Tracking and Evaluation of Benefits and Impacts of Greenhouse Gas Limits in Disadvantaged Communities: Initial Report

Office of Environmental Health Hazard Assessment
California Environmental Protection Agency

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SCIENCE FOR A HEALTHY CALIFORNIA

Preface

This report has been prepared in response to a directive issued by Governor Brown for an analysis of the state's response to climate change under the Global Warming Solutions Act of 2006 (AB 32). Specifically, the directive calls for the Office of Environmental Health Hazard Assessment (OEHHA) to prepare a report analyzing the benefits and impacts of the greenhouse gas emissions limits adopted by the California Air Resources Board (ARB) within disadvantaged communities. OEHHA is to update the report at least every three years.

The state's climate policies (e.g., Cap-and-Trade, zero emissions vehicles, renewable energy, low carbon fuel standard) are reducing greenhouse gas emissions statewide as well as contributing to reductions in other pollutants. This report is the first step in an investigation of whether the design and implementation of these climate policies are facilitating decreases or increases in pollutants of concern in disadvantaged communities.

OEHHA's mission is to protect and enhance public health and the environment of California through the evaluation of risks posed by hazardous substances. To carry out that mission, OEHHA provides scientific assistance to the state's other environmental and health agencies on projects involving hazard identification, exposure and toxicity assessment, and health and ecological risk assessment. The mission of ARB is to promote and protect public health, welfare and ecological resources through the effective and efficient reduction of air pollutants while recognizing and considering the effects on the economy of the state.

The focus of this initial report is on large stationary sources in the Cap-and-Trade Program, one of the elements of the state's climate change programs that is aimed at gradually reducing greenhouse gas emissions from large industrial sources through a market-based mechanism. It is limited in scope, but aims to be a starting point for future analyses. Later reports will also address the benefits and impacts of other AB 32 programs to reduce greenhouse gas emissions. The report does not explore the benefits associated with investments of Cap-and-Trade auction revenue. Subsequent reports will investigate impacts such as changes in toxic air contaminants emitted by mobile sources.

This report is one of several efforts by researchers and government entities to address air-quality impacts on disadvantaged communities. Cushing *et al.* (2016) investigated the locations and pollution from large stationary sources of greenhouse gas emissions in California that are covered under the Cap-and-Trade Program. ARB continues to implement its adaptive management program to identify and track emissions increases, if any, that are attributable to implementing the Cap-and-Trade Program. AB 197 (Garcia, Statutes of 2016) directs ARB to prioritize programs to achieve direct emissions reductions from large stationary sources and mobile sources. AB 197 also requires ARB to graphically display data on the emissions of greenhouse gases, criteria pollutants, and toxic air contaminants on its website. These efforts over time will improve our knowledge of how California's climate change programs and older, more established regulatory programs affect emissions levels of criteria and toxic pollutants, and improve our understanding of emissions changes attributable to actions taken pursuant to AB 32.

In summary, OEHHA's work here complements other efforts underway to understand potential impacts from the state's various programs to reduce greenhouse gas emissions. There are also efforts to increase access to information on stationary-source emissions for a range of pollutants. This information is expected to inform future proposals to require further reductions in emissions of criteria, toxic, and greenhouse gases from industrial sources.

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Executive Summary

In the ten years since the enactment of the California Global Warming Solutions Act of 2006 (also known as AB 32), concerns have been expressed that the state's trailblazing efforts to reduce greenhouse gas (GHG) emissions may unintentionally impact low-income communities that are already burdened by pollution from multiple sources. More specifically, the concerns are that the state's GHG-reduction programs could prompt regulated businesses to make decisions resulting in more air pollution from facilities in those communities than would otherwise be the case even while statewide GHG emissions decrease.

Conversely, California's climate-change programs also offer the potential to benefit these low-income industrial communities, to the extent that the programs prompt investments by regulated businesses that reduce emissions of both GHGs and conventional air pollutants in the communities where they operate.

In December 2015, Governor Brown directed the Office of Environmental Health Hazard Assessment (OEHHA) to analyze possible benefits and impacts to communities identified as disadvantaged under SB 535 (De León, Chapter 830, Statutes of 2012) from the GHG-emissions limit adopted by the California Air Resources Board. These benefits and impacts include changes in emissions of GHGs, toxic air contaminants, and criteria air pollutants.

This is an initial report that provides the starting point for future, more comprehensive analyses of the impacts on disadvantaged communities of GHG-emission limits. As discussed below and in the body of the report, the emissions data available at this time do not allow for a conclusive analysis. This report makes some preliminary findings that OEHHA expects to build upon in future analyses as it acquires and evaluates more data. It does not provide definitive findings regarding the effects of the GHG limit on any individual community, or disadvantaged communities in general.

The focus of this first report is on one specific AB 32 program, the state's Cap-and-Trade Program. This program regulates facilities that produce a significant fraction of the state's GHG emissions, as well as toxic co-pollutants. There are adequate data available from the Cap-and-Trade Program to begin an evaluation of potential benefits and impacts from changes in emissions. Other GHG reduction programs will be covered in later report as more data related to these programs become available.

In time, the analysis of the Cap-and-Trade Program aims to address the following key questions:

- *How do emissions of GHGs relate to emissions of toxic air contaminants and criteria air pollutants from the same facility?*

- *Are emissions disproportionately occurring in SB 535 disadvantaged communities? Do disadvantaged communities benefit from or are they negatively impacted by changes in GHG emissions from facilities subject to Cap-and-Trade?*
- *Are the benefits and impacts due to the design of the Cap-and-Trade Program?*

While challenges described in this report preclude definitive answers to these questions, OEHHA's initial analysis in this report makes the following findings:

1. A disproportionate number of facilities subject to the Cap-and-Trade Program are located in SB 535 disadvantaged communities. The Cap-and-Trade Program covers several hundred facilities from different industrial sectors that are located across the state. Of the 281 facilities with street addresses that could be geocoded, more than half (57 percent) are located in or within one-half mile of an SB 535 disadvantaged community[1]. More specifically, 15 of 20 refineries (75 percent), 5 of 7 hydrogen plants (71 percent) and 72 of the 110 facilities classified by ARB as "other combustion source" facilities (65 percent) are located in or within one-half mile of a disadvantaged community. While people's actual exposures to toxic co-pollutants emitted from these facilities would depend on various factors such as meteorological conditions and smokestack heights, changes in co-pollutant emissions resulting from the Cap-and-Trade Program would nonetheless tend to have disproportionate benefits (if emissions decrease) or adverse impacts (if emissions increase) on disadvantaged communities because of their proximity to these facilities.

2. There were moderate correlations between GHG emissions and the emissions of criteria air pollutants. The strongest correlation was with fine particulate matter emissions (PM2.5). There was also moderate correlation between GHG and toxic chemical emissions across the entire set of Cap-and-Trade facilities with covered emissions. Some individual industrial sectors showed greater correlations between emissions of GHGs and toxic co-pollutants. Refineries overall showed a strong correlation, while cement plants showed a moderate correlation. Oil and gas production facilities also showed a moderate correlation, depending on the statistical measure used. Facilities in certain sectors with broad ranges in emissions levels (e.g. electricity generation facilities) showed increased correlation with a specific statistical analysis (logarithmic transformation). This report only looked at emissions from one recent year (2014), however, because this was the only year for which air toxics data could be obtained in time for this analysis.

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[1] Identified in 2014. More on the identification of these communities can be found on CalEPA's website at the following URL: http://calepa.ca.gov/EnvJustice/GHGInvest/.

3. OEHHA also conducted a more detailed case study of nine cement plants and 19 refineries. These facilities have relatively high toxicity-weighted emissions, and data for the years 2011-2014 were available. The different plants showed varying levels of correlation among GHG, toxicity-weighted emissions, and PM2.5 emissions during the four-year period. Several cement facilities showed modest positive correlations between GHG and toxicity-weighted emissions, while two cement facilities showed poorer correlations. For refineries, there generally was a positive correlation between GHG and toxicity-weighted air emissions. Facilities with high levels of GHG emissions generally had higher PM2.5 and toxicity-weighted emissions. There were some differences among individual refineries in the relationships between GHGs, toxicity-weighted and PM2.5 emissions, perhaps reflecting differences in the kinds of products made at each of the refineries.

4. These results indicate that the relationship between GHGs and other pollutant emissions is complex. GHG facilities that emit higher levels of GHGs tend to have higher emissions of toxic air contaminants and criteria air pollutants. There is a need for additional investigation into the factors that drive emission changes, how GHG emission reductions are likely to be achieved in different industrial sectors, and what that may mean for concomitant changes in emissions of toxic air pollutants. Nonetheless, these analyses suggest that reductions in greenhouse gas emissions are likely to result in lower pollutant exposures in disadvantaged communities, based overall on the positive correlations observed for the 2014 data.

Limited data availability prevented OEHHA from conducting a more comprehensive analysis in time for this report. The Cap-and-Trade Program is a relatively new program, with the first auction of emissions instruments occurring in 2012. In 2013-2014, the program covered large industrial sources and electricity generation. In 2015, the program expanded to cover emissions from combustion of gasoline and diesel, as well as natural gas use in commercial and residential applications. In these early days of the program, it is hard to discern trends and make firm conclusions regarding patterns of changes in GHG emissions resulting from the program.

Further, data are not yet available to broadly cover emissions of toxic air pollutants from all facilities subject to the Cap-and-Trade Program. Data on emissions of GHGs, criteria air pollutants and toxic air pollutants are collected by multiple entities under different programs and statutory mandates. To date, there is no co-reporting of GHG and toxic emissions, and differences in reporting requirements across regulatory programs complicates data analysis. OEHHA will continue to acquire and analyze data for future reports, which will build upon the initial findings presented in this report.

In addition, toxic emissions data for many facilities are only updated every four years, further limiting conclusions that can be reached. OEHHA currently only has a limited set of data to examine changes in emissions that would illuminate statewide patterns, especially with respect to disadvantaged communities. A further complexity for the analysis is that the relationships between GHG and co-pollutant emissions vary across different industrial sectors (and even within facilities within a sector) with the differences in fuel types and sources, industrial processes and chemical feedstocks.

Therefore, at this point in time, when the program is still new, OEHHA cannot make definitive conclusions regarding changes in emissions due to the Cap-and-Trade Program that may disproportionately affect disadvantaged communities. OEHHA expects with time the picture will become clearer. As the program continues to generate data over the next several years, it will be easier to detect and evaluate emissions trends. OEHHA intends to update the analysis in subsequent reports as additional types of data and years of data emerge. Co-reporting of high quality data on criteria, air-toxic and GHG emissions for the facilities subject to the Cap-and-Trade Program would substantially aid the investigation of emissions impacts.

In future reports, OEHHA also plans to expand the analysis to cover AB 32 programs in addition to the Cap-and-Trade Program. It will be important to evaluate the Cap-and-Trade Program in concert with other climate policies to gauge how the entire climate change program in aggregate may impact or benefit individual disadvantaged communities and as a whole. Examination of emissions changes in the transportation sector resulting from the large and varied AB 32 programs affecting it will be an important part of this more comprehensive evaluation.

I Introduction

In the ten years since the enactment of the California Global Warming Solutions Act of 2006 (also known as AB 32), concerns have been expressed that the state's trailblazing efforts to reduce greenhouse gas (GHG) emissions may unintentionally impact low-income communities that are already burdened by pollution from multiple sources. A concern is that the state's GHG-reduction programs could prompt regulated businesses to make decisions resulting in higher emissions of conventional air pollutants at facilities in those communities than would otherwise be the case even while statewide GHG emissions decrease.

Conversely, California's climate-change programs also offer the potential to benefit these low-income industrial communities, to the extent that the programs prompt investments by regulated businesses that reduce emissions of both GHGs and conventional air pollutants in the communities where they operate.

In December 2015, Governor Brown directed the California Environmental Protection Agency's Office of Environmental Health Hazard Assessment (OEHHA) to analyze and periodically report on the impacts and benefits on disadvantaged communities related to the state's emission controls to mitigate climate change:

> *"I am directing that the Office of Environmental Health Hazard Assessment (OEHHA) prepare by December 1, 2016, a report analyzing the benefits and impacts of the greenhouse gas emissions limits adopted by the State Air Resources Board pursuant to Division 25.5 (commencing with Section 38500) of the Health and Safety Code within disadvantaged communities described in Health and Safety Code Section 39711. The report shall be made available to the public and the Legislature. OEHHA shall update the report at least every three years.*
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> *The report, at a minimum, shall track and evaluate (a) greenhouse gas emissions, criteria air pollutants, toxic air contaminants, short-lived climate pollutants, and other pollutant emission levels in disadvantaged communities; and (b) public health and other environmental health exposure indicators related to air pollutants in disadvantaged communities."*

This report is the initial response to this directive. OEHHA has examined readily available information to evaluate possible analytical approaches, and has conducted an initial analysis of one major activity to reduce greenhouse gas (GHG) emissions – the Cap-and-Trade Program. The California Air Resources Board (ARB) established this program in regulation[2] pursuant to

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[2] Originally adopted in 2011. The current Cap-and-Trade regulation can be found at the following URL: https://www.arb.ca.gov/cc/capandtrade/capandtrade.htm.

Health and Safety Code Section 38500 enacted by Assembly Bill (AB) 32 (Núñez, Statutes of 2006), also known as the Global Warming Solutions Act of 2006).

Under the Cap-and-Trade Program, ARB applies a statewide cap on GHG emissions from a number of entities that are responsible for emissions of GHGs. The covered entities represent a variety of industrial sectors. These include electricity generators, food processors, other industrial facilities that burn large quantities of fossil fuels, as well as mobile sources. Facilities are required to surrender state-issued emission allowances and emission offset credits equal to their reported and verified GHG emissions. Over time, the aggregate cap (the total amount of GHG emissions allowed from all covered facilities declines). The regulation provides flexibility in how covered GHG emitters may comply with the overall emissions cap, allowing them to seek the least costly options. Reductions of GHGs may have the added benefit of reducing emissions of toxic air contaminants, ozone-producing gases and criteria air pollutants. The varied distribution on where facilities are located across California and the flexibility of the program can mean that changes in emissions of GHGs do not occur evenly across communities.

A variety of factors in addition to the Cap-and-Trade Program can affect the amount of GHG emitted by a facility including regional or global economic trends and consumer demand, drought, facility shutdowns (e.g., the shutdown of the San Onofre Generating Station) and responses to other policies (e.g., the renewable portfolio standard for electricity generation).

While this initial report focuses on the Cap-and-Trade Program, future reports will also include assessment of other GHG emission reductions programs set in place to meet AB 32 requirements. Some of these other programs are expected to significantly benefit and possibly impact communities' exposures to co-pollutants. These analyses should prove useful for informing future decisions by the state's climate change programs, including mitigating unintended impacts and maximizing benefits from reductions of co-pollutant emissions in disadvantaged communities. However, the Cap-and-Trade Program is still relatively new, with the first auction of emissions instruments occurring in 2013. In these early days of the program, it is hard to discern trends and make firm conclusions regarding patterns of emissions resulting from the program.

This report also highlights the need for data collection practices that would be helpful in enabling ongoing tracking of changes that may be occurring across California communities from the state's efforts to address climate change.

Finally, as described later in this report, GHG, criteria and air-toxic emissions are regulated under different programs. ARB regulates GHG emissions pursuant to AB 32, while local air districts regulate criteria and air-toxic emissions from facilities through their permitting processes. Each of these programs can affect emissions levels of these three classes of pollutants, and make evaluation of emissions of air toxic contaminants and criteria air pollutants that are attributable to the cap-and-trade program challenging.

II Scope of Analysis

This report is directed at the question of whether certain communities, especially disadvantaged communities, are positively or negatively impacted from changes in exposures to environmental pollutants as a result of regulatory responses to the statewide GHG emissions limit adopted pursuant to AB 32. The scope of the analysis is necessarily limited in this initial report because of the limited data currently available, and the relatively short period of time since the implementation of the Cap-and-Trade Program. This section describes some methods that will be used to characterize benefits and impacts of the GHG reduction program, the definition of disadvantaged communities for the analysis, and the GHG reduction program of initial focus.

Benefits and Impacts

For this report, "benefits and impacts" are changes in pollutant exposures in communities resulting from changes in response to the Cap-and-Trade Program. The directive requires that the report, at a minimum, track and evaluate "greenhouse gas emissions, criteria air pollutants, toxic air contaminants, short-lived climate pollutants, and other pollutant emission levels" in disadvantaged communities, and also track and evaluate "public health and other environmental health exposure indicators related to air pollutants" in disadvantaged communities. This report provides information on levels of GHG emissions in communities, while using indicators of levels of criteria air pollutants, toxic air contaminants and other pollutants. Later reports will also identify and track public and environmental exposures indicators as measures of benefits and impacts, and will examine the effects of other GHG reduction programs in addition to the Cap-and-Trade Program. For example, the transportation sector, which is the largest source of GHG, criteria pollutant, and toxic emissions, will be addressed in later reports.

For this first report, we investigate the following emissions in communities:

- Greenhouse gases, including non-CO_2 compounds with global warming potential
- Criteria air pollutants
- Toxic air contaminants

Disadvantaged Communities

The directive requires that benefits and impacts be analyzed within "disadvantaged communities" as described in H&SC Section 39711, established by Senate Bill (SB) 535 in 2012. SB 535 requires the California Environmental Protection Agency (CalEPA) to identify disadvantaged communities for investment of Cap-and-Trade proceeds. These communities are to be identified based on geographic, socioeconomic, public health and environmental hazard criteria, and may include, but are not limited to, either of the following:

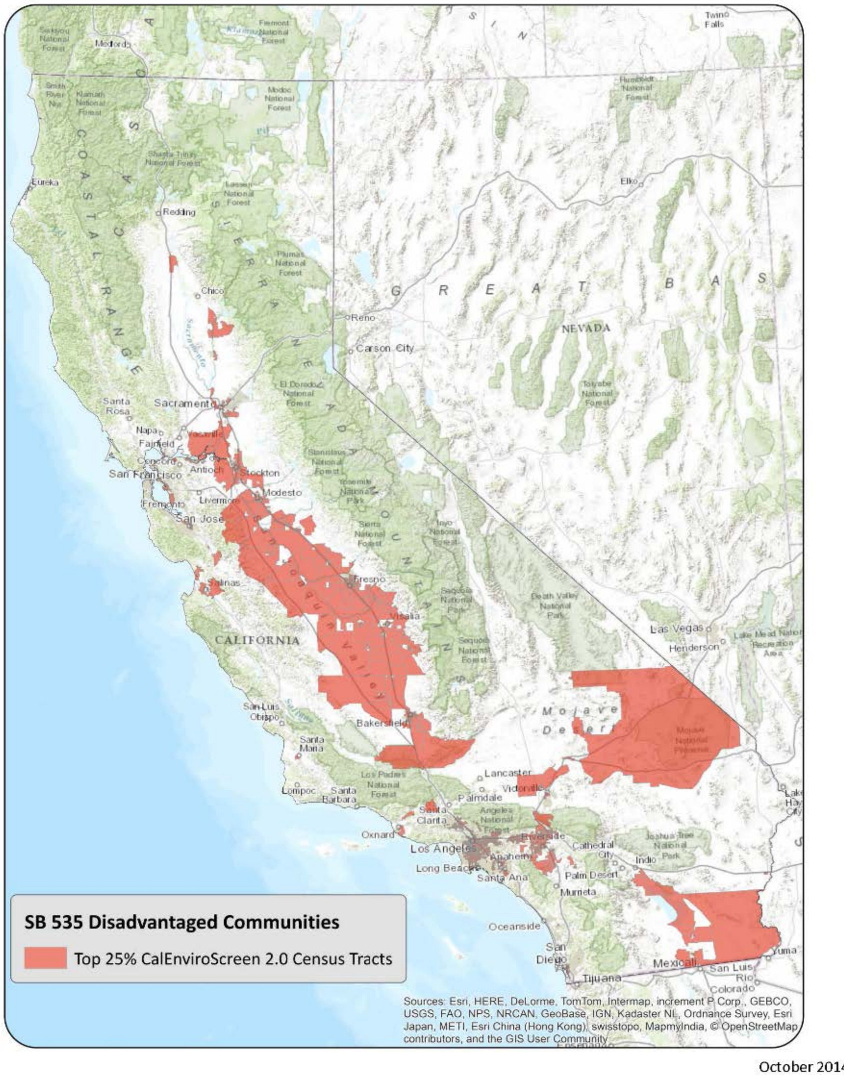
(1) Areas disproportionately affected by environmental pollution and other hazards that can lead to negative public health effects, exposure, or environmental degradation.
(2) Areas with concentrations of people that are of low income, high unemployment, low levels of homeownership, high rent burden, sensitive populations, or low levels of educational attainment.

In October 2014, following a series of public workshops to gather public input, CalEPA released its list of disadvantaged communities for the purpose of SB 535. CalEPA based its list on the most disadvantaged communities identified by the California Communities Environmental Health Screening Tool (CalEnviroScreen), a tool developed by OEHHA that assesses all census tracts in California to identify areas disproportionately burdened by and vulnerable to multiple sources of pollution.

The analyses described and presented here focus on those California communities (census tracts) identified in 2014 by CalEPA as disadvantaged using Version 2.0 of the CalEnviroScreen tool.[3] These communities are the highest-scoring census tracts in the state using the results of the tool, and represent about 25% of the state's population (see Figure 1 below).

[3] Information on the specific communities/census tracts identified as "disadvantaged" for purposes of SB 535 can be found on CalEPA's website at the following URL: http://calepa.ca.gov/EnvJustice/GHGInvest/.

Figure 1. Communities Identified as “Disadvantaged” under SB 535 (in Red) Using CalEnviroScreen Version 2.0 Results (October 2014).



OEHHA updated its statewide analysis of communities with the public release of Version 3.0 of CalEnviroScreen in January 2017. Later in the year CalEPA will make a new identification of “disadvantaged communities” that is expected to rely at least in part on the CalEnviroScreen 3.0 results. Since that new designation has yet to be made, this evaluation of the Cap-and-Trade Program utilizes CalEPA’s 2014 designation of disadvantaged communities.

Greenhouse Gas Emissions Limits Adopted by the State Air Resources Board

The directive specifically calls for OEHHA to analyze the benefits and impacts of the greenhouse gas emissions limits adopted by ARB pursuant to AB 32.

AB 32 requires California to reduce its GHG emissions to 1990 levels by 2020. This has been estimated to require a reduction of approximately 15 percent below emissions expected under a "business as usual" scenario. More recently, Senate Bill (SB) 32 (Pavley, Chapter 249, Statutes of 2016) requires ARB to ensure that GHG emissions are reduced to at least 40 percent below the 1990 statewide GHG emissions limit no later than December 31, 2030.

AB 32 requires ARB and other state agencies to adopt regulations to achieve the maximum technologically feasible and cost-effective GHG emission reductions. The goals of AB 32 are also being accomplished through a combination of policies, planning, direct regulations, market approaches, incentives, and voluntary efforts. The full implementation of AB 32 and SB 32 is expected to improve energy efficiency, expand the use of renewable energy resources, and result in cleaner transportation and reduced waste.

ARB's *Climate Change Scoping Plan*, which is required to be updated at least once every five years, describes its strategy for meeting the GHG limits. Its 2014 *Update* described the status of the various measures to reduce GHG emissions.[4] Table 1 below shows a number of the programs that are in place or under development.

Table 1. AB 32-Related Programs and Initiatives to Reduce GHG Emissions.

Economic Activity	Program	
Large Industry, Electricity Generators, Fuel Distributors	• Cap-and-Trade Regulation • Energy Efficiency and Co-Benefits Audits for Large Industrial Sectors	
Transportation	• Advanced Clean Cars • Low Carbon Fuel Standard • Regional Transportation-Related Greenhouse Gas Targets • Vehicle Efficiency Measures • Ship Electrification at Ports • Cap-and-Trade	• Goods Movement Efficiency Measures • Heavy-Duty Vehicle Emission Reduction • Medium- and Heavy-Duty Vehicle Hybridization Voucher Incentive Project • High Speed Rail
Electricity and Natural Gas Use	• Building Energy Efficiency • Appliance Energy Efficiency • Utility Energy Efficiency • Solar Water Heating • Combined Heat and Power Systems	• 33 Percent Renewable Portfolio Standard • Senate Bill 1, Million Solar Roofs • Cap-and-Trade

[4] The 2014 First Update to the AB 32 Scoping Plan, including Appendix B, can be found at the following URL: https://www.arb.ca.gov/cc/scopingplan/document/updatedscopingplan2013.htm.

Economic Activity	Program	
Water Production, Distribution, and Use	• Water Use Efficiency • Water Recycling • Water System Energy Efficiency	• Reuse Urban Runoff • Renewable Energy Production
Green Buildings	• State Green Building Initiative • Green Building Standards Code	• "Beyond Code: Voluntary Programs at the Local Level" • Greening Existing Buildings
Oil and Gas Extraction, Distribution, and Refining	• Oil and Gas Extraction GHG Emission Reduction • GHG Emissions Reduction from Natural Gas Transmission and Distribution • Cap-and-Trade	• Refinery Flare Recovery Process measures, consultation with air districts on amendments to rules for existing leak detection and repair at industrial facilities, including methane leaks
Recycling and Waste Management	• Landfill Methane Control Measure • Increase the Efficiency of Landfill Methane Capture • Mandatory Commercial Recycling	• Increase Production and Markets for Compost and Other Organics, Anaerobic/Aerobic Digestion • Extended Producer Responsibility • Environmentally Preferable Purchasing
Forestry	• Sustainable Forest Target	
Controls on High Global Warming Potential Gases	• Motor Vehicle Air-Conditioning Systems: Reduction of Refrigerant Emissions from Non-Professional Servicing • SF_6 Limits in Non-Utility and Non-Semiconductor Applications • Reduction of Perfluorocarbons in Semiconductor Manufacturing	• Limit Use of Compounds with High Global Warming Potentials in Consumer Products • Stationary Equipment Refrigerant Management Program • SF_6 Lead Reduction Gas Insulated Switchgear

Initial Focus of AB 32 Impact and Benefit Analysis: Cap-and-Trade Program

Many of the AB 32-related GHG emission reduction programs should carry the benefit of reduced exposures to co-pollutants in affected neighborhoods. For example, energy efficiency in electrical power generation and other sectors brings reduced releases of combustion by-products; reduced gasoline use from vehicle efficiency brings lower exposure to a number of gasoline-related toxicants; and improved control of fugitive emissions from natural gas transmission and distribution can reduce benzene releases.

The breadth of activities being undertaken to reduce GHG emissions in California makes a full analysis in this first report of the overall AB 32 program infeasible given the one-year timeframe for conducting the analysis. OEHHA is therefore placing an initial focus on California's Cap-and-Trade Program. This program has been chosen as the initial focus for the following reasons:

- GHG emissions from facilities and sources that are regulated under the Cap-and-Trade Program constitute about 85 percent of the state's GHG emissions.[5]
- Facilities regulated under the Cap-and-Trade Program commonly emit toxic air pollutants in addition to GHGs, and the emissions of GHGs may correlate with toxic co-pollutants. Thus reductions or increases in GHGs may be accompanied by corresponding changes in toxicant emissions.
- Many of the facilities are also located in low-income communities with high non-white populations. An evaluation of this program is consistent with the directive's intent to examine impacts in disadvantaged communities.
- Substantial data describing emissions of GHGs and toxic air contaminants by the covered entities are available.

This initial analysis will become part of a larger ongoing effort to understand the co-benefits and impacts of California's GHG reduction programs. In future reports, OEHHA plans to expand the analysis to cover AB 32 programs in addition to the Cap-and-Trade Program.

The Cap-and-Trade Program

Upon initial implementation in 2012, the Cap-and-Trade Program covered large industrial facilities and electricity generators each annually emitting more than 25,000 metric tons of carbon dioxide equivalent ($MTCO_2e$).[6] Distributors of transportation, natural gas, and other fuels were added to the program beginning in 2015. Presently the program covers about 450 entities.

Facilities in industrial sectors are annually allocated some free allowances to emit a portion of their GHG emissions. An allowance is a tradable permit to emit one metric ton of a CO_2-equivalent greenhouse gas emission (one $MTCO_2e$). Each allowance has a unique serial number to enable its tracking. The initial allocation of allowances for most industrial sectors was set at about 90 percent of average emissions, and was based on benchmarks that reward efficient facilities.[7] A facility's allocation is generally based on its production levels and is updated annually. Utilities that distribute electricity and natural gas are given free allowances whose

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[5] Overview of ARB Emissions Trading Program available at URL: https://www.arb.ca.gov/cc/capandtrade/guidance/cap_trade_overview.pdf.

[6] Carbon dioxide (CO_2) is the primary GHG, but other chemical emissions have global warming potential, including methane (CH_4), black carbon, nitrous oxide (N_2O), and hydrofluorocarbons. Emissions of GHGs are reported as CO_2 equivalents, where emissions rates for GHGs other than CO_2 are adjusted by a multiplier. For example, the multipliers for methane and nitrous oxide are 21 and 310, respectively, indicating higher global warming potential on a mass basis (CO_2 = 1).

[7] Overview of ARB Emissions Trading Program. Available at URL: https://www.arb.ca.gov/cc/capandtrade/guidance/cap_trade_overview.pdf.

value must be used to benefit ratepayers and reduce GHG emissions. Electrical distribution utilities also receive an allocation of about 90 percent of average emissions. The allocation for natural gas utilities is based on 2011 levels of natural gas supplied to non-covered entities.

The Cap-and-Trade Program regulations enable trading and limited banking of allowances, as well as obtaining a limited number of "offset" credits. An offset credit is equivalent to a reduction or increase in the removal of one $MTCO_2e$. Offset projects are developed by third parties and have included projects to remove CO_2 from the atmosphere through forestry projects, control of livestock-related biogas emissions, and projects to reduce use of refrigerants. These projects may occur out-of-state.

Allowances and offset credits are together referred to as "compliance instruments." Regulated entities surrender compliance instruments equivalent to their total GHG emissions by established deadlines within specific compliance periods.[8] Compliance instruments can be obtained from the entity's free allocation, purchase of allowances at auctions or reserve sales, purchase of offset credits, and transfer of allowances or offset credits between entities. Use of offset credits is limited to up to eight percent of a facility's compliance obligation. Every year, covered entities turn in allowances and offsets for at least 30 percent of previous year's emissions.[9]

Under the program, the annual emissions budgets decline 2-3% annually, but emissions in any year can fluctuate somewhat due to banking of allowances and offsets. The "cap" is the sum of the emissions allowances plus the allowable offset in aggregate for the compliance period.

California's program is designed to be linked to other similar programs outside of the state. This linkage allows covered California entities to use compliance instruments from GHG trading systems outside of California (and vice versa). This linkage creates a larger program and increases the total emission reduction achieved. Since 2014, the state's program has been linked to the program in Québec, Canada.

The first auction of allowances occurred in November 2012. Compliance obligation began in January 2013. In 2015, the compliance obligation began for distributors of transportation fuels, natural gas, and other fuels.

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[8] The first compliance period was the years 2013 and 2014; the second and third compliance periods are 2015-2017 and 2018-2020, respectively.

[9] At the end of the compliance period, covered facilities must surrender all instruments to cover the remaining emissions, that is 100% of final year and 70% of earlier years.

III Facilities Subject to the Cap-and-Trade Program: Description and Proximity to Disadvantaged Communities

What Are the GHG Facilities?

The Cap-and-Trade Program has required compliance by sources of GHGs that emit more than 25,000 $MTCO_2e$ per year since it began in 2012. These include facilities associated with electricity generation as well as large stationary sources of GHG emissions. Based on industrial classification, ARB has grouped the facilities into broad sectors for reporting purposes. These are: cement plants, cogeneration facilities, electricity generators, hydrogen plants, oil and gas production facilities, refineries, and "other combustion sources."

For the initial analysis here, OEHHA will continue to use these broad sectors to characterize possible differences in emissions of GHGs and air toxics.

In 2015, the Cap-and-Trade Program incorporated fuel suppliers. These are suppliers of petroleum products (including gasoline and diesel fuel), biomass-derived transportation fuels, natural gas (including operators of interstate and intrastate pipelines), liquefied natural gas, and liquefied petroleum gas. These entities are not included in the current analysis, in part because of how recently they have been included, but also because the emissions of GHGs and air toxics from these entities are distributed too widely to be included in the facility-based analysis conducted for this report. (However, refineries are a point source of emissions and the facility emissions resulting from the production of fuels are included in the analysis.) The current analysis focuses on facilities that produce more localized emissions. Furthermore, the sector representing electricity importers was also excluded from the present analysis.

Table 2 below shows industrial sectors included in the Cap-and-Trade Program, and the amount of GHGs emitted in 2014.[10] The largest contributors are from electricity generation and petroleum and gas refining, which together account for over half of the localized GHG generation covered by the Program (emitter covered emissions). On a facility basis, refineries also dominate, with average facility levels of 1.7 million $MTCO_2e$. However, within all but one sector, there is at least one facility producing more than 1 million $MTCO_2e$.

[10] Data available pursuant to California's Regulation for the Mandatory Reporting of Greenhouse Gas Emissions at URL: https://www.arb.ca.gov/cc/reporting/ghg-rep/reported-data/ghg-reports.htm.

Table 2. GHG Emissions in 2014 by Cap-and-Trade Program Industry Sector for Facilities Reporting Emissions (Emitter-Covered Emissions in $MTCO_2e$).

Sector	No. Facilities / Entities	Total $MTCO_2e$ by Sector	Range of $MTCO_2e$ per Facility	Median $MTCO_2e$ per Facility	Mean $MTCO_2e$ per Facility
Cement Plant	9	7,653,163	123 – 1,968,656	935,061	850,351
Cogeneration	48	10,510,133	14,515 – 1,397,718	118,818	218,961
Electricity Generation	81	34,523,656	16 – 2,501,899	133,550	426,218
Hydrogen Plant	7	3,291,235	38,815 – 839,224	615,058	470,176
Oil and Gas Production [a]	50	16,256,368	13,155 – 3,246,254	44,572	325,127
Refinery [b]	18	31,266,353	3 – 6,363,590	1,112,508	1,737,020
Other Combustion Source [c]	116	8,326,559	747 – 1,412,648	44,534	71,781
Total	**329**	**111,827,467**			

[a] Includes eight facilities that also supply natural gas, natural gas liquids, or liquefied petroleum gas.

[b] Includes 15 facilities that also supply transportation fuel or CO_2, and/or operate a hydrogen plant.

[c] Includes one facility that also supplies CO_2.

What Are the Sources of Emissions from GHG Facilities Covered by the Cap-and-Trade Program?

The Cap-and-Trade Program covers several hundred industrial facilities that represent a wide variety of processes and activities. As a result of these activities, GHGs as well as other pollutants are commonly released into the atmosphere.

Table 3 below describes the facility sectors that report GHG emissions under the Cap-and-Trade Program and some of the processes used within these sectors that generate both GHGs and emissions of air toxics. In most sectors, the combustion of fuel is an important contributor to both GHG and air toxics emissions. For some sectors, GHGs are generated from processes other than fuel combustion (for example, CO_2 generated from the production of clinker in the manufacture of cement or CO_2 released from the production of hydrogen gas in the steam reformation process). Nearly all processes also generate air toxics. Criteria air pollutants and toxic air contaminants can be generated by non-combustion processes that may not be related to GHG emissions.

Table 3. GHG- and Air Toxic-Generating Activities and Processes in Primary Sectors of GHG Facilities Covered by the Cap-and-Trade Program (based on 2014 Inventory of Facilities).

Sector	Activities	Processes	Main Processes Generating CO_2e and Air Toxics
Cement Plants	Production of cement from limestone, clay and sand.	The mixture of limestone, clay, and sand is heated at high temperatures in a kiln to form clinker. Clinker is cooled and ground with various additives to produce cement. Key steps: 1. Raw materials acquisition and handling 2. Kiln feed preparation 3. Pyro-processing (calcining) 4. Finished cement grinding Most cement plants use short kilns with preheaters and pre-calciners for pyro-processing in clinker production. Some use long dry kilns without preheaters.	Pyro-processing (calcining) Fuel combustion (frequently coal)
Cogeneration Facilities	Generation of electrical power and useful heat, including waste heat recovery, from the same original fuel energy. Also known as combined heat and power.	Electricity and thermal energy are generated onsite at cogeneration facilities, where waste heat recovery also occurs. Some examples of cogeneration include: 1. Gas or other fuel combustion, sometimes to heat water to produce steam. 2. Gas or steam turbine to generate electricity 3. Exhaust energy convert to steam, exported to a host facility	Fuel combustion (fossil fuels or biomass)
Electricity Generation Facilities	Generating electrical power	1. Gas turbine: fuel combustion to generate electricity 2. Boiler: to capture exhaust heat to make steam 3. Steam turbine: to produce additional electricity	Fuel combustion (fossil fuels or biomass) Fugitive emissions
Hydrogen Plants	Producing hydrogen from feedstock for refineries, food industries, and fertilizer production	Steam methane reforming (SMR) method (for example): 1. Feedstock hydrogenation and sulfur removal 2. Reforming in the SMR 3. Shift conversion 4. Hydrogen purification	Fuel combustion Feedstock consumption[11] All steps

[11] Produces mainly CO_2.

Sector	Activities	Processes	Main Processes Generating CO_2e and Air Toxics
Oil and Gas Production Facilities	Extraction of crude petroleum and natural gas from geological formations. May include well stimulation such as thermal (steam), waterflood, or gas injection techniques	1. Extraction of oil/water emulsion from the geological formation via a mechanical or submergible pump 2. Separation of emulsion into water, oil, and gas 3. Storage and transfer or oil and water; processing of natural gas for sale or use	Fuel combustion (frequently natural gas for steam generation) Fugitive emissions Flaring Dehydration processes
Refineries	Production of petroleum products, including transportation fuels (gasoline diesel), asphalt, and other products (kerosene, liquefied petroleum gas, feedstock for production of other materials)	Refineries can vary in the complexity of their processes. Topping refineries have small throughput, primarily separating crude oil into intermediates or simple products (e.g., asphalt). Hydro-skimming facilities include reforming and desulfurization process units as well as topping activity. More complex facilities produce transportation fuels and other products, and tend to use more energy, using processes including distillation, reforming, hydrocracking, catalytic cracking, coking, alkylation, blending, isomerization, amine treating, mercaptan oxidation. Many refineries have on-site hydrogen production, calciners, and sulfuric acid plants. Heavy crude oil inputs and production of lighter/cleaner products require more energy.	Combustion of refinery gas, syngas, and petroleum coke Fuel combustion for distillation Hydro-treating Catalytic reforming Sulfur removal Hydrogen generation
Other Combustion Sources	Multiple	Numerous industries are represented by facilities identified under the “other combustion source” sector. Facilities include those that manufacture nitrogenous fertilizer, alcoholic beverages, food and dairy products, paper and paperboard, gypsum products, soda ash, glass and glass containers, milling of iron and steel and rolled steel shapes, forging, lime, and mineral wool. Industrial activities can include canning, secondary smelting, and poultry processing. GHG emissions from colleges, universities, and professional schools are also included in this category.	Industry-dependent

Where Are GHG Facilities?

OEHHA has analyzed the location of 281 GHG facilities covered by the Cap-and-Trade Program for which street addresses could be geocoded from a 2014 inventory of facilities[12]. In this case, the distance from each GHG facility to the nearest SB 535 disadvantaged community was evaluated. Facilities were grouped by industrial sector to determine whether some sectors were more likely to be in or near disadvantaged communities. Facility locations are shown in Figure 2 below. The analysis of the percent of each sector's facilities in or within specific distances of disadvantaged communities is presented in Table 4 below. Since disadvantaged communities represent 25% of the census tracts in the state, Table 4 shows that GHG facilities are disproportionately located within disadvantaged communities for all sectors. Over 50% of facilities for all but the cogeneration sector fall within one-half mile of a disadvantaged community.

[12] Because oil and gas production facilities can cover large geographic areas, the proximity analysis to disadvantaged communities will require more in-depth spatial analysis. For this reason, 48 oil and gas production facilities with geocoded street addresses are not included in this analysis.

Figure 2. California Map Showing the Locations of GHG Facilities and SB 535 Disadvantaged Communities.

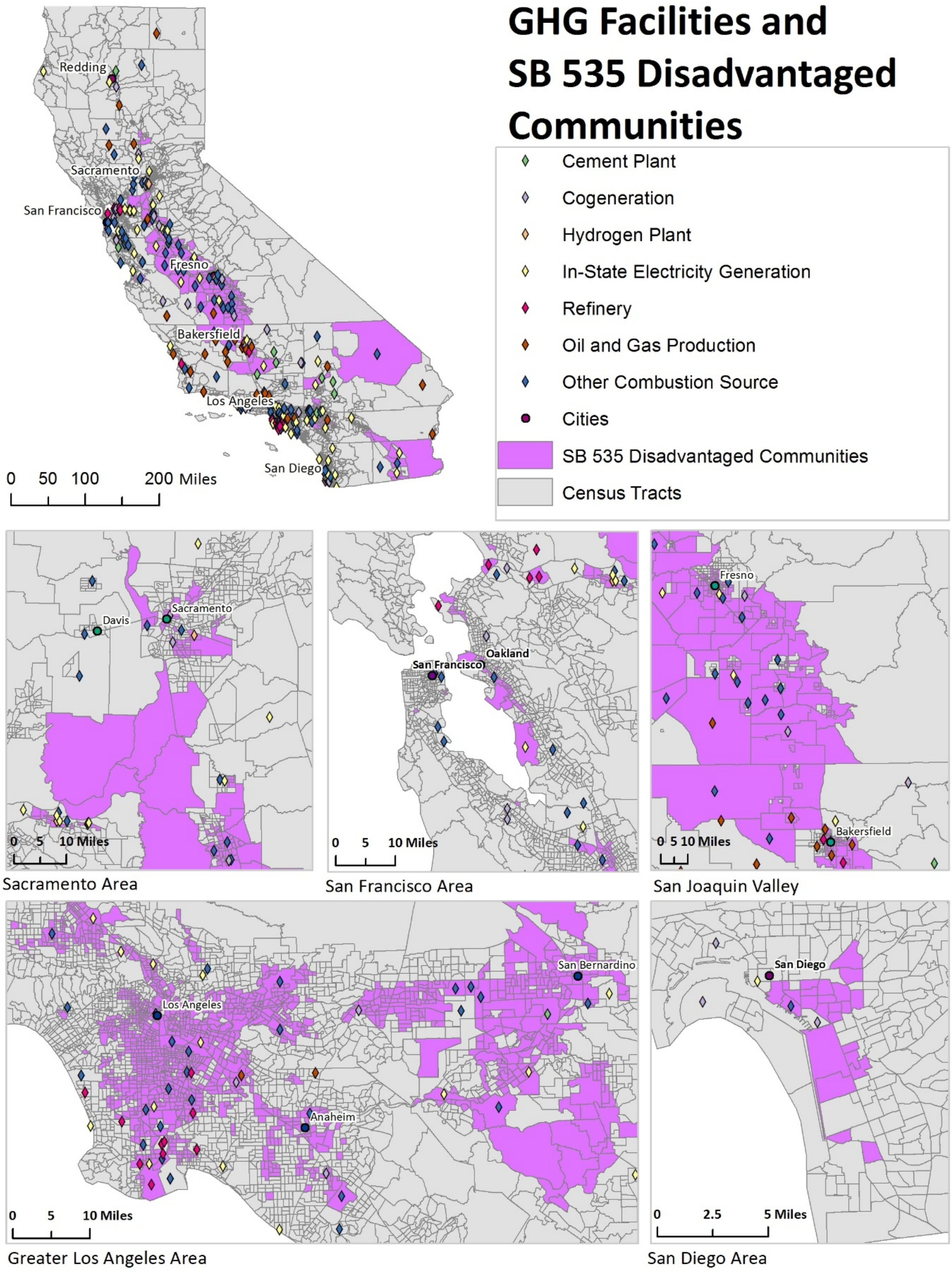

Table 4. Analysis of Proximity of GHG Facilities to SB 535 Disadvantaged Communities (Based on Geocoding by Facility Street Addresses).

Sector	No. Facilities	% of Facilities in or near SB 535 DACs [a]		
		Within	<0.5 mi	<1.0 mi
Cement Plant	9	33	56	56
Cogeneration	59	29	41	42
Electricity Generation	76	41	51	58
Hydrogen Plant	7	43	71	86
Refinery	20	65	75	85
Other Combustion Source	110	56	65	66
Total	281	46	57	60

[a] The SB 535 disadvantaged communities include about 15.5% of California's land area. With the additional 0.5 and 1.0 mile buffers, the land area represents 16.9 and 18.1% of California's land area, respectively. The total land area in California is estimated at 155,779 square miles. Greater buffer distances represent cumulative percent of facilities within a given distance. Facilities are treated here as points. Since many facilities cover large areas (footprint), the proximity to disadvantaged communities may be underestimated in this analysis.

In total, 46 percent of the GHG facilities covered by the Cap-and-Trade Program were located within SB 535 disadvantaged communities, 57 percent were in or within 0.5 miles of one, and 60 percent were in or within one mile of an SB 535 community. Generally, the sectors with the greatest likelihood of having a facility in or near an SB 535 disadvantaged community were from the sectors for refineries, hydrogen plants, and "other combustion source" sectors. Since the majority of GHG facilities are in close proximity to SB 535 disadvantaged communities, changes in emissions generally represent potential for differential increases or decreases in exposure in these communities.

These results are consistent with a recent report from academic researchers that examined the locations of many of the GHG facilities covered under the Cap-and-Trade Program. Cushing *et al.* (2016)[13] describe a geographic analysis of 321 facilities that reported GHG emissions that were covered by the Cap-and-Trade Program during the 2013-2014 compliance period. And of these, 255 were within 2.5 miles of a resident population. Areas in proximity to these facilities

[13] Cushing LJ, Wander M, Morello-Frosch R, Pastor M, Zhu A, Sadd J (2016). A Preliminary Environmental Equity Assessment of California's Cap-and-Trade Program. Research Brief – September 2016. UC, Berkeley, University of Southern California, San Francisco State University, and Occidental College. Available at URL: http://dornsife.usc.edu/PERE/enviro-equity-CA-cap-trade.

were examined with respect to CalEnviroScreen 2.0 scores (highest 10 and 20% of scores) as well as the percentages of people of color and living in poverty.

The analysis found that census block groups within 2.5 miles of the GHG facilities had higher mean non-white populations, higher mean poverty levels, and a higher likelihood of being in a high-scoring CalEnviroScreen 2.0 census tract compared to block groups farther from GHG facilities. Many block groups are also within 2.5 miles of more than one facility. As the number of facilities near block groups increases, communities tend to have higher populations of color and higher rates of poverty.

IV Proposed Analytic Approach to Characterize Benefits and Impacts

Key Questions

The overall analysis of Cap-and-Trade facilities aims to answer the following key questions, in due course:

- *How do emissions of GHGs relate to emissions of toxic air contaminants and criteria air pollutants from the same GHG facilities?* Since the Cap-and-Trade Program aims to reduce aggregate GHG emissions, understanding how reductions or increases in GHG emissions may relate to changes in emissions of toxic air pollutants that could result in human exposure is critical to analyzing potential benefits and impacts.
- *Are emissions disproportionately occurring in SB 535 disadvantaged communities? Do disadvantaged communities benefit from or are they negatively impacted by changes in emissions from GHG facilities subject to Cap-and-Trade?* The SB 535 communities face burdens from multiple sources of pollution and population vulnerability factors. Equity analyses will address whether changes are occurring that may disproportionately affect these communities.
- *Are the benefits and impacts due to the design of the Cap-and-Trade Program?* The directive seeks to analyze benefits and impacts attributable to the AB 32 program. Therefore, an ultimate goal of the analyses will be to understand what changes in emissions can be attributed to responses to the program rather than external factors, such as economic conditions and drought.

Challenges in Evaluating the Benefits and Impacts of the Cap-and-Trade Program

The ability to examine relationships between Cap-and-Trade Program activities, outputs, and outcomes/impacts is complicated by a number of factors. These include:

- *The diversity of industries and facilities covered by the program.* Uniformity is not expected in how industries are able or likely to achieve compliance with the Cap-and-

Trade Program. The types and amounts of GHG and air toxics emissions that result from changes in industrial activities to comply with Cap-and-Trade are also expected to vary. Thus, the relationships between GHG and co-pollutant emissions vary across different industrial sectors (and even within facilities within a sector) with the differences in fuel types and sources, industrial processes and chemical feedstocks. For example, certain industrial processes may require fuels that burn at high temperatures. The emissions profile (specific chemicals emitted and levels at which they are emitted) typically varies with the temperature of combustion. Alternative fuels can also have different emissions profiles from conventional fuels.

- *The limited availability of data about GHG program activities, associated emissions, and health and other outcomes.* Some information regarding program activities is limited due to the need to protect confidential business information and market sensitivity of the information. This information could inform analyses of the relationship between GHG and co-pollutant emissions and facilities. Possible examples of such information include the mix and quantity of products made at specific facilities, and emissions produced per unit of product manufactured at a facility. However, such information may potentially provide economic advantage to competitors if made publicly available.

  Other limitations in data are that information relevant to the analysis of outcomes – especially co-pollutants – has not to date been required to be co-reported with GHG emissions. As a result, these data must be obtained from sources resulting from other federal, state and local regulatory programs, such as permitting and reporting requirements and emissions monitoring by local air districts. Differences in reporting requirements across regulatory programs can complicate the analysis. Optimally, this analysis would have data reporting for co-pollutants and GHG emissions within the same time period, and over time. Changes in data collection practices can make it difficult to establish relationships between activities and outcomes over time.
- *The flexibility of the Cap-and-Trade Program.* The program has a number of components, including the aggregated nature of the GHG emissions cap and provisions to minimize "leakage" in which economic/industrial activity may move out of state. Facilities are also provided with numerous options for how compliance can be achieved, including "banking" of compliance instruments to provide flexibility while the program overall still meets the goals of GHG emission reductions. Also, the phase-in of different industrial sectors has occurred in different years.
- *Confounding factors that affect emissions and related outcomes that are unrelated to the Cap-and-Trade Program*. As one important example, industrial activity in California is affected by the overall economy and market factors, and may also be affected by other state, regional, or local regulatory activity. This can influence levels of GHG and air toxics

emissions. For example, the US and California experienced a severe economic recession from the late 2000s into the early 2010s, followed by an economic recovery, which occurred in the same period over which the Cap-and-Trade Program was launched and has developed. Another example includes the recent and persistent California drought. Because a large fraction of the state's electricity supply is derived from hydropower, the recent drought has necessitated additional generation of electricity from thermal power plants. Further, during the analysis period, the San Onofre Generating Station (a large nuclear power plant) was decommissioned. This resulted in more in-state emissions than would otherwise have occurred due to electricity generation from thermal power plants.

Practical Steps for Initial Analysis

Limitations to the readily available data place some constraints on the initial analysis described here. More public data are available to describe potential overall changes in pollutant emissions in disadvantaged communities than are available to specifically characterize Cap-and-Trade Program activities that may be influencing those emissions changes (see Section V below). For this reason, OEHHA is first examining the emissions data, and later intends to identify potential regulatory activities that may be contributing to changes in emissions, especially in disadvantaged communities. This report focuses on identifying and describing relevant data sources and how they can be used, gathers readily available data, and presents initial findings regarding those data.

V Data Used to Characterize Emissions of GHG and Air Toxics Emissions from GHG Facilities

Various types of information are collected by state and federal agencies on emissions of GHGs and toxic air pollutants from facilities and other entities covered by the Cap-and-Trade Program. Below are the sources of information that provided emissions data for the analysis of impacts and benefits of California's Cap-and-Trade Program described in this report.

Mandatory Reporting of Greenhouse Gas Emissions

GHG emissions must be reported to ARB annually by many industrial sources, fuel suppliers, and electricity importers under the Mandatory Reporting Rule (MRR).[14] Of these

[14] More detailed information on Mandatory Greenhouse Gas Emissions Reporting is available from ARB's website at URL: https://www.arb.ca.gov/cc/reporting/ghg-rep/ghg-rep.htm.

facilities/entities, many are also subject to the Cap-and-Trade Program. For such facilities, the submitted emissions data are verified by an accredited third party. The table below describes some of the publicly available data through the MRR.

Table 5. Partial List of Information Available from Mandatory Greenhouse Gas Emissions Reporting.

Source of Information	Description of Available Data
Facility Data	• Facility name, ARB identification code, ZIP Code/city, industrial sector, industrial classification code (NAICS)
Total Emissions	• Total CO_2e from combustion, process, vented, and supplier (in $MTCO_2e$); includes both fossil and biomass-derived fuels
Facility Reported GHG Data (in $MTCO_2e$)	• CO_2e from non-biogenic sources and CH_4 and N_2O from biogenic fuels[15] as emitters and fuel suppliers • CO_2e from biogenic fuels as emitters and fuel suppliers • Electricity importer CO_2e
ARB Calculated Covered Emissions (in $MTCO_2e$)	• Covered emissions as emitters, fuel suppliers, and electricity importers • Total covered emissions (combined for entities with multiple) • Total non-covered emissions

ARB has publicly provided information on GHG emissions for each year since 2008. However, emissions data for the years 2008 to 2010 are not directly comparable to later years. This is a result of changes in methodology to harmonize with U.S. EPA's GHG reporting regulation. An additional industrial sector has also been brought into the program since GHG reporting began, namely fuel distributors.

In 2015, GHG emissions data were reported for over 800 facilities, 724 of which reported GHG emissions greater than zero. The number of facilities in sectors expected to have on-site emissions was 589 (excluding electricity importers and suppliers of natural gas and transportation fuel). Not all facilities that report GHG emissions under the MRR are required to participate in the Cap-and-Trade Program.

[15] Biomass fuels are derived from biomass products and byproducts, wastes, and residues from plants, animals, and microorganisms. Emissions from combustion of biomass fuels that meet certain criteria are considered biogenic and are exempt from a compliance obligation in the Cap-and-Trade regulations.

ARB also provides data related to how each entity covered by the Cap-and-Trade regulation meets it compliance obligation in terms of the total number of allowances and offsets surrendered each year.[16]

Table 6. Information Available in the Annual Compliance Report for the Cap-and-Trade Program (ARB).

Type of Information	Description of Available Data
Facility information	Facility name and ARB identification number
Compliance Instrument Data	• 2013-2014 triennial surrender obligation • Total instruments surrendered • Total allowances surrendered • Offsets surrendered and the types of offset credits and specific offset projects those credits are from • Compliance status ("fulfilled" or "unfulfilled")

The Cap-and-Trade Program has established definitions of "facility" that clarify the extent of facilities operations that are required to report as a single entity. These definitions are provided in Appendix A.

Air Toxics "Hot Spots" Emission Inventory

Information on emissions of toxic substances from facilities in California is available from the Air Toxics "Hot Spots" Emissions Inventory. Emissions inventory plans are intended to provide "a comprehensive characterization of the full range of hazardous materials that are released, or that may be released, to the surrounding air from the facility" and includes all continuous, intermittent, and predictable air releases (Health and Safety Code section 44340(c)(2)). The Air Toxics "Hot Spots" Information and Assessment Act of 1987 (Health and Safety Code section 44300-44394, as amended) requires reporting of site-specific emissions of toxic substances based on criteria and guidelines adopted by ARB.[17] These guidelines outline:

- *The facilities that are subject to reporting.* Generally, any facility[18] or business in California that emits more than 10 tons per year of organic gases, particulate pollution, nitrogen oxides, or sulfur oxides, is subject to "Hot Spots" requirements. Certain smaller

[16] This information is made available through ARB's website at URL: https://www.arb.ca.gov/cc/capandtrade/capandtrade.htm (see Publicly Available Market Information).
[17] AB 2588 Air Toxics "Hot Spots" Emission Inventory Criteria and Guidelines Regulation (Guidelines). The current regulation and a detailed description of the guidelines are available on ARB's website at https://www.arb.ca.gov/ab2588/2588guid.htm#current.
[18] See Appendix A for definition of "facility" under this program.

facilities like gas stations, dry cleaners, and chrome platers are also subject to the requirements. Some "low level" facilities are exempt from further update reporting unless specified reinstatement criteria are met. Reductions in emissions from changes in activities or operations may also exempt some facilities from further reporting requirements. Facilities that have been exempted from compliance with this program may also be reinstated under certain conditions (for example, emissions of a newly listed substance, the establishment of a nearby sensitive receptor such as a school, or an increase in the potency of a substance that it emits).

- *The groups of substances to be inventoried.* Different chemical substances have different reporting requirements. Emissions must be quantified for over 500 specific substances. Production, use, or other presence must be reported for an additional ~200 substances. Facilities must report whether they manufacture an additional ~120 substances.
- *When facilities are required to report.* This is based on prioritization scores, risk assessment results, or *de minimis* thresholds. Emissions inventories developed under the "Hot Spots" Program are updated every four years.
- *The information a facility operator must include in a facility's update to their emission inventory.*
- *Criteria by which "Hot Spots" reporting is integrated with other air district programs.*
- *The information that must be included in the air toxics emission inventory plan and report by a facility operator.*
- *The source testing requirements, acceptable emission estimation methods, and reporting formats.*

Criteria Air Pollutant Emissions

Emissions data for criteria air pollutants from California facilities are collected by county or regional air districts as a result of both state and federal laws. The district data are then reported to ARB. Generally, large facilities report these emissions annually, though facilities with lower rates of emissions may only be required to report every three years.

Data on the emissions of criteria air pollutants for some facilities that are subject to the Cap-and-Trade regulation have recently been made available on ARB's Integrated Emissions Visualization Tool.[19] This includes data by facility for the years 2008 to 2014 on emissions of

[19] Available at URL: https://www.arb.ca.gov/ei/tools/ievt/. For additional information comparing the reporting of GHG and criteria air pollutant emissions, see also URL: https://www.arb.ca.gov/ei/tools/ievt/doc/ievt_notes.pdf.

ozone-producing volatile organic compounds (VOCs), nitrogen oxides (NOx), sulfur oxides (SOx), particulate matter (PM 2.5 and PM10), and ammonia (NH_3).

Toxic Release Inventory (TRI; US Environmental Protection Agency)

Another source of emissions data for toxic substances is the US Environmental Protection Agency's (US EPA) Toxic Release Inventory (TRI).[20] Under this program, facilities[21] in certain industrial categories with more than 10 full-time equivalent employees that manufacture, process, or otherwise use chemicals are required to report chemical emissions. Industries covered include certain electric power utilities, chemical manufacturing, mining, hazardous waste treatment, and federal facilities.

The list of chemicals for which reporting is required currently contains almost 600 individual chemicals, plus 31 chemical categories. Facilities are required to report emissions that manufacture or process more than 25,000 pounds, or otherwise use more than 10,000 pounds of any listed chemical in the course of a calendar year. Lower thresholds are in place for facilities that manufacture, process, or use certain persistent bioaccumulative toxic (PBT) chemicals.

For industries and facilities required to report, the minimum amounts that must be reported are on the order of 0.1 to 1 pounds per year. Reporting levels for PBT chemicals have no minimum levels. For qualifying facilities, reporting occurs annually.

General Limitations to the Use of Emissions Data as an Indicator of Benefits and Impacts

Emissions data are being used in this report as a proxy for potential exposures to air pollutants that arise from industrial sources, and do not directly correspond to health risks to individuals in communities near facilities. Health risks are typically estimated through health risk assessments of the facilities themselves. Such assessments can take into account a large number of factors, such as: the specific location of the emissions, the fate and transport of the substances emitted (in consideration of stack height, meteorology and terrain), the estimated concentrations of chemicals where people are, the duration of exposures, and the toxicity characteristics of the substances informed by health guidance values (such as cancer potencies and reference exposure levels). However, for an initial screen of potential concerns related to emissions of toxic air pollutants, emissions data provides information to use as a basis for

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[20] Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA, or Title III of the Superfund Amendments and Reauthorization Act of 1986, Public Law 99-499). Additional information available through U.S. EPA's website at URL: https://www.epa.gov/toxics-release-inventory-tri-program.
[21] See Appendix A for definition of "facility" under this program.

relative comparison (changes in emissions) and can illuminate the nature of potential hazards arising from facilities.

To address variations in the toxicity of the emitted chemicals, this report performs a toxicity weighting of the emitted chemicals. This weighting puts a greater emphasis on the more highly toxic emitted chemicals than on emitted chemicals with relatively low toxicity.

There are uncertainties associated with emissions data themselves. While the emissions reporting described below is required by law under different statutes, the amounts and types of emissions are self-reported by the regulated industries. This means they may be subject to some reporting errors. Different regulatory programs have different practices in place to verify submitted data, though there may be inaccuracies that are difficult to identify. Reporting requirements can change over time to include additional types of emissions and emission processes. Factors that are used to estimate emissions from specific processes can also be revised over time, leading to changes in the estimates.

VI Toxicity of GHGs and other Air Pollutants

Greenhouse Gases

There is generally low concern for human health from localized emissions of carbon dioxide (CO_2), the primary GHG that is driving climate change. Only at very high concentrations does CO_2 affect human health. For this reason, emissions of CO_2 itself are not considered to be contributing to localized impacts from facilities where it is emitted.

Other GHGs are the “short-lived climate pollutants” including methane, fluorinated gases, and black carbon. Methane is more potent than CO_2 as a GHG, but is generally emitted at lower rates than CO_2. Sources of methane include agriculture, the oil and gas industry, and from the treatment of waste. Methane is generally not expected to have health effects from localized emissions due to its low toxicity.

Fluorinated gases include chlorofluorocarbons, hydrochlorofluorocarbons, and hydrofluorocarbons, many of which are being phased out of use because of their ozone-depleting potential. Most of the emissions of this class of compound arise from leakage of refrigeration systems. As such, they provide a relatively limited contribution to emissions from facilities regulated under the Cap-and-Trade Program. Similarly, sulfur hexafluoride has numerous uses, but is regulated from early actions outside of the Cap-and-Trade Program due to its very high global warming potential and increasing levels in recent years.

Black carbon is generally created as a product of incomplete combustion of organic fuels, including diesel fuels. Black carbon is a component of particulate pollution (including PM2.5, see below) and diesel particulate matter, both of which have well-described human health toxicity concerns, including increasing risk of premature death and cancer. California has substantially reduced black carbon from diesel exhaust from many sources over the past 20 years, corresponding to a 13% reduction in the total annual CO_2 emissions in California.

Criteria Air Pollutants

The criteria air pollutants are common air pollutants for which federal standards are established under the Clean Air Act (42 U.S. Code Chapter 85). The six criteria air pollutants are ozone, particulate matter, sulfur dioxide, nitrogen dioxide, carbon monoxide, and lead. California has established more protective standards in some cases. The standards are established to protect even the most sensitive individuals, such as children and elderly. Some of the common sources of exposure and key health effects are described in Table 7 below.

Table 7. Sources of Exposure and Health Effects of Criteria Air Pollutants.

Criteria Air Pollutant	Sources of Exposure	Health Effects
Ozone	Generated from interaction of sunlight with volatile organic compounds (reactive organic gases), especially hydrocarbons, and nitrogen oxides; ozone formation may be distant from the source of these emissions. Sources include vehicles, industrial facilities, and consumer products, among others.	Damage to the respiratory tract; worsening of symptoms for respiratory diseases like asthma, bronchitis, and emphysema; reduction in lung function; increased susceptibility to infections. People who spend more time outdoors may be especially susceptible.
Particulate matter (PM)	Many sources of PM; generated by the combustion of most fuels, which produces most of fine PM (particles less than 2.5 microns in diameter, PM2.5); larger particles (PM10) can be generated by blowing dusts. Particles can vary greatly in their composition.	Worsening of heart and lung disease; decreases in lung function and respiratory symptoms, such as coughing or shortness of breath; increases in hospitalizations and deaths. People with heart and lung disease, as well as children and elderly, may be especially susceptible to the effects.

Criteria Air Pollutant	Sources of Exposure	Health Effects
Sulfur dioxide	Combustion of fuel containing sulfur. Industrial sources include certain petroleum refining processes. Other sources are locomotives, ships, and certain diesel equipment.	Respiratory effects include shortness of breath and wheezing. Increases in mortality have been observed from sulfur dioxide exposure. Children, elderly, asthmatics, and people with existing heart disease may be especially sensitive to the effects.
Nitrogen dioxide	Combustion of fuel by cars, trucks, and at power plants.	Damage to the respiratory tract. Asthmatics may be especially susceptible to the harmful effects of nitrogen dioxide exposures.
Carbon monoxide	Produced from the incomplete combustion of fuels from a variety of sources.	Dizziness and confusion at high levels of exposure, though unlikely outdoors. Individuals with heart or lung disease may be especially susceptible.
Lead	Multiple sources, especially processing of metals, waste incineration, battery manufacturing, and aircraft burning leaded aviation fuel.	Harmful to the nervous, cardiovascular, immune, reproductive and developmental systems. Children are especially sensitive to the effects of lead.

Toxic Air Contaminants

"Toxic air contaminants" are defined in California law as air pollutants which may cause or contribute to an increase in mortality or in serious illness, or which may pose a present or potential hazard to human health (Health and Safety Code section 39655). There are currently almost 200 substances or groups of substances identified as toxic air contaminants by ARB.[22] These substances show a wide range of toxicity characteristics and physical properties that could influence the likelihood of health effects if they are emitted to air.[23]

[22] The current list can be found on the ARB website at URL: https://www.arb.ca.gov/toxics/quickref.htm#TAC.
[23] Information on the types of hazards for many identified toxic air contaminants is available at URL: https://www.arb.ca.gov/toxics/cattable.htm.

Some toxic air contaminants were listed because they were federally designated hazardous air pollutant (pursuant to subsection (b) of Section 112 of the federal act (42 U.S.C. Sec. 7412(b)). ARB designated others based on evaluations performed by OEHHA that meets specific criteria described in California law (Health and Safety Code section 39660).

VII Results

Toxicity-Weighted Emissions to Air

Most GHG facilities covered by the Cap-and-Trade Program emit a combination of GHGs, criteria air pollutants, and toxic air contaminants. While GHGs themselves tend to be relatively less toxic, co-pollutants that are emitted can vary significantly by facility with respect to their composition and potential toxicity. To provide additional information on how these facilities vary with respect to overall toxicity of emissions, OEHHA derived a "toxicity-weighted" emissions score for each of the facilities for which emissions data were available. The purpose of this analysis was to screen for higher-concern facilities with respect to emission levels and potential chemical toxicity.

The data were derived from the California Air Toxics "Hot Spots" Emissions Inventory for GHG facilities that could be matched across both the "Hot Spots" and Cap-and-Trade Programs. This matching was performed by investigators from UC Berkeley and San Francisco State University. The facility matching involved geocoding facility addresses that were available for each Cap-and-Trade Program GHG facility. The location information was then matched to location information for "Hot Spots" facilities that was made available by ARB. Facilities with close proximity to a listed address and similar facility names were presumed to match. Comparable identities were confirmed by visual inspection of satellite imagery and internet research. In developing this facility data set, some facility locations were adjusted so that they more closely spatially aligned with likely point sources of emissions.

There are several uncertainties associated with the matching of Cap-and-Trade and "Hot Spots" facilities due to the differences between the two regulatory programs. These uncertainties come from differences in how facilities are defined under each program. In some cases, facilities may have multiple operations that are combined for the purpose of reporting GHG emissions. However, these operations may be reported separately for air toxics and criteria air pollutant emissions.

Of the full set of Cap-and-Trade covered facilities from sectors that were expected to produce localized emissions, a subset of 374 facilities were tentatively identified as likely matches to "Hot Spots" facilities. Emissions information for 365 of these facilities was provided to OEHHA by ARB for the 2014 reporting year. These data included annual emissions amounts for individual criteria air pollutants (or their precursors for those with ozone-forming potential) and individual chemicals for which reporting is required under the "Hot Spots" Program. A smaller subset of 77 facilities had risk assessments prepared under the "Hot Spots" Program. In these cases, emissions were modeled to identify potential risks in neighboring communities. Since these data were somewhat limited in availability across Cap-and-Trade Program covered facilities, they are not currently being used in the analysis described here.

Because facilities emit multiple chemicals and not all chemicals are equally toxic, OEHHA applied weighting factors to the air toxics emissions data for each facility. OEHHA calculated a toxicity-weighted emissions score for each of the 365 facilities using an approach comparable to that used to calculated toxicity-weighted emissions under US EPA's Toxic Release Inventory Program. To apply a comparable methodology here, US EPA's Inhalation Toxicity Scores for individual chemicals were matched and applied to the chemical emissions levels for air toxics (pounds emitted per year) from each facility.[24] Some chemicals whose emissions are required to be reported in the "Hot Spots" Program did not have US EPA toxicity weights available. These compounds are currently excluded from the analysis. Toxicity weights may be established for these compounds in the future.

Toxicity weight is described by US EPA as follows: [25]

> *"This weight is a proportional numerical weight applied to a chemical based on its toxicity. The toxicity of a chemical is assessed using EPA-established standard methodologies. For each exposure route, chemicals are weighted based on their single, most sensitive adverse chronic human health effects (cancer or the most sensitive noncancer effect). In the absence of data, the toxicity weight for one pathway is adopted for the other pathway. The range of toxicity weights is approximately 0.02 to 1,400,000,000."*

This type of weighting was also used in characterizing air toxics emissions in the California Communities Environmental Health Screening Tool (CalEnviroScreen). Toxicity weights do not include the criteria air pollutants (NO_x, PM2.5, etc.). Those pollutants are evaluated separately below.

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[24] OEHHA used US EPA values here because they were readily available. Since California-specific risk and toxicity data may be available for many chemicals, these values will be updated for future analyses. As an example, US EPA does not include a toxicity weight for diesel exhaust, which can be an important contributor to cancer risk from facilities.

[25] Further information is available on U.S. EPA's website at URL: https://www.epa.gov/trinationalanalysis/hazard-and-risk-tri-chemicals-2014-tri-national-analysis.

As discussed above, the toxicity weights themselves for each compound are not a measure of risk or likelihood of harm, but provide a way to screen overall emissions from facilities that allows comparisons and the identification of those emissions of highest overall concern.

The emissions characteristics of facilities differ by industry. Using the information on emissions reported by facilities, the most frequently reported specific chemical emissions are described in Table 8 below. Across sectors, numerous air toxics are reported to be emitted that are commonly created by fuel combustion. These include formaldehyde, benzene, toluene, xylenes, 1,3-butadiene, diesel particulate matter, and polycyclic aromatic hydrocarbons (PAHs). The composition of chemicals emitted from fuel combustion depends on the type of fuel burned (oil, coal, natural gas, biomass). Other emissions are likely to be associated with a type of industry. For example, nearly all cement plants report emissions of nickel, naphthalene, lead, formaldehyde, hexavalent chromium, cadmium, beryllium, benzene, and arsenic. (One cement plant in this data set reported very low activity in 2014 with respect to both GHG and air toxics emissions.) Oil and gas production facilities emit numerous organic chemicals: benzene, formaldehyde, naphthalene, toluene, xylenes, acetaldehyde, PAHs, acrolein, ethylbenzene, and 1,3-butadiene.

Toxicity-weighted emissions values were calculated for each of the facilities for which air toxics emissions data were available, as described above. The highest-scoring 25 facilities are presented in Table 9 below. While multiple sectors are represented in this group, some sectors appear more frequently among those with the highest toxicity-weighted emissions. The highest-scoring 25 facilities in the state include several cement plants (6), refineries (6), and facilities associated with oil and gas production (6).

Table 8. Frequency of Specific Chemical Emissions for Facilities with Reported Air Toxics Emissions by Cap-and-Trade Sector (Criteria Air Pollutants Excluded).

Sector	Facilities*	Chemicals most frequently reported emitted (number of occurrences) *		
Cement Plants	9	Nickel (8) Naphthalene (8) Lead (8) Formaldehyde (8) Hexavalent chromium & compounds (8) Cadmium (8) Beryllium (8) Benzene (8) Arsenic (8) Selenium (7) Mercury (7) Manganese (7)	Copper (7) Zinc (6) Xylenes (mixed) (6) Toluene (6) Hydrochloric acid (6) Chromium (6) Benzo(a)pyrene (6) Acetaldehyde (6) 2,3,7,8-Tetrachlorodibenzo-p-dioxin (6) 1,3-Butadiene (6) Silica, crystalline (respirable) (5) Indeno(1,2,3-cd)pyrene (5)	Ethyl benzene (5) Dibenz(a,h)anthracene (5) Benzo(k)fluoranthene (5) Benzo(b)fluoranthene (5) Benz(a)anthracene (5) 2,3,7,8-Tetrachloro-dibenzofuran (5) 2,3,4,7,8-Pentachloro-dibenzofuran (5) 1,2,3,4,6,7,8-Heptachloro-dibenzo-p-dioxin (5) 1,2,3,4,6,7,8-Heptachlorodibenzofuran (5)

Sector	Facilities*	Chemicals most frequently reported emitted (number of occurrences) *		
Cogeneration Facilities	48	Formaldehyde (43) Benzene (43) Toluene (35)	Ammonia (34) Naphthalene (31) Acetaldehyde (29)	Xylenes (mixed) (27) Acrolein (26) 1,3-Butadiene (26)
Electricity Generation Facilities	90	Formaldehyde (80) Benzene (80) Ammonia (71) Naphthalene (60)	1,3-Butadiene (50) Toluene (47) Arsenic (46) Nickel (45)	Lead (45) Cadmium (45) Hexavalent chromium & compounds (40) Xylenes (mixed) (39)
Hydrogen Plants	6	Formaldehyde (6) Benzene (6)	Ammonia (5) PAHs, total (4)	Naphthalene (4)
Oil and Gas Production Facilities	47	Benzene (40) Formaldehyde (38) Naphthalene (32)	Toluene (28) Xylenes (mixed) (25) Acetaldehyde (25)	PAHs, total (24) Acrolein (24)
Refineries	20	Ammonia (19) Benzene (18) Formaldehyde (17) Nickel (16)	Lead (16) Hexavalent chromium & compounds (16) Cadmium (16) Naphthalene (15)	Arsenic (14) Beryllium (13) 1,3-Butadiene (13) PAHs, total (12)

Sector	Facilities*	Chemicals most frequently reported emitted (number of occurrences) *
Other Combustion Sources	114	Numerous industrial activities are represented in the “Other Combustion Sources” category. A few examples are presented below. **Fruit and Vegetable Canning** Toluene (8) Formaldehyde (8) Benzene (8) Xylenes (mixed) (6) Propylene (6) Nitrous oxide (6) Naphthalene (6) Methane (6) Hexane (6) Ethyl benzene (6) Carbon dioxide (6) Acrolein (6) Acetaldehyde (6) PAHs, total (5) Ammonia (5) Diesel engine exhaust, particulate matter (Diesel PM) (4) **Dry, Condensed, and Evaporated Dairy Product Manufacturing** Diesel engine exhaust, particulate matter (Diesel PM) (5) Xylenes (mixed) (4) Toluene (4) Propylene (4) PAHs, total (4) Nitrous oxide (4) Naphthalene (4) Methane (4) Hexane (4) Formaldehyde (4) Ethyl benzene (4) Carbon dioxide (4) Benzene (4) Acrolein (4) Acetaldehyde (4) **Paperboard Mills** Formaldehyde (3) Benzene (3) Toluene (2) Nickel (2) Naphthalene (2) Lead (2) Hexavalent chromium & compounds (2) Cadmium (2) Arsenic (2) Ammonia (2) Acetaldehyde (2) **Colleges, Universities, and Professional Schools** Formaldehyde (8) Benzene (8) Nickel (7) Lead (7) Hexavalent chromium & compounds (7) Cadmium (7) Arsenic (7) Naphthalene (6) Mercury (6) Toluene (5) Methylene chloride (5) Manganese (5) 1,3-Butadiene (5) Xylenes (mixed) (4) Acrolein (4) Acetaldehyde (4)

* Facility count is the number of facilities for which air toxics emissions data are available, but did not report emitter-covered GHG emissions in 2014.

Table 9. Twenty-Five Cap-and-Trade Facilities with the Highest Toxicity-Weighted Air Emissions.* Shaded Facilities Are In or Within ½ Mile of an SB 535 Census Tract.

Facility Name and Approximate Location	Sector	Tox-Weighted Air Emissions	CEIDARS ID	ARB ID
CalPortland Company, Mojave Plant, Mojave	Cement Plant	11,128,486,856	15_KER_9	101029
California Resources Elk Hills, LLC, 35R Gas Plant, Tupman	Oil & Gas Production, Supplier of NG/ NGL/ LPG	8,019,256,117	15_SJU_2234	104014
Riverside Cement Company, Oro Grande	Cement Plant	4,773,322,002	36_MOJ_1200003	100013
Cemex Construction Materials Pacific LLC, Victorville Plant	Cement Plant	3,981,635,547	36_MOJ_100005	101476
Lake Shore Mojave, LLC (Shutdown), Boron	Cogeneration	3,154,251,353	KER_593	100218
U.S. Borax, 93516, Boron	Other Combustion Source	3,154,251,353	15_KER_28	100300
PG&E Hinkley Compressor Station, Hinkley	Oil & Gas Production	2,695,090,703	36_MOJ_1500535	101290
Lehigh Southwest Cement Co., Tehachapi	Cement Plant	2,565,789,410	15_KER_20	101461
Mitsubishi Cement 2000, Lucerne Valley	Cement Plant	2,073,213,791	36_MOJ_11800001	101010
Shell Oil Products US, Martinez	Refinery, Hydrogen Plant	1,916,625,223	7_BA_11	100914
PG&E Topock Compressor Station, Needles	Oil & Gas Production	1,576,205,185	36_MOJ_1500039	101031
ExxonMobil Oil Corporation, Torrance Refinery Torrance	Refinery, Hydrogen Plant, CO_2 Supplier	1,531,495,371	19_SC_800089	100217
Searles Valley Minerals Inc., Trona	Other Combustion Source	1,487,264,625	36_MOJ_900002	100011
Southern California Gas Co., South Needles Facility, Needles	Oil & Gas Production	1,401,623,408	36_MOJ_3100068	101346
Coso Power Developers (Navy II), Geothermal, Little Lake	In-State Electricity Generation	1,280,562,586	15_KER_328	101669
National Cement Company, Lebec	Cement Plant	1,151,169,990	15_KER_21	101314
Freeport-McMoRan Oil & Gas LLC, SJV Basin Facility, Fellows	Oil & Gas Production	1,090,450,784	15_SJU_1372	104081
Imerys Minerals California, Inc., Lompoc	Other Combustion Source	1,047,824,807	42_SB_12	101318
Grayson Power Plant, Glendale	In-State Electricity Generation	873,364,347	19_SC_800327	100181
Valero Refining Company, Refinery and Asphalt Plant, Benicia	Refinery, Hydrogen Plant, CO_2 Supplier	830,573,455	48_BA_12626	100372
Tesoro Refining and Marketing Co., Martinez	Refinery, Hydrogen Plant, CO_2 Supplier	786,966,781	7_BA_14628	101331
Southern California Gas Co - Aliso Canyon Facility, Northridge	Oil & Gas Production	716,224,953	19_SC_800128	101349
Spreckels Sugar Company, Inc., Brawley	Other Combustion Source	708,360,193	2014_13_IMP_10	101241
Chevron Products Company, El Segundo	Refinery, Hydrogen Plant, CO_2 Supplier	697,864,142	2014_19_SC_800030	100138
Phillips 66 Company, Los Angeles Refinery, Wilmington	Refinery, Hydrogen Plant, CO_2 Supplier	673,822,489	2014_19_SC_171107	100329

*Top 25 of the 297 facilities for which scores could be calculated using 2014 emissions data.

Air Toxics and GHGs Emissions

Plotting data graphically for visual inspection and calculation of correlation coefficients are approaches to the evaluation of data that may be informative with respect to relationships between greenhouse gas emissions and toxic air contaminants.

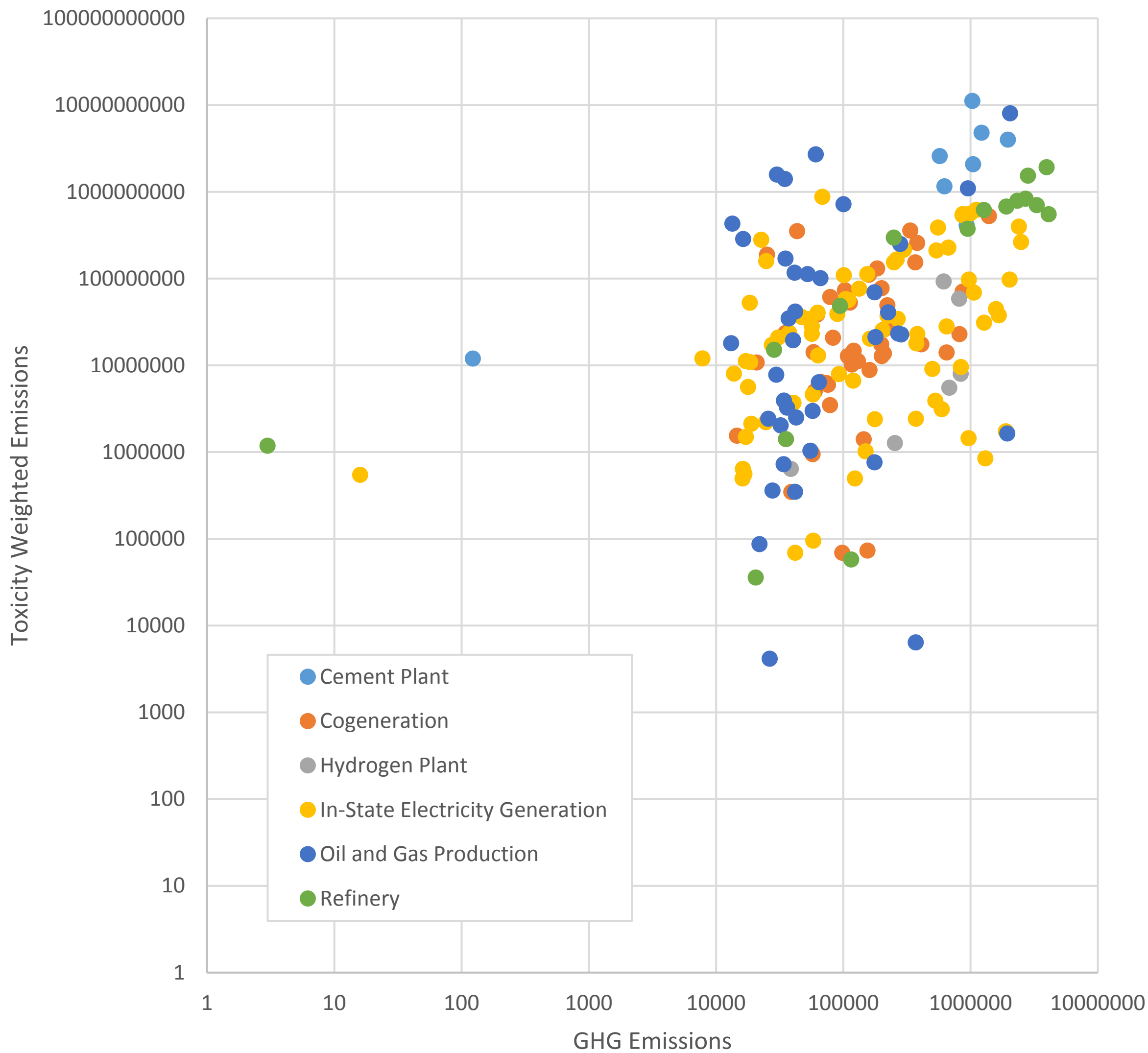
The Pearson correlation coefficient is a measure of the linear dependence between two variables, in this case between GHG emissions and a number of different pollutant emission measures. A Pearson correlation coefficient is high when the relationship between two measures increases linearly in proportion to each other. Generally, high positive correlation produces a coefficient r-value of greater than 0.8, with moderately high correlation above 0.5, moderate when the measures are between 0.3 and 0.5, and low when below 0.3 to zero but statistically significant. Inversely correlated values are negative. The Pearson correlation is vulnerable to outlier data, especially when there is a large range of values represented in the analysis. For this reason, an additional correlation analysis was conducted using the Spearman correlation coefficient. In this analysis, the rank order of each of two sets of measures is compared. This coefficient is better able to identify data sets that may be related, but the relationship may be more complex than linear. Another method to address data over a larger range is to make logarithmic transformations. For several of the data sets here, logarithmically transforming the data strengthened the correlations.

Figure 3 shows a scatterplot of GHG emissions versus toxicity-weighted emissions from facilities for which both types of data are available. The GHG emissions used are emitter-covered emissions for the year 2014, excluding emissions by facilities that were not covered by the program (e.g., biomass) and emissions related to electricity imports that were not local. This analysis only included facilities with emitter-covered emissions for which 2014 air toxics data were available ($n = 298$). Overall, this correlation was moderate, positive and highly significant by both measures (Pearson coefficient, $r = 0.32$; Spearman coefficient, $r = 0.44$; both statistically significant, $p<0.0001$).

When facilities were subdivided by Cap-and-Trade Program industrial sectors, some sectors showed considerably higher positive relationships. The scatterplots and correlations are presented in Figure 4 and Table 10 below, respectively. Refineries overall showed high positive correlations ($r \cong 0.8$), followed by oil and gas production facilities, hydrogen plants, and cement plants, each of which were moderately correlated using the Pearson coefficient ($r \cong 0.5$). For refineries, GHG emissions were highly correlated with toxicity-weighted air toxics emissions, as indicated by both the Pearson (0.82) and Spearman (0.86) correlation coefficient ($p\leq0.0001$ for both coefficients). The Pearson correlations for hydrogen and cement plants were also supported by positive correlations using the Spearman coefficient. For the oil and gas production facilities, both measures showed positive correlation, but only the Pearson was statistically significant, suggesting that outliers or extreme values may have contributed to the Pearson correlation. It is also likely that the nature of the relationship between emissions of GHGs and air toxics varies substantially across these types of facilities. Also, how these facilities are defined differs across the different regulatory programs (see Appendix A for the definitions).[26] For electricity generation facilities, GHG emissions and toxicity-weighted emissions also showed low correlation; however, emissions levels across facilities varied broadly and logarithmic transformation resulted in a moderate (Pearson $r = 0.41$) and a highly significant correlation ($p<0.001$).

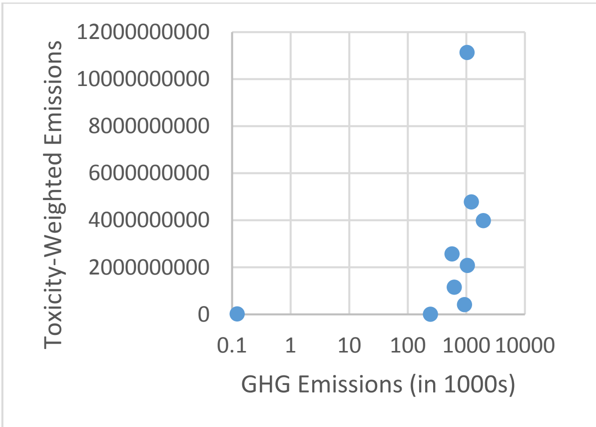
[26] ARB provides additional information on the differences between oil and gas facilities under different programs. See URL: https://www.arb.ca.gov/ei/tools/ievt/doc/ievt_oil_gas_crosswalk.pdf. The crosswalk table described in this document was not used for the initial analysis performed by OEHHA in this report.

Figure 3. Scatterplot of Toxicity-Weighted Emissions vs GHG Emissions from GHG Facilities with Emissions Data, by Cap-and-Trade Program Sectors (n=201)*

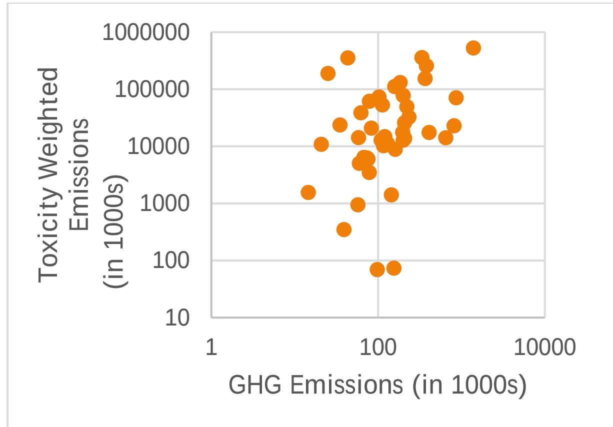


*The figure excludes "Other Combustion Sources" Category. GHG Emissions in $MTCO_2e$. Plotted on a Logarithmic Scale).

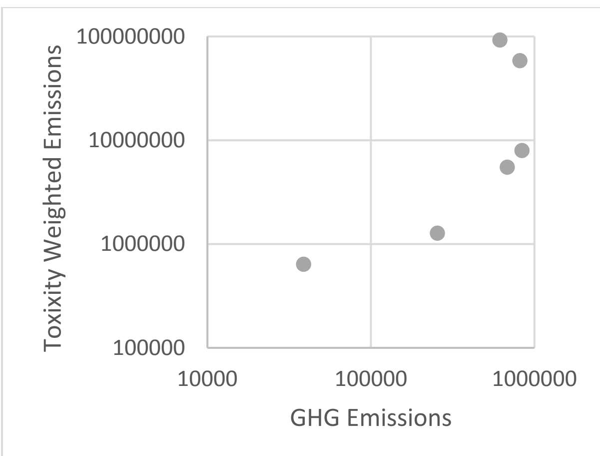
Figure 4. Scatterplots of Toxicity-Weighted Emissions vs GHG Emissions ($MTCO_2e$) by Cap-and-Trade Program Sectors (plotted on logarithmic scale).



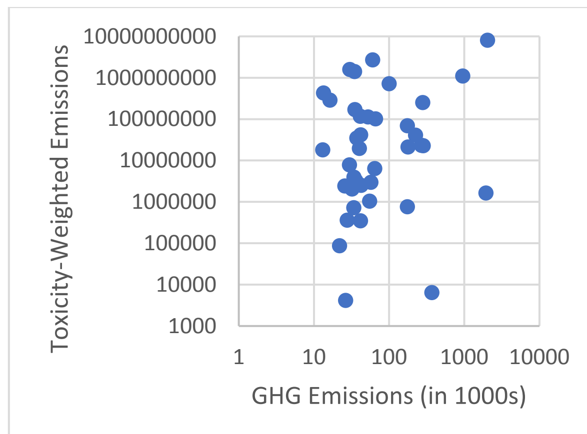
Cement Plants (n = 9)



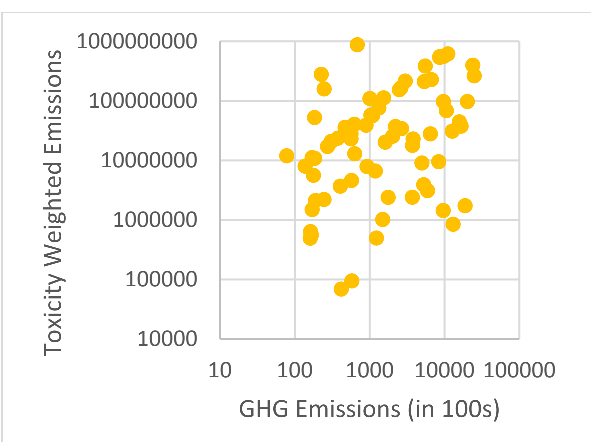
Cogeneration Facilities (n = 45)



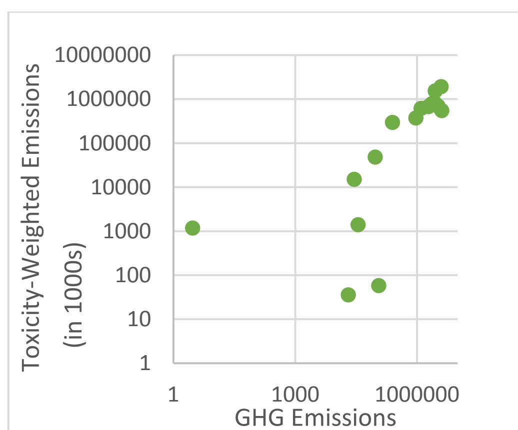
Hydrogen Plants (n = 7)



Oil and Gas Production Facilities (n = 41)



Electricity Generation Facilities (n = 83)



Refineries (n = 16)

Table 10. Correlation for GHG Emissions vs. Toxicity-Weighted Air Toxics Emissions for Cap-and-Trade Facility by Sector (2014 Emissions Data; Shaded r-Values Represent Statistically Significant Results, p<0.05).

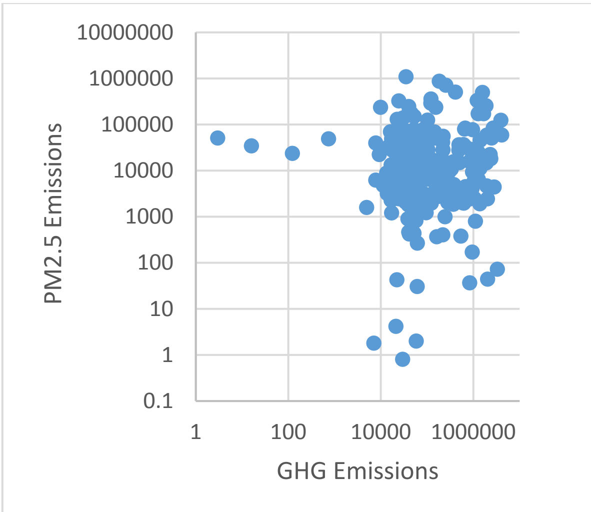
Sector	No.	Pearson (r-value)	Stat. Sig. (p-value)	Spearman (r-value)	Stat. Sig. (p-value)
Cement Plants	9	0.474	0.198	0.733	0.025
Cogeneration	45	-0.004	0.979	0.243	0.108
Hydrogen Plants	7	0.481	0.274	0.714	0.071
Oil & Gas Production	41	0.555	0.0002	0.100	0.533
Electricity Generation	83	0.173	0.119	0.282	0.0098
Refineries	16	0.818	0.0001	0.862	<0.0001

Criteria Air Pollutant and GHG Emissions

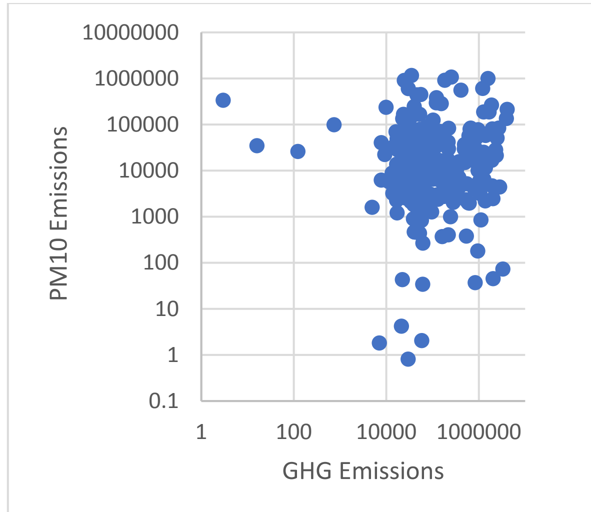
The relationships between GHG emissions and the emissions of specific criteria air pollutants from facilities were investigated in a manner similar to the analysis above using toxicity-weighted emissions. Figure 5 below show scatterplots of emissions of GHGs from facilities (as above) versus emissions of criteria air pollutants using data provided by ARB. Table 11 below shows the Pearson and Spearman correlation coefficients for each of the comparisons. This analysis includes facilities from all sectors for which data are available.

Because of the wide range of emissions of both GHGs and criteria air pollutants and the diverse nature of the industries analyzed here, the Spearman correlation likely provides more insight into probable relationships than the Pearson correlation. Here, Spearman correlations were moderately positive ($r \cong 0.5$) for total PM, PM10, PM2.5, SOx and NOx, individually. Correlations were poorer, though still positive, for organic and volatile gases (ozone-precursors), and carbon monoxide. Each of these correlations was statistically significant.

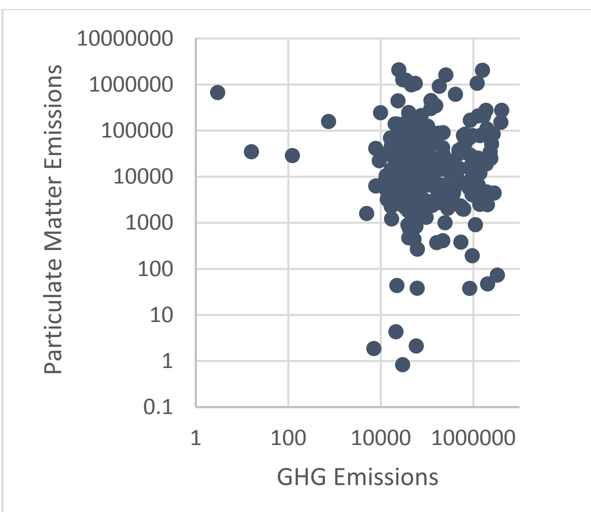
Figure 5. Scatterplots of Criteria Air Pollutant Emissions from All GHG Facilities with Emissions Data for the 2014 Reporting Year (n ≈ 316; Criteria Air Pollutant Emissions vs. GHG Emitter-Covered Emissions in $MTCO_2e$).



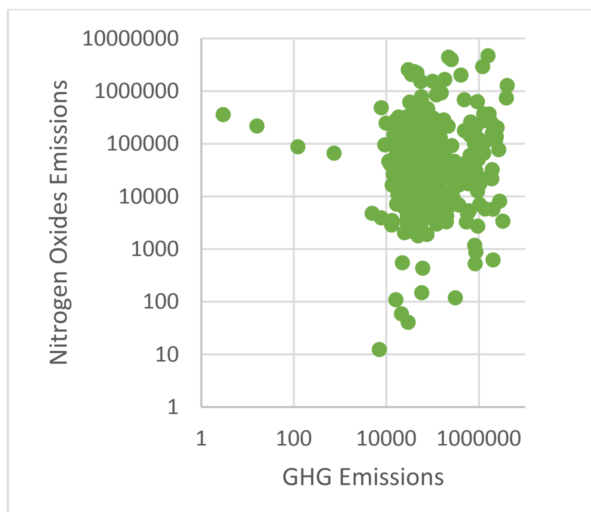
PM2.5



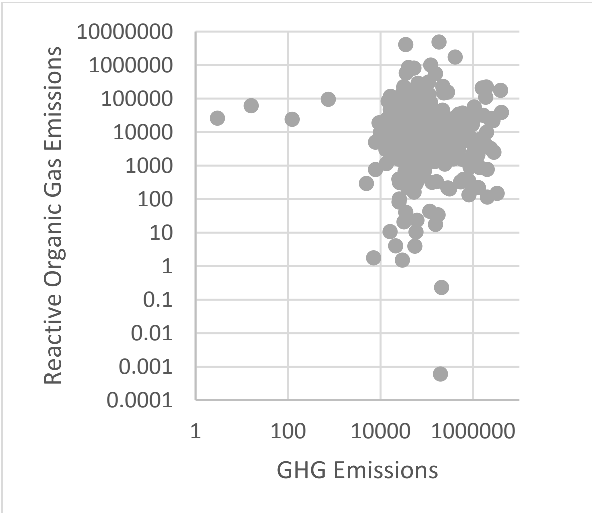
PM10



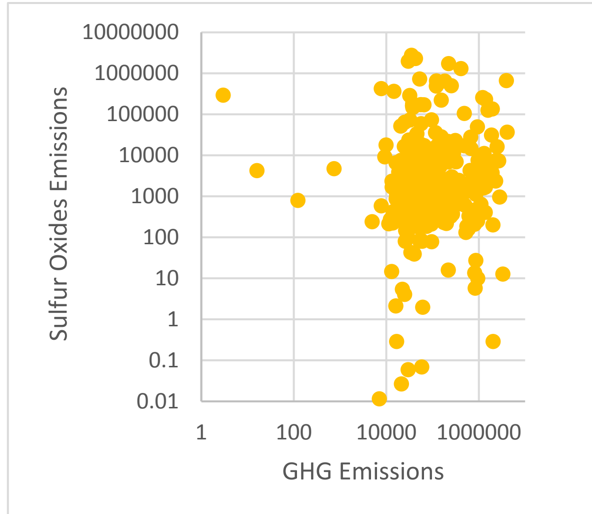
Total PM



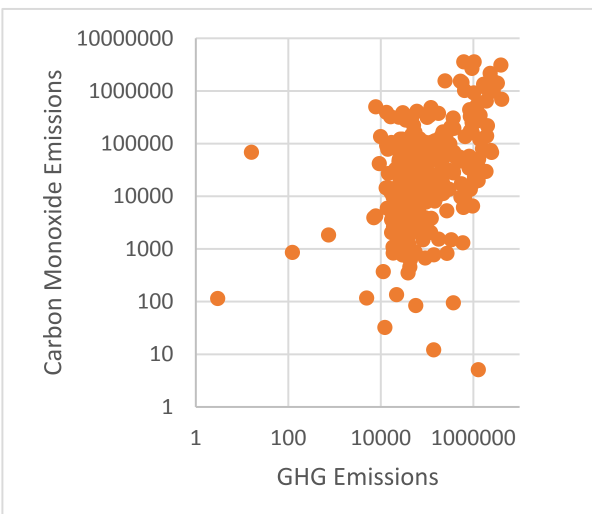
Oxides of Nitrogen (NOx)



Ozone-Generating Compounds (Reactive Organic Gases)



Oxides of Sulfur (SOx)



Carbon Monoxide

Table 11. Correlations between Emitter Covered GHG Emissions (in $MTCO_2e$) and Criteria Air Pollutant Emissions (in pounds) for All Cap-and-Trade Facilities with Emissions Data (2014 Data).

Pollutant	Correlation (r-value)*	
	Pearson	**Spearman**
CO	0.451	0.394
NOx	0.515	0.508
SOx	0.460	0.564
PM	0.467	0.455
PM10	0.617	0.499
PM2.5	0.718	0.554
ROG	0.642	0.246
TOG	0.693	0.389
VOCs	0.652	0.246

* All correlation r-values for both tests were statistically significant ($p<0.0001$).

OEHHA also examined relationships between individual criteria air pollutants and GHG emissions by industrial sector. These correlations are presented in a table in the Appendix (p. A-3). For refineries and in-state electricity generation facilities, correlations were moderate to high. All were statistically significant ($p<0.05$). Other sectors with high correlations include cement plants (NOx, PM, PM10, and VOCs) and hydrogen plants (TOG, VOCs).

Case Study: Cement Plants

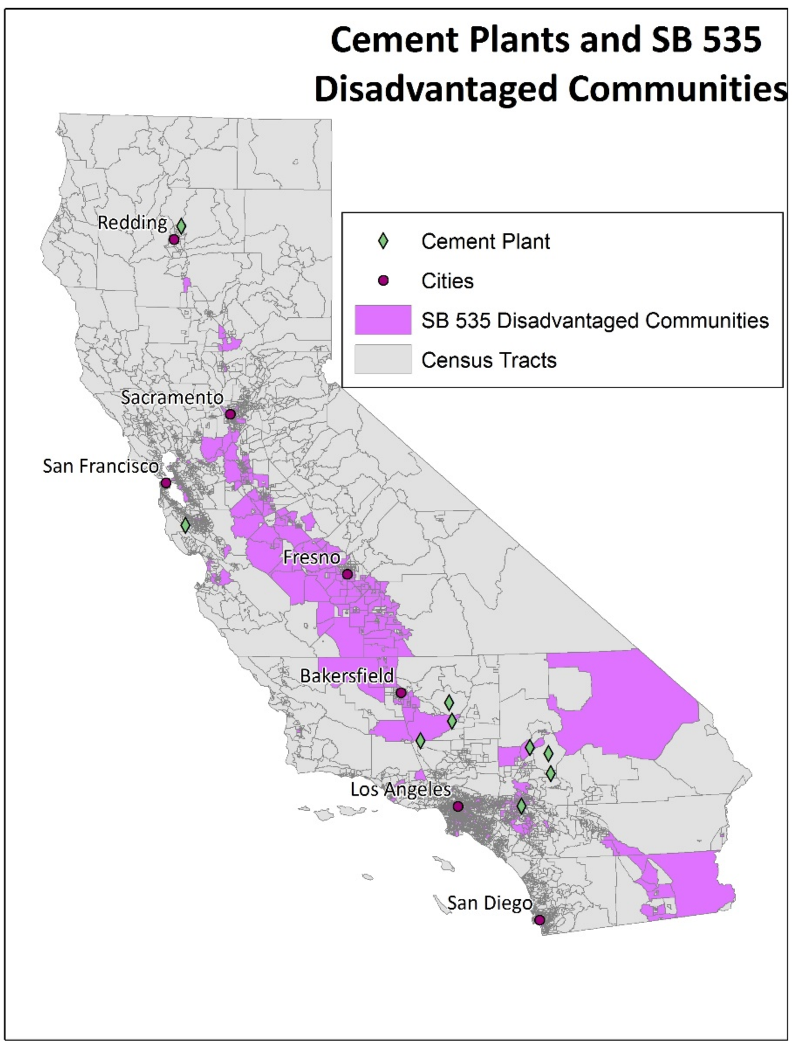
Cement manufacturing facilities were selected for a further analysis of the relationship between GHG emissions and emissions of toxic air contaminants. This sector was selected because (1) many of these facilities are among the highest scoring with respect to toxicity-weighted emissions to air (see Table 9) and (2) multi-year air toxics and criteria air pollutant emissions data are available from US EPA's Toxic Release Inventory (TRI) Program and ARB, respectively. While TRI data have not yet been broadly matched for each facility across all Cap-and-Trade facility sectors, TRI emissions data are available for the nine cement plants that are currently covered by the Cap-and-Trade Program. The nine facilities are listed in Table 12 below and shown on the map in Figure 6.

Table 12. California Cement Plants Evaluated for GHG and Air Toxics Emissions.

Facility Name	Approx. Location
*CalPortland Co Colton Plant**	Colton
CalPortland Co Mojave Plant	Mojave
Cemex Construction Materials Pacific LLC	Victorville
Lehigh Southwest Cement Co Cupertino	Cupertino
Lehigh Southwest Cement Co Redding	Redding
Lehigh Southwest Cement Co Tehachapi	Tehachapi
Mitsubishi Cement Corp	Lucerne Valley
National Cement Co Of California Inc	Lebec
Riverside Cement Oro Grande Plant	Oro Grande

*This facility ceased kilning operations in 2009; however, the plant retains grinding and distribution activities.

Figure 6. Location of Cement Plants Covered by the Cap-and-Trade Program.



The emissions data for these facilities were obtained for the years 2011-2014. GHG emissions were represented by those emissions that occurred locally and were covered by the Cap-and-Trade Program (emitter-covered emissions). TRI data obtained were toxicity-weighted emissions to air, as described above.[27] Since US EPA provides a calculated toxicity-weighted score for each facility, it was not necessary to adapt any of the chemical-specific scores, as was done for the data that originated from California's "Hot Spots" Program.[28] PM2.5 emissions data were obtained from ARB's CEIDARS (California Emission Inventory Development and Reporting System) data, which was downloaded from ARB's Integrated Emissions Visualization Tool.

Trends in emissions of both GHGs, air toxics, and PM2.5 are represented in Figure 7 below for each cement plant. One plant, CalPortland Colton, reported very low levels of GHGs and air toxics across all four years because it ceased kilning operations in 2009, though it continued to grind cement products. (This facility was excluded from the chart.) Across years within a given facility, there tended to be reasonable correlations in trends over time between GHG and toxicity-weighted emissions (for example, Cemex Construction Materials Pacific, Lehigh Southwest Cement Cupertino, Mitsubishi Cement, and Riverside Cement Oro Grande). Others showed poorer correlation (for example, CalPortland Mojave and National Cement). The pattern for National Cement is notable for a sudden increase in toxicity-weighted emissions in 2014. Further investigation of the specific chemical emissions data for this facility revealed that this increase was attributable to new reporting of chromium compound emissions in 2014, a departure from previous years. Since chromium emissions are generally consistently reported from cement plants, it is likely that the lack of chromium emissions for 2011-2013 is anomalous.

While year-over-year emissions at individual cement plants show some positive correlations, relative emissions of GHGs and toxicity-weighted air pollutants across facilities show fewer positive relationships. For example, Cemex Construction Materials Pacific had among the highest GHG emissions in this sector, while it was among the lower-scoring facilities for overall toxicity-weighted emissions, as reported to US EPA in their TRI program.

Although the observations from this specific industry are not directly applicable to other industries, this limited set of data suggests that year-over-year changes in GHGs within a facility are potentially meaningful in estimating changes in more toxic pollutants.

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[27] TRI data were obtained through the TRI.NET tool available at URL: https://www.epa.gov/toxics-release-inventory-tri-program/download-trinet.

[28] Toxicity-weighted emissions from TRI are not directly comparable to those calculated from California "Hot Spots" emissions data. These are different regulatory programs with different reporting requirements.

Figure 7. Cement Plants: Emitter Covered Emissions of GHGs (MTCO2e, MRR Data) (Top), Toxicity-Weight Air Emissions (TRI Data) (Middle) and PM2.5 Emissions (in tons, CEIDARS Data) (Bottom) over the Years 2011-2014.

Pearson and Spearman correlation coefficients were calculated using 2014 data on emissions of GHGs, air toxics, and PM2.5 and are shown in Table 13. The 2014 data used to calculate the correlations is shown graphically in Figure 7. GHG emissions and toxicity-weighted air emissions (TRI data) were not found to be correlated. A significant relationship (Spearman r $\cong$ 0.786, p-value = 0.0208) was observed between GHG emissions and PM2.5 emissions.

Table 13. Correlations for Emitter Covered Emissions of GHGs (MRR Data) vs. Toxicity-Weighted Air Emissions (TRI Data) or PM2.5 Emissions (CEIDARS Data) for Eight Cement Plants

GHG Emissions vs. --	No.	Pearson (r-value)	Stat. Sig. (p-value)	Spearman (r-value)	Stat. Sig. (p-value)
Toxicity-weighted air emissions	8	0.097	0.82	0.405	0.32
PM2.5	8	0.593	0.122	0.786	0.0208

*2014 Emissions Data; Shaded r-Values Represent Statistically Significant Results, $p<0.05$

Case Study: Refineries

Refineries represent another industrial sector covered by the Cap-and-Trade Program for which both GHG emissions and air toxics emissions data are available. Facilities from this sector were also identified as having among the highest toxicity-weighted emissions (see Table 9 above). Table 14 below lists 19 refineries reporting covered emissions in 2014. Most of these facilities are within one-half mile of an SB 535 disadvantaged census tract. Facilities have been grouped here by additional activities performed by the facilities that are relevant to GHG emissions, namely hydrogen production (generally for use by the refinery) and CO_2 production for off-site distribution.

Table 14. California Refineries Evaluated for GHG and Air Toxics Emissions. Shaded Rows Indicate Facilities within One-Half Mile of an SB 535 Disadvantaged Census Tract.

Facility Name	Approx. Location	Sectors*
Alon Bakersfield Refinery, Areas 1 & 2	Bakersfield	Refinery
Edgington Oil Company	Long Beach	Refinery
Kern Oil Refinery	Bakersfield	Refinery
Lunday-Thagard Company, DBA World Oil Refining	South Gate	Refinery
Paramount Petroleum Corporation Refinery	Paramount	Refinery
Phillips 66 Company, Santa Maria Refinery	Arroyo Grande	Refinery
Ultramar Inc, Valero Wilmington	Wilmington	Refinery
Phillips 66 Company, San Francisco Refinery	Rodeo	Refinery, H_2
San Joaquin Refining Company	Bakersfield	Refinery, H_2
Shell Oil Products US	Martinez	Refinery, H_2
Chevron Products Company	El Segundo	Refinery, H_2, CO_2
Chevron Products Company	Richmond	Refinery, H_2, CO_2
ExxonMobil Oil Corporation	Torrance	Refinery, H_2, CO_2
Phillips 66 Company, Los Angeles Refinery	Carson	Refinery, H_2, CO_2
Phillips 66 Company, Los Angeles Refinery	Wilmington	Refinery, H_2, CO_2
Tesoro Refining & Marketing Company LLC, Los Angeles Refinery	Carson	Refinery, H_2, CO_2
Tesoro Refining and Marketing Company	Martinez	Refinery, H_2, CO_2
Valero Refining Company, Refinery and Asphalt Plant	Benicia	Refinery, H_2, CO_2

* Refinery activities include production of hydrogen (H_2) on-site and production of CO_2 for distribution.

Figure 8. Location of Refineries Covered by the Cap-and-Trade Program.

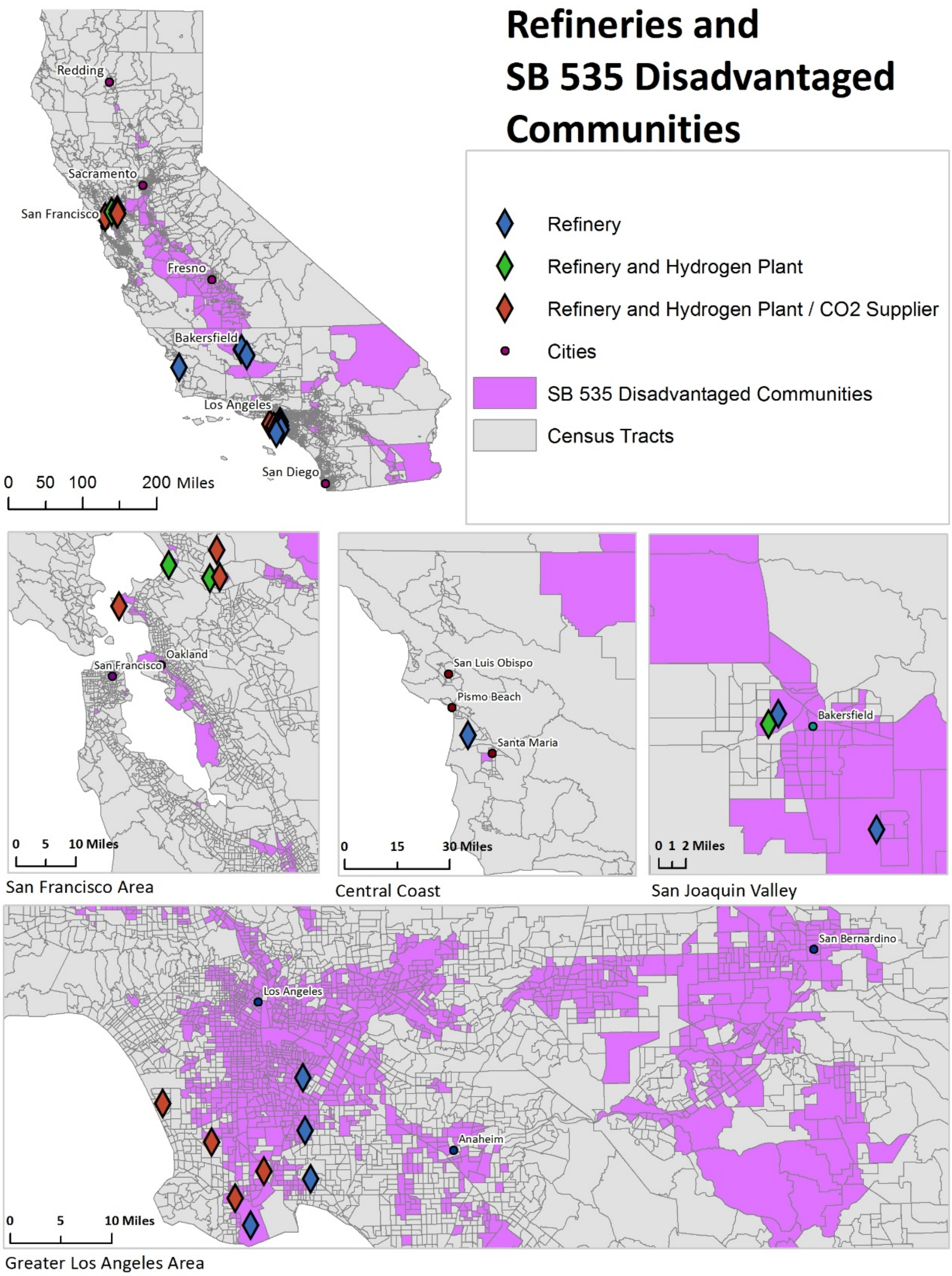
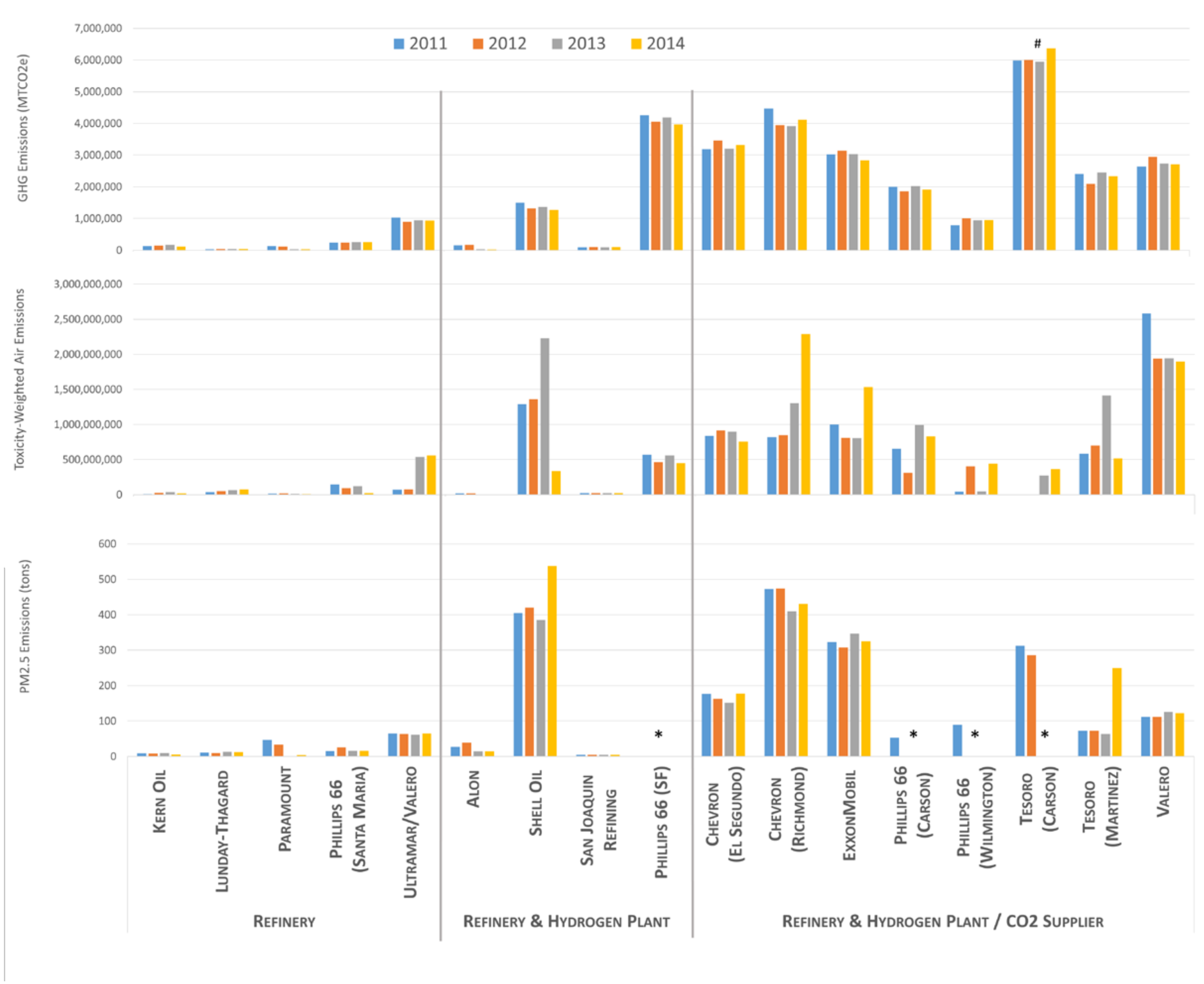


Figure 9. Refineries: Emitter Covered Emissions of GHGs (MRR Data) (Top), Toxicity-Weighted Air Emissions (TRI Data) (Middle), and PM2.5 Emissions (CEIDARS Data) (Bottom) for 18 Refineries Over the Years 2011-2014.



* Complete data (2011-2014) for PM2.5 emissions were not available for four facilities.

Emissions for three Tesoro refineries in Carson were combined in 2014 and are reported here as Tesoro (Carson). The emissions from the three facilities were added for the each of the 2011-2013 reporting years to produce the Tesoro (Carson) estimates.

Charts showing the trends in GHG, air toxics, and PM2.5 emissions over the years 2011-2014 are shown in Figure 8. Edgington Oil Company was omitted from the chart because emissions levels were negligible over this reporting period.

Correlations between covered GHG emissions and toxicity-weighted air emissions from refineries were positive and statistically significant using this US EPA data set for air toxics emissions (Pearson r-value = 0.56; p = 0.015; Spearman r-value 0.81, p<0.0001); the correlations increased with logarithmic transformation (Pearson r-value = 0.87, p<0.00001). Visual inspection of the overall patterns also suggests facilities with higher emissions of GHGs tend to have higher emissions of both toxicity-weighted emissions and PM2.5.

In certain cases, the emission levels across these types of facilities did not correlate well. For example, the Shell Oil refinery and hydrogen plant (Martinez) produced moderate GHG emissions, but it was one of the highest sources of PM2.5 emissions across all facilities. Similarly, the Valero refinery, hydrogen plant, and CO_2 distributor (Benicia) also produced modest levels of GHGs, but it had among the highest rates of toxicity-weighted air emissions. Differences in relative emissions may correspond, for example, to the types of products that are made at different facilities.

Table 15. Correlations for Emitter Covered Emissions of GHGs (MRR Data) vs. PM2.5 Emissions (CEIDARS Data) or Toxicity-Weighted Air Emissions (TRI Data) for Refineries*.

GHG Emissions vs. --	No.	Pearson (r-value)	Stat. Sig. (p-value)	Spearman (r-value)	Stat. Sig. (p-value)
Toxicity-weighted air emissions	18	0.563	0.0150	0.806	<0.0001
PM2.5	14	0.914	< 0.00001	0.916	< 0.00001

*2014 Emissions Data; Shaded r-Values Represent Statistically Significant Results, p<0.05

VIII Discussion & Conclusions

This initial analysis is intended to inform future investigation of potential benefits and impacts to disadvantaged communities from emissions of toxic air pollutants, especially to the extent they are influenced by the greenhouse gas limits put in place through activities pursuant to AB 32. However, there are not enough emissions data available at this time to allow for a comprehensive and conclusive analysis. This report makes some preliminary findings that OEHHA expects to build upon in future analyses as it acquires and evaluates more data, but does not provide definitive findings regarding the effects of the GHG limit on any individual community, or disadvantaged communities in general.

Still, at this point in time, the analysis shows that many SB 535 disadvantaged communities are likely to see benefits or impacts from changes in emissions from the facilities covered under the Cap-and-Trade Program. This is because a disproportionate number of these facilities are located in or very close to these communities, and 2014 data show that overall GHG emissions appear to be positively correlated with criteria air pollutants and toxic air contaminants, although within specific industrial sectors not all correlations are statistically significant. In addition, some of the most highly polluting of these facilities are more likely to be located in these communities.

The relationship between greenhouse gas and toxic air pollutant emissions is complex. Fuel combustion is a primary source of GHG emissions across many of the industrial sectors that are currently covered by the Cap-and-Trade Program. Fuel combustion is also likely to produce a number of toxic air pollutants. For this reason, responses by facilities to the Cap-and-Trade Program that result in reductions in fuel use or increases in fuel efficiency are likely to have benefits from reductions of toxic pollutants at similar levels of production. Toxic air pollutants from activities other than fuel combustion are likely to vary widely by industrial processes. Additional investigation is warranted to understand how industrial facilities will comply with the Cap-and-Trade Program's requirements over time and how this may affect the release of air toxics.

For calendar year 2014 data, there are positive correlations between GHG, PM2.5 and toxic air pollutant emissions. The correlation between GHG and toxic emissions is especially notable in this initial analysis for refineries, hydrogen plants, and cement plants, although the total number of facilities in each of these sectors is relatively small. Further analysis by industrial sector and by specific chemical pollutants may reveal additional important relationships.

Future Data Collection and Analysis

The key challenge in analyzing the benefits and impacts of climate-change programs on disadvantaged communities is acquiring adequate data. As discussed in this report, data on emissions of GHGs, criteria air pollutants and toxic air pollutants are collected by multiple entities under different programs and statutory mandates. To date, there is no co-reporting of GHG and toxic emissions, and differences in reporting requirements across regulatory programs can complicate data analysis. In addition, toxic emissions data for many facilities are only updated every four years, further limiting conclusions that can be reached. Co-reporting of criteria, air-toxic and GHG emissions for the facilities subject to the Cap-and-Trade Program would aid investigation of emissions impacts. OEHHA will continue to acquire and analyze data for future reports, which will build upon the initial findings presented in this report.

Also, the Cap-and-Trade Program is still new, making it difficult to discern trends in how the program over time may be affecting emissions of criteria air pollutants and toxic air contaminants. As the program continues to generate data over the next several years, it will be easier to detect and evaluate any such trends. It will also be important to evaluate the Cap-and-Trade Program in concert with other climate policies to evaluate the entire climate change program in aggregate.

In the near-term, OEHHA intends to obtain pre-2014 toxic air pollutant data to investigate how such data can be used to analyze impacts in SB 535 disadvantaged communities. OEHHA will also explore how Cap-and-Trade Program data may be helpful to understanding the drivers of changes in toxic pollutant emissions.

OEHHA also intends to further examine relationships between the emissions of GHGs and toxic air pollutants in specific industrial sectors in order to gain a better understanding of likely benefits or impacts that may result from changes in GHG emissions, even if air toxics emissions data are not available.

Lastly, OEHHA will explore opportunities to examine potential benefits and impacts in disadvantaged communities for other AB 32 programs outside of the Cap-and-Trade Program. OEHHA will work with ARB in developing analyses to support implementation of the Cap-and-Trade Adaptive Management Program to identify and track any emissions increases that could be attributable to the Cap-and-Trade Program.

Appendix A

California's Cap-and-Trade Program, Air Toxics "Hot Spots" Program, and US EPA's Toxic Release Inventory Program each has slightly different definitions of "facility". Some of these differences may have implications for how emissions data are reported such that there may not be an exact one-to-one relationship.

The following definitions of "facilities" are from different programs:

Cap-and-Trade Program

(144) (A) "Facility," unless otherwise specified in relation to natural gas distribution facilities and onshore petroleum and natural gas production facilities as defined in section 95802(a), means any physical property, plant, building, structure, source, or stationary equipment located on one or more contiguous or adjacent properties in actual physical contact or separated solely by a public roadway or other public right-of-way and under common ownership or common control, that emits or may emit any greenhouse gas. Operators of military installations may classify such installations as more than a single facility based on distinct and independent functional groupings within contiguous military properties.

(B) "Facility," with respect to natural gas distribution for the purposes of sections 95150 through 95158 of MRR, means the collection of all distribution pipelines and metering-regulating stations that are operated by a Local Distribution Company (LDC) within the State of California that is regulated as a separate operating company by a public utility commission or that are operated as an independent municipally-owned distribution system.

(C) "Facility," with respect to onshore petroleum and natural gas production for the purposes of sections 95150 through 95158 of MRR, means all petroleum and natural gas equipment on a well-pad, or associated with a well pad or to which emulsion is transferred and CO_2 EOR operations that are under common ownership or common control including leased, rented, or contracted activities by an onshore petroleum and natural gas production owner or operator and that are located in a single hydrocarbon basin as defined in section 95102(a) of MRR.

When a commonly owned cogeneration plant is within the basin, the cogeneration plant is only considered part of the onshore petroleum and natural gas production facility if the onshore petroleum and natural gas production facility operator or owner has a greater than fifty percent ownership share in the cogeneration plant. Where a person or entity owns or operates more than one well in a basin, then all onshore petroleum and natural gas production equipment associated with all wells that the person or entity owns or operates in the basin would be considered one facility.

Air Toxics 'Hot Spots' Program

Health and Safety Code, Section 44304 defines facility as "every structure, appurtenance, installation, and improvement on land which is associated with a source of air releases or potential air releases of a hazardous material." The Guidelines further state that: "[e]xcept for the oil production operations defined in section X.14(b), for purposes of this regulation, the phrase "every structure, appurtenance, installation" shall mean all equipment, buildings, and other stationary items, or aggregations thereof, (A) which are associated with a source of air emission or potential air emission of a listed substance; (B) which involve activities that belong to the same two-digit Standard Industrial Classification code, or are part of a common operation; (C) which are located on a single site or on contiguous or adjacent sites; and (D) which are under common ownership, operation, or control, or which are owned or operated by entities which are under common ownership, operation, or control."

US EPA Toxic Release Inventory Program

Facility definition: "An entire facility means all buildings, equipment, structures, and other stationary items which are located on a single site or on contiguous or adjacent sites and which are owned or operated by the same person (or by any person which controls, is controlled by, or under common control with such person). A facility may contain more than one establishment."

Table A1. Pearson (P) & Spearman (S) Correlation Coefficient R-Values for Criteria Air Pollutants and GHGs by Industrial Sector. Shaded Boxes Indicate Statistically Significant Correlations.

	Cement Plants		Cogeneration		Hydrogen Plants		Electricity Generation		Oil & Gas Production		Refineries		Other Combustion	
	P	S	P	S	P	S	P	S	P	S	P	S	P	S
CO	0.094	0.050	-0.031	0.197	-0.072	0.464	0.262	0.465	0.519	0.073	0.802	0.918	0.318	0.186
NOx	0.877	0.883	0.128	0.363	0.612	0.786	0.472	0.728	-0.026	0.122	0.913	0.921	0.884	0.306
SOx	0.193	0.467	0.211	0.484	0.574	0.771	0.487	0.651	0.265	0.361	0.675	0.797	0.202	0.544
PM	0.785	0.867	0.025	0.220	0.538	0.500	0.699	0.648	0.259	0.184	0.883	0.906	0.414	0.442
PM10	0.748	0.833	0.095	0.294	0.574	0.679	0.711	0.655	0.260	0.190	0.898	0.944	0.509	0.499
PM2.5	0.645	0.817	0.137	0.377	0.608	0.786	0.713	0.663	0.261	0.189	0.908	0.944	0.616	0.598
ROG	0.604	0.467	0.267	0.108	0.547	0.643	0.441	0.439	0.155	0.207	0.833	0.965	-0.003	0.043
TOG	0.525	0.467	0.331	0.148	0.799	0.821	0.556	0.660	0.255	0.271	0.892	0.959	0.075	0.141
VOCs	0.698	0.667	0.267	0.152	0.765	0.714	0.505	0.480	0.155	0.207	0.845	0.956	0.006	0.044