



A PRELIMINARY ENVIRONMENTAL EQUITY ASSESSMENT OF CALIFORNIA'S CAP-AND-TRADE PROGRAM

By Lara J. Cushing^{1,5} Madeline Wander⁴ Rachel Morello-Frosch^{1,2}
Manuel Pastor⁴ Allen Zhu³ James Sadd⁶

University of California, Berkeley

¹ Department of Environmental Science, Policy, and Management

² School of Public Health

³ School of Engineering

⁴ University of Southern California, Program for Environmental and Regional Equity (PERE)

⁵ San Francisco State University, Department of Health Education

⁶ Occidental College, Department of Geology

USC
Dornsife
*Program for
Environmental and
Regional Equity*



OVERVIEW

California's cap-and-trade program is a key strategy for achieving reductions in greenhouse gas (GHG) emissions under AB32, the California Global Warming Solutions Act. For residents living near large industrial facilities, AB32 offered the possibility that along with reductions in GHGs, emissions of other harmful pollutants would also be decreased in their neighborhoods. Carbon dioxide (CO₂), the primary GHG, indirectly impacts health by causing climate change but is not directly harmful to health in the communities where it is emitted. However, GHG emissions are usually accompanied by releases of other pollutants such as particulate matter (PM₁₀) and air toxics that can directly harm the health of nearby residents.

In this brief, we assess inequalities in the location of GHG-emitting facilities and in the amount of GHGs and PM₁₀ emitted by facilities regulated under cap-and-trade. We also provide a preliminary evaluation of changes in localized GHG emissions from large point sources since the advent of the program in 2013. To do this, we combined pollutant emissions data from California's mandatory GHG and criteria pollutant reporting systems,^{1,2} data on neighborhood demographics from the American Community Survey, cumulative environmental health impacts from the California Environmental Protection Agency's CalEnviroScreen tool, and information from the California Air Resources Board (CARB) about how regulated companies fulfilled their obligations under the first compliance period (2013-14) of the cap-and-trade program. Our methodology is described in greater detail in the appendix to this report.

In this analysis, we focus primarily on what are called "emitter covered emissions," which correspond to localized, in-state emissions (derived mostly from fossil fuels) from industries that are subject to regulation under cap-and-trade. The cap-and-trade program also regulates out-of-state emissions associated with electricity imported into the state and, beginning in 2015, began regulating distributed emissions that result from the burning of fuels such as gasoline and natural gas in off-site locations (e.g., in the engines of vehicles and in homes).

We found that regulated GHG-emitting facilities are located in neighborhoods with higher proportions of residents of color and residents living in poverty. In addition, facilities that emit the highest levels of both GHGs and PM₁₀ are also more likely to be located in communities with higher proportions of residents of color and residents living in poverty. This suggests that the public health and environmental equity co-benefits of California's cap-and-trade program could be enhanced if there were more emissions reductions among the larger emitting facilities that are located in disadvantaged communities. In terms of GHG emission trends, in-state emissions have increased on average for several industry sectors since the advent of the cap-and-trade program, with many high emitting companies using offset projects located outside of California to meet their compliance obligations. Enhanced data collection and availability can strengthen efforts to track future changes in GHG and co-pollutant emissions and inform decision making in ways that incentivize deeper in-state reductions in GHGs and better maximize public health benefits and environmental equity goals.

FINDINGS

1. Facilities that emit localized GHGs are located in more disadvantaged communities.

On average, neighborhoods with a facility that emitted localized GHGs within 2.5 miles³ have a 22 percent higher proportion of residents of color and 21 percent higher proportion of residents living in poverty than neighborhoods that are not within 2.5 miles of such a facility. Neighborhoods within 2.5 miles of a facility are also more than twice as likely to be among the worst statewide in terms of their CalEnviroScreen score, a relative ranking of cumulative impact based on indicators of social and environmental stressors to health (Table 1⁴).

TABLE 1
Characteristics of Neighborhoods within 2.5 miles of GHG-emitting Facilities
(N=255 facilities)

	Block groups with at least one facility within 2.5 miles (N=6,397)	Block groups with no facilities within 2.5 miles (N=16,705)
Mean % People of Color	66%	54%
Mean % People Living Below Twice the Poverty Level	41%	34%
% of Block Groups in a “Top 10%” CalEnviroScreen tract	17%	7%
% of Block Groups in a “Top 20%” CalEnviroScreen tract	31%	15%

2. Many of California’s residential communities are within 2.5 miles of more than one GHG-emitting facility (Figure 1⁵).

These communities are home to a higher proportion of residents of color and people living in poverty than communities with no or few facilities nearby. Indeed, the higher the number of proximate facilities, the larger the share of low-income residents and residents of color (Figure 2).

FIGURE 1

Residential Proximity to Facilities Reporting Emitter Covered GHG Emissions during the 2013-14 Compliance Period (N=321 facilities)

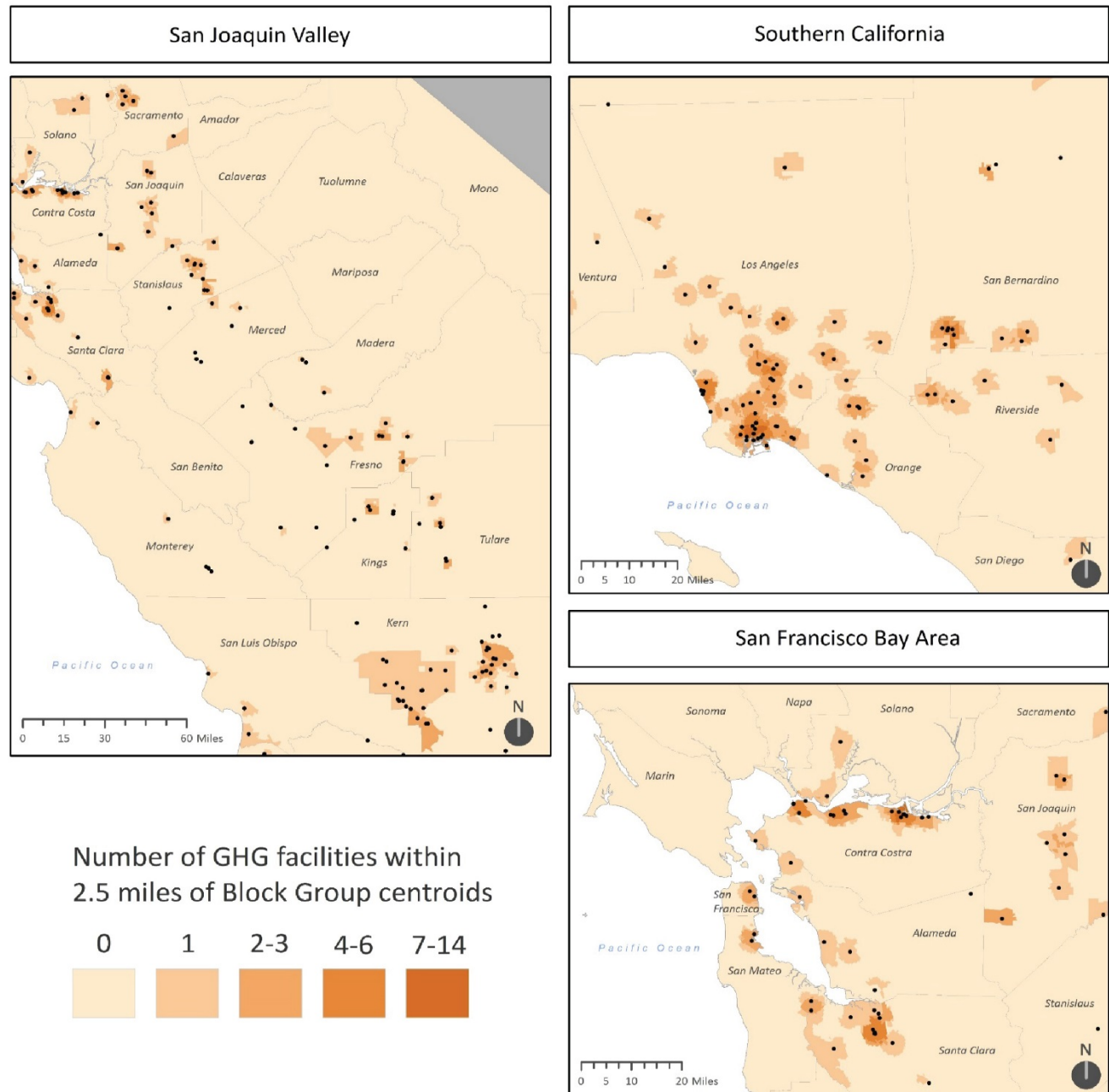
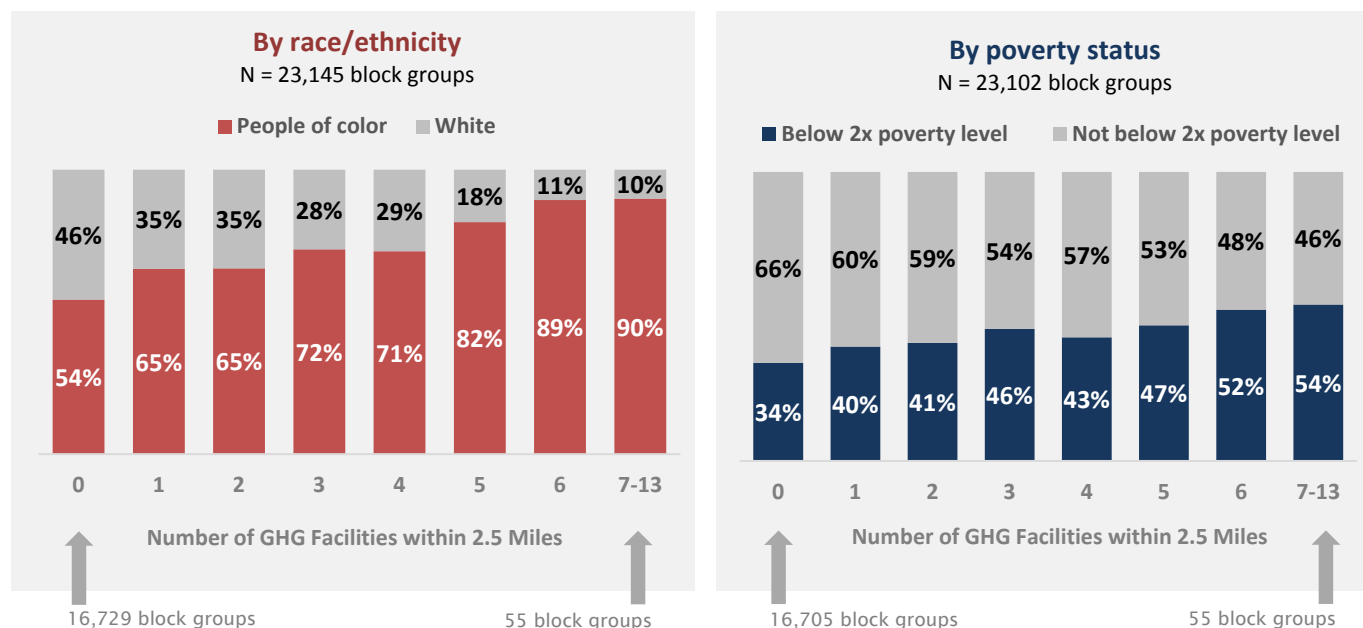


FIGURE 2
Demographics in Block Groups near GHG-emitting Facilities (N=255 facilities)

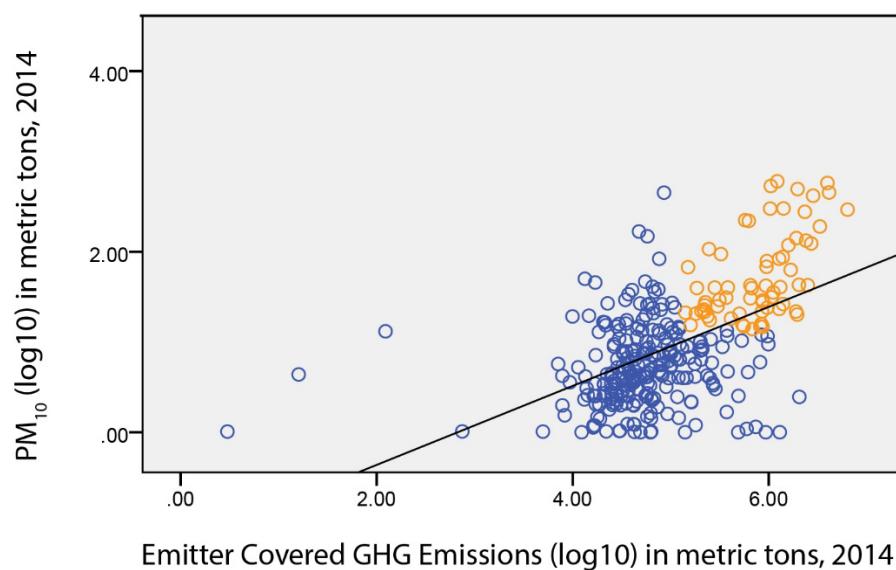


3. While GHG emissions do not generally have direct health impacts, co-pollutants such as particulate matter (PM_{10}) do. Such emissions are correlated (Figure 3⁶), with large GHG emitters reporting that they emit more particulate matter. The largest emitters of both GHGs and PM_{10} also tend to be located near neighborhoods with higher proportions of disadvantaged residents (Table 2⁷).

The neighborhoods within 2.5 miles of the 66 largest GHG and PM_{10} emitters (defined as the top third in emissions of both PM_{10} and GHGs and highlighted in orange in **Figure 3**) have a 16 percent higher proportion of residents of color and 11 percent higher proportion of residents living in poverty than neighborhoods that are not within 2.5 miles of such a facility (**Table 2**). Compared to other parts of the state, nearly twice as many neighborhoods within 2.5 miles of these highest-emitting facilities are also among the worst statewide in terms of their CalEnviroScreen score. We also found that 40 (61 percent) of these high-emitting facilities reported increases in their localized GHG emissions in 2013-14 relative to 2011-12, versus 51 percent of facilities overall. Neighborhoods near the top-emitting facilities that increased emissions had higher proportions of people of color than neighborhoods near top-emitting facilities that decreased their emissions (**Table 6** in the Appendix).

FIGURE 3

Correlation between Emitter Covered GHG Emissions and Particulate Matter (N=317 facilities)

**TABLE 2**Characteristics of Neighborhoods within 2.5 miles of the top GHG- and PM₁₀- Emitting Facilities (N=66 facilities)

	Block groups within 2.5 miles of the largest GHG and PM ₁₀ emitters (N=1,290)	All other block groups (N=21,812)
Mean % People of Color	66%	57%
Mean % People Living Below Twice the Poverty Level	40%	36%
% of Block Groups in a "Top 10%" CalEnviroScreen tract	18%	9%
% of Block Groups in a "Top 20%" CalEnviroScreen tract	35%	19%

4. While overall, GHG emissions in California have continued to drop from a peak in 2001, we find that, on average, many industry sectors covered under cap-and-trade report increases in localized in-state GHG emissions since the program came into effect in 2013.⁸

Only a portion of the state's total GHG emissions are regulated under the cap-and-trade system. For example, the industrial and electrical sectors accounted for about 41 percent of the state's estimated total GHGs emissions in 2014.⁹ (The remainder originated from sectors such as transportation, commercial and residential buildings, and agriculture.) As a result, overall emissions and emissions regulated under cap-and-trade can exhibit slightly different patterns. Moreover, not all emissions regulated under the cap-and-trade program occur in-state. For example, according to CARB's 2016 Edition of the California GHG Emission Inventory, emissions from electrical power decreased by 1.6 percent between 2013 and 2014. However, when these emissions are disaggregated, we see that it is the emissions associated with *imported* electricity that decreased, while emissions from *in-state* electrical power generation actually increased.⁸

Figure 4 shows the distribution of the change in localized GHG emissions regulated under cap-and-trade for two time periods: the two years prior and the two years after the program came into effect. We present the range in emissions changes reported by individual facilities within seven industry sectors for 2013-14 versus 2011-12; this includes the median (50th percentile), mean (average), and 10th to 90th percentile of changes in emitter covered emissions for 314 GHG facilities. For example, six of the nine cement plants included in **Figure 4** reported increases in emissions during 2013-14 relative to 2011-12. The median value corresponds to the 143,295-ton increase reported by the cement plant in the middle of the distribution (5th highest emitting facility out of the nine total). Similarly, the 25th and 75th percentiles correspond to the increases reported by the 3rd and 7th highest emitting facilities. The facilities with the minimum and maximum emissions changes are not shown in this graph to make it more legible; for example, the Cemex Victorville cement plant reported an increase of over 843,000 tons, an amount that far exceeds the range portrayed in **Figure 4**.

FIGURE 4
Change in Emitter Covered GHG Emissions by Industry Sector (N=314 facilities)

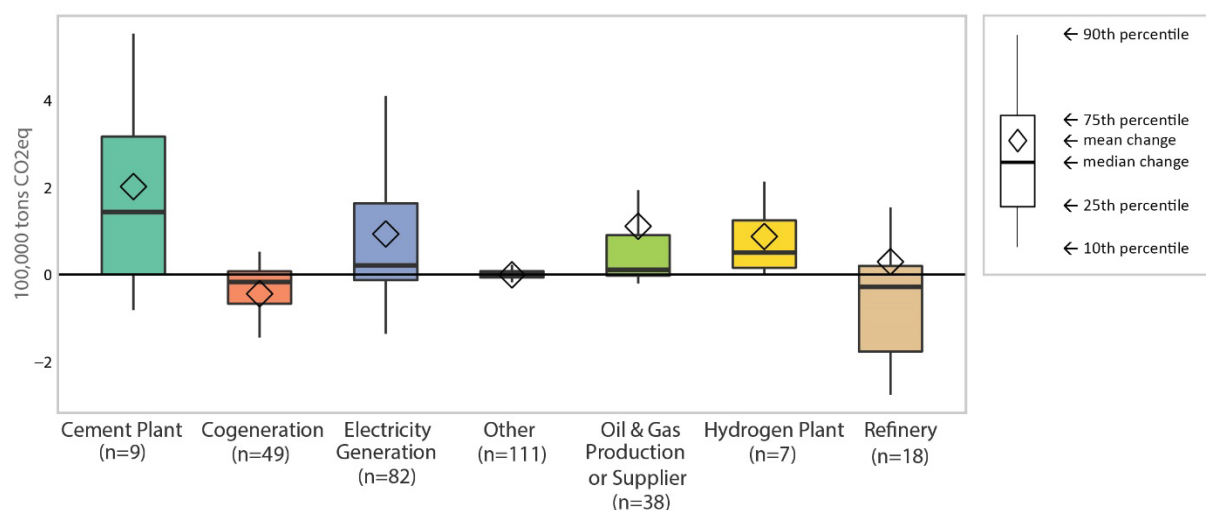
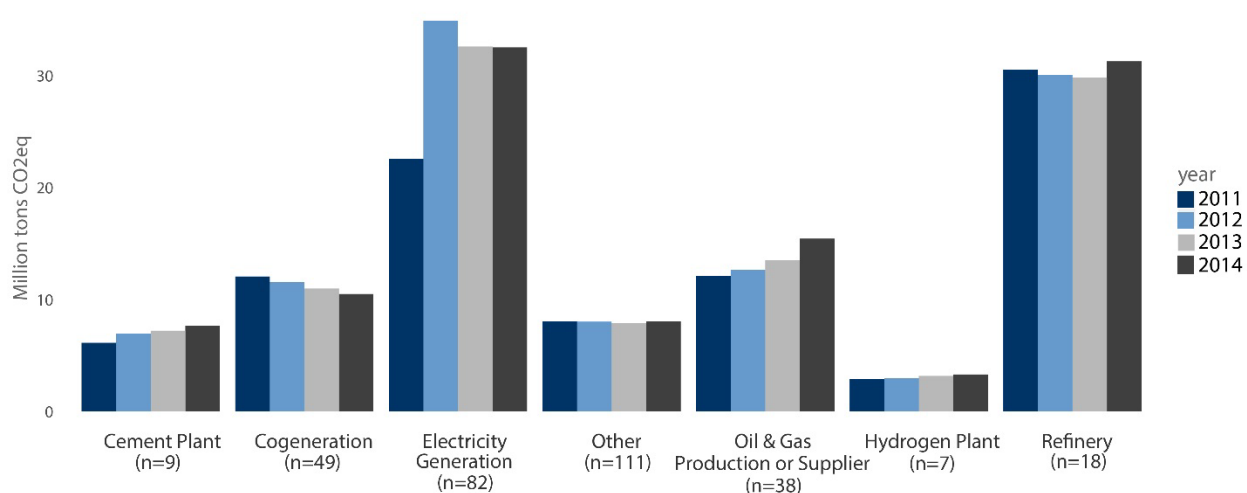


Figure 5 shows temporal trends in total emitter covered emissions (the sum of emissions from all individual facilities) by industry sector for 2011-2014. The number of facilities can change from year to year due to shutdowns, startups, and changes in emissions that affect whether facilities are required to report GHG emissions to CARB. In both **Figure 4** and **Figure 5**, we included only those facilities that: 1) report to the inventory every year during the four-year period, and 2) report at least some emitter covered emissions during those same four years. Again, the upward trend in several sectors is notable.

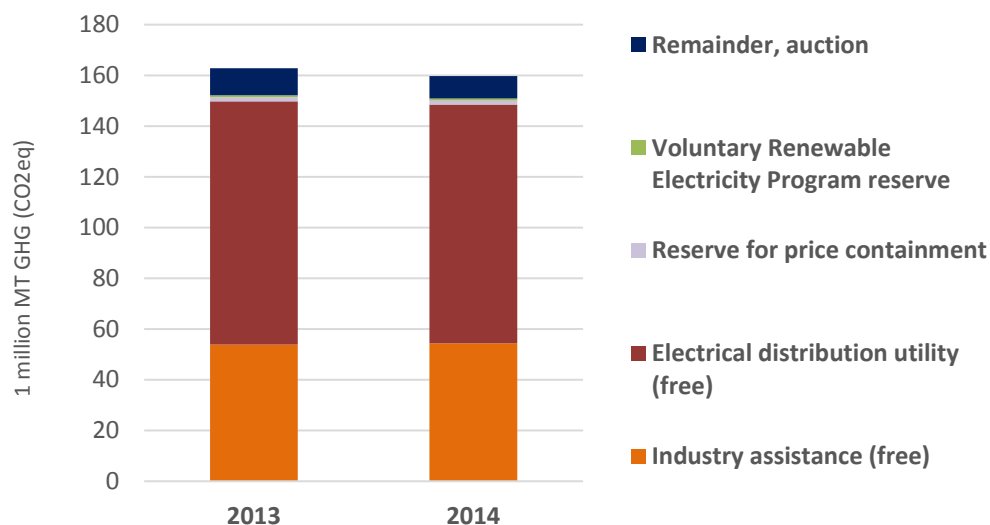
FIGURE 5
Temporal Changes in Total Emitter Covered GHG Emissions by Industry Sector



5. Between 2013 and 2014, more emissions “offset” credits were used than the total reduction in allowable GHG emissions (the “cap”). These offsets were primarily linked to projects outside of California, and large emitters of GHGs were more likely to use offset credits to meet their obligations under cap-and-trade.

The cap-and-trade program requires regulated companies to surrender one compliance instrument—in the form of an allowance or offset credit—for every ton of qualifying GHGs they emit during each compliance period. These instruments are bought and sold on the carbon market. The total number of allowances is set by the “cap,” which decreases by roughly 3 percent per year in order to meet GHG reduction targets. In 2013 and 2014, most allowances were given to companies for free for leakage prevention, for transition assistance, and on behalf of ratepayers (**Figure 6**). Additional offset credits were generated from projects that ostensibly reduce GHGs in ways that may cost less than making changes at a regulated facility.

FIGURE 6
Allocation of Allowances



Regulated companies are allowed to “pay” for up to 8 percent of their GHG emissions using such offset credits. The majority of the offset credits (76 percent) used to date were generated by out-of-state projects (**Figure 7**). **Figure 8** shows that most offset credits were generated from projects related to forestry (46 percent)¹⁰ and the destruction of ozone-depleting substances (46 percent). Furthermore, over 15 percent of offset credits used during the first compliance period were generated by projects undertaken before final regulations for the cap-and-trade program were issued in 2011, calling into question whether these GHG reductions can be attributed to California’s program, or whether they might have happened anyway.

FIGURE 7
Origin of Offset Credits

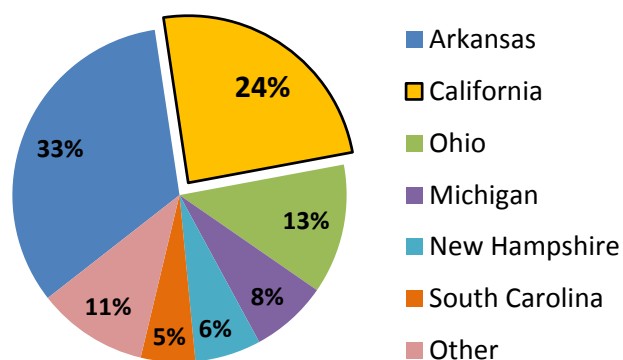
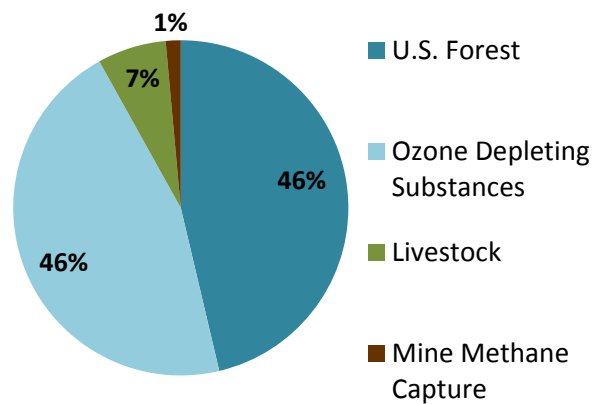


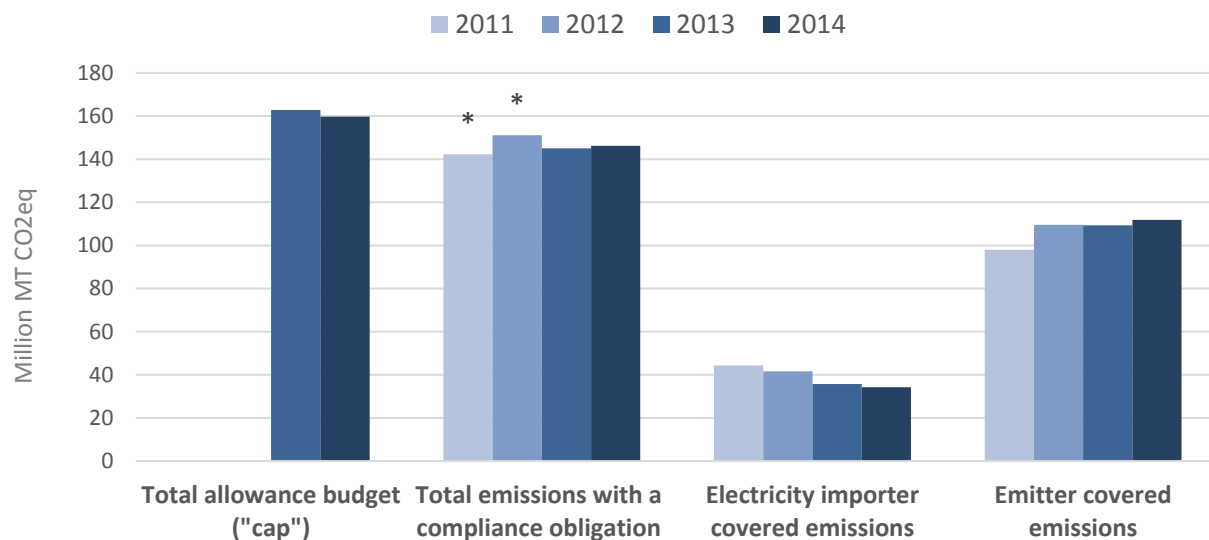
FIGURE 8
Offset Credits by Project Type



During the first compliance period of 2013-14, the total emissions that were subject to a compliance obligation (the second set of columns in **Figure 9**) were lower than the cap set by the allowance budget (left-most set of columns in **Figure 9**). This total includes both the emitter covered emissions that have been the focus of our analysis so far (right-most set of columns in **Figure 9**) and out-of-state emissions associated with imported electricity (which went down every year during the four-year period as shown by the third set of columns in **Figure 9**). Offset credits worth more than 12 million tons of CO_{2eq} were utilized to meet these obligations. These offsets represent 4.4 percent of the total compliance obligation of all regulated companies and over four times the targeted reduction in GHG emissions from 2013 to 2014 as established by the cap (**Figure 10**).

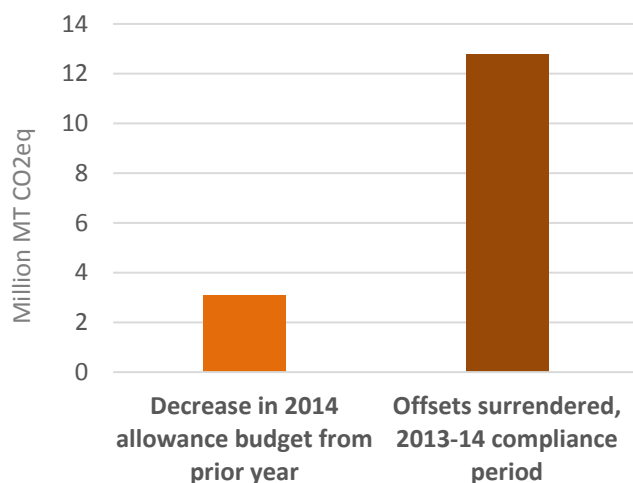
We found that the majority of companies did not use offset credits to meet their compliance obligation; however, those companies that *did* use offsets tended to have larger quantities of GHG emissions. The top 10 users of offsets account for 36 percent of the total covered emissions and 65 percent of the offsets used. These top offset users included Chevron (1.66 million offsets), Calpine Energy Services (1.55 million offsets), Tesoro (1.39 million offsets), SoCal Edison (1.04 million offsets), Shell (0.62 million offsets), PG&E (0.44 million offsets), Valero (0.43 million offsets), La Paloma Generating Company (0.40 million offsets), San Diego Gas & Electric (0.39 million offsets), and NRG Power (0.33 million offsets).

FIGURE 9
Total GHG Budget



* Only emissions during 2013 and 2014 were subject to a compliance obligation. Estimates of comparable emissions during 2011 and 2012 were derived by summing the "emitter covered" and "electricity importer covered" emissions reported by regulated facilities for those years.

FIGURE 10
Offset Credits vs. Decrease in Allowance Cap



CONCLUSIONS

California's efforts to slow climate change by reducing GHG emissions can bring about additional significant co-benefits to health, particularly in disadvantaged communities. Preliminary analysis of the equity implications of California's cap-and-trade program indicates that regulated GHG-emitting facilities tend to be located in neighborhoods with higher proportions of residents of color and residents living in poverty. There is a correlation between emissions of GHGs and PM₁₀, and facilities that emit the highest levels of both GHGs and PM₁₀ are similarly more likely to be located in communities with higher proportions of residents of color and residents living in poverty. This suggests that the public health and environmental equity co-benefits of California's cap-and-trade program could be enhanced if there were more emissions reductions among the larger emitting facilities that are located in disadvantaged communities.

Currently, there is little in the design of cap-and-trade to ensure this set of localized results. Indeed, while the cap-and-trade program has been in effect for a relatively short time period, preliminary evidence suggests that in-state GHG emissions from regulated companies have increased on average for several industry sectors and that many emissions reductions associated with the program were linked to offset projects located outside of California. Large GHG emitters that might be of most public health concern were the most likely to use offset projects to meet their obligations under the cap-and-trade program.

Further research is needed before firm policy conclusions can be drawn from this preliminary analysis. As regulated industries adapt to future reductions in the emissions cap, California is likely to see more reductions in localized GHG and co-pollutant emissions. Thus far, the state has achieved overall emissions reductions in large part by using offsets and replacing more GHG-intensive imported electricity with cleaner, in-state generation. Steeper in-state GHG reductions can be expected going forward if the use of offsets were to be restricted and the opportunity to reduce emissions by replacing imported electricity with in-state generation becomes exhausted.

However, ongoing evaluation of temporal and spatial trends in emissions reductions will be critical to assessing the impact of the cap-and-trade program. Several recommendations would strengthen future analyses and facilitate better tracking of the public health and environmental equity aspects of the cap-and-trade program going forward.

These include:

- Building better linkages between state facility-level databases on GHG and co-pollutant emissions. To conduct this preliminary analysis, we had to do a series of matches between datasets with different facility ID codes (see Appendix for details). Harmonization of facility ID codes between relevant data sources could be built into facility emissions reporting requirements going forward in order to facilitate analysis of temporal and spatial GHG and co-pollutant emissions trends.
- Publicly releasing data on facility- and company-specific allowance allocations.
- Tracking and making data available on facility- and company-specific allowance trading patterns.

Good quality, publicly accessible data and robust analysis will be critical to informing policy discussions and improving regulatory implementation of California's climate law in ways that incentivize deeper in-state GHG reductions and that achieve both sustainability and environmental equity goals.

ACKNOWLEDGEMENTS

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APPENDIX

This appendix includes a description of the methods used in our preliminary environmental equity assessment of California's cap-and-trade program. We also present supplemental analyses, including a comparison of neighborhood demographics near regulated GHG facilities using different buffer distances to define proximity.

Methods

GREENHOUSE GAS EMISSIONS

To start, we downloaded annual, facility-specific GHG emissions data for 2011-2014 from the Mandatory Reporting of Greenhouse Gas Emissions (MRR) program.¹ The MRR includes self-reported estimates of annual emissions of greenhouse gases (GHGs)—carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and fluorinated GHGs—from regulated industries that have been verified by an independent third party. Emissions are given in units of CO₂-equivalents, a metric that combines the quantity of individual gases emitted with the potency of each gas in terms of its contribution to climate change over a 100-year time frame (also known as “global warming potential”). Our analysis focused on one class of emissions included in this database called “emitter covered emissions,” which corresponds to localized, in-state emissions resulting from “the combustion of fossil fuels, chemical and physical processes, vented emissions...and emissions from suppliers of carbon dioxide”¹¹ as well as emissions of GHGs other than CO₂ from biogenic fuel combustion. The term “covered” refers to the fact that these emissions are subject to a compliance obligation under the cap-and-trade program; releases of CO₂ that result from the combustion of biogenic fuels, for example, are exempted. The cap-and-trade program also regulates out-of-state emissions associated with electricity imported into the state and, beginning in 2015, began regulating distributed emissions that result from the burning of fuels such as gasoline and natural gas in off-site locations (e.g., in the engines of vehicles and in homes); although we did not analyze distributed emissions in this report, this category of emissions will be a future research topic.

The number of facilities reporting to the MRR can change from year to year due to shutdowns, startups, and changes in emissions that affect whether facilities are required to report. In our analysis of trends in emissions across industry sectors, we excluded facilities that did not report to the emissions inventory every year during 2011-14, as well as facilities that reported no emitter covered emissions during the four-year period. Facilities were categorized according to the sector reported in the MRR with slight modifications to reduce the number of categories. Facilities described as a refinery alone or in combination with any of the following were categorized as a refinery: hydrogen plant, CO₂ supplier, or transportation fuel supplier. Facilities described as “other combustion source” or “other combustion source/ CO₂ supplier” were categorized as “other.”

We determined or confirmed the geographic location of each facility using a variety of data sources and methods. Geographic point locations for some facilities were obtained directly from the California Air Resources Board (CARB), and facility addresses reported in CARB's online GHG visualization tool were geocoded.¹² We located some sites using individual internet searches. All locations inside California were visually confirmed, and point locations were adjusted for accuracy using aerial imagery in Google Earth Pro.

CO-POLLUTANT DATA (PM₁₀)

We obtained emissions of criteria air pollutants from the California Emission Inventory Development and Reporting Systems (CEIDARS) database for years 2011-14.² Reporting requirements, including the way in which facilities are defined, the numeric identifier attached to each facility, and the frequency of reporting, differ between CEIDARS and the MRR GHG database. This presents a challenge for combining emissions estimates from the two sources. In particular, criteria air pollutants are not required to be reported annually, and emissions estimates contained in the 2014 CEIDARS database may correspond to estimates from prior years. We joined data on PM₁₀ emissions from the 2014 CEIDARS with GHG emissions information from the MRR GHG database based on the facility name, city, and ZIP code. For some GHG facilities listed in the MRR GHG database, we obtained addresses from CARB's Facility GHG Emissions Visualization and Analysis Tool.¹² Since the CEIDARS database also contains addresses, we were able to use the address field to confirm and find additional matches. When all variables (facility name, city, and ZIP code) did not match between the two data sources, matches were confirmed by hand through internet searches of company websites and online databases containing facility names and addresses.

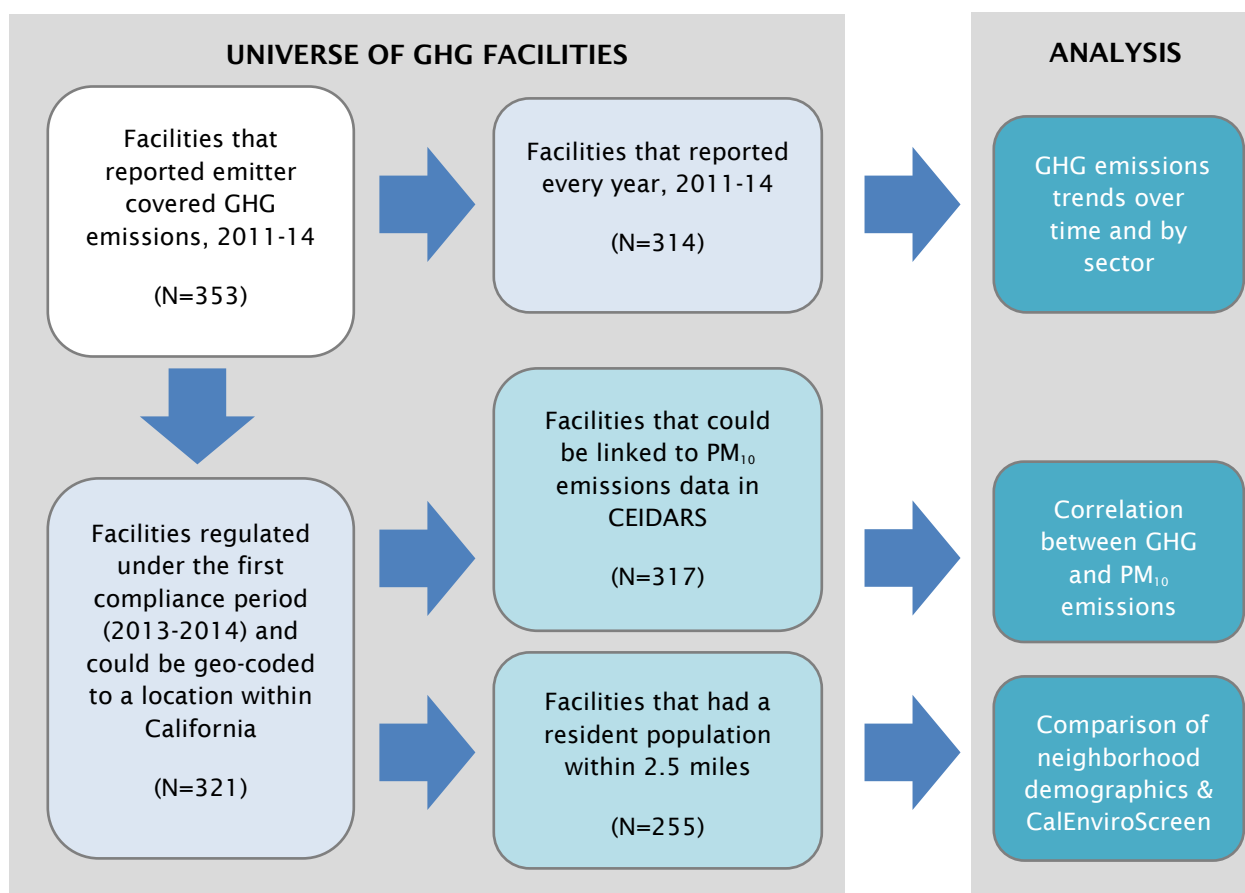
NEIGHBORHOOD DEMOGRAPHICS AND CUMULATIVE IMPACT

We defined neighborhoods on the basis of 2010 vintage Census block group boundaries provided by the U.S. Census.¹³ Block group centroids were created by using the point-to-polygon tool in ArcGIS and the distance between block group centroids and GHG facility locations was calculated using the point-distance tool in ArcGIS (ESRI, Redlands, CA).

Demographic information for each block group was obtained from the 2014 5-year American Community Survey estimates. White individuals were defined as those who self-identified as white but not Hispanic. People of color were defined as all other individuals, including those who identified as multiracial or of Hispanic ethnicity. Poverty was defined as twice the federal poverty level (FPL) to reflect increases in the cost of living since the FPL was established and California's high cost of living.

CalEnviroScreen is a state-level screening tool developed by the California Environmental Protection Agency that helps identify California communities that are disproportionately burdened by multiple sources of pollution.¹⁴ It includes indicators of proximity to environmental hazards and population vulnerability to derive a relative score of cumulative environmental health impact. We assigned block groups the most recent CalEnviroScreen score of their census tract in order to compare CalEnviroScreen rankings near GHG facilities to the rest of the state. **Figure 11** summarizes the construction of our facility-level dataset.

FIGURE 11 – Construction of the Dataset



ALLOWANCES AND OFFSETS

Unlike the emissions data, information on the allocation of allowances and ways in which regulated industries are complying with the cap-and-trade program is reported on an industry- and company-specific basis, rather than at the facility level. One company may own several regulated facilities. Information on the allocation of allowances was compiled from the California Code of Regulations (17 CA ADC § 95841 and 17 CCR § 95870) and CARB publications on the public allocation of allowances and estimates of state-owned allowances.¹⁵ We obtained the number of allowances and offsets surrendered by each company at the completion of the first compliance period from CARB's 2013-14 Compliance Report.¹⁶ Information on individual offset projects was compiled from CARB documents on offsets issued as of August 10, 2016¹⁷ and individual project descriptions provided in the American Carbon Registry and Climate Action Reserve carbon offset registries.¹⁸

Supplemental Analyses

Consistent with the findings presented in **Table 1** in the main text, **Table 3** shows that neighborhoods within 1.5 miles of a facility with localized GHG emissions have a 16 percent higher proportion of residents of color, a 26 percent higher proportion of residents living in poverty, and a higher likelihood of scoring among the worst statewide in terms of their CalEnviroScreen score than neighborhoods that are not within 1.5 miles of such a facility. **Table 4** and **Table 5** show similar trends when neighborhoods up to a larger distance of 3.5 and 6 miles away are considered. These results confirm that the findings presented in our main analysis were not sensitive to our choice of buffer distance.

TABLE 3
Characteristics of Neighborhoods within 1.5 miles of GHG-emitting Facilities
(N=255 facilities)

	Block groups with at least one facility within 1.5 miles (N=2,710)	Block groups with no facilities within 1.5 miles (N=20,392)
Mean % People of Color	66%	57%
Mean % People Living Below Twice the Poverty Level	44%	35%
% of Block Groups in a “Top 10%” CalEnviroScreen tract	20%	9%
% of Block Groups in a “Top 20%” CalEnviroScreen tract	36%	18%

TABLE 4
Characteristics of Neighborhoods within 3.5 miles of GHG-emitting Facilities
(N=255 facilities)

	Block groups with at least one facility within 3.5 miles (N=9,991)	Block groups with no facilities within 3.5 miles (N=13,111)
Mean % People of Color	66%	51%
Mean % People Living Below Twice the Poverty Level	39%	33%
% of Block Groups in a “Top 10%” CalEnviroScreen tract	15%	6%
% of Block Groups in a “Top 20%” CalEnviroScreen tract	29%	13%

TABLE 5

Characteristics of Neighborhoods within 6 miles of GHG-emitting Facilities
(N=255 facilities)

	Block groups with at least one facility within 6 miles (N=16,365)	Block groups with no facilities within 6 miles (N=6,737)
Mean % People of Color	65%	41%
Mean % People Living Below Twice the Poverty Level	37%	32%
% of Block Groups in a “Top 10%” CalEnviroScreen tract	13%	3%
% of Block Groups in a “Top 20%” CalEnviroScreen tract	25%	7%

In the main text, we defined the 66 largest GHG and PM₁₀ emitting facilities as those that were within the top third in terms of their 2014 emissions of both PM₁₀ and localized GHGs, and highlighted them in orange in **Figure 2**. We found that 40 (61 percent) of these high-emitting facilities reported increases in their localized GHG emissions in 2013-14 relative to 2011-12, versus 51 percent of facilities overall. Neighborhoods near the top-emitting facilities that increased emissions had higher proportions of people of color than neighborhoods near top-emitting facilities that decreased their emissions (**Table 6**).

TABLE 6

Characteristics of Neighborhoods near top GHG- and PM₁₀-Emitting Facilities that Increased and Decreased GHG Emissions (N=66 facilities¹⁹)

	Block groups within 2.5 miles of at least one top emitting facility that increased GHG emissions (N=675)	Block groups within 2.5 miles of at least one top emitting facility that decreased GHG emissions (N=669)
Mean % People of Color	74%	58%
Mean % People Living Below Twice the Poverty Level	46%	34%
% of Block Groups in a “Top 10%” CalEnviroScreen tract	25%	14%
% of Block Groups in a “Top 20%” CalEnviroScreen tract	46%	28%

ENDNOTES

¹ Mandatory Reporting of Greenhouse Gas Emissions (MRR), <http://www.arb.ca.gov/cc/reporting/ghg-rep/reported-data/ghg-reports.htm>.

² CEIDARS, <http://www.arb.ca.gov/ei/disclaim.htm>; <http://www.arb.ca.gov/ei/drei/maintain/dbstruct.htm>.

³ GHG facilities were limited to those that report emitter covered emissions during the first compliance period of cap-and-trade (2013-14), could be geo-coded in California, and had a resident population within 2.5 miles (N=255). We define neighborhoods using Census block groups. Residential proximity to a GHG facility was based on the distance between the facility location and each block group's centroid. We chose a 2.5 mile distance due to its common use in other environmental justice analyses. The Appendix gives results using alternative distance buffers.

⁴ For calculations in Table 1, we used the universe of block groups for which there are valid data (i.e., non-missing data) for all four measures shown. However, the results were the same when we included all block groups with valid data for each measure on an individual basis.

⁵ The map in Figure 1 shows 66 additional facilities that are not included in Table 1 and Figure 2 because they are not within 2.5 miles of a block group centroid with a resident population. See Figure 11 in the Appendix for details.

⁶ Because there are several PM₁₀ values that are between zero and one metric ton, in Figure 3 we added 1 to the PM₁₀ value for all facilities prior to taking the log10 to avoid reporting negative values.

⁷ Similar to Table 1, for calculations in Table 2, we used the universe of block groups for which there are valid data (i.e., non-missing data) for all four measures shown. However, the results were the same when we include all block groups with valid data for each measure on an individual basis.

⁸ The results were qualitatively similar when we compared 2014 emissions to 2012 emissions. That is, the median and mean for each industry sector were in the same direction as shown in Figure 4 (above, near, or below zero), with one major exception: electricity generators on average decreased their emitter covered emissions in 2014 relative to 2012.

⁹ California GHG Emission Inventory, 2016 Edition, http://www.arb.ca.gov/cc/inventory/pubs/reports/2000_2014/ghg_inventory_trends_00-14_20160617.pdf.

¹⁰ Some have critiqued the appropriateness of forestry projects for carbon offset purposes. For example, tree planting projects can take decades to reach maturity in terms of their ability to sequester carbon. Younger trees sequester less carbon and often take decades to fully mature. Moreover, it is challenging to measure and quantify the ability of forestry projects to sequester carbon over time. In particular, the permanence of forestry projects cannot be guaranteed as they remain susceptible to fire, disease, natural decay, clearing, or mismanagement. Forestry projects are also vulnerable to "leakage." This refers to the fact that, unless global demand for wood products goes down, a reduction in logging in one location can simply result in greater deforestation in another location. (See http://www.ipcc.ch/ipccreports/sres/land_use/index.php?idp=0 and <http://www.web.uvic.ca/~repa/publications/REPA%20working%20papers/WorkingPaper2007-02.pdf> for overviews of these issues.)

¹¹ <https://www.arb.ca.gov/cc/reporting/ghg-rep/reported-data/2014-ghg-emissions-2015-11-04.xlsx>

¹² http://www.arb.ca.gov/ei/tools/ghg_visualization/

¹³ https://www.census.gov/geo/maps-data/data/cbf/cbf_blkgrp.html

¹⁴ <http://oehha.ca.gov/calenviroscreen/report/calenviroscreen-version-20>

¹⁵ <http://www.arb.ca.gov/cc/capandtrade/allowanceallocation/publicallocation.htm>;

<http://www.arb.ca.gov/cc/capandtrade/allowanceallocation/edu-ng-allowancedistribution/electricity-allocation.pdf>;

<http://www.arb.ca.gov/cc/capandtrade/stateauction.htm>

¹⁶ <http://www.arb.ca.gov/cc/capandtrade/2013-2014compliance/2013-2014compliance/2013-2014compliancereport.xlsx>

¹⁷ http://www.arb.ca.gov/cc/capandtrade/offsets/issuance/arb_offset_credit_issuance_table.pdf

¹⁸ <http://americancarbonregistry.org>; <http://www.climateactionreserve.org>

¹⁹ 66 GHG facilities fell in the top third in terms of both PM₁₀ and localized GHG emissions. We found that 40 of these facilities increased localized GHG emissions, 23 decreased emissions, and three did not report to the database all four years (2011-2014) so we could not determine an increase or decrease.