Key Emitters and Costs of Capture for California Industrial Decarbonization

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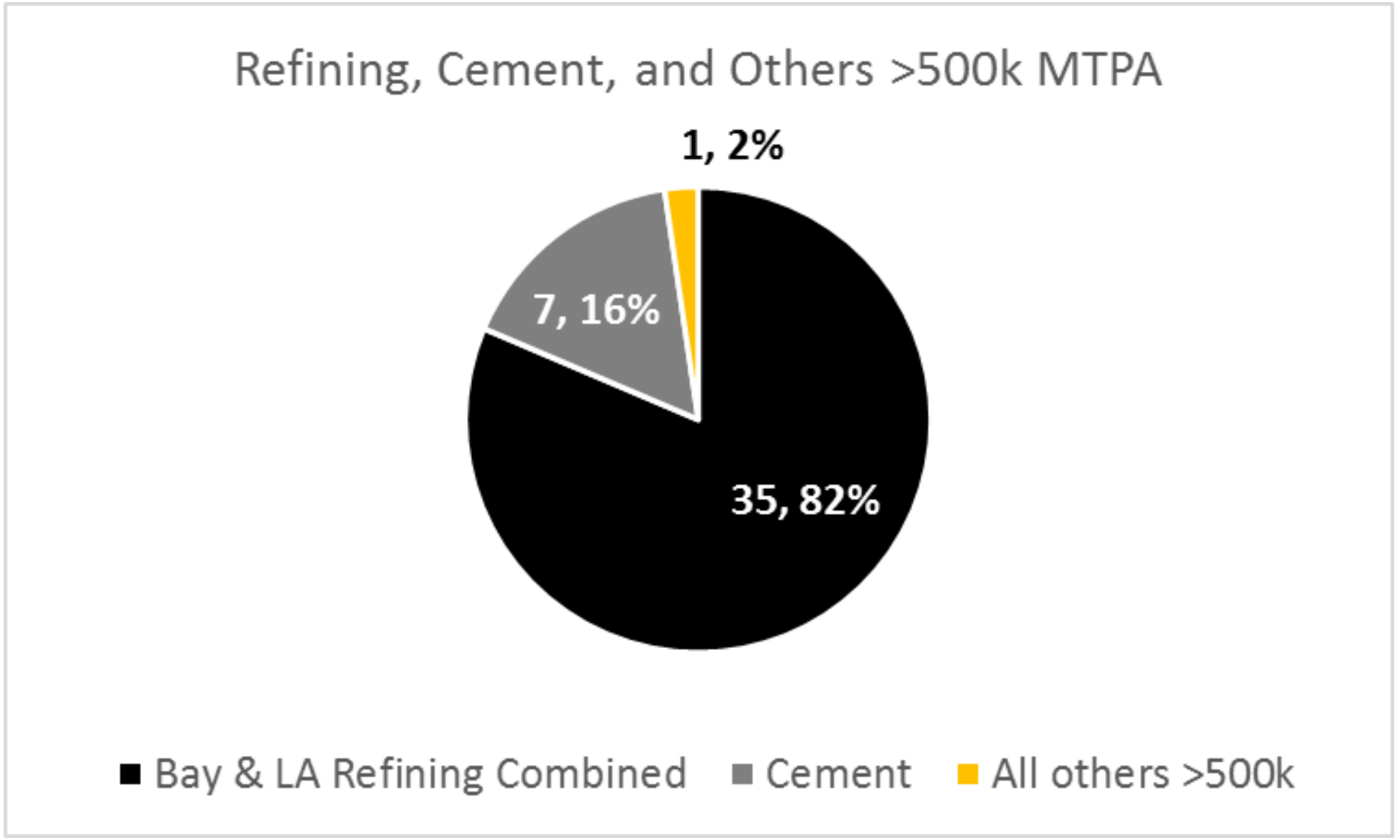
Key Points/Topics

- Who are major industrial emitters, and what's their relative size vs. power sector?
- What are likely costs of capture of the subset of industrial emissions that are most practical to capture?
- How do industrial sector emitters compare in cost to power sector emitters?
- What do existing reports say on this topic?
- How do CARB rules, and changes to those rules, on both cap-and-trade and LCFS, help or hurt the prospects for industrial capture?
- What are other regulatory or permitting issues that need special focus?

Of Large Emitters: 64% Industrial vs. 36% Power

California Emitters > 500,000 MT/yr 2017*			
Category	**# Reporters**	**CO2 Emissions millions**	**%**
Bay Area Refiners & Associated Hydrogen Plants > 500k	8	16	24%
Los Angeles Refiners & Associated Hydrogen Plants >500k	9	19	28%
Bay & LA Refining Combined	17	35	52%
Cement	7	7	10%
Power Plants > 500k	21	24	36%
All others >500k	5	1	1%
	50	67	100%
*402 Emitters in GHGRP in CA totalling 93 million MT/yr in 2017, so these 50 emitters are 72% of total			

Focus on Industrial Emissions



Focus on Refineries

CEC Name: Refinery >50,000	EPA Name	Company	BOPD	City	County	EPA FLIGHT #
Chevron Richmond	Chevron Products, El Segundo Refinery	Chevron	245,271	Richmond	Contra Costa	**1007978**
Phillips 66 Rodeo	San Francisco Refinery @ Rodeo	Phillips 66	78,400	Rodeo	Contra Costa	**1006395**
Shell Oil Products US Martinez	REFINERY	Shell	156,400	Martinez	Contra Costa	**1001804**
Marathon Golden Eagle Martinez/Avon	TESORO REFINING AND MARKETING COMPANY GOLDEN EAGLE REFINERY	Marathon	166,000	Martinez	Contra Costa	**1007390**
Valero Benecia (excl asphalt)	VALERO REFINING CO - CALI FORNIA BENICIA REFINERY	Valero	145,000	Benecia	Solano	**1008504**
Chevron El Segundo	Chevron Prods. Co Richmond Refy	Chevron Corp	269,000	El Segundo	LA	**1003610**
Tesoro-Marathon Carson	Los Angeles Refinery (LAS)	Tesoro Ref & Mkt	382,000	Carson+Wilmington	LA	**1006627**
Phillips 66 Wilmington	Phillips 66 LA Refinery - Wilmington & Phillips 66 LA Refinery--Carson	Phillips 66	139,000	Wilmington	LA	**1006843 Wilm. & 1001964 Carson**
PBF Energy Torrance	TORRANCE REFINING COMPANY LLC	Torrance Ref Co	151,300	Torrance	LA	**1007329**
Valero-Ultramar Wilmington (excl ashphalt)	ULTRAMAR INC WILMINGTON REFINERY--now VALERO	Ultramar	85,000	Wilmington	LA	**1002461**

Refineries: 30-50 CMS-Tracked Stacks, But Only a Few Matter Practically

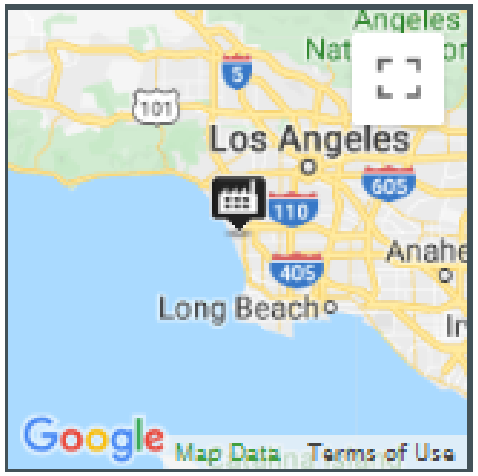
Chevron El Segundo and Nearby Air Liquide Hydrogen Plant: 4.0 MMTPA combined. My estimate is about 1.8 MMTPA (45%) could be captured economically.

- Stationary Combustion:
  - 2.3 MMTPA @ 22 stacks.
  - 0.8 MMTPA @ powerplant
- Hydrogen:
  - 0.5 MMTPA @ Chevron & 0.6 @ Air Liquide (not shown)
- Refining
  - 0.53 MMTPA @ 6 stacks
  - 0.50 MMTPA from FCCU catalyst regenerator

Data Year 2018

CHEVRON PRODUCTS, EL SEGUNDO REFINERY

324 W EL SEGUNDO BLVD
EL SEGUNDO, CA, 90245



Latitude: 33° 54.49' N
Longitude: 118° 24.51' W

GHGRP Id: 1007978
FRS Id: 110002899908
NAICS Code: 324110

View reported data

Download reported data (XML)

Facility Information | Facility Emissions by Year

Total Facility Emissions in metric tons CO_2 equivalent (mt CO_2e) (AR4 GWPs, excluding Biogenic CO_2)	3,441,664
Emissions by Gas in mt CO_2e (AR4 GWPs)	
Carbon Dioxide (CO_2)	3,428,459
Methane (CH_4)	6,953
Nitrous Oxide (N_2O)	6,252
Emissions by Source/Process in mt CO_2e (AR4 GWPs, excluding Biogenic CO_2)	
Stationary Combustion	2,358,162
Hydrogen Production	549,171
Petroleum Refining	534,331
Information on Stationary Combustion	
Types of Fuels Used	Distillate Fuel Oil No. 2, Fuel Gas, Motor Gasoline, Natural Gas, Propane
Measurement Methods Used	Mass Balance
Number of equipment groupings	22

Carbon Capture is Cost-Effective: Preliminary Revised Estimates of Capture Costs Compare Favorably to Other Low and Zero-Carbon Options

Capture Category (CO2% is molar concentration)	Main Equipment Needed	Industrial Application	US$ per MT Captured/Compressed
Pure CO2 emissions	Compression & Dehydration only	Ethanol, Natural Gas Processing, Ammonia	$15-20/metric ton
CO2 emissions @ **16-50%** concentration	Amine CO2 separation equipment plus Compression	Hydrogen Plants, Cement, Fluidized Catalytic Cracking Unit (Refineries), Blast Furnace Gas Combustion (Steel)	$40-60
CO2 emissions @ **~13-15%** concentration		Pulverized Coal Power Plants	$55-65
CO2 emissions @ **~4%**		Natural Gas Combined Cycle Power Plants	$65-75 @ 85% NCF $105-115 @ 50% NCF

Key price assumptions: $50/MWh for electricity, $3.50/MMBtu natural gas, 10% Capital Recovery Factor.
Capture plant size: For amine solvent carbon capture systems cited above (all at 85% capacity factor) capture plant size for hydrogen is 350k MTPA (metric tons per annum), cement 1 million MTPA, FCCU 500k MTPA, Blast Furnace 3 million MTPA, Pulverized Coal Power 3 million MTPA, NGCC, 1.5 million MTPA. Pure emissions have compression/dehydration only.
Power and steam supply: Coal power plants and NGCCs can supply parasitic electric and steam loads from the power plants themselves, or can buy grid electricity and build separate steam boilers. The exact impact of this supply decision depends on power plant value, fuel costs, and the local grid

EFI Report on California Decarbonization

Industrial Sector (including petroleum refining)
2016 emissions: 100.4 million tons
2030 target emissions: 60.2 million tons
needed reductions: 40.2 million tons
potential reductions via carbon capture: 12.8 million tons p.a. *(32% of total industrial sector reductions needed)*

Petroleum Refining & H2 Production
2016 emissions: 29.6 million tons (30% of Industrial)
potential reductions via carbon capture: 9.7 million tons (24% of total industrial sector reductions needed)

Electricity Sector
2016 emissions: 68.6 million tons
2030 target emissions: 41.2 million tons
needed reductions: 27.4 million tons
potential reductions via carbon capture: 17.7 million tons p.a. *(65% of total electricity sector reductions needed)*

EFI Continued

Industrial Emissions Reduction Pathways - 2030

Industry Sector	2016 Emissions	2030 Target	Reductions Needed	Carbon Capture	Fuel Switch to H2 or Electrification	Best Management Practices	New Technology Adoption	Fuel Switch to Natural Gas	Biogas Collection	Renewable Natural Gas	Reduce Fugitive Emissions	Combined Heat & Power (CHP)	Energy Efficiency
Cement	7.6			(1.4)			(0.7)	(1.0)					
Chemical & Allied Products	6.2											(0.4)	
Food Products	3.3												
Industrial CHP	8.0							(0.6)					
Landfills & Waste Treatment	8.9								(4.3)				
Oil & Gas Production & Processing	18.0			(1.7)							(1.1)		
Petroleum Refining & H2 Production	29.6			(9.7)				(2.7)				(0.6)	
Transmission & Distribution Pipelines	5.1										(2.0)		
Other	13.9				(7.3)	(6.6)	(4.8)			(3.6)			(0.1)
	100.4	60.2	40.2										
emissions reductions potential				**(12.8)**	**(7.3)**	**(6.6)**	**(5.5)**	**(4.3)**	**(4.3)**	**(3.6)**	**(3.1)**	**(1.0)**	**(0.1)**
% of needed 2030 target reductions				**32%**	**18%**	**16%**	**14%**	**11%**	**11%**	**9%**	**8%**	**2%**	**< 0.5%**

Key Assumptions:

CCUS applied to fuel combustion emissions except for Cement which also included the capture of non-combustion emissions. Two regional clusters of industrial facilities located near potential sequestration sites were identified as candidates for CCUS and included four cement plants, one large cluster of natural gas processing facilities, and seven oil refineries. These clusters include the large oil refinery capacity in the Bay Area and the large gas production and processing operation near Bakersfield.

Cap-and-Trade and LCFS

- Refinery and related hydrogen plants--LCFS: Big opportunity because 2018 LCFS changes removed former cap on the amount of carbon capture that could be used against refinery CI deficit, and also allowed excess allowances to be sold. Prices of $200/MT are clearly attractive—if regulatory issues can be solved with certainty (next slide).
- Cement—Cap-and-Trade: Marginal but could be saved. 2019 weight-averaged pricing for current allowances was $16.77/MT area (vs. reserve price/floor of $16.68). Level is at the edge of feasibility incentivize capture, assuming full use of Federal 45Q tax credit. Further, no protocol for sequestration under cap-and-trade, and that would be have to be resolved quickly before 45Q expiry of 2023.

Additional Key Issues

- CO2 pipeline routing from Bay Area and LA Basin—time sensitive unless 45Q extended
- Class VI Primacy and EPA Class VI personnel constraints unless EOR is storage mechanism
- Coordination of EPA Class VI with current CARB sequestration protocol
- Environmental justice issues—may be favorable on oil FFCU and perhaps cement
- Lack of floor on LCFS