State Gift to Big Oil Keeps Pollution Profitable Under "Cap-and-Trade"

Californians should know: If state lawmakers accept oil refiners' current proposal for avoiding direct local emissions control, we can expect more severe toxic pollution impacts on our health, worsening environmental injustice—and the failure of California's climate initiative.

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Founded in 1978, Communities for a Better Environment (CBE) is one of the preeminent environmental justice organizations in the nation. The mission of CBE is to build people's power in California communities of color and low-income communities to achieve environmental health and justice by preventing and reducing pollution and building green, healthy and sustainable communities and environments. CBE provides residents in blighted and heavily polluted communities in California with organizing skills, leadership training and legal, scientific and technical assistance so that they can successfully confront threats to their health and wellbeing.

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California's Gift to Big Oil: Cap-and-Trade

Key Findings

Under California's cap-and-trade program during 2013–2015, a period when there was no direct limit on greenhouse gas (GHG) emissions from refineries:

- State officials gave oil refiners approximately 86 million tonnes of emission allowances free of charge.
- Refiners leveraged the gift to process cheaper, dirtier-than-average crude oil and boost production for export of polluting fuels Californians no longer needed, exceeding otherwise achievable refinery and refined fuel combustion emission rates by some 33 million and 175 million tonnes CO_2e, respectively.
- Toxics emitted with these GHG increments caused serious health hazards, including substantial risk of death in the state's refining regions, and disparately severe impacts in low-income communities of color near the refineries.
- These excess GHG increments alone approached the total to be emitted from all sources statewide in 2050 if California's climate goal is to be achieved, showing that further oil industry expansion risks statewide climate protection failure.
- Refiners pursued plans for capacity expansions that could operate and increase emissions for several decades, asserting that cap-and-trade would allow the resultant emissions, and showing it did not discourage those plans.

Direct observations disprove the hypothesis that cap-and-trade alone will encourage a transition to low carbon technologies in the oil refining sector. Instead, the scheme is giving refiners emission allowances free of charge, allowing them to emit more per barrel of crude refined than any other U.S. refining region, emit more from excess production to export polluting fuels, and further expand the industry's carbon footprint globally.

A new cap-and-trade extension proposal blessed by the Governor threatens to pave the way for expanding oil infrastructure in California. Once it makes those investments, the oil industry will move even more aggressively to protect them in the political arena, further corrupting our democratic processes at the state and local levels, and entrenching environmental injustice in the shadow of its smoke stacks. The state's climate initiative could fail, with devastating effects for millions of Californians living in low-income communities of color.

California's Gift to Big Oil: Cap-and-Trade

Introduction

A review of public records to quantify basic aspects of the state's cap-and-trade program performance and oil refining industry performance under this program was initiated following a proposal by oil companies[1] to support reauthorization of the program in return for a prohibition on direct control of greenhouse gas (GHG) emissions from oil refineries.

Cap-and-trade's basic structure provides for economy-wide trading of allowances, each authorizing one tonne of GHG emission, with the intent to encourage lower-emitting technologies through appropriate pricing of the allowances. Thus, the effects of providing and acquiring allowances on technology choice and emissions provide a measure of the scheme's basic functional integrity. Oil refining is the state's highest-emitting industrial sector and part of its highest-emitting primary energy source.[2, 3]

The review focused on emissions associated with the provision, acquisition, and observed functional use of allowances in California's oil refining industry under the scheme during 2013–2015, a period when there were no direct limits on GHG emissions from refineries.

Preliminary results identified a serious and urgent problem and are being released for public and policy maker review for this reason. **Under its cap-and-trade scheme the state is giving refiners emission allowances free of charge, allowing them to export polluting fuels and expand the industry's carbon footprint globally while emitting more carbon per barrel of crude refined than any other U.S. refining center.**

Cap-and-trade allocated approximately 86 million tonnes of free allowances to refineries during the three year period from 2013–2015. Excess emissions associated with oil refining this giveaway allowed totaled ≈ 208 million tonnes (Mt) of CO_2e from 2013–2015, including ≈ 33 Mt of direct refinery emissions and ≈ 175 Mt of GHGs emitted indirectly by the use of polluting fuels made here and sold outside the state. Some 140 Mt of the 208 Mt total excess was linked to excess refinery production here for the export of fuels that were burned in other nations.

Tonne: metric ton

Mt: Megaton; 1 million tonnes

CO_2e: carbon dioxide equivalents

Barrel (oil): 42 U.S. gallons

"Excess emissions" include:

(1) emitting more per barrel of oil refined than the U.S. average,

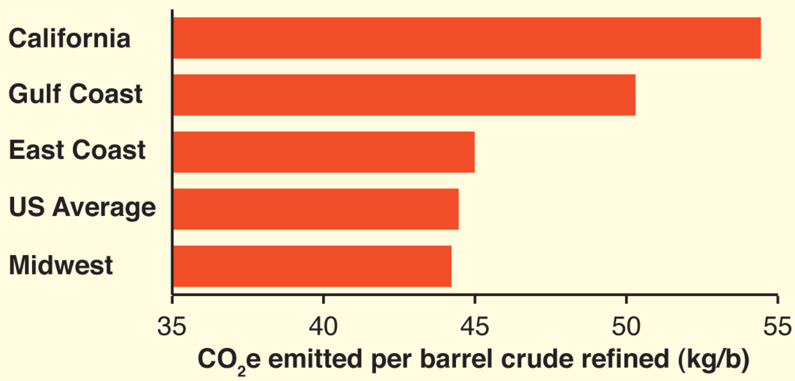
(2) emitting more by refining more oil to export refined fuels, and

(3) indirect emissions from those polluting refined fuel exports

California's Gift to Big Oil: Cap-and-Trade

Free allowances to poor climate performance

California refineries emitted ten kilograms more carbon per barrel of oil refined than the average U.S. refinery from 2013–2015. Their collectively high carbon intensity was driven primarily by their choice of lower quality, denser crude oil feedstock,[4,5] and caused ≈ 18.8 Mt of excess GHG emissions from refineries statewide in this period.



Carbon Intensity of Oil Refining by U.S. Region

California and US averages from 2013–2015;[18–21] other data[4] from 2004–2008

Additional direct emissions of GHGs by California refineries, because of excess production of fuels for sale elsewhere, totaled ≈ 17.4 Mt in this period, with ≈ 7.6 Mt of these excess production emissions linked to foreign exports. Their combined production of gasoline and distillate-diesel exceeded statewide demand for those fuels, and they sold the excess in other states, and then, increasingly, to other nations.

These emissions are linked to the refiners' free emission allowances, which were said to be necessary for cost containment and to prevent "leakage" (see inset), but instead ended up allowing the excess refinery emissions in two ways. First, the free allowances drove refiners' already low cap-and-trade allowance costs down to an average of roughly 12 cents per barrel of oil refined, allowing them to profit on lower quality, higher-emitting grades of oil that were selling at a minimum average price discount of approximately $1/barrel.

> "Leakage:" A reduction in emissions of greenhouse gases within the state that is offset by an increase in emissions of greenhouse gases outside the state.
>
> Health and Safety Code § 38505(j)

Statewide refinery emissions, cap-and-trade emission allowances provided to refiners free of charge, and estimated price discount on lower-quality statewide crude feed, 2013–2015.

Direct emissions of CO_2e from refineries	(tonnes)	102,400,000
Free CO_2e emission allowances to refiners	(tonnes)	86,000,000
	(value)*	$ 1,178,000,000
Remaining allowance cost to refiners	($/barrel)*	$ 0.12
Price discount on lower-quality crude feed	($/barrel)*	≥ $ 1.00

* *Values at auction mean of $13.70/tonne, 25.6 °API (Calif.) v. 31.2 °API (U.S.) average crude feed qualities, and 1.718 million barrels/day statewide crude rate.*

Second, instead of using the free allowances for 84 % of its emissions (<u>see</u> table above; ref. 17) to avoid fuel imports from dirtier refineries elsewhere ("leakage"), the statewide industry expanded exports as Californians used less refined fuel. And it did that through excess production from the most carbon-intensive refining fleet in the U.S. Approximately 3.2 Mt of the excess refinery emissions caused by California refiners' high carbon intensity from 2013–2015 would not have emitted if this extra production for out-of-state sales had not occurred.

Indirect emissions from excess refinery production

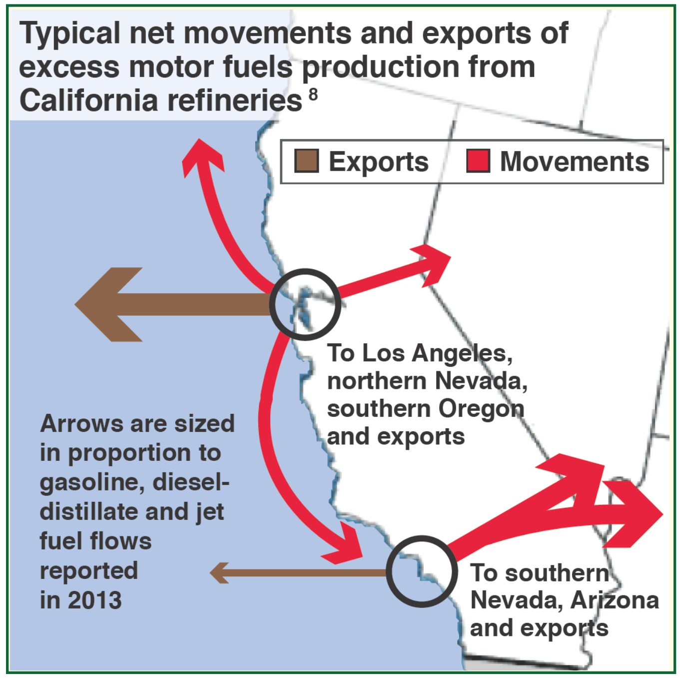
Refinery production of gasoline and distillate combined *v.* taxable sales in California, 2013–2015

Production:	63.5 billion gallons
In-state sales:	52.7 billion gallons

Excess production for export emitted ≈ 175 Mt more CO_2e from burning fuels that California refineries produced to sell outside California from 2013–2015. Substantial contributions to these emissions came from burning excess production of high-value gasoline and diesel/distillate, and also from burning the petroleum coke by-product of processing the California refiners' low quality, high emission-intensity oil feeds.

Approximately 131 Mt of these indirect emissions are accounted for by excess production to sell in new, growing foreign markets.[12] California refineries produced ≈ 10.8 billion gallons more gasoline and distillate/diesel combined than the state used from 2013–2015, and sold the excess in other states and nations.[6, 7, 8] Refiners here exported directly,[8] and the statewide motor fuel production excess of 10.8 billion gallons drove net exports of motor fuels from the U.S. West Coast of approximately 5.7 billion gallons in this period.[9]

Increasing polluting exports in response to decreasing domestic demand[9] for gasoline and diesel fuel—and the provision of free allowances for direct emissions associated with this expansion of the industry's global GHG foot print—indicate a severe problem with the cap-and-trade-only approach to oil refining.



Direct and indirect emissions from California refineries including excess emissions linked to cap-and-trade allowances provided free of charge, 2013–2015

Mt: Megaton; 1 million tonnes	GHG emitted as CO_2e (Mt)	GHG emitted as CO_2e (Mt/year)
Direct refinery emissions		
From all causes	102.4	34.1
Excess emissions*	33.0	11.0
From excess carbon intensity	18.8	6.3
From excess production	17.4	5.8
Indirect emissions from refined product (gasoline and distillate) and by-product (petroleum coke) sales for combustion		
From all causes	654.3	218.1
Excess from out-of-state sales	175.4	58.5
Excess portion from exports	131.3	43.8

* *Direct emission excess totals less than the sum of carbon intensity and production excesses to avoid double-counting the portion of the carbon intensity excess that occurred because of excess production for out-of-state sales.*

California's Gift to Big Oil: Cap-and-Trade

The emissions in context

Toxic combustion products are causally, strongly, and positively correlated with GHG emissions from refineries. Despite 50 years of effort to control them without GHG limits, these toxic and smog-forming pollutants continue to cause serious widespread health impacts that are disparately severe in low-income communities of color near refineries.

For example, in May 2017 a group of independent health experts[10] estimated Bay Area mortality impacts from refinery $PM_{2.5}$ increments co-emitted with refinery GHG increments of 5.9–16 Mt/yr,[11] a range spanning the 11 Mt/yr direct refinery emission excess allowed by cap-and-trade from 2013–2015. The health experts found that those emission increments could cause 800–3,000 deaths regionally over the 40-year operating span of planned oil projects, with disparately severe impacts, 8–12 times the regional per capita mortality risk, in communities within 2.5 miles of the refineries.

The excess direct and indirect emission increment that cap-and-trade allowed from refineries during 2013–2015 (≈ 69 Mt/yr) approaches the <u>total</u> to be emitted from all sources across the state in 2050 if California is to achieve its 80 percent emission reduction goal (≈ 86 Mt/yr).[3] In other words, cap-and-trade is allowing refinery emissions that would make it impossible for everyone else in the state to achieve the state's 2050 emission target using known technically feasible technology.

This comparison alone illustrates how relying on cap-and-trade *instead of* direct emission control could foreclose the possibility of achieving California's climate protection goal, but the problem runs deeper. Oil infrastructure operates and emits for decades once built, and the industry is expanding it now,[11] under cap-and-trade allowances.

Plans to expand low-quality oil refining and refined product export capacities could create decades-long capital commitments to further increased emissions.

Direct emissions of GHGs and $PM_{2.5}$ from refineries could as much as double in the plausible worst case tar sands oil refining scenario, based on peer-reviewed data[4, 5] and analysis of planned and proposed Bay Area oil infrastructure projects.[11]

Meanwhile, the low and rising per capita oil consumption of the 3.5 billion people living in 21 nations across the Pacific that have begun to import oil-based fuels from the U.S.,[12] and the free allowance-linked push by refiners here into those markets, suggest that cap-and-trade could allow them to turn California into the gas station of the Pacific rim.

Discussion

Inextricably linked to the toxic injustice local communities face here—the global carbon footprint of the oil industry in California is far more significant than state officials who portray themselves as global carbon champions appear willing to admit. Remarkably, the state does not appear to have quantified the emission effects of free allowances to oil refineries under its cap-and-trade program. This review shows that can be done. Moreover, our findings generally align with those of previous research by others—previous findings that the architects of cap-and-trade-only proposals also appear to have ignored.

Pastor et al. (2010) showed that people of color near refineries face disparately severe health risk from GHG co-pollutants under cap-and-trade.[13] Cushing et al. (2016) showed that refiners were among the largest users of offsets that allowed them to avoid direct emission reductions under cap-and-trade.[14] OEHHA (2017) showed that $PM_{2.5}$ emissions are strongly correlated with CO_2e emissions from refineries.[15] BAAQMD (2017)[2] showed direct limits on refinery emissions are needed, because cap-and-trade has not controlled those emissions adequately, and state climate targets are unlikely to be met if refinery emission increases that are foreseeable under cap-and-trade become manifest.

Quantitative results from this preliminary review may be revised as more data become available and, more importantly, refinery emission rates can change. In fact, refinery emissions could have increased more than this review documents, but for the stands against refinery expansion and tar sands refining projects in recent years by local communities—communities from Richmond to Wilmington, San Luis Obispo, Benicia, Rodeo and Crockett, among others. In its opposition to refinery emission limits proposed by the Bay Area Air District,[16] the oil industry itself has asserted that fully implementing its infrastructure plans will require allowing refinery emissions of both GHGs and criteria air pollutants to increase.

This information is relevant to consideration of the oil industry's current legislative proposal to block any direct control of refinery GHG emissions, even the proposed Bay Area limits to prevent or "cap" increasing refinery emissions, which would allow emissions at current rates.

Oil interests have framed a false choice between protecting our most vulnerable communities' rights to environmental health in the shadow of the smoke stacks, and protecting our climate to avert catastrophic impacts that threaten us all. It is a false choice because the policy they offer to support in this trade-off has proven ineffective for either purpose based on real-world observations of its performance in California.

Data and Methods, Annotated Table

Tonnes (t); barrels (b)	2013	2014	2015	2013–2015
Free CO_2e allowances allocated to refineries (t)[a]	29,163,759	28,424,228	28,420,127	86,008,114
Total CO_2e emissions from California refineries (t)[b]	34,482,701	34,536,973	33,401,000	102,420,674
Calif. total crude rate (b)[c]	623,685,000	635,688,000	621,953,000	1,881,326,000
Calif. refinery carbon intensity, in kg/b (kilograms emitted ÷ barrels refined)[d]				54.44
U.S. refinery emissions (t)[e]	268,000,000	261,000,000	255,000,000	784,000,000
U.S. total crude rate (b)[f]	5,739,260,000	5,896,940,000	5,997,315,000	17,633,515,000
U.S. refinery carbon intensity, in kg/b (kilograms emitted ÷ barrels refined)[d]				44.46
Excess Calif. refinery carbon intensity *v.* the U.S. average (kg/b)				9.98
California average refinery crude feed quality (°API)[g]				25.6
U.S. average refinery crude feed quality (°API)[g]				31.2
Minimum average price discount on California *v.* U.S. crude feed quality ($/b)[h]				$1.00
California refinery emissions *minus* free allowances to refiners, in tonnes				16,412,560
Estimated cap-and-trade allowance price from 2013–2015 ($/tonne)[i]				$13.70
Remaining allowance cost to refiners ($/barrel)[i]				$0.12
California refinery fuel production (supply) and fuel sales (Calif. demand), in barrels				
Gasoline production[j]	366,402,200	380,814,100	370,151,000	1,117,367,300
Distillate/diesel prod.[j]	130,041,000	136,664,000	127,055,000	393,760,000
Jet fuel production[j]	100,119,000	106,128,000	104,422,000	310,669,000
Gasoline sales[k]	346,023,677	350,062,677	359,651,163	1,055,737,517
Distillate/diesel sales[k]	65,245,373	66,099,532	67,253,805	198,598,710
Jet fuel sales[k]	3,209,271	3,040,139	3,420,338	9,669,747
Gasoline+distillate prod.[j]	496,443,200	517,478,100	497,206,000	1,511,127,300
Gasoline+distillate sales[k]	411,269,050	416,162,209	426,904,968	1,254,336,226
Excess G+D production	85,174,150	101,315,891	70,301,032	256,791,074
West Coast (PADD 5) refined product net exports to other nations, in barrels[l]				
Gasoline exports	11,467,205	16,820,295	9,642,205	37,929,705
Distillate/diesel exports	42,613,750	36,895,295	33,123,750	112,632,795
Jet fuel exports	-2,373,230	1,963,700	-14,013,080	-14,422,610
Petroleum coke exports	43,351,250	43,860,955	42,400,955	131,613,160
Gasol+dist.+jet exports (b)	51,707,725	55,679,290	28,752,875	136,139,890
Excess direct emissions from California refineries from 2013–2015 (tonnes)				
Excess emissions from excess California refinery carbon intensity (CI)[m]				18,775,000
Portion from excess CI and excess production for out-of-state sales[m]				3,191,000
Portion from excess CI and excess production for foreign exports[m]				1,691,000
Excess direct emissions from excess production for out-of-state sales[n]				17,405,000
Portion emitted from excess production for foreign exports[n]				9,227,000

Continued next page

Data and Methods, Annotated Table *continued*

Tonnes (t); barrels (b)			**2013–2015**
Emission factors for combustion of refined product fuels [o]			
Gasoline	373.4	(kg CO_2/b)	
Distillate/diesel	426.7	(kg CO_2/b)	
Petroleum coke	617.4	(kg CO_2/b)	
Indirect emissions from California refineries from 2013–2015 (tonnes) [p]			
Indirect Calif. refinery emissions from all gasoline, distillate and coke sales			654,300,000
Excess indirect Calif. refinery emissions from portion sold out-of-state			175,400,000
Excess indirect Calif. refinery emissions from portion sold for export			131,300,000
Direct and indirect Calif. refinery emissions associated with foreign exports (t)			140,527,000

a. Total cap-and-trade emission allowances allocated to refineries and their captive fossil fueled hydrogen plants free of charge as reported by CARB. CARB reported these data with "true-up" revisions in public record documents dated 14 November 2014 (years 2013 and 2014) and 22 December 2014 (Y-2015).[17]

b. Total direct emissions from refineries and their captive hydrogen plants reported by CARB.[18]

c. Total crude oil supplied to California refineries reported by the California Energy Commission.[19]

d. Refinery carbon intensity (CI), measured as mass emitted/volume crude refined, has been shown to be strongly and positively associated with refinery energy intensity and, for average emissions from multiple plants with well mixed crude feeds, with refinery crude feed quality.[4, 5] Midwest, East Coast and Gulf Coast refinery CI values in the chart shown above are from previously reported peer-reviewed data.[4]

e. Total direct refinery emissions of CO_2 reported by the USEIA in the Annual Energy Outlook.[20]

f. U.S. Gross Inputs to Refineries from USEIA's U.S. Refinery Utilization and Capacity database.[21]

g. Crude feed quality is the primary causal factor driving variability in average refinery energy intensities and carbon intensities among U.S. refining regions and years.[4, 5] Average California refinery crude feed quality during 2013–2015 was estimated based on peer-reviewed data for the measured average California refinery crude feed density from 2004–2009.[5] Average U.S. crude feed quality was estimated as the mean of U.S. refinery crude feed densities reported for 2013, 2014, and 2015 by the USEIA.[22]

h. The USEIA reports domestic crude oil first purchase prices,[23] landed costs of imported crude,[24] and U.S. FOB costs of crude[25] for various crude density ranges. This estimate compared crude prices reported by USEIA for density from 30.1–35.0 °API (spanning the 31.2 °API U.S. crude feed from 2013–2015) with those for density from 25.1–30.0 °API. The 25.6 °API California crude feed from 2013–2015 is near the low-quality end of this range, making this estimation method conservative. The lower-quality, 25.1–30 °API crude was consistently lower-priced by each of these measures in 2013, 2014, and 2015, but the average price discount on it from 2013–2015 ranged from $1.00/barrel (FOB) to $5.51/barrel (first purchase).[23–25] The estimate used in this report is based on the minimum average price discount measurement, at $1.00/barrel.

i. Allowance price data were reported for 13 cap-and-trade auctions from 13 November 2012 through 17 November 2015.[26] More price data were available for the 2013 and 2014 auctions; only clearance and reserve price data were available for 2015. The estimate used in this report is

based on the mean prices from the 2013 and 2014 auctions and the clearance prices from the 2015 auctions, and weighted each year equally to yield a grand mean allowance price of $13.70 for this three-year period. To account for the free allowances and allow comparison with crude price discounts, this price was expressed in dollars per barrel, using the equation:
price/barrel = price/tonne • (tonnes emitted – free allowances) ÷ barrels refined

j. Data from California Energy Commission Weekly Fuels Watch reports.[6] Note that because California's refining industry has outsized capacity for hydrocracking,[5] which can "swing" between gasoline and distillate production,[4] and its export markets tend to demand more distillate than gasoline,[8, 9] combined gasoline and distillate production is a more reliable metric for excess production than either fuel alone.

k. Data from California Bureau of Equalization taxable sales.[7] These data were considered to better represent in-state demand for high-volume motor fuels (gasoline and diesel/distillate) than other data such as USEIA "prime supplier" sales data (per. comm., G. Karras, CBE, with G. Schremp, CEC). USEIA "product supplied" data were not available for California alone. For jet fuel, however, the dominance of its use for interstate transport and resultant tax and accounting questions could make in-state production/demand comparisons based on these data uncertain. Jet fuel was excluded from such comparisons in this report.

l. Net exports (exports – imports; negative values indicate net imports) from USEIA.[9] Attribution of gasoline, distillate/diesel, and jet fuel exports to excess California production was inferred from its substantially larger volume than export volume for these fuels, their value in domestic markets and transport logistics. However, petroleum coke is a low value byproduct and poor quality, dirty-burning fuel, with more restricted domestic uses and demand, that each refinery using the coking process may export for sale as a cheaper option than disposal in a U.S. landfill. For these reasons, only the portion of the pet coke exports corresponding to California's portion of PADD 5 coking capacity in these years was attributed to California production. Based on USEIA refinery capacity data[27] California had approximately 85% of PADD 5 coking capacity from 2013–2014.

m. From kg/barrel • crude rate in barrels • 1 tonne/1,000 kg = tonnes emitted. Thus, for mass caused by the CI increment at the total crude rate: 9.98 • 1,881,326,000 • 1/1,000 = 18,775,435 tonnes from 2013–2015. For the portion of this CI increment associated with out-of-state sales, and foreign exports, respectively, the crude rate in barrels is the total crude rate multiplied by (excess fuels production ÷ total fuels production), and multiplied by (total motor fuels export ÷ total fuels production), respectively.

o. Emission factors from USEIA "Carbon Dioxide Emissions Coefficients by Fuel.[28]

p. Indirect emissions were estimated based on the USEIA emission factor (note o) and volume of each fuel. For example, emissions from burning all the gasoline California refined from 2013–2015 were estimated as 1,117,367,300 b • 373.4 kg/b • 1 tonne/1,000 kg = 417,224,950 tonnes. Out-of-state sales volumes were taken from the difference between California refinery production and California sales. Export volumes were taken from the net export volumes in the table. Emissions were estimated as the sum of emissions from gasoline, distillate, and pet coke. 85% of West Coast pet coke exports were attributed to California refineries (*see* note "l" above). As described in that previous note, the 85% (0.85) scaling factor for coke was judged appropriate based on fuel-specific and context-specific evidence that other refineries in PADD 5, outside California, may export this byproduct in proportion to their relative coking capacity.

No other scaling factor was applied to the refined fuel export emissions, but some evidence suggests larger scaling factors, exceeding 1.00. Large fossil fuel subsidies can affect nations' development.[29] It is possible that the free emission allowances to oil refining for export here, which are pushing subsidized, excess fossil fuel production into nations with low and rising energy use,[12] may be altering energy development choices to the peril of a sustainable climate. That analysis is beyond the scope of this preliminary review and is left to future work.

References

(1) California Assembly Bill 398, as proposed on 10 July 2017, reads in part: "[§ 38594] (b) A district shall not adopt or implement an emission reduction rule for carbon dioxide from stationary sources that are also subject to a market-based compliance mechanism adopted by the state board pursuant to subdivision (c) of Section 38562." Further, § 38562 (c) of proposed AB398 reads in part: "In furtherance of achieving the statewide greenhouse gas emissions limit, the state board may adopt a regulation that establishes a system of market-based declining annual aggregate emissions limits for sources or categories of sources that emit greenhouse gases. ..."

Consistent with that intent in now-proposed AB398, leaked draft legislative language that was received by CBE in June 2017 reads in part:
"The state board shall designate the market-based compliance mechanism established pursuant to Section 38562(c) as the rule for petroleum refineries and oil and gas production facilities to achieve their greenhouse gas emission reductions." …
"NO LOCAL AIR DISTRICT REGULATION OF GHG EMISSIONS
"Section 38594 of the Health and Safety Code is amended to read:
…
"(b) The state board shall have the exclusive authority for, and a district shall not adopt or retain in effect, any stationary source or source category rule or regulation that addresses greenhouse gas emissions or establishes a greenhouse gas emission or performance standard if such stationary source or source category is subject to the market-based compliance mechanism established pursuant to Section 38562 (c)."

(2) BAAQMD, 2017. *Regulation 12, Rule 16: Petroleum Refining Greenhouse Gas Emission Limits, Revised Final Staff Report;* Bay Area Air Quality Management District: San Francisco, CA. June 2017.

(3) *The 2017 Climate Change Scoping Plan Update;* California Air Resources Board: Sacramento, CA. 20 January 2017. *See* esp. figures I-1, I-3.

(4) Karras, 2010. Combustion Emissions from Refining Lower Quality Oil: What is the Global Warming Potential? *Environmental Science & Technology*. 2010 (44): 9584–9589. DOI: 10.1021/es1019965. *See* esp. this paper's *Supplemental Information* data confirming substantial differences in average refinery carbon intensity among refining regions that have persisted, supporting the representativeness of data in the chart on page 4.

(5) UCS, 2011. Oil Refinery CO_2 Performance Measurement. Union of Concerned Scientists (UCS): Berkeley, CA. Technical analysis prepared for UCS by G. Karras, Communities for a Better Environment. Peer reviewed by UCS. September 2011. *See* esp. this paper's *Supplemental Information* data confirming substantial differences in average refinery carbon intensity among refining regions that have persisted, supporting the representativeness of data in the chart on page 4.

(6) *Weekly Fuels Watch Report;* California Energy Commission: Sacramento, CA. Annual reports; 2013, 2014, and 2015 Weekly Fuels Watch reports; http://energy.ca.gov/almanac/petroleum_data/fuels_watch.

(7) *Fuel Taxes Statistics & Reports;* California Bureau of Equalization: Sacramento, CA. Taxable gasoline gallons, taxable diesel gallons, and taxable jet fuel gallons 10-year reports; www.boe.ca.gov/sptaxprog/spftrpts.htm.

(8) *PADD 5 Transportation Fuels Markets;* U.S. Energy Information Administration: Washington, D.C. www.eia.gov/analysis/transportationfuels/padd5.

(9) *West Coast (PADD 5) Supply and Disposition;* U.S. Energy Information Administration: www.eia.gov/dnav/pet/pet_sum_snd_d_r50_mbblpd_m_cur.htm.

(10) Independent health experts' assessment of the impact of Rule 12-16 on mortality associated with exposure to $PM_{2.5}$ from processing heaver oil in Bay Area Refineries. In: *Health impacts and implications should be included in the No Project and alternative scenarios and the environmental and regulatory settings sections of the EIR for BAAQMD Rule 12-16;* Broome, C.; Brunner, W.; Gould, R.; Heller, J.; Jackson, R.; Kirsch, J.; Neutra, R.; Newman, T.; Ostro, B.; Rudolph, L.; Shonkoff, S.; Sutton, P.; and H. Kuiper. 8 May 2017.

(11) *Combustion Emissions from Refining Lower Quality Oil Part 2: How much could a switch to 'tar sands' oil increase direct emissions of $PM_{2.5}$ and CO2 from northern California oil refineries?;* A CBE Technical Report. Karras, G. 2 December 2016.

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