Results** – presents an evaluation of background and local contributions to pollutant concentrations in the PTCA community and an analysis of the potential for acute respiratory impacts from flaring events at the Chevron Refinery.
3. **Chevron Inventory Update** – summarizes a 2021emissions inventory for Chevron Refinery that was assembled following the development of the initial 2019 baseline inventory that is presented in Chapter 5 of the PLAN.
4. **Emissions Forecasts** – summarizes "business as usual" emissions inventories for 5- and 10-year milestones (2029 and 2034) after PLAN approval.

The following sections cover each of these topic areas in detail, with the section on Chevron inventory updates being of special interest for tracking emissions changes in the community going forward.

Technical Approach

Technical analyses for the PTCA area were guided, in part, by the California Air Resources Board's (CARB) Community Air Protection Program Blueprint (California Air Resources Board, 2018a), which outlines a general methodology for community-scale technical assessments. Key requirements in the CARB Blueprint include a community-scale emissions inventory and a source attribution analysis to estimate the relative contribution of sources or categories of sources to elevated air pollution exposure in the community. Methods and datasets used to conduct these analyses are discussed in the sub-sections that follow.

Emissions Inventory Development

As part of the technical assessment process, CARB prescribes the development of a planning emissions inventory for all AB 617 communities. This inventory must include criteria pollutants[1] and toxic air contaminants (TACs)[2] for all sources within the community boundary for a selected base year (California Air Resources Board, 2019). The District worked with CARB to establish a base year (2019) and planning inventory domain for the PTCA community. The inventory domain was defined as a rectangular area that aligns with a network of 1-km x 1-km grid cells from CARB's

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[1] Criteria pollutants include carbon monoxide (CO), nitrogen oxides (NOx), total organic gases (TOG), reactive organic gases (ROG), ammonia (NH_3), sulfur oxides (SOx), particulate matter 10 microns or smaller (PM_{10}), and particulate matter 2.5 microns or smaller ($PM_{2.5}$).

[2] TACs, or "air toxics," have been identified by CARB or the U.S. Environmental Protection Agency (EPA) as pollutants that may cause cancer or other serious health effects (e.g., birth defects).

statewide modeling domain (California Air Resources Board, 2020). As shown in Figure A-1, this rectangular emissions inventory boundary covers the PTCA area, as well as surrounding areas with emission sources that are likely to impact the community.

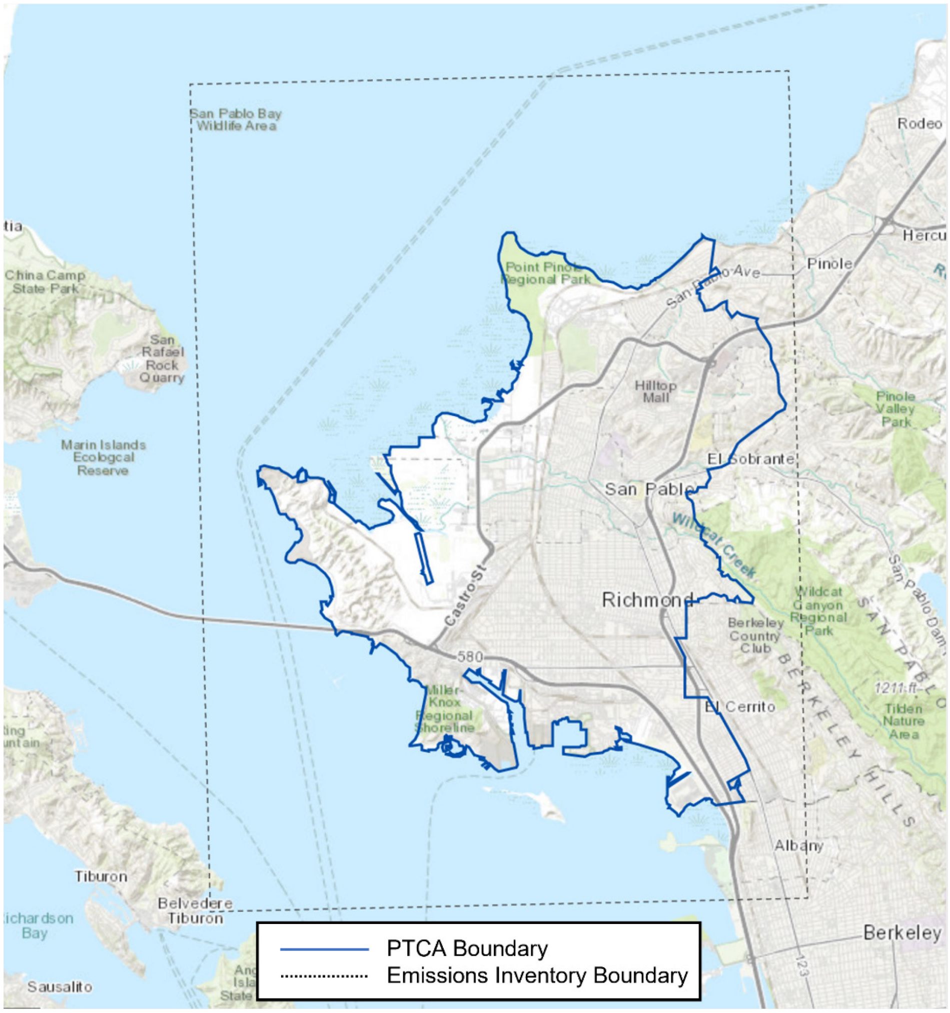

Figure A-1. Map showing the emissions inventory boundary in relation to the PTCA community boundary.

Emissions inventories are often organized into four broad source sectors: point sources, area sources, on-road mobile sources, and off-road mobile sources. Table A-1 provides a definition of these source sectors and summarizes the general methods used to estimate their emissions in the PTCA area. Note that the baseline inventory represents a combination of information from the Air District and CARB, and that detailed local data were used where available.

Table A-1. Emissions inventory methods by source sector.

Source Sector	Definition	Methodology
Point	Stationary sources that are permitted or otherwise treated as individual facilities (e.g., refineries and power plants)	Emissions based on data reported to the Air District annually by each permitted facility and reviewed by District engineers. Emissions estimated at the process/device level using a variety of methods and datasets, including source tests and emission factors.

Area	Stationary sources that are too small or dispersed to be treated individually (e.g., residential sources)	Emissions estimated by CARB or the District at the county level and down-scaled using spatial surrogates such as land use or population data. For commercial cooking, the District developed restaurant-specific estimates that were based on generalized assumptions about the type and quantities of meat cooked at various types of restaurants.
On-road	Mobile sources that operate on roadways (e.g., cars and trucks)	Roadway emissions based on detailed traffic data from Bentley's Streetlytics dataset and emission factors from CARB's EMFAC model.[a] Emissions also estimated for operations at truck-based businesses using results of a truck activity survey conducted by District staff.
Off-road	Mobile sources such as ships, locomotives, and construction equipment that do not operate on roadways	Emissions for rail lines, railyards, ferries, and construction activities prepared by the District based on local data. Emissions for remaining off-road sources (e.g., ocean-going vessels) were prepared by CARB using a variety of approaches.

[a]The 2019 on-road inventory was originally developed using data from EMFAC2017v1.0.2 (California Air Resources Board, 2018b). Resulting emissions estimates were adjusted to reflect data from EMFAC2021 (California Air Resources Board, 2021a) when that version of the model was released.

Note that for permitted sources, emissions data in the PTCA inventory were generally consistent with the reporting year 2019 datasets submitted to CARB under the Criteria Pollutant and Toxics Emissions Reporting (CTR) program, with updates to emissions at four facilities to reflect data recently compiled by the District for rulemaking efforts. For example, $PM_{2.5}$ emissions from the Chevron Refinery were updated to align with analyses recently conducted in support of amendments to Rule 6-5, which regulates particulate emissions from petroleum refinery fluidized catalytic cracking units. The $PM_{2.5}$ inventory assembled for Chevron as part of the Rule 6-5 analyses includes adjustments to reflect the impacts of a recent modernization project (Bay Area Air Quality Management District, 2021). In addition, air toxics emissions from Chevron, Chemtrade, and the West Contra Costa County Sanitary Landfill were updated using preliminary inventories developed to support upcoming Health Risk Assessments (HRAs) for those facilities.

More generally, CARB has established a methodology for developing community-scale TAC emissions inventories and for comparing the relative toxicity of different compounds through the calculation of toxicity weighted emissions (TWE). In this methodology, point source emissions are based on toxics inventories reported to air districts by individual permitted facilities. For area, on-road mobile, and off-road mobile sources, TAC emissions are calculated by applying chemical speciation profiles to PM and TOG emissions. These speciation profiles, which are maintained by CARB, break down PM and TOG emissions for a given source category into individual chemical species. Then all the species that are listed in Appendix A-I of AB 2588 Air Toxics "Hot Spots" Emission Inventory Criteria and Guidelines Regulation are filtered out as toxics (California Air Resources Board, 2021b). TWE are then calculated by multiplying the mass emissions for each TAC by corresponding health values from the Office of Environmental Health Hazard Assessment (OEHHA). These health values include cancer potency factors and non-cancer chronic and acute reference exposure levels (RELs), and the TWE calculations also include molecular weight adjustment factors to account for the molecular weight fraction of a compound associated with the specific health effects (California Air Resources Board, 2021b). As noted above, the resulting TWE provide a useful means of comparing the relative toxicity of TACs in an inventory; however, TWE do not quantify specific health risks, which are based on exposures to concentrations of specific TACs rather than emission levels only.

Once the planning inventory was complete, emissions estimates for $PM_{2.5}$ and TACs were configured for use in dispersion modeling efforts. Modeling inventories were developed for all sources for which sufficient information (e.g., emissions rate, physical characteristics, spatiotemporal resolution) was available at the time of analysis.

Air Quality Modeling

Once emitted to the atmosphere, pollutants are subject to processes such as dispersion, chemical transformation, and wet and dry deposition. Air quality models use emissions inventories, meteorological data, and other inputs to simulate these processes and provide estimates of pollutant concentrations in specified locations of interest. To quantify concentrations of PM2.5 and other pollutants in the PTCA community, the Air District used three different air quality models, as described below.

First, the **Community Multiscale Air Quality (CMAQ)** model was used to provide an estimate of "background" concentrations in the PTCA community (i.e., concentrations that would exist in the absence of any local sources due to pollutant transport). CMAQ, a complex photochemical grid model, was used to evaluate the impact of these transported emissions. CMAQ requires a variety of input data, including meteorological information such as temperature, wind speeds, and precipitation rates. Air District staff prepared gridded meteorological inputs for CMAQ using the Weather Research and Forecasting (WRF) model, version 4.1. An existing CMAQ platform for 2016 (Tanrikulu et al., 2019) was then updated and used to conduct a baseline simulation for the entire Bay Area for 2018. In addition to the 2018 baseline simulation, a second 2018 CMAQ simulation was performed that excluded local emissions sources within the PTCA community. Differences between these two CMAQ runs were used to estimate background concentrations in the PTCA community, as shown in Table A-2. Further discussion of the relationship between background concentrations and local source impacts is provided in the "Additional Modeling Results" section of this appendix.

Table A-2. Background pollutant concentrations and cancer risk for the PTCA area.

Parameter	Value	Units
$PM_{2.5}$ concentration	6.03	Micrograms per cubic meter (µg/m^3)
DPM concentration	0.15	Micrograms per cubic meter (µg/m^3)
Cancer risk	149	Additional cancer cases per million people

In addition, the **California Puff (CALPUFF)** model was used to estimate $PM_{2.5}$ concentrations resulting from emissions sources at the Chevron Refinery in Richmond. This CALPUFF modeling was initially done to assess the air quality and health impacts of $PM_{2.5}$ emissions from Chevron in support of amendments to Rule 6-5, which limits emissions from refinery fluidized catalytic cracking units. CALPUFF was run for the entire Bay Area at 1-km grid resolution and for a smaller study area at 100-m grid resolution.[3] The use of the 100-m sub-domain allowed for a more detailed analysis of refinery impacts than was available using CMAQ, which is typically run at 1-km or coarser grid resolutions. In addition, CALPUFF is able to use gridded meteorological information from WRF over the entire area where the emissions plume is expected to travel, which provides an advantage over dispersion models that use meteorological information at source locations only (Bay Area Air Quality Management District, 2021a). Because the detailed CALPUFF modeling of Chevron $PM_{2.5}$ emissions was already available, those results were used to quantify $PM_{2.5}$ concentrations resulting from that facility's operations. Modeled impacts for receptors in the PTCA community were extracted from the overall CALPUFF outputs and used for source attribution and exposure analyses.

Lastly, the **American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD)** was used to estimate pollutant concentrations for other local sources in the community. AERMOD is U.S. EPA's preferred model for near-field dispersion modeling and is required for all health risk assessment (HRA) modeling performed by or for the Air District (Bay Area Air Quality Management District, 2020b). In addition, AERMOD is the only model currently approved by U.S. EPA for mobile source applications such as PM hot-spot analyses (U.S. Environmental Protection Agency, 2021). Because of its ability to handle multiple source types, AERMOD was used to model dispersion from all local sources assessed in the PTCA emissions domain, except for the use of existing CALPUFF results to quantify impacts of PM2.5 emissions from the Chevron Refinery, as described above.[4]

In general, AERMOD applied using approaches consistent with those previously developed during the technical assessment for the West Oakland AB 617 community (Bay Area Air Quality Management District, 2019). One key difference from the West Oakland approach involves the meteorological data used for dispersion modeling. AERMOD is run using meteorological data that is representative of a single location, unlike the gridded meteorological fields that are used by CMAQ and CALPUFF. However, unlike West Oakland, the PTCA area is a challenging locale to model using only one meteorological set due the line of hills that run from Point San Pablo in the north southeast to Point Richmond, flat lands in the central area east of the domain, hills to the east of the flats, and a complex shoreline that surrounds the area on three sides. Because no single set of meteorological observations would be representative of this complex topography, the Air District relied on modeled meteorological data from WRF to run AERMOD, consistent with the modeled datasets used to run CMAQ and CALPUFF. An EPA utility program called the Mesoscale Model Interface Program (MMIF) was used to create AERMOD-ready meteorological for four representative sub-domains across the PTCA area. All sources within a given sub-domain were then modeled with AERMOD using the appropriate meteorological dataset.

AERMOD also requires a receptor file defining locations for which the model will estimate pollutant concentrations. A master receptor grid was generated with receptors spaced every 50 m in the x and y directions within the receptor domain, resulting in 76,072 discrete receptor locations. A spacing of 50 m was selected to sufficiently resolve spatial concentration gradients around emissions sources while keeping model runtimes reasonable (the more receptors that are defined, the longer it takes AERMOD to complete an annual simulation).

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[3] The 100-m domain covered areas from the 1-km CALPUFF run with simulated $PM_{2.5}$ concentrations above 0.1 $\mu g/m^3$.

[4] Air toxics emissions from Chevron were evaluated in keeping with the HRA approach being implemented for Rule 11-18, which relies on AERMOD to characterize pollutant dispersion.

Exposure Assessment

To estimate air pollution exposures for community residents, annual average pollutant concentrations from the local-scale modeling were combined with Census population data. The latest decennial U.S. Census, conducted in 2020, provides residential population counts at the Census block level. This modeled population reflects a residential ("nighttime") population, similar to that used in most large-scale epidemiological studies of outdoor air pollution. Total population exposure has units of persons multiplied by concentration (e.g., person-µg/m^3). We computed average exposures by first computing total exposures at Census-block resolution. We then computed an average exposure for all residents in the PTCA area by summing population exposure across all Census blocks and dividing by the sum of population. Consistent with epidemiological studies, we use "average exposures" interchangeably with "population-weighted concentrations," or, equivalently, exposures "per capita." These all have the same units as modeled concentrations. For $PM_{2.5}$, for example, the units are micrograms per cubic meter (µg/m^3).

To support PLAN strategy development, the contribution of individual sources and groups of sources to average residential exposure values were estimated based on air quality modeling results. This process is generally termed "source attribution" or "source apportionment," and in this analysis, the results were already attributed to sources by virtue of having run each source individually in AERMOD. Because modeling was performed for each emissions source separately, the contributions from each source to modeled parameters (e.g., $PM_{2.5}$ concentrations or cancer risk) at each receptor location could be tracked and compared to contributions from other sources. Then, the total for a given parameter at a receptor could be calculated as the sum of contributions from individual sources. This process supported the analysis of how different source groups contribute to pollutant concentrations, exposures, and cancer risk in various parts of the community.

Additional Modeling Results

This section supplements the modeling results presented in Chapter 5 by presenting: (1) a modeled evaluation of total pollutant concentrations in the PTCA community that includes both background concentrations and local source impacts; and (2) a modeling analysis of the potential for acute respiratory impacts from flaring events at the Chevron Refinery.

Background Concentrations

Pollutant concentrations in the PTCA community are the result of both local emission sources and regional pollution that is transported from outside the study area. In other words, local sources contribute an incremental concentration that is added to the existing "background" concentration for a given pollutant, resulting in a total concentration to which residents are exposed. This total pollutant exposure can vary from year to year based on differences in emissions levels, meteorology, and other factors. For example, ambient monitoring data from 2013-2022 shows that annual average $PM_{2.5}$ concentrations at the San Pablo station have varied from 7.8 µg/m^3 (2019) to 12.7 µg/m^3 (2018) and averaged 10.1 µg/m^3 across that decade. And though the PLAN is focused on reducing the local portion of that total exposure, it is useful to understand the relative contributions of local vs. regional sources to those total exposures. Therefore, the Air District performed regional- and local-scale modeling to estimate those contributions.

Figure A-2 shows annual average residential concentrations of $PM_{2.5}$ and Diesel Particulate Matter (DPM),[5] and average residential cancer risk[6] for the PTCA community, all based on combined regional and local modeling results. For $PM_{2.5}$, the modeled regional component is 6.0 µg/m^3 and the modeled local component is 1.1 µg/m^3, or 15% of the total (7.1 µg/m^3). The large regional component is partly due to secondary $PM_{2.5}$ that forms from interactions of precursor species such as NOx, SOx, and ammonia. Because these interactions take time to complete, secondary $PM_{2.5}$ formation generally happens well downwind of emissions sources. It should also be noted that the local $PM_{2.5}$ component is underestimated due to sources omitted from the local-scale modeling.[7] Some sources, such as residential fuel combustion and lawnmower use, were too small and dispersed to be included in the dispersion modeling, and these sources account for 19% of total $PM_{2.5}$ emissions in the PTCA planning inventory.

For most TACs, secondary formation is not an important issue, so the local component is generally higher than was the case for PM2.5. For DPM, local sources account for 40% of the annual average residential concentration of 0.25 µg/m3. Similarly, local sources account for 36% of the average cancer risk value of 232 in a million. These findings illustrate how local source impacts, which vary by pollutant, represent incremental increases on top of existing background concentrations and lead to disparities in air pollution exposure.

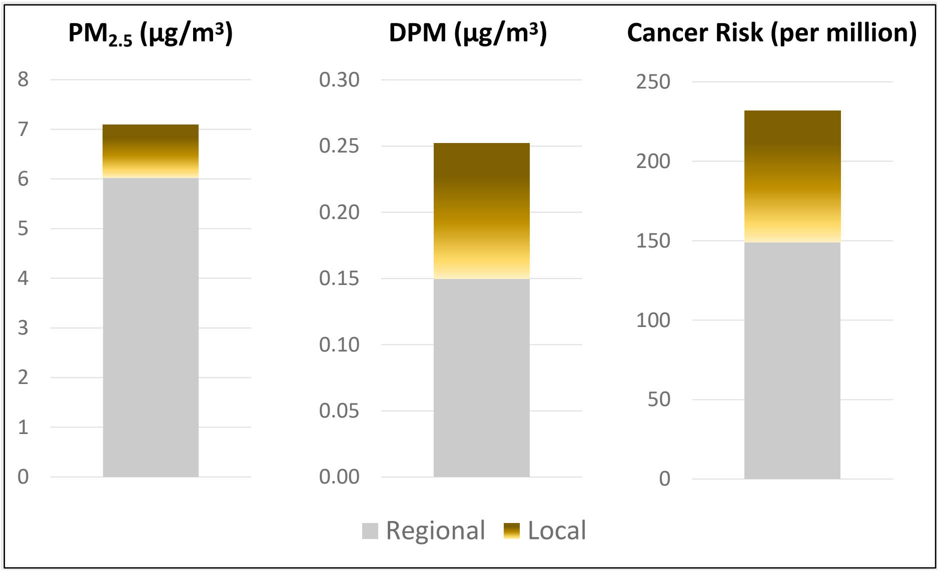

Figure A-2. Regional vs. local contributions to $PM_{2.5}$ and DPM concentrations and cancer risk.

Potential Impacts From Chevron Flaring Events

Responding to community concerns about the impact of Chevron flaring events on respiratory health in the PTCA community, Air District staff undertook a model-based evaluation of these

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[5] These are the modeled pollutant concentrations to which the average PTCA area resident would be exposed.

[6] Regional modeling results for chronic HI are not available, as the regional model can only be configured to simulate a limited number of TACs, and the District has historically focused on compounds that are key drivers of cancer risk.

[7] Ambient monitoring data appear to confirm this underestimate; as previously noted, the San Pablo station reported an annual average $PM_{2.5}$ concentration of 7.8 µg/m^3 in 2019, which is 0.7 µg/m^3 higher than the modeled total of 7.1 µg/m^3 (regional plus local).

events. The evaluation focused on releases of sulfur dioxide (SO_2) due to: (a) the ready availability of daily SO_2 emissions data; and (b) the potential for acute SO_2 exposures to result in respiratory impacts. For example, in its rulemaking for the current national 1-hour SO_2 standard of 75 parts per billion (ppb), the U.S. Environmental Protection Agency noted that exposure to SO_2 at levels as low as 200 ppb for 5-10 minutes has been experimentally shown to cause moderately or severely decreased lung function in some exercising asthmatics.[8]

To support this analysis, reported daily SO_2 emissions totals for each flare at the Chevron Refinery were obtained for dates during 2020-2022 when any flare was reported as emitting 1,000 pounds of SO_2 or more (see Table A-3). To develop hourly emission rates, these daily totals were divided by the durations provided in the causal reports that described those specific flaring events. An SO_2 emission rate of 100 grams per second (g/s) was selected as a benchmark for modeling, a rate that is likely to occur at least several times per year, assuming the 2020-2022 data are predictive. To provide information on potential impacts of smaller or larger flaring events, emission rates of 30 g/s and 300 g/s were also modeled (note that the 2020-2022 data show multiple instances with estimated SO2 emission rates of 300 g/s or higher).

Table A-3. Reported daily total SO_2 emissions for flares at the Chevron refinery during selected events. Source: https://www.baaqmd.gov/about-air-quality/research-and-data/flare-data.

Date	**Flare**	**SO_2 (lb)**	**Duration (h)**	**Rate (g/s)**
2022-12-28	S6013: North Isomax Flare V-281	2,415	1.5	205
2022-08-18	S6010: High Level Flare, LSFO	1,520	10.6	18
2022-08-02	S6016: FCC Flare V-731	1,722	6.8	32
2022-03-04	S6013: North Isomax Flare V-281	2,148	2.0	135
2022-02-25	S6013: North Isomax Flare V-281	9,552	3.9	313
2021-12-30	S6013: North Isomax Flare V-281	23,178	9.4	309
2021-12-13	S6019: Alky-Poly Flare V-732	2,230	5.9	48
2021-12-13	S6016: FCC Flare V-731	1,566	5.8	34
2021-11-05	S6013: North Isomax Flare V-281	2,254	16.8	17
2021-11-04	S6013: North Isomax Flare V-281	2,048	—	—
2021-11-03	S6013: North Isomax Flare V-281	1,468	—	—
2021-11-02	S6013: North Isomax Flare V-281	4,580	—	—
2021-10-30	S6013: North Isomax Flare V-281	2,682	10.2	33
2021-10-28	S6013: North Isomax Flare V-281	1,868	—	—
2021-10-27	S6013: North Isomax Flare V-281	3,915	1.4	344
2021-10-25	S6016: FCC Flare V-731	4,734	—	—
2021-10-25	S6013: North Isomax Flare V-281	1,434	—	—
2021-10-24	S6039: Lube Flare V-3501	1,264	11.1	14
2021-10-24	S6013: North Isomax Flare V-281	10,379	13.0	101
2021-10-24	S6010: High Level Flare, LSFO	2,123	7.1	37
2021-08-14	S6039: Lube Flare V-3501	8,909	2.5	458
2021-05-14	S6039: Lube Flare V-3501	6,988	0.7	1,355

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[8] Federal Register, Vol. 75, No. 119 / Tuesday, June 22, 2010.

2021-05-02	S6013: North Isomax Flare V-281	7,217	4.0	226
2021-01-21	S6010: High Level Flare, LSFO	2,472	1.7	185
2021-01-16	S6013: North Isomax Flare V-281	3,626	—	—
2020-02-22	S6010: High Level Flare, LSFO	14,531	3.8	484
2020-02-16	S6013: North Isomax Flare V-281	1,286	0.3	463

The benchmark SO_2 emission rates of 30, 100 and 300 g/s were used as input for an AERMOD dispersion modeling simulation that was configured to predict the maximum 1-hour modeled impact for each potential downwind location in the community. Under these worst-case conditions, whenever the SO_2 emission rate for a simulated flare equaled or exceeded 100 g/s, the possibility of 1-hour average SO2 concentrations exceeded 75 ppb was noted in all modeled residential areas. This means that a 100 g/s SO2 emission rate could result in such an impact at any residential location in the community, given the right conditions (e.g., wind direction and speed). Even with rates as low as 30 g/s, the modeling still indicated potential for such impacts in neighborhoods close to the refinery.

Additional simulations were run to assess the likelihood of impacts to a substantial number of residents under less-than-worst-case conditions. Census data (2020) were used to represent the locations of residents, and meteorological conditions were drawn from the Air District's most recent annual application (2018) of the Weather Research and Forecasting (WRF) model. For a 100 g/s SO_2 release matched to a randomly selected set of hourly conditions, the modeling indicated at least a 5% chance of exposing at least 1,000 residents to a 1-hour average SO_2 level of 75 ppb or more (Table A-4). For a larger event (300 g/s), the probability increased to 15% or more, depending on which flare was the source. This indicates a meaningful chance of such an impact occurring during a typical year, given historical patterns of flaring activity and meteorology.

Table A-4. Modeled likelihoods at least 1,000 PTCA residents being exposed to a 1-hour SO_2 concentration of 75 ppb or more under various emissions scenarios.

Results for Various Simulated 1-Hour SO2 Emission Rates (g/s)

Modeled Source	**30 g/s**	**100 g/s**	**300 g/s**
Alky-Poly Flare	0.01%	4.9%	15%
FCC Flare	0.00%	4.6%	15%
Hydrogen Plant Flare	0.31%	6.9%	18%
LSFO High Level Flare	0.06%	7.7%	21%
Lube Flare	0.00%	4.7%	15%
North Isomax Flare	0.00%	5.2%	16%
South Isomax Flare	0.00%	5.1%	15%

It should be noted that several aspects of the modeling approach could lead to underestimates of the potential for acute respiratory impacts from flaring. First, although the modeled SO_2 emission rates were informed by historical data, they were likely under-estimates of actual peak 1-hour SO_2 emission rates: a closer look at a sample of continuous emissions monitoring data showed that for some of the events that staff examined (Table A-3), most of the SO_2 was released over two consecutive hours or less, while the reported event durations were considerably longer. Second, conversion of total reduced sulfur compounds other than hydrogen sulfide (H_2S) may not have been fully factored into reported SO_2 totals. Third, simulations were run one flare at a time, while in reality, flaring events can involve multiple flares simultaneously. Fourth, flaring is known to result in emissions of pollutants other than SO_2—including fine particulate matter ($PM_{2.5}$) and some toxic air contaminants (TACs)—that can also contribute to respiratory impacts.[9] At the same time, there are uncertainties attributable to the model used (AERMOD), and to the meteorological data (from WRF), which could lead to over-prediction of ground-level SO_2 concentrations.

Insights from modeling can sometimes be corroborated by air monitoring if some of the modeled potential scenarios actually occurred. As noted above, model predictions carry a degree of uncertainty, which is generally larger for more specific predictions (like what would happen under a single set of circumstances, rather than across a range of possibilities), so it is unreasonable to expect perfect agreement. Holding this aside, if air monitoring data do not show the same distribution of SO_2 levels that the modeling predicted (in this case, 1-hour averages over 75 ppb), it still does not mean that such impacts could not occur in the future under the right combination of conditions. Predicted impacts could also have occurred in the past, but at a location that did not have an SO_2 monitor.

With these limitations in mind, staff conducted a preliminary review of available SO_2 data from Air District monitoring sites and Chevron Ground Level Monitors (GLMs) in the PTCA region from 2017–2021. Numerous occurrences of hourly SO_2 concentrations above typical hourly levels were observed, including some occurrences of hourly concentrations approaching 75 ppb (Figure A-3). While none appeared to be traceable to a reported flaring event,[10] the possibility still remains of flaring-related impacts at non-monitored locations, as well as the potential for future impacts at any location in the PTCA region. There are additional types of monitoring systems in place in the PTCA region, including refinery fenceline monitoring, that may add to our understanding of SO_2 emissions that cross the fenceline from flaring and non-flaring sources. Analyses of fenceline monitoring data in context with other monitoring information and modeling results can be included in future air quality assessments.

Based on the modeling results and related uncertainties, staff concluded that recent patterns of flaring have the potential to cause adverse respiratory impacts to sensitive groups in the Path to Clean Air (PTCA) community.

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[9] Suboptimal flaring conditions, which this analysis did not model, can increase emissions of these co-pollutants.

[10] These observations could indicate the potential for SO_2 impacts from industrial sources other than flaring.

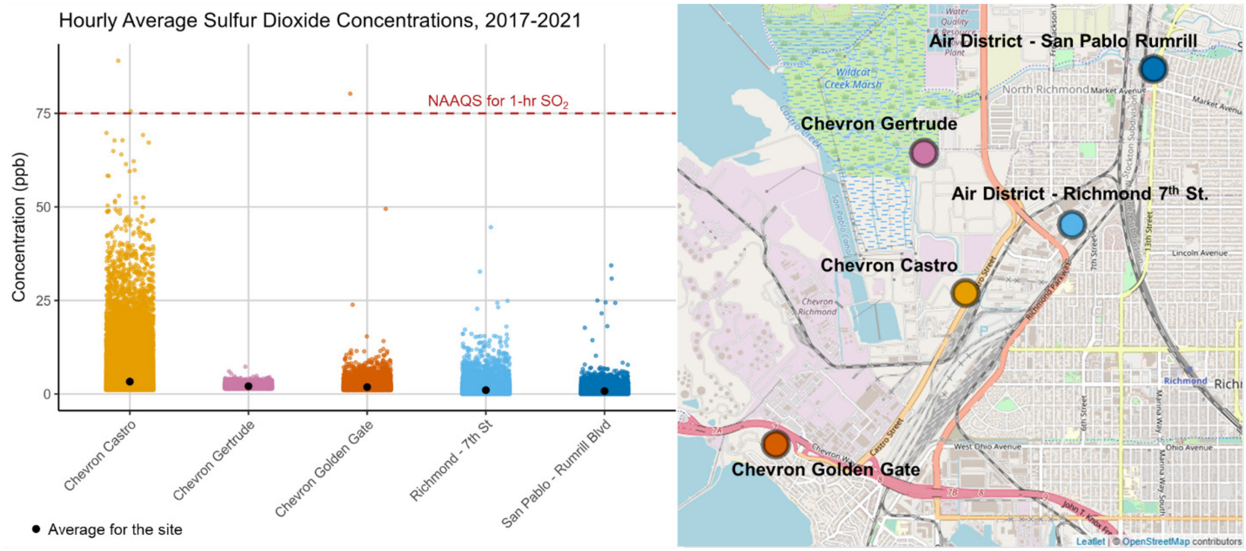

Figure A-3. Hourly average SO_2 concentrations at Chevron Ground Level Monitors (GLMs) and selected Air District monitoring sites for the period 2017–2021 (left), and map of monitoring site locations (right).

Chevron Inventory Updates

As documented in Chapter 5 of the PLAN, the Air District developed a 2019 baseline inventory that included emissions estimates for the Chevron Refinery and other permitted sources in the PTCA area. However, compiling an emissions inventory for a complex facility like Chevron is an iterative process, through which data are continually collected, quality assured, and integrated by source and pollutant type to improve the reliability and completeness of emissions estimates. Annual variations in emissions data may occur due to differing assumptions, associated levels of production, the availability of improved information, and other factors.

To both illustrate this iterative process and provide the latest information on Chevron, this section summarizes a more recent 2021 emissions inventory that was compiled for the refinery near the end of the PLAN development process. This inventory not only represents a more current year, but also incorporates findings from the Air District's Heavy Liquids Study (HLS), which was conducted to improve estimation of organic emissions from fugitive leaks from refinery components (e.g., valves, connectors, etc.). The HLS established a set of average emission rates and pollutant profiles to be applied to fugitive emission components, many of which are associated with storage devices such as tanks.

A summary of the 2021 inventory and comparisons against the original 2019 baseline inventory are provided in the sub-sections that follow. These comparisons include a discussion of reasons for emission changes between 2019 and 2020, which may involve actual increases or decreases in emissions (e.g., due to changes in production or new sources coming online), improved information (e.g., results from the HLS), or both.

Toxic Air Contaminants

Table A-5 summarizes toxicity-weighted emissions from processes at the Chevron Refinery for 2021, with corresponding 2019 values shown alongside. Overall, total cancer TWE are 81% higher in the 2021 inventory than in the 2019 inventory, while total chronic TWE are 33% higher in 2021. For cancer TWE, the largest change occurs in fugitive emissions, specifically leaks from valves, flanges, connectors, pumps, and compressor seals. These changes are associated with the HLS and are attributable to an improved understanding of emissions from these devices rather than an actual emissions increase. For chronic, TWE, the largest change occurs in emissions from boilers and process heaters, with much of the change attributable to reformer furnaces at the hydrogen plant.

Table A-5. Summary of cancer and chronic TWE from Chevron Refinery by process type.

	Cancer TWE		**Chronic TWE**	
Process Type	**2021**	**2019**	**2021**	**2019**
Boilers/Process Heaters	20,576.43	18,728.09	877.35	144.98
Sulfur Plants	NA	NA	517.82	195.35
Catalytic Cracking	179.00	1,064.00	224.01	592.81
Cogeneration	5,368.80	722.86	271.66	469.47
Storage Tank	2,047.80	633.95	23.38	12.53
Fugitives	12,106.51	231.91	18.26	15.02
Vapor Recovery/Flares	117.63	1,064.79	10.46	21.92
Other	108.55	153.03	2.94	4.25
Tanker Loading	18.34	NA	1.97	<0.01
Generator	1,236.15	34.24	1.83	0.05
Barge Loading	10.14	12.30	1.09	0.42
Backup Generator (Bug)	419.19	507.60	0.62	0.75
Coating And Cleanup	0.56	0.75	0.57	0.61
Cooling Towers	231.49	214.68	0.47	0.35
Storage/Transport Container Cleaning	2.89	4.33	0.31	0.15
Tank Cars and Trucks - Working Losses	10.42	10.46	0.27	0.27
Wastewater Treatment	7.61	82.67	0.17	5.15
Incineration	2.69	NA	0.07	NA
Surface Blasting	0.03	0.05	<0.01	0.01
Gasoline Dispensing	0.13	<0.01	<0.01	<0.01
Chevron Refinery Total	42,444.36	23,465.71	1,953.26	1,464.10

In PLAN Chapter 5, Tables 5-10 and 5-11 provide summary information for 12 individual TACs that accounted for 97% of the cancer TWE and 93% of the chronic TWE at Chevron in the 2019 inventory. However, in the 2021 inventory, a few other TACs emerge as important, including polycyclic aromatic hydrocarbons (PAHs), naphthalene, and ethylene dichloride. Table A-6 provides summary information for an expanded list of 20 high-priority TACs that account for 98% of the cancer TWE and 95% of the chronic TWE at Chevron in the 2019 inventory. Note that PAHs, which were included in the 2021 inventory based on HLS findings, are now the second highest contributor to cancer TWE at Chevron, behind only hexavalent chromium. It should also be noted that sulfuric acid emissions, which contribute to chronic health risks, are more than two times higher in the 2021 inventory than in the 2019 inventory.

Table A-6. Summary of cancer and chronic TWE from Chevron Refinery by pollutant.

	Cancer TWE		**Chronic TWE**	
Pollutant	**2021**	**2019**	**2021**	**2019**
Hexavalent Chromium	17,953.88	17,782.84	1.33	1.32
PAHs	10,580.29	17.14		

Naphthalene	2,807.87	144.41	20.41	1.05
Ethylene dichloride	1,967.83	0.04	0.52	0.00
DPM	1,732.91	541.84	2.57	0.80
Benzene	1,607.98	1,397.03	41.10	35.71
Formaldehyde	1,481.52	985.50	61.01	40.58
Cadmium	1,458.46	197.23	38.61	5.22
Arsenic	1,258.54	818.78	56.54	36.78
Nickel	686.09	539.71	419.16	329.73
1,3-butadiene	182.53	652.89	1.19	4.27
Ethylbenzene	56.42	32.95	0.03	0.01
Hydrogen Cyanide (HCN)			141.02	174.40
Acrolein			43.18	1.21
Toluene			0.53	1.84
Xylene			0.34	1.12
Manganese			223.09	434.32
Hydrochloric Acid			117.73	59.80
Sulfuric Acid			677.46	246.31
Hydrogen Sulfide (H2S)			19.32	10.96

The 2021 inventory also includes changes to criteria air pollutant (CAP) emissions, as shown in Table A-7. In general, CAP emissions are higher in the 2021 inventory, with percentage changes provided in the bottom row of the table. For example, NOx emissions are 54% higher in 2021 than in 2019, due largely to higher emissions from boilers and process heaters. However, $PM_{2.5}$ emissions are 8% lower in 2021 than in 2019, due largely to lower emissions from catalytic cracking. Specifically, PM2.5 emissions from the Fluidized Catalytic Cracking Unit (FCCU) decreased by about 28%, dropping from 228.6 tons per year (tpy) to 164.5 tpy. This decrease is consistent with the percent changes in throughput of refinery coke and barrels of fresh feed processed. $PM_{2.5}$ emissions from cogeneration are also lower in the 2021 inventory, which partly reflects a redistribution of emissions between gas cogeneration turbines and associated heat recovery steam generators (HRSG), which are reported under the “Boilers/Process Heaters” process type. Total $PM_{2.5}$ emissions from the cogeneration/HRSG units decreased by about 45% between 2019 and 2021, which reflects similar changes in throughput for these sources.

Table A-7. Summary of criteria air pollutant emissions from Chevron by process type.

	2021 Inventory (tons/year)					**2019 Inventory (tons/year)**				
Process Type	**NO_x**	**TOG**	**SO_x**	**$PM_{2.5}$**	**CO**	**NO_x**	**TOG**	**SO_x**	**$PM_{2.5}$**	**CO**
Backup Generators (BUG)	5.18	0.08	0.01	0.16	1.46	1.63	0.04	<0.01	0.10	0.36
Barge Loading	2.41	23.08	0.06	0.33	0.97				0.12	
Boilers/Process Heaters	472.26	59.78	36.07	80.62	45.26	300.21	37.11	43.05	54.18	172.42
Catalytic Cracking	83.07	6.03	164.47	165.24	40.44	101.96	7.72	200.46	228.61	28.84
Coating And Cleanup		0.08		0.01			0.01			
Cogeneration	142.49	53.91	19.82	49.83	240.08	33.47	15.36	4.16	91.17	0.63
Cooling Towers		7.08		126.43			6.13		76.34	
Fugitives		33.74		<0.01		0.02	86.09			0.07
Gasoline Dispensing		0.09					0.18			
Generators	11.55	0.84	0.05	0.20	23.12	0.66	0.06	<0.01	0.01	0.11
Incineration	0.03	0.19			0.07					
Other	0.66	54.00	0.05	1.34	1.00	8.44	53.69	0.30	0.75	3.20
Storage/Transport Container Cleaning	0.69	6.59	0.02	0.09	0.28					
Storage Tanks		102.60	0.59	0.71			119.43	0.10	0.12	
Sulfur Plants	15.43	0.42	24.55	5.52	40.07	28.83	0.20	68.09	19.54	
Surface Blasting				0.00						
Tank Cars and Trucks - Working Losses		22.30					29.21			
Tanker Loading	4.37	41.80	0.11	0.59	1.75				0.68	
Vacuum Distillation							0.02			
Vapor Recovery/Flares	7.82	51.62	174.17	3.33	37.81	9.82	30.70	5.92	1.36	1.23
Wastewater Treatment		43.24					13.32			
Totals	745.96	507.48	419.98	434.40	432.32	485.04	399.28	322.08	473.01	206.86
Percentage change from 2019	54%	27%	30%	-8%	109%	--	--	--	--	--

Emissions Forecasts

Forecasted emissions inventories were developed for all sources described in PLAN Chapter 5. As a starting point, a new baseline inventory was developed that combined the updated 2021 Chevron inventory described in the previous section of this appendix with 2019 baseline emissions for all other sources. Forecasted emissions were then estimated by combining the baseline data with ancillary datasets that provide growth factors and control factors based on business-as-usual (BAU) conditions. Here, "growth" refers to anticipated changes in activity (e.g., increases in vehicle miles traveled for the on-road fleet), while "control" refers to changes in emission characteristics (e.g., lower motor vehicle emission factors due to new technology introduced into the fleet). The BAU scenarios only consider controls resulting from existing ("on the books") regulations and can be viewed as conditions that are projected to occur in the PTCA area without the implementation of the PLAN. These BAU conditions could also be called "without Plan" or "no Plan" scenarios.

The BAU forecasts were prepared using a variety of datasets:

- Growth profiles and control factors developed by the Air District as part of a recent trends analysis for criteria air pollutants (Bay Area Air Quality Management District, 2023). Growth profiles were based on socio-economic indicators and demographic data, while control factors reflect the anticipated impact of existing District regulations.
- Forecasting scalars provided by CARB that combine growth and control factors for future years out to 2034. These scalars were based on data from CARB's California Emissions Projection Analysis Model (CEPAM) and reflect forecasts from the 2019 ozone state implementation plan (SIP) emissions inventory.
- Emission reduction factors from CARB that reflect impacts of recently adopted statewide regulations that were not considered in the CEPAM data referenced above. These statewide regulations largely address NOx and PM emissions from mobile sources, and descriptions of these regulations are provided in Table A-8.

Table A-8. Descriptions of recently adopted statewide regulations.

Regulation	Description	Adoption Date
Advanced Clean Cars II (ACCII)	Reduces emissions from new light- and medium-duty vehicles beyond the 2025 model year and increases the number of zero-emission vehicles for sale.	November 2022
Advanced Clean Fleets (ACF)	Aims to achieve a zero-emission truck and bus fleet by 2045 and significantly earlier for certain market segments (e.g., last-mile delivery and drayage applications)	April 2023
Heavy-Duty Inspection and Maintenance (HDIM)	Expands existing I&M programs to ensure all vehicle control systems (e.g., diesel particulate filters) are adequately maintained	December 2021
Small Off-Road Engine (SORE) Amendment	Accelerates the transition of SORE equipment (e.g., leaf blowers, portable generators) to zero-emission equipment starting in 2024	December 2021
Transport Refrigeration Unit (TRU) Regulation	Requires diesel-powered TRU to transition to zero-emission technology in two phases	February 2022
Commercial Harbor Craft (CHC) Regulation	Requires zero-emission options where feasible and Tier 3 and 4 engines on all other vessels	March 2022

In-Use Locomotive Regulation	Reduces harmful emissions from locomotives, in part to address long-standing environmental justice concerns for communities near railyards	April 2023

Note that for permitted sources in the PTCA community, emissions were generally held constant for the 5- and 10-year BAU forecasts. For the Chevron Refinery, the impact of amendments to Air District Rule 6-5 on emissions from the FCCU unit was estimated for future years,[11] but emissions for other processes were kept at baseline levels due to a lack of information on future changes in throughput levels at the refinery.

Table A-9 provides a comparison between baseline and future year emissions for two example CAPs, NOx and $PM_{2.5}$, which are the pollutants most impacted by recently adopted statewide regulations, as noted above. Compared to baseline levels, total NOx emissions are 21% lower in 2029 and 29% lower in 2034. Similarly, total $PM_{2.5}$ emissions are 18% lower than baseline levels in 2029 and 19% lower in 2034. Due to the impact of Rule 6-5, Chevron's contribution to total $PM_{2.5}$ emissions decreases from 61% in the baseline inventory[12] to 56% in the future year inventories. For NOx, emissions reductions are largely due to changes in the on-road fleet, as emissions from Vehicles & Trucks are 66% lower in 2029 than baseline levels and 76% lower in 2034.

Table A-9. Baseline and future year NOx and $PM_{2.5}$ emissions in the PTCA area.

	NOx Emissions (tpy)			**$PM_{2.5}$ Emissions (tpy)**		
Emissions Source	**Baseline**	**2029 BAU**	**2034 BAU**	**Baseline**	**2029 BAU**	**2034 BAU**
Permitted Fuel Refining Sources	761.0	761.0	761.0	437.9	330.5	330.5
- *Chevron Refinery (2021)*	746.0	746.0	746.0	434.4	327.0	327.0
- *Other Fuel Refining*	15.1	15.1	15.1	3.5	3.5	3.5
Marine & Rail	1,167.0	1,002.4	834.5	26.7	18.6	15.9
- *Ocean Going Vessels*	587.8	690.2	670.2	12.4	13.6	14.7
- *Ferries*	122.9	67.7	45.4	3.1	0.8	0.2
- *Commercial Harbor Craft*	259.4	128.6	75.1	7.9	2.1	0.4
- *Cargo Handling Equipment*	5.7	2.0	0.8	0.0	0.0	0.0
- *Railyards*	44.4	33.6	14.4	0.9	0.7	0.3
- *Rail lines*	146.8	80.2	28.6	2.4	1.4	0.4
Industrial & Commercial Sources	73.9	73.9	73.9	107.2	103.0	105.7
- *Permitted Sources (non-refining)*	66.6	66.6	66.6	26.3	26.3	26.3
- *Restaurants*	0.0	0.0	0.0	12.0	11.8	12.4
- *Construction (non-mobile)*	0.0	0.0	0.0	11.0	12.8	14.8
- *Residential wood combustion*	7.4	7.4	7.4	57.9	52.2	52.2
Vehicles & Trucks	635.3	213.4	152.2	52.2	48.7	46.9
- *Trucks*	472.8	114.6	68.8	12.0	7.2	6.1
- *Light Duty Passenger Vehicles*	108.0	49.2	34.3	5.4	5.3	3.6

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[11] Rule 6-5 was assumed to reduce future year emissions of PM2.5 and associated air toxics by 65% (BAAQMD, 2021b).

[12] The baseline inventory in Table A-9 includes 2021 emissions for Chevron and 2019 emissions for all other sources. When Chevron's 2019 inventory is used, the refinery accounts for 63% of total $PM_{2.5}$, as documented in PLAN Chapter 5.

- Buses	10.9	7.3	5.9	0.2	0.2	0.2
- Motor Homes	2.5	1.5	1.3	0.1	0.1	0.1
- Motorcycles	12.2	11.5	11.6	0.1	0.1	0.1
- Road Dust	0.0	0.0	0.0	33.7	35.8	36.8
- Transportation Refrigeration Units	28.8	29.3	30.3	0.7	0.1	0.1
Misc. Sources	605.2	512.1	496.5	93.2	84.1	81.3
- Offroad Equip. (Construction, etc.)	179.1	116.5	105.3	14.3	10.5	9.6
- Recreational Boats	76.0	63.7	60.2	14.4	9.4	8.0
- Fuel Combustion (non-permitted)	318.5	301.6	301.5	55.5	54.9	54.5
- Other	31.7	30.1	29.4	8.9	9.3	9.2
Total - All Sources	**3,242.4**	**2,562.9**	**2,318.1**	**717.2**	**584.9**	**580.2**

Table A-10 provides a comparison between baseline and future year emissions for air toxics, focusing on cancer and chronic TWE. Compared to baseline levels, total cancer TWE are 40% lower in 2029 and 49% lower in 2034, changes that are largely due to decreases in mobile source DPM emissions.[13] Changes in total chronic TWE are more modest, decreasing by 11% in 2029 and by 13% in 2034 relative to baseline levels. It should also be noted the contribution of Chevron and other fuel refining sources to the TWE inventories changes over time. For example, permitted fuel refining sources account for 17% of total cancer TWE in the baseline inventory[14] but about 30% of cancer TWE in the future year inventories.

Table A-10. Baseline and future year toxicity weighted emissions in the PTCA area.

	Cancer TWE			**Chronic TWE**		
Emissions Source	**Baseline**	**2029 BAU**	**2034 BAU**	**Baseline**	**2029 BAU**	**2034 BAU**
Permitted Fuel Refining Sources	42,577.6	42,500.6	42,500.6	2,020.2	1,987.7	1,987.7
- Chevron Refinery (2021)	42,444.4	42,367.4	42,367.4	1,953.3	1,920.8	1,920.8
- Other Fuel Refining	133.2	133.2	133.2	66.9	66.9	66.9
Marine & Rail	99,005.8	55,877.2	41,789.6	248.2	193.6	176.5
- Ocean Going Vessels	29,180.9	31,827.5	36,062.6	144.5	157.7	167.8
- Ferries	15,220.7	3,959.6	908.8	22.6	5.9	1.3
- Commercial Harbor Craft	38,490.9	10,155.2	2,036.8	57.1	15.1	3.0
- Cargo Handling Equipment	241.9	89.1	0.0	0.4	0.1	0.0
- Railyards	4,035.1	3,077.3	968.3	6.2	4.8	1.7
- Rail lines	11,836.3	6,768.5	1,813.1	17.5	10.0	2.7
Industrial & Commercial Sources	4,403.8	4,595.1	4,982.1	131.9	141.0	155.5
- Permitted Sources (non-refining)	1,258.4	1,258.4	1,258.4	19.8	19.8	19.8
- Restaurants	38.3	39.9	42.0	2.1	2.1	2.2
- Construction (non-mobile)	2,417.1	2,684.2	3,069.0	88.7	100.2	114.6
- Residential wood combustion	690.0	612.6	612.6	21.3	18.9	18.9

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[13] Total DPM emissions in the PTCA area are projected to decrease by 54% between 2019 and 2029 and by 65% between 2019 and 2034, largely due to reductions in mobile source emissions.

[14] Note that when Chevron's 2019 inventory is used as the baseline, permitted fuel refining sources accounts for only 11% of total cancer TWE, as documented in PLAN Chapter 5.

Vehicles & Trucks	37,945.8	11,281.7	8,446.0	325.9	234.0	208.3
- *Trucks*	29,067.9	6,123.0	4,356.1	130.6	67.0	53.1
- *Light Duty Passenger Vehicles*	4,325.2	2,130.6	1,362.1	76.1	48.0	34.5
- *Buses*	649.1	92.6	72.3	1.7	0.9	0.9
- *Motor Homes*	280.7	174.3	128.1	0.8	0.5	0.4
- *Motorcycles*	1,565.5	1,403.6	1,394.9	32.2	28.9	28.7
- *Road Dust*	792.7	843.7	866.3	82.7	87.9	90.3
- *Transportation Refrigeration Units*	1,264.7	513.9	266.2	1.9	0.8	0.4
Misc. Sources	59,500.0	31,886.0	27,380.2	714.0	517.7	480.8
- *Offroad Equip. (Construction, etc.)*	36,857.0	17,249.0	13,748.0	163.5	106.6	90.4
- *Recreational Boats*	10,317.8	6,536.3	5,473.0	231.2	145.8	123.1
- *Fuel Combustion (non-permitted)*	4,871.8	4,894.3	4,941.8	135.4	133.8	133.4
- *Other*	7,453.3	3,206.4	3,217.4	183.9	131.4	133.9
Total (All Sources)	**243,433.0**	**146,140.6**	**125,098.4**	**3,440.1**	**3,074.1**	**3,008.8**

Though Tables A-9 and A-10 include anticipated emission reductions associated with the recently adopted statewide regulations listed in Table A-8, those tables do not provide any information on the impact of each regulation individually. Therefore, Table A-11 summarizes emission reductions associated with each statewide regulation. As previously noted, these regulations primarily impact NOx and PM emissions, so reductions for NOx, PM2.5 and DPM are shown in Table A-11. Collectively, these recently adopted regulations account for about 40% of the total NOx and DPM reductions projected to occur by 2029 and 2034. For $PM_{2.5}$, these regulations account for about 10% of the projected reductions for those future years.

Table A-11. PTCA emission reductions associated with recently adopted statewide regulations.

Sector	**Regulation**	**Emissions Reductions (tpy)**					
		NOx		**$PM_{2.5}$**		**DPM**	
		2029	**2034**	**2029**	**2034**	**2029**	**2034**
On-road	ACCII	4.84	19.03	0.76	2.94	<0.01	<0.01
	ACF	7.55	13.50	0.07	0.24	0.03	0.11
	HDIM	30.22	29.00	0.19	0.18	0.20	0.19
Off-road	SORE	6.35	10.33	0.94	1.84	0.00	0.00
	TRU	2.20	2.58	0.17	0.21	0.18	0.22
	CHC	169.61	229.91	7.05	8.60	7.36	9.04
	Locomotive	22.10	72.42	0.41	1.43	0.44	1.55
TOTAL		242.86	376.78	9.58	15.44	8.21	11.11

The 2029 and 2034 BAU forecasts summarized in this appendix are intended to serve as a starting point for tracking emissions changes over time. Emission reductions associated with specific PLAN actions will be discussed or quantified during the PLAN implementation phase. In addition, changes to the baseline or BAU inventories may be made as new information becomes available over time.

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