Flaring Prevention Measures

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Communities for a Better Environment (CBE)

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A CBE report
April 2007

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CBE

The mission of **Communities for a Better Environment** (CBE) is to achieve environmental health and justice by building grassroots power in and with communities of color and working class communities. Founded in 1978, CBE combines in-house scientific, legal and organizing expertise to leverage plant-specific pollution prevention and regional policy progress that could not be achieved using science, organizing or legal advocacy alone. More than 200 industrial facilities have changed production, transport or disposal practices to prevent millions of pounds of pollution annually as a direct result of our efforts. Thousands of CBE members and supporters live in the greater Los Angeles and San Francisco Bay areas. Hundreds of CBE members live in working class communities of color near oil refineries and engage in our work directly.

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Glossary

Backup compressor capacity The amount of gases that separate compressors can handle when the primary compressors break down or cannot handle the entire gas stream produced.

Baseline flare gas flow Flow through a flare gas system during typical normal conditions.

C2- Hydrocarbon with two or less carbon atoms per molecule: methane, ethane and ethylene.

C3-5 Hydrocarbon (in the propane-pentane range) with 3-5 carbon atoms per molecule.

Catalytic cracking A process that uses high heat and a catalyst to break large hydrocarbon molecules into smaller ones of the right size for gasoline, diesel and jet fuel.

Coking A process that uses high heat and pressure to break large hydrocarbon molecules into smaller ones for use in gasoline, diesel and jet fuel and that also produces petroleum coke.

Compressor A machine that puts gases under pressure and thereby reduces their volume.

Distillation A process that uses heat to separate hydrocarbons that boil at different temperatures.

Emergency A situation arising from sudden and reasonably unforeseeable events beyond the control of the refinery, that requires immediate corrective action to restore normal operation.

Episodic flaring Flaring episodes that burn more than 500,000 standard cubic feet of gases per day, emit more than 500 pounds of hydrocarbon per day and/or emit more than 500 pounds of sulfur dioxide per day.

Feedstock Raw or partially processed material that is fed into a process unit for manufacturing.

Gas quality The types and concentrations of chemicals in a mixture of gases.

H_2 Hydrogen.

H_2S Hydrogen sulfide. A toxic gas with a rotten-egg odor. Flaring H_2S creates sulfur dioxide.

Hydrocracking A process that uses catalytic cracking with hydrogen and very high pressure.

mmscf Million standard cubic feet. Gas volume at standard temperature and pressure.

N_2 Nitrogen.

Process A plant or operation that produces particular kinds of chemical reactions and products.

Process rate The speed of production in a process, often measured in barrels of feedstock processed per day.

Recovery/reuse The collection, treatment, and use of gases–often as fuel gas–instead of flaring.

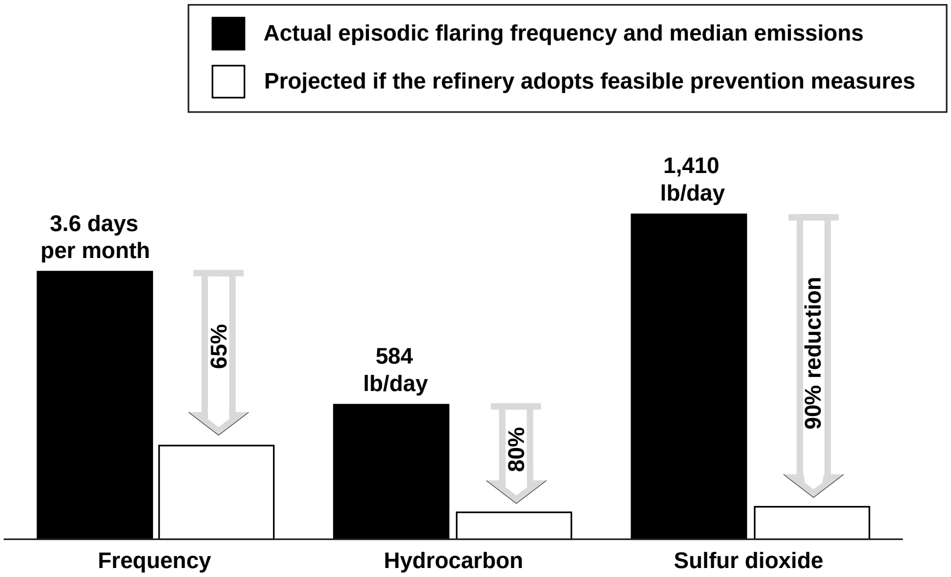
Root-cause analysis Investigation of a specific incident to find its underlying causes for the purpose of follow-up action to prevent the same factors from causing another incident.

SO_2 Sulfur dioxide. A toxic gas. SO_2 is created from hydrogen sulfide (H_2S) by flaring.

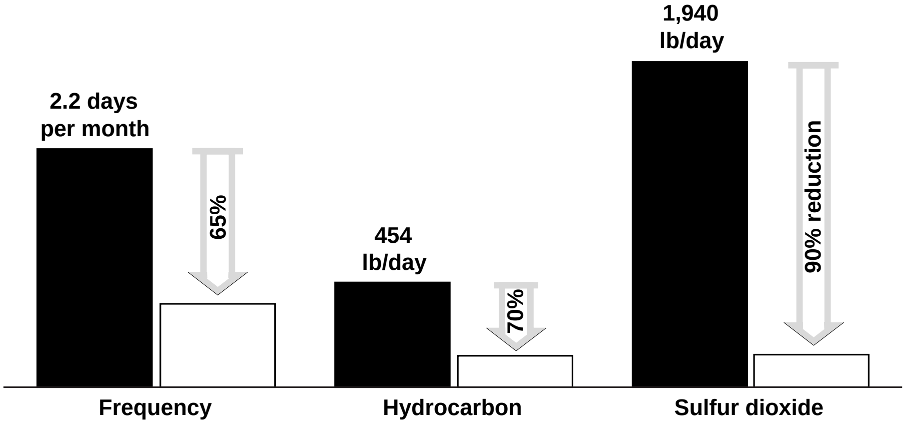
Flaring Prevention Measures

Feasible pollution reductions:

Minimum projected reductions in frequency and magnitude of episodic flaring achievable by prevention measures demonstrated in practice.



Chevron Richmond refinery achievable reductions in major flaring



ConocoPhillips Rodeo refinery achievable reductions in major flaring

Summary of data and projections presented in this report (CBE, 2007). See esp. tables 2, 3 and 11.

Figure ES-1

Executive Summary

Oil refinery flaring causes episodic exposures to pollutants that may cause lung disease, cancer and other health problems. This report is about stopping the pollution. It documents feasible flaring prevention measures, and is a resource for community members, workers, and public officials who participate in decisions on stopping pollution from flares.

A community campaign won monitoring of Bay Area refinery flares in 2003 with Rule 12-11 and, with the adoption of Rule 12-12 in July 2005, won the nation's first comprehensive requirements for limiting refinery flares to their legitimate use as emergency safety devices. Instead of simply prohibiting planned and routine flaring, however, the rule requires each refiner to adopt all feasible prevention measures in a "Flare Minimization Plan." Whether the industry does that in fact depends on public pressure and official action. Now, in April-May 2007, the public has the opportunity to comment on the industry's first plans proposed under the new rule.

Although monitoring and investigations of flaring remain problematic, improved monitoring over the past three years supports perhaps the most complete regional data set on refinery flaring to date. Analysis of these data across the five Bay Area refineries–Chevron in Richmond, ConocoPhillips in Rodeo, Shell in Martinez, Tesoro in Avon, and Valero in Benicia–shows that:

- Flaring episodes still impact local air quality frequently.
- Some refineries emit much more episodic flare pollution than other refineries.
- The quality of flared gases drives these differences in emissions between refineries.
- Process sources drive these differences in gas quality between refineries; refiners that flare from dirtier types of refining processes cause the worst flare emissions.
- One refinery has virtually eliminated episodic flaring from dirtier-flaring processes.
- Measures achieved in practice could dramatically reduce the frequency and magnitude of episodic flaring by refineries that flare from dirtier-flaring processes.

Among the five Bay Area refineries, Chevron and ConocoPhillips flare from dirtier process sources the most often and flare the largest episodic emissions.

The Shell refinery uses dedicated backup compressors for flare gas recovery with separate process compressors and procedures that adjust process rates to safely prevent flaring. These measures largely eliminated episodic flaring from Shell's dirtier-flaring processes. Other refiners can apply these measures. The measures can prevent recurrent causes of episodic flaring at Chevron and ConocoPhillips. These feasible measures could reduce the frequency of this flaring at Chevron and ConocoPhillips by at least 65% and, when it occurs, make the flare episodes shorter and reduce their emissions by at least 70-90%.

Chevron's flaring has increased since the flare rule was adopted. Flaring could increase further if Chevron and ConocoPhillips are allowed to refine cheaper low-quality crude oil, as they now propose, without applying the measures in place at Shell. This "dirty crude refining" produces larger volumes of toxic gases from dirtier-flaring processes.

Flaring Prevention Measures

Crude slate switching, underbuilt capacity for handling gases, and failure to operate refineries in balance with their gas handling capacity are ***preventable*** root causes of flaring. Measures that prevent the flaring are demonstrated in practice, and necessary to address frequently-recurring episodic pollution and serious environmental health and justice concerns.

Recommendations

1 All Bay Area refiners should apply the flaring prevention measures that are in place at Shell. The Bay Area Air Quality Management District should identify the specific measures and episodic flaring reductions applicable to the Tesoro and Valero refineries and require them. The Air District should require that Chevron and ConocoPhillips, at a minimum:

install dedicated backup compressor capacity and related equipment sufficient to prevent planned flaring and flaring caused by foreseeable and manageable malfunctions;

employ operating procedures that adjust process rates to prevent and minimize flaring whenever this is consistent with safe and reliable operation; and

reduce episodic flaring frequency by at least 65% and episodic flare emissions by 70-90%.

2 Flare minimization plans should ***not*** allow planned flaring, flaring caused by foreseeable and preventable malfunctions, or flaring caused by failure to install and operate equipment that can manage foreseeable flare gas flows and quality. To ensure that flaring is limited to emergencies, the Air District should establish emission limits based on feasible measures. (Lack of such limits has predictably increased industry secrecy claims and the public resource burden to investigate causes of flaring.) At Chevron and ConocoPhillips, these limits should reduce episodic flaring frequency by at least 65% and emissions by 70-90%.

3 The Bay Area Air District should ensure that all potential flaring impacts of projects to expand dirty crude refining are analyzed and that all measures necessary to prevent non-emergency flaring are required through its public reviews of flare minimization plans.

4 The City of Richmond and Contra Costa County should assess the cumulative impacts from projects to expand dirty crude refining, and support community participation in assessment of alternatives to these projects. These Environmental Quality Act reviews should ensure that this analysis is not piecemealed, and require net reductions in refinery pollution beyond those already promised by existing requirements.

5 All refineries should apply all flaring prevention measures that are demonstrated in practice at another facility. Air districts should require each refinery in their districts to apply these measures. The California Air Resources Board should ensure that air districts take this action.

6 The Bay Area Air District should enforce existing flare rule requirements for complete root-cause analysis and refinery gas system audits; and should expand flare monitoring and reporting to include nitrogen compounds, air toxics, carbon dioxide, and hourly gas quality.

Flaring still impacts local air quality frequently.

Flaring by five Bay Area refineries emitted a combined total of more than three million pounds of pollutants since January 2004. Nine-tenths of that pollution comes from flaring that occurs on only about one-tenth of all days. See Table 1. This means on some days episodic emissions are much larger than if the same total amount of pollution was emitted at a constant rate.

Table 1. Flare emissions from five Bay Area refineries in pounds, January 2004–December 2006.

	Sulfur dioxide	Non-methane hydrocarbon	Sulfur dioxide and NM hydrocarbon	Percent of emissions	Percent of days in period
All flaring	1,970,000	1,140,000	3,110,000	100%	62%
Episodic flaring	1,900,000	955,000	2,850,000	92%	12%

Data from refiners' reports under AQMD Rule 12-11. Episodic totals include all days when more than 500,000 standard cubic feet of gases were flared and/or more than 500 lbs of sulfur dioxide or non-methane hydrocarbon were emitted.

Episodic air pollution caused by refinery flaring has been documented in the Bay Area. (CBE, 2005; AQMD, 2006.) This previous work corroborates refinery neighbors' reports of acute exposure symptoms during and after flaring. It can also be used to put the ongoing flaring into context. Local air impacts are strongly associated with high flare emission concentration and mass, and can occur at emissions below 500 pounds per day. (CBE, 2005.)

Flaring episodes still burn more than half a million cubic feet of gases and/or emit more than 500 pounds of pollutants per day frequently. This flaring by the Chevron Richmond Refinery is 80% more frequent since the adoption of the flare rule in July 2005 than in the 19 months before its adoption–and now averages three or four days per month. See Table 2. Although three other refiners reduced their frequencies of these episodic flaring days by 64-74% since then, each of the other four refiners still flares above this threshold an average of about two days per month.

Some of these episodes cause massive pollutant emissions of 10,000-100,000 pounds per day, and median emissions from days of episodic flaring exceed 500 pounds/day at four of the five refineries. See Table 3. Nearly two years after the adoption of the Bay Area flare control rule, flaring still impacts local air quality frequently.

The flares still burn more than half a million cubic feet of gases and emit more than 500 pounds of pollutants in a day. This happens two to four times a month.

Table 2. Frequency statistics for days of episodic flaring, January 2004–December 2006.

	Total days of episodic flaring		Days of episodic flaring/month		
	Jan. 2004 -Jul. 2005	Aug. 2005 -Dec. 2006	Jan. 2004 -Jul. 2005	Aug. 2005 -Dec. 2006	Percent change
Chevron Richmond Refinery	38	61	2.0	3.6	+ 80%
ConocoPhillips Rodeo Refinery	50	38	2.6	2.2	– 15%
Tesoro Avon Refinery	135	43	7.1	2.5	– 64%
Valero Benicia Refinery	107	34	5.6	2.0	– 64%
Shell Martinez Refinery	139	32	7.3	1.9	– 74%

Data from AQMD Rule 12-11 flare monitoring reports for all days when more than 0.5 million standard cubic feet of gases were flared and/or more than 500 pounds of sulfur dioxide or non-methane hydrocarbon were emitted.

Table 3. Emission magnitude statistics for days of episodic flaring, August 2005–December 2006.

		Sulfur dioxide (SO_2) emission			**Non-methane hydrocarbon emission**		
	Median gas flow (scf/day)	Median concentration (mg/scf)	Median mass (lb/day)	Maximum mass (lb/day)	Median concentration (mg/scf)	Median mass (lb/day)	Maximum mass (lb/day)
Chevron	817,000	932	1,410	33,000	293	584	105,000
ConocoPhillips	1,540,000	350	1,940	17,100	122	454	2,010
Tesoro	1,350,000	343	597	10,800	84	289	1,700
Valero	1,000,000	27	214	4,190	363	1,130	11,900
Shell	2,630,000	5	40	1,530	53	174	1,210

Data from AQMD Rule 12-11 flare monitoring reports for all days when more than 0.5 million standard cubic feet of gases were flared and/or more than 500 pounds of sulfur dioxide or non-methane hydrocarbon were emitted. Concentrations in milligrams emitted per standard cubic foot of gases flared. Mass in pounds per day. Gas flow in standard cubic feet/day. The median flow and emission is shown instead of the mean because this better characterizes episodic data.

Some refiners emit more flare pollution than others.

Chevron, ConocoPhillips and Tesoro emit more sulfur dioxide (SO_2) than Shell and Valero from episodic flaring. See Table 3. Chevron, ConocoPhillips and Valero emit more hydrocarbon than Shell. Chevron and ConocoPhillips cause the largest emissions–and emit drastically more pollution than Shell from episodic flaring. Chevron's median SO_2 emission is 35 times Shell's. ConocoPhillips' SO_2 emission is 48 times Shell's.

This is true despite Shell's larger gas volumes flared because the other refiners flare gases with much higher pollutant concentrations. For example, Shell flares about three times more gases than Chevron but Chevron's SO_2 emission concentration is about 180 times Shell's.

Flare Episodes

In this report, "episodic flaring" means flaring that burns more than 500,000 standard cubic feet of gases per day, emits more than 500 pounds of sulfur dioxide per day, and/or emits more than 500 pounds of hydrocarbon/day.

Some of these "episodes" last more than a day, and exceed this threshold on some days but not on other days.

The report looks at days of episodic flaring above this threshold to assess air quality impacts (see pages 1-3). This is because flaring impacts local air quality on the days when the emissions occur. We know this from past work, including CBE's 2005 report, *Flaring Hot Spots,* and the Air District's March 2006 Staff Report for strengthening the flare rule.

Then, the rest of the report looks at the episodes from start to finish, to analyze prevention measures. This is because preventable causes of flaring may occur before, or after, the worst-emitting day of a flaring episode.

Process sources drive differences in flare emission between refineries.

Chevron and ConocoPhillips flare the dirtiest among Bay Area refineries mostly because they flare from dirtier process sources the most often.

Different refining processes are designed for different feedstock, products, and operating conditions, and produce gases of different quality. This is well known in the industry. It is further confirmed by recent Bay Area data. Analysis of flaring episodes at the five refineries shows that the mix of processes a refinery flares from strongly affects that refinery's flare emission concentrations. Four processes–*distillation, catalytic cracking, coking* and *hydrocracking*–flare gases with significantly higher hydrocarbon and/or sulfur content than the other types of processes that flare frequently at Bay Area refineries. See Appendix 1 for details of this analysis.

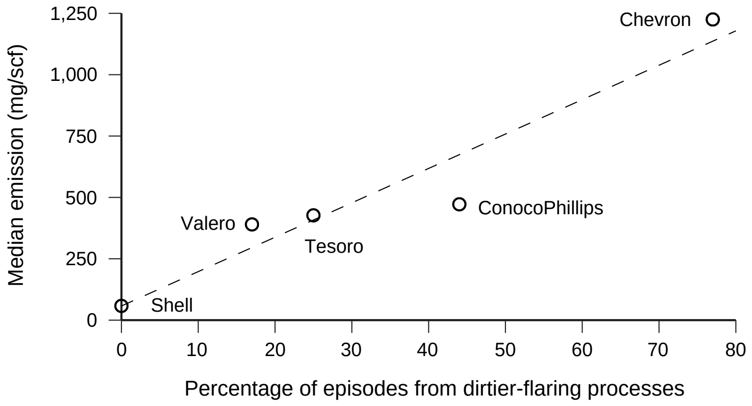
Refiners that flare from dirty processes dominate a pattern of high pollution flaring at relatively lower gas flows.

Distillation separates crude oil into different "fractions" that boil at different temperatures. Crude distillation is an early step in refining and occurs before much of the further processing that removes contaminants such as sulfur from the partially processed feedstocks. Distillation produces gases with high hydrocarbon and hydrogen sulfide (H_2S) content. (Flaring H_2S emits SO_2.)

Catalytic cracking, coking and *hydrocracking* use high temperature and pressure to break large hydrocarbon molecules into gasoline-sized hydrocarbons. Cat-cracking and hydrocracking also use catalysts to speed and control these "cracking" reactions. These reactions create gases with high hydrocarbon and/or H_2S content.

The bigger the portion of a refinery's flaring that burns gases from these dirtier-flaring processes, the higher its flare emission concentrations. Figure 1 shows this for combined emissions of SO_2 and non-methane hydrocarbon.

Figure 1. Episodic flare emission v. percentage of episodes from dirtier-flaring processes.



Concentration of SO_2 and non-methane hydrocarbon, August 2005-December 2006. Sum of medians from Table 3. Percentage of episodes in this period that flared from cat-cracking, coking, distillation and/or hydrocracking processes from refiners' reports that identify primary sources under AQMD rules 12-11 and 12-12 and Shell/EPA Consent Decree.

Chevron flares from dirty processes in almost 80% of its flare episodes and has the highest emission concentration among Bay Area refiners. ConocoPhillips flares from dirty processes in nearly 45% of its events and has the second highest concentration. Dirtier-flaring processes account for 25%, 17% and 0% of the flaring mix at Tesoro, Valero and Shell, respectively. This is for August 2005-December 2006. Appendix 1 confirms a similar pattern since at least 2003.

Refiners that flare from dirtier processes cause the worst emissions.

Flaring Prevention Measures

One refinery has virtually eliminated episodic flaring from dirtier processes.

In contrast to Chevron and ConocoPhillips, the Shell Martinez Refinery appears to have largely stopped episodic flaring from dirtier processes. Table 4 shows the total number of flaring events for which these processes were reported as contributing sources by the three refiners. No counts are shown for catalytic cracking at ConocoPhillips and coking at Chevron because these refineries do not use these respective processes. From 2001 through 2003, all three refiners reported flaring from these dirtier processes; but from 2004-2006, Chevron and ConocoPhillips continued episodic flaring from these processes while Shell did not.

Table 4. Counts of flaring events from dirtier-flaring process sources reported by three Bay Area refiners.

	Chevron Events		ConocoPhillips Events		Shell Events	
Process	2001-03	2004-06	2001-03	2004-06	2001-03	2004-06
Catalytic Cracking	5	7			3	0
Coking[a]			5	5	5	0
Distillation	3	4	0	1	1	0
Hydrocracking	22	21	11	3	7	0
Subtotals:	30	32	16	9	16	0

Includes all events with these process sources identified as reported under Rule 12-11, Rule 12-12, AQMD Information Request dated 5/21-22/02, ConocoPhillips Land Use Permit and Shell/EPA Consent Decree. [a]Excludes Shell's FXU process.

Flaring from dirtier processes may be more frequent than reported. Chevron and ConocoPhillips do not report flare gas sources or only report “various sources” for many events, and Air District rules require source reporting only for episodic events. Yet even in light of those limitations, Shell reports no episodic flaring from these dirtier processes during 2004-2006. This is because Shell has done things that Chevron and ConocoPhillips have not yet done to prevent flaring.

Shell reports prevention measures that integrate a three-part design: equipment with reliable capacity to recover and reuse gases instead of flaring; process operations that maintain refinery gas balance within this capacity, and root-cause analysis to prevent recurrent causes of flaring.

Equipment

Shell’s flare gas recovery compressor, treatment and reuse capacities for flare systems serving its cat-cracking, delayed coking, distillation and hydrocracking processes are shown in Table 5. During normal operation with both compressors in service, the Light Oil Processing (LOP) system can recover flare gas flows up to 0.267 million standard cubic feet per hour (mmscf/h) and the Delayed Coking Area (DCU) system can recover flows up to 0.333 mmscf/h. Gas treatment and reuse capacities match these flows. (FMP at 4-2, 4-16, 4-23, 4-32.)

Each of the two compressors serving each flare system can recover the typical “baseline” flare gas flow of its recovery system by itself, and each one is dedicated only to flare gas recovery service. That is important because compressors need more maintenance to prevent malfunctions than many other components of refinery gas systems. Each of Shell’s compressors can go off line for preventive maintenance while the other one provides enough “backup” capacity to recover gases instead of flaring during typical flow conditions. This is a reliable design.

Table 5. Flare gas recovery/reuse capacity of Shell Martinez systems serving dirtier-flaring processes.

mmscf/hour	**Flare gas recovery (FGR) compressor capacity** Unit	Usage	Rating	Normal Cap.	Maintenance	**Treatment & Reuse capacity**	**Baseline FG flow** (typical/average)
Light Oil Processing	J-65	FGR	0.133	0.267	0.133	≥ 0.267	0.104
(LOP) FGR system	J-66	FGR	0.133				
Delayed Coking Area	J-205	FGR	0.167	0.333	0.167	≥ 0.333	0.092[a]
(DCU) FGR system	J-206	FGR	0.167				

Data from Rule 12-12 Flare Minimization Plan (FMP), September 2006. [a]DCU includes Opcen hydrocarbon area flows.

Process compressors and their piping connections have been reconfigured to remove some of the loads from the flare gas compressors–especially for "wet gas" with condensable liquids. (FMP at 3-6.) A process compressor upgrade significantly reduced Shell's DCU flaring. (FMP at 4-29.) Piping is designed for flexibility in routing gases between the many refinery processes that produce, handle, and/or use them as fuel. (FMP at 3-6, 4-1, 4-21.) This supports operational measures that prevent flaring.

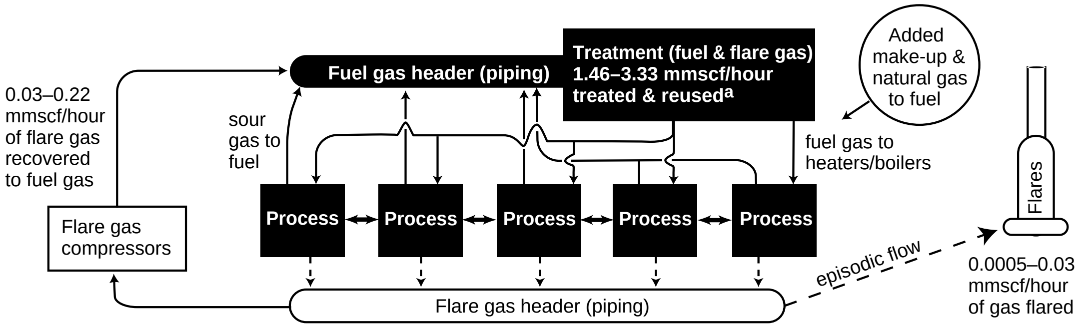
Prevention measures have a three-part design: Equipment with reliable capacity to recover and reuse gases; operation that maintains refinery gas balance, and root-cause analysis.

Process operations

Shell's operating policies state: "We will adjust the operation of process units to minimize flaring when consistent with safe and reliable operation." (FMP at 3-1.) Its refinery operators change process rates to keep gases safely in balance instead of flaring. That increases flare gas recovery/reuse capacity by leveraging the greater capacity of refinery fuel gas systems. This capacity difference is huge, as suggested in Figure 2: Typical average flows through five refiners' fuel gas systems range from 1.46-3.33 mmscf/h (shaded portion of figure), while those through their flare gas compressors range from 0.03-0.22 mmscf/h (left-hand portion of figure).

When a refinery is in ideal balance, process gases flow to its fuel gas system header and treatment, then back to the processes for use as fuel, as illustrated by the shaded parts of Figure 2. Gases flow to the flare gas header only if the fuel gas system cannot accept them directly, and those gases are flared only if the flare gas compressors and fuel gas system cannot recover, treat and reuse these gases. Routine flaring does not occur.

Figure 2. Typical average flows through Bay Area refinery flare gas and fuel gas systems.



Range of typical average flows from Rule 12-12 and 12-11 data for Bay Area systems with flare gas recovery.
[a]Flows treated and reused not available for Shell; ConocoPhillips data based on treatment capacity.

Thus, operating measures can maintain refinery gas balance to prevent flaring by taking advantage of the refinery's fuel gas system capacity. Adjusting the rates of gas production and usage by various refinery processes can do this in several ways:

- Adjusting process rates can make room in the fuel gas system to treat and reuse the recovered gases. Shell reports this capacity to match treatment and reuse capacities to its maximum flare gas compressor capacity. (FMP at 4-15, 4-16, 4-32.)
- Adjusting process rates can reduce baseline flare gas flows to increase the amount of available compressor capacity when gas flows increase or compressor capacities decrease due to equipment maintenance outages and process upsets. Shell's operating procedures include such measures. (FMP at 4-15, 4-16, 4-29, 4-32.)
- Adjusting process rates can moderate "spikes" in flare gas flow and fuel gas quality so that flare gases from maintenance activities stay within the range that can be recovered and reused. Shell shows that it has largely eliminated planned maintenance flaring from its LOP and DCU systems by carefully managing equipment depressuring, shutdown, and startup activities. (FMP at 3-6, 4-6, 4-13, 4-14, 4-30; Cause reports.)
- When flaring does occur, adjusting interconnected process and gas systems can also minimize emissions by flaring from less dirty sources. Shell monitors gas quality and avoids flaring gas flows with high H_2S content. (FMP at 3-6.)

These operating measures work together with equipment measures to prevent flaring.

Root-cause analysis and prevention

Shell and the other Bay Area refiners have been required to investigate and report on flaring episodes under a variety of requirements established between 2001 and 2006. (Shell/EPA Consent Decree; ConocoPhillips Land Use Permit; Rule 12-12 § 406; Rule 12-11 § 401.6.) This "root-cause analysis" investigates the causes and contributing factors of flaring episodes, and implements measures to prevent them from happening again. Shell's root-cause reports to EPA are more complete than other refiners' reports under the flare rule. (See e.g., CBE, 2006.)

Root-cause analysis identifies specific equipment and operational measures that can prevent flaring, and may also prevent some massive refinery flaring events, spills, fires and/or explosions. Table 6 shows specific examples for Shell.

Table 6. Cause analysis and prevention for flaring involving Shell flare gas compressor malfunctions.

	Flare gas compressor malfunction	Prevention measure done after flaring event
9/25/01	Condensable liquids trip (shut down) compressors	Process (wet gas) compressor equipment measures
3/22/02	Compressor trips; backup is in maintenance outage	Preventive maintenance measures expanded
5/14/02	Compressor trip; backup in maint.; coker blowdown	Wet gas reliability & process operation measures
2/12/03	Condensable liquids trip compressors	Wet gas compressor eqpmnt./operations measures
6/7/03	Compressor trip after hydrocracker P.R. valve lift	Capacity increased by rerouting gas flows to coker
12/18/05	Loss of cooling and compressors in electrical fault	Electrical insulation eqpmnt. & operating measures

Data from Flare Minimization Plan (FMP), causal reports under rules 12-11 and 12-12 and Shell/EPA Consent Decree.

Cause analyses in Table 6 identified several of Shell’s measures to upgrade process compressors and keep wet gas from overwhelming flare gas recovery; its equipment and operating measures that increase this capacity during maintenance and upsets, and its measures that improve preventive maintenance and the reliability of recovery equipment.

From 2001-2003, equipment and operational problems caused flaring at Shell almost as often as they have at Chevron and ConocoPhillips during 2004-2006, but in the recent period these problems occurred far less often at Shell. See Table 7. Compressor problems–the most common equipment problem involved in flaring at these plants–now occur less often at Shell, after the reliability upgrades to this equipment and its operation. Further, gas handling problems no longer contribute to Shell’s LOP and DCU flaring after its measures to adjust process rates, and to better manage depressuring, shutdown and startup of process units in planned maintenance. These are all still frequent problems at Chevron and ConocoPhillips.

Table 7. Recurrent causes of flaring identified from causal analysis at three Bay Area refineries.[a]

Number of times causes identified	Shell 2001-2003	Shell 2004-2006	Chevron 2004-2006	ConocoPhillips 2004-2006
Flare gas recovery compressor problem	5	1	9	7
Flare gas recovery compressor limitation	4		5	20
Process compressor problem	6	2	5	3
Valve, gasket or coupling problem	6	1	10	7
Electrical problem	1	1	2	3
Exchanger leak or plugging			3	2
Cooling problem		1	2	1
Pump failure			1	1
Equipment Problems Subtotal	**22**	**6**	**37**	**44**
Hydrogen handling problem	7		2	13
Nitrogen handling problem			4	5
Flare gas steam handling problem	1		3	2
Wet gas liquids handling problem	2		2	2
Flare gas abrasive salts problem			4	
Hydrate plugging problem			2	
H2S gas recovery/reuse problem			1	1
General recovery/reuse limitation	3	1		3
Operational Problems Subtotal	**13**	**1**	**18**	**26**
Prevention Analysis Problems				
Root-cause not reported[b]	**5**		**22**	**13**

CBE review of refiner's cause analysis reports under Shell/EPA Consent Decree, Rule 12-12, Rule 12-11, and ConocoPhillips Land Use Permit; for Shell LOP & DCU, Chevron N. & S. yard, and ConocoPhillips Main & MP30 flare systems. [a] These are minimum estimates; many events have multiple causes but some are not reported: [b] No cause, or no root-cause of an identified initiating cause or contributing factor, is reported for 40 flaring events in the periods shown. 2001-2003 reporting by Chevron and ConocoPhillips is too incomplete for this comparison.

However, Shell still causes frequent high-volume flaring episodes. (Tables 2 and 3.) Its flexicoker (FXU) complex includes a treatment process that produces low-hydrocarbon, low-H_2S, high-nitrogen gases Shell burns in some 19 heaters via a separate reuse system with no flare gas recovery compressor. (FMP at 3-5, 4-41.) This situation, which is not comparable to Chevron or ConocoPhillips, is the source of nearly all Shell’s episodic flaring. It should be investigated for NOx emission, and because it appears to be *designed* to flare periodically.

Flaring Prevention Measures

Measures achieved in practice can prevent flaring by Chevron and ConocoPhillips.

Equipment

Chevron and ConocoPhillips flare repeatedly because they lack adequate backup compressor capacity that is dedicated to flare gas recovery service. ConocoPhillips has one compressor in flare gas recovery service, unit G-503. (FMP[1] at Attachment B.) It has no backup. (Id.) ConocoPhillips cannot recover flare gases at any time when compressor G-503 is out of service. Table 8 shows examples of that.

Table 8. Backup flare gas compressor problems reported in flaring episodes at two refineries, 2004-2006.

	Refinery	Source(s)	Flare gas compressor problem that caused or contributed to flaring
10/27/04	ConocoPps.	Various sources	No backup compressor for compressor G-503 maintenance outage
12/28/04	ConocoPps.	Various sources	No backup compressor for maintenance to fix compressor loader
3/12/05	Chevron	Hydrocracking, others	Inadequate backup capacity for planned compressor maintenance
5/9/05	Chevron	Hydrocracking, others	Inadequate backup capacity for compressor maintenance outage
9/14/05	ConocoPps.	Various sources	No backup compressor for maintenance to fix compressor valve
1/10/06	ConocoPps.	Various sources	No backup compressor for maintenance to fix compressor loader
1/11/06	Chevron	Various sources	Inadequate backup capacity for compressor maintenance outage
1/23/06	Chevron	Various sources	Inadequate backup capacity for compressor maintenance outage
4/21/06	Chevron	Hydrocracking	Inadequate backup capacity for compressor maintenance outage
5/10/06	Chevron	Distillation	Backup compressors off line during main compressor maintenance
6/13/06	ConocoPps.	Various sources	No backup capacity for main compressor cooling loss shutdown
7/21/06	Chevron	Distillation	Compressor capacity exceeded in "hot" (86º F Max) weather
8/9/06	Chevron	Distillation	Compressor capacity exceeded in "hot" (92º F Max) weather
8/30/06	Chevron	Distillation	Off-gas shuts down backups and overwhelms main compressor

Data from refiner's reports for Rule 12-12, Rule 12-11, and ConocoPhillips Land Use Permit.

Chevron lacks adequate backup compressor capacity dedicated to flare gas recovery service because backup compressors K-1960 in its North Yard, and K-1171 and K-1171A in its South Yard are in dual service–their primary function is in process service. (FMP at 5, 27.) This lack of compressor capacity is a serious problem, as illustrated by three distillation flaring episodes that are listed at the bottom of Table 8. Compressors K-1171/A are distillation process compressors. (Id.) Chevron reports that on August 30, 2006:

> “Flaring occurred when the flare gas recovery (FGR) capacity in the Distillation and Reforming (D&R) business area was reduced due to the shut-down of the vent gas recovery compressors K-1171/A. The shut-down was caused by high liquid levels in the knockout drum V-1171 due to the increased off-gas production from the Reflux Drum V-1190 and overloading of the E-1190 fin fan coolers in the #4 Crude Unit. Mis-directed nitrogen (N_2) gas flow to the knock-out drums of the overhead gas compressors K-1100A/B caused the increase of the V-1190 off-gas rate and overloaded the E-1190.” (8/30-31/06 Cause Report.)

Chevron’s backup flare gas recovery was unavailable August 30th because its “backup” compressors were in process service at the same process where they were supposed to handle flare

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[1] FMP citations refer to the Flare Minimization Plan of the refinery discussed in the text.

gases, and lacked adequate spare capacity for flare gas recovery. The same compressors were in process service when recovery was overwhelmed on August 9, 2006. (8/9/06 Cause Report.) Flaring from the same cause occurred July 21, 2006. (Id.)

Compressor issues that are addressed by measures in place at Shell contributed to at least 41 flaring episodes at Chevron and ConocoPhillips since January 2004.

In these three episodes, process compressors let gases into the flare system *and* flare gas recovery compressors let them be flared. Flare flows stayed below 0.1 mmscf/h (12-11 reports) and *should* have been recovered. A cause in at least two of the episodes–related to hot weather–was clearly foreseeable. Chevron reported flaring caused by the "heat of the day" repeatedly; in May-July 2001, and in May 2002 when its distillation processes served by compressors K-1171/A "pressured up due to [the] high amount of light products in [the] crude slate and [the] heat of the day." (November 26, 2002 Response to AQMD 5/21/05 Information Request for Flaring.)

Flaring from such minor upsets in gas balance is clearly preventable, but it requires dedicated backup flare compressor capacity. This is because compressors need frequent maintenance but the timing of process upsets cannot always be predicted *and* the upsets can make "dual service" process compressors unavailable for flare gas recovery, as in the examples above. Chevron and ConocoPhillips clearly lack adequate dedicated backup capacity, as shown in Table 9.

Table 9. Dedicated backup flare gas recovery capacity at Chevron, ConocoPhillips and Shell.

mmscf/hour	Dedicated backup FGR Capacity[a]	Baseline flare gas flow (typical/avg.)	Dedicated backup average margin
Chevron North Yard Sysem	0.165	0.158	4%
Chevron South Yard System	0.000	0.046	−100%
ConocoPhillips refinery	0.000	0.092	−100%
Shell LOP System	0.133	0.104	28%
Shell DCU System	0.167	0.092	82%

Data from ConocoPhillips and Shell FMPs, and Chevron FMP revised April 5, 2007 per. com. with AQMD staff.

[a] Total capacity of any and all compressors dedicated to flare gas recovery that remain in service when one such compressor is out of service. Excludes Chevron's "dual use" process/flare gas compressors.

Chevron's and ConocoPhillips' over-reliance on process compressors to back up flare gas compressors lets process gases into their flare systems *and* fails to recover the resultant flare gases. This inherently unreliable equipment design limits opportunities for compressor maintenance, overworks compressors, and provides less total capacity to recover episodic process and flare gas loads. It is implicated in at least 41 flare gas compressor malfunctions and limitations that contributed to recurrent episodic flaring by the two refiners since January 2004. See Table 7. By comparison, Shell reported flaring from this cause once in the same period.

Chevron's compressor problems have caused recurrent flaring since at least 2001. (Tables 7 and 8; CBE, 2004.)

Installing dedicated backup capacity to avoid flaring when any one compressor is down for maintenance, and keeping all of it on line at other times, could solve this problem. It did at Shell. Piping upgrades might also be needed. Shell rerouted gases along with its process compressor upgrades, and rerouted its Opcen hydrocarbon gases to its DCU flare gas compressors. (FMP at 3-6, 4-34, 4-39.) To fully utilize the existing and future equipment capacity, however, each refiner must balance its *operation.*

Process operations

Gas handling problems that contributed to episodic flaring occurred at least 18 times at Chevron and 23 times at ConocoPhillips from 2004-2006. (Table 7.) Failure to operate the refineries in balance with the gas handling capabilities of existing equipment is an underlying cause of this flaring. Shell has virtually eliminated episodic flaring caused by such gas quantity and quality issues in its comparable systems. (Table 7.) Chevron and ConocoPhillips have not applied Shell's measure that directs refinery operators to minimize and prevent flaring by adjusting process rates whenever it is safe to do so. By applying this measure they could:

- *Prevent flaring* by making more room in their fuel gas systems to treat and reuse the gases their compressors can recover now, and in the future, when the needed upgrades to their compressor capacities are installed.
- *Prevent flaring* by further reducing baseline flare gas flows to further increase available recovery/reuse capacity during compressor maintenance, process maintenance, malfunctions and process upsets.
- *Minimize flare emissions* by better routing gases between their various process and gas handling equipment to avoid flaring from dirtier processes.
- *Better manage planned maintenance* by moderating peak gas flows from these activities and mixing these flows with other refinery gases (after separating reuse-ready maintenance streams) to avoid gas quantity and quality issues and ensure that the gases can be recovered and reused. This can prevent planned maintenance flaring episodes, as Shell has shown.

When Chevron and ConocoPhillips fix their equipment problems there will be fewer occasions when intensive management and process adjustments are needed to prevent flaring peak maintenance flows. This is illustrated by the–now hypothetical–example in Table 10. Until then, operating their existing equipment within its capacity requires ramping down process rates more than they do now in order to avoid flaring as a method of planned waste disposal.

Table 10. Hours of flaring[a] above and below total achievable future recovery capacity,[b] for 19 flare episodes during maintenance of cracking or coking processes at Chevron and ConocoPhillips.

	All flow rates	Below achievable[b] recovery capacity	1-2 times achievable[b] recovery capacity	2-4 x achievable[b] recovery capacity
Hours of flaring[a]	933	880	26	27
Percentage	100%	94%	3%	3%

[a] Based on flare gas flow for each hour ≥ 0.01 mmscf in episodes starting 2/7/04, 2/15/04, 7/23/04, 10/20/04, 10/31/04, 11/4/04, 2/11/05, 2/23/05, 3/3/05, 3/5/05, 3/12/05, 9/26/05, 10/10/05,10/23/05,11/30/05, 2/24/06, 3/8/06, 4/21/06 and 6/25/06 from Rule 12-11, Rule 12-12 and ConocoPhillips land use permit data.

[b] Rough projection to illustrate operational measures. Assumes equipment installed to solve identified backup flare gas and process compressor problems doubles total available capacity during planned maintenance to 0.767, 0.479 and 0.333 mmscf/h for Chevron North and South Yards and ConocoPhillips, respectively. Includes "dual use" process compressors. For reference, the Valero refinery's FMP reports a total flare gas recovery compressor capacity of 0.5 mmscf/h today.

The Chevron Richmond Refinery reported emitting an estimated 114,000 pounds of non-methane hydrocarbon and SO_2 from its flares on October 12, 2005. This is the worst day of flare emission reported by any Bay Area refinery since improved monitoring began in January 2004. Here is the full text of the “root-cause” report Chevron submitted to the Air District, under Rule 12-12, for that flaring event:

"Start Date: 10-Oct. Start Time: 10:30.
Description: Residual liquids/gases were purged and flared prior to performing maintenance activities on equipment within process plants in the Cracking Area Business Unit (ABU).
Primary Cause: Flaring from FCC and Alky-Poly Flares was caused by the need to perform periodic maintenance and catalyst replacements within the FCC, Alky, SHU and Poly process plants within the Cracking ABU. Flaring from RLOP flare was caused by liquid buildup in the North Yard Flare Gas Recovery System header line from steaming and depressuring activities during the Cracking ABU Shutdowns.
Contributing Factors: None identified.
Measures to Be Implemented: Install temporary drain line and initiate routine duty to manually drain accumulated liquids from North Yard Flare Gas Recovery Header line to a recovery vessel. Action Complete. Design and install an automatic system to drain accumulated liquids from the North Yard Flare Gas Recovery Header line to a recovery vessel. Action expected complete by end of 2006.
Measures Considered but not Implemented: None identified. Justification for not Implementing: Not applicable.
Consistent w/ FMP? This section does not apply until 11/1/2006.
Emergency explanation: Not applicable."

Chevron October 2005 Flaring Cause Investigation Report

Process adjustments that route gases to avoid flaring the dirtiest gas flows are especially important at Chevron and ConocoPhillips. Shell uses this measure, and has largely eliminated episodic flaring from dirtier processes. Chevron and ConocoPhillips cause the worst flare pollution among Bay Area refineries mostly because they flare from dirtier processes the most often. Applying this measure would take advantage of the high hydrocarbon content of the gases from dirtier-flaring processes for use as fuel, and it would greatly reduce flare emissions.

Root-cause prevention

At least 35 cause reports by Chevron and ConocoPhillips do not report a cause of the flaring, or do not report the root cause of an initiating cause or contributing factor in the flaring. See Table 7. For example, Chevron cited the initiating condition of a flaring event–planned maintenance–as its “primary cause” instead of seeking the root cause in its management of this planned flaring. See the box above. Failure to find root causes of flaring is a barrier to flaring prevention.

When they identified causes of their flaring, both refiners often failed to implement known prevention measures. Their recurrent compressor failures are examples of this problem. (Tables 7-9.) ConocoPhillips and Chevron either ignored or rejected measures to provide reliable backup of a failure-prone flare system component. This error violates basic engineering principles for redundancy in critical components of hazardous systems. Recurrent flaring from this cause indicates a chronic failure to complete the implementation step in root-cause analysis.

Shell’s root cause analysis identified and applied compressor upgrade, reliability and operations measures that reduced its flaring. Chevron and ConocoPhillips still flare often from the same causal factors that Shell has addressed. Complete root-cause analysis would help to prevent their flaring.

Chevron and ConocoPhillips often failed to prevent known causes of their flaring from recurring.

Flaring Prevention Measures

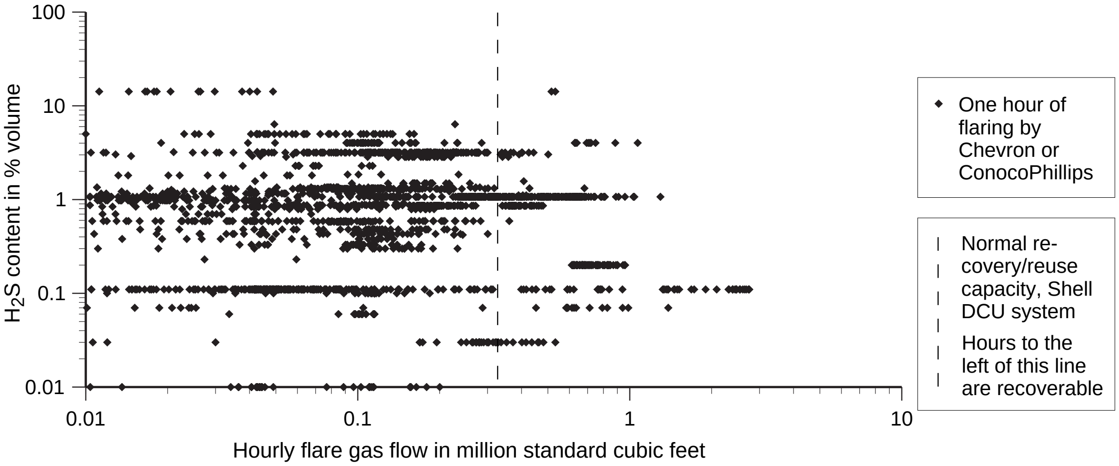
Feasibility

Measures in place at Shell can be used by other refineries to prevent flaring. Compressors are standard, well-understood technology within the industry. Process and flare system evidence shows that the compressors at issue would recover the same types of dirtier-flaring process gases as Shell recovers. Root-cause analyses show that they would address the same problems. All refiners routinely adjust the balance of processing rates between their interconnected units. Chevron admits the technical feasibility of process rate adjustments that help to prevent flaring (FMP at 19, 24-30), as does ConocoPhillips (FMP at 4-9 to 4-14). These measures are demonstrated in practice, transferable between refineries, and feasible at Chevron and ConocoPhillips.

Effectiveness

Applying measures used by Shell would cut Chevron's and ConocoPhillips' flaring dramatically. Recovery/reuse upgrade effectiveness is illustrated in Figure 3. The figure shows individual hours of episodic flaring by Chevron and ConocoPhillips from January 2004 through August 2006. Higher flow hours are toward the right, and episodes with higher H_2S concentrations are toward the top of the chart. The chart uses a log-scale so that flaring hours which are bunched together at lower flows can be pictured. The dashed line shows the normal recovery/reuse capacity of the Shell DCU system for comparison. This comparison shows that most of the hourly gas flows could be recovered and reused to prevent flaring.

Figure 3. Flare gas recovery/reuse potential for episodic flaring by Chevron and ConocoPhillips: Hours of episodic flaring plotted by hourly flare gas flow and episode-specific H_2S content.



Flare gas flow for each hour ≥ 0.01 mmscf and flare gas H_2S content in each flaring episode. For all episodes exceeding 0.5 mmscf/d, 500 lb/d SO_2 and/or 500 lb/d hydrocarbon reported with flow/hr from Jan. 2004-Aug. 2006 (60 episodes). Data from Rule 12-11, Rule 12-12 and ConocoPhillips land use permit reports. Shell DCU capacity from Table 5.

One of Shell's DCU backup compressors recovers up to 0.075 mmscf/h after handling baseline flow during maintenance of the other compressor, and 0.167 mmscf/h in normal operation, when the other unit handles baseline flow. (Table 5.) Applying this added capacity to the hourly flows from each flaring episode at Chevron and ConocoPhillips would reduce the frequency, duration and mass emission magnitude of their episodic flaring by 60%, 35-70% and 70-85%, respectively. See Table 11. Then, modest operational and root-cause prevention measures to avoid flaring from dirtier processes as much as the average performance of the Shell, Valero and Tesoro refineries would further reduce episode frequency (−65%) and SO_2 emissions (−90%). This second part of the projection calculates the percentage difference between the average process factor from the three other refiners combined and those of Chevron and ConocoPhillips,[2] and applies those percentage reductions in emission concentration to the actual concentration and remaining hourly flow volumes of each event.

Applying measures that are already being used by Shell could prevent at least 65% of the flaring episodes at Chevron and ConocoPhillips and cut emissions from their remaining episodes by at least 70-90%.

Table 11. Reductions in frequency and magnitude of episodic flaring at Chevron and ConocoPhillips projected from application of prevention measures demonstrated in practice at the Shell Martinez refinery.

	Episode frequency	Episode duration	Median episode emission	
			Hydrocarbon	Sulfur dioxide
Chevron Richmond Refinery	−60 to −65 %	−70 %	−80 %	−80 to −90 %
ConocoPhillips Rodeo Refinery	−60 to −65 %	−35 %	−70 %	−85 to −90 %

Estimates based on added flare gas recovery and reuse of 0.075 mmscf/h during compressor maintenance and 0.167 mmscf/h in other conditions, and actual hourly gas flows flared at Chevron and ConocoPhillips in all episodes from 1/1/04-8/31/06. Rule 12-11 reports. The lower frequency (−65%) and SO_2 (−90%) also reflect measures to avoid dirtier-flaring process sources, based on event-specific gas quality improved in proportion to the average achieved at Shell, Tesoro and Valero. See Appendix 1. For episodes that exceed 0.5 mmscf vent gases flared, 500 lb SO_2 emission and/or 500 lb hydrocarbon emission on any day.

Flare gas recovery/reuse accounts for most of this projected reduction. That is because it would prevent flaring of the toxic gases in so many low flow-high emission hours of flaring from dirtier processes at Chevron and ConocoPhillips.

Table 11 presents a conservative projection. Chevron and ConocoPhillips may need more recovery/reuse capacity than that of Shell's DCU system to recover some high-flow hours, unless they better manage maintenance. Also, ConocoPhillips relies on one flare gas recovery system for its entire refinery. This conservative projection assumes no effect from those additional measures: It assumes adding only Shell's DCU backup capacity cited above and no change in the hourly gas flows from managing planned maintenance. It further assumes no additional reduction in flaring frequency from root-cause analysis. Shell has largely eliminated flaring from dirtier processes, and applying its refinery-wide process factor[2] would reduce emission from episodic flaring at Chevron and ConocoPhillips by 99%.

Feasible prevention measures would be highly effective in reducing the frequency and magnitude of flaring, and its episodic air quality impacts.

This analysis conservatively projects 65% fewer flaring episodes that, when they occur, would be shorter and would emit 70-90% less episodic pollution. Applying measures already being used by Shell at Chevron and ConocoPhillips would be highly effective in reducing the frequency and magnitude of flaring known to cause episodic local air quality impacts.

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[2] Process factors quantify the mix of processes each refiner flares from, as detailed in Appendix 1.

Flaring Prevention Measures

Industry cost-benefit arguments do not refute the feasibility of these measures.

Refinery officials argue that the benefits of flaring prevention beyond their proposed plans are not worth the cost. (See FMPs.) However, the flare rule requires all prevention measures that are “[c]apable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, legal, social and technological factors.” Rule 12-12 §§ 202, 401.4. The refiners’ argument fails to address this requirement.

First, the refiners do not refute the technological feasibility and affordability of these measures; and could not, since the measures are demonstrated in practice and cost only pocket change in comparison with their record-breaking profits.

Second, the refiners’ argument ignores a crucial environmental factor by ignoring episodic impacts. Benefits of preventing episodic emissions are reaped at the moment when the emissions would occur. (AQMD, 1997.) However, the refiners’ cost-benefit arguments rely on long-term average emission estimates. This erroneous approach to a fundamentally *episodic* emission source ignores their flares’ most pronounced environmental impacts. Localized air quality impacts of Bay Area refinery flares have been demonstrated precisely because these episodic impacts occur when episodic flaring occurs, and not during the longer periods between episodes, which typically feature lower, if any, flare emissions. (CBE, 2005; see also AQMD, 2006.) Thus, the industry’s cost-benefit argument does not account for the benefits from preventing the best-documented, most serious environmental impact from its flaring.

A similar error ignores Chevron’s and ConocoPhillips’ concentrated emissions from dirtier-flaring processes at relatively lower flare gas flows. This error projects emission reductions using long-term average emission concentrations and daily flow instead of episode-specific concentrations and hourly flows. The result is that the industry’s cost-benefit argument underestimates the environmental benefits that are available from the feasible measures to prevent flaring still further. See Table 12. In one example, ConocoPhillips estimates only an 11% cut instead of the 70-90% reduction documented above, even though it assumes a larger new compressor.

Table 12. Estimation error from applying longterm average statistics to episodic event recovery/reuse.

	Longterm Average Projection Basis[a]		Episodic Event Projection Basis[b]		Difference
	Capacity added	Emission reduction	Capacity added	Emission reduction	(% error)
Chevron	0.167 mmscf/h	–44 %	0.167 mmscf/h	–80 to –90 %	82 to 104 %
ConocoPhillips	0.250 mmscf/h	–11 %	0.167 mmscf/h	–70 to –90 %	530 to 720 %

Comparison of projected reductions in combined emissions of sulfur dioxide and hydrocarbon. [a] Longterm average basis from longterm average concentrations and daily flows: Chevron FMP at 34 and 38 for 4 mmscf/d analysis; ConocoPhillips FMP "Case 2" 6 mmscf/d analysis. [b] Episodic event basis from episode concentrations and hourly flow: See Table 11.

Third, the refiners’ argument fails to consider important social factors. It ignores the disproportionate impacts of flare emissions on workers and working class communities of color near the refineries. This omission exacerbates a well-documented pattern of institutionalized environmental racism and injustice in the U.S.

The flare rule requires *all* prevention measures that are capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, legal, social and technological factors.

Oil companies' interest in profit maximization may conflict with preventing flaring. Valero flared gases it could have recovered to speed maintenance and ramp up gasoline production more quickly. (9/7/05 Cause Report.) Chevron and ConocoPhillips appear to give shifting explanations for declining to apply Shell's measure, which avoids flaring by adjusting process rates whenever this is consistent with safe and reliable operation, to their major maintenance activities.[3]

Refiners say periodic planned process shutdowns for maintenance "turnarounds" are essential for safe and reliable operation, and that is certainly true, but turnarounds may also occur when a refiner switches to a cheaper source of crude oil inputs. Refiners that routinely switch crude inputs generally must do turnarounds to prepare process equipment for the new feedstock. (Per. Com., 3/21/07 Air Resources Board staff.) If they flare in these cases, both their choice to switch crude sources, and their failure to manage turnaround activities with measures such as those demonstrated at Shell, would be preventable causes of that flaring.

Even more troubling, workers in at least two California refineries report the concern that short staffing may force them to choose between controlling process upsets and the other measures that prevent and minimize flaring.[4] An upset that requires efforts to prevent and minimize flaring also requires efforts to prevent it from escalating to cause a potentially catastrophic spill, fire or explosion–and often these tasks must be done at the same time. This concern, that refiners might cut corners on staffing a shift in which a major incident may occur, must be taken seriously.

Refiners' arguments do not account for these factors that support explicit requirements for both operational measures that prevent flaring, and adequate staffing for safety.

Oil industry arguments that environmental benefits of preventing flaring are not worth the cost fail to address the flare rule's actual requirement for all feasible measures. The industry's arguments do not refute the feasibility of the measures at issue here.

The cost-benefit argument also ignores other requirements to maintain adequately sized safety systems and achieve maximum emission control when refineries add new sources of gases and emissions. Chevron and ConocoPhillips are in the midst of major expansions, as shown below, so all of these requirements should apply to their intertwined processes and flare systems.

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[3] ConocoPhillips asserted a need to consider "minimization of loss of products to the market" and Chevron asserted "the need to prepare equipment for maintenance within a reasonable and practical period of time" in previous draft FMPs (at 4-9 and 22, respectively), but they replaced these statements with lists of other claimed limitations on process rate adjustment measures to prevent flaring in their March 2007 FMPs (ConocoPhillips FMP at 4-12 and 4-13; Chevron FMP at 26-28, 40).

[4] These conversations, with several representatives of CBE, occurred in the 2005-2007 time frame. CBE confirmed that the workers' concern is accurately restated with a refinery workers' labor union. The refinery staff who reported this information are not named here to protect them from potential retaliation, in light of current, arguably inadequate whistleblower protection laws and enforcement.

Flaring Prevention Measures

A switch to cheaper and dirtier crude oil threatens to increase flaring.

Refineries are expanding their capacity to convert low-quality oil into high-value fuels. This increases the production of gases from dirtier-flaring processes. Some have not upgraded gas system capacity enough to prevent flaring from the initial steps toward refining cheaper crude. This type of “dirty crude refining” expansion is designed to flare. The Shell Martinez refinery expanded gas handling when it expanded dirty crude processing, and largely eliminated episodic flaring from dirtier processes. Chevron and ConocoPhillips now propose dirty crude refining expansions, but they have not yet committed to those steps that Shell has taken.

Different crude oils have different mixtures of smaller hydrocarbons with few carbon atoms per molecule and larger ones with many carbons. Refiners call crude with more small molecules “light” and crude with more of the larger ones “heavy.” The difference can be huge: A refinery’s *distillation* process can get ten times more gasoline per barrel from lighter crude than from heavier crude, which can yield mostly gas oil and asphalt-like oils. See Figure 4. To make more gasoline, diesel and jet fuel, refiners “crack” these large molecules into smaller ones. Refiners that run heavier crude use more *catalytic cracking, hydrocracking* and/or *coking* capacity.

Different crudes also have different amounts of sulfur and other contaminants. The most contaminated crude can have 30 times more sulfur and 11-36,000 times more toxic trace metals than the least contaminated crude. See Table 13. Refiners call high-sulfur crude “sour” and low-sulfur crude “sweet.” They hydro-treat it to remove much of the sulfur and nitrogen, which can poison catalysts used in refinery processes. Hydrotreating also removes some metals. Thus, refiners running sour crude slates use more *hydrotreating.*

Table 13. Ranges of selected contaminants measured in different types of crude oil.

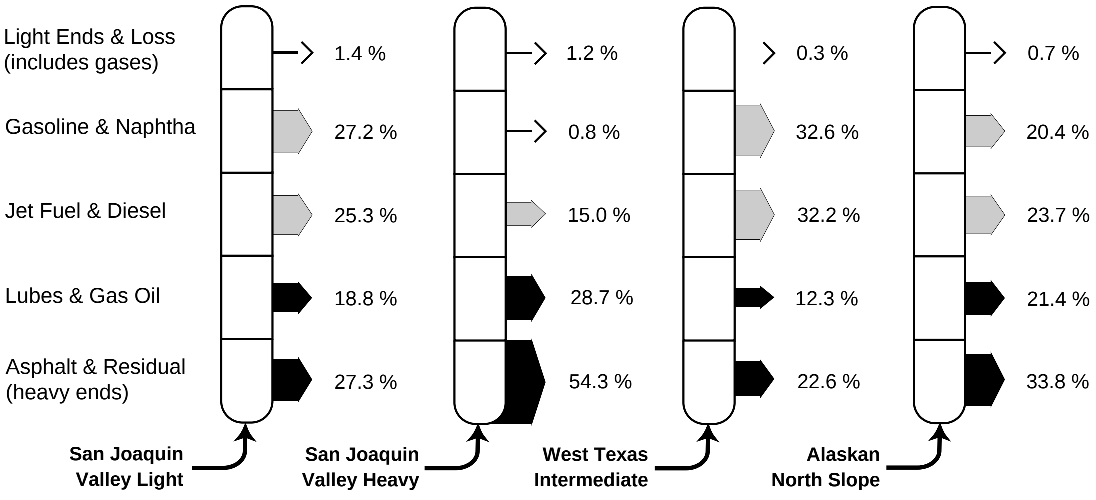
		Low-contaminant Sample Results		High-contaminant Sample Results		Difference
	units	Crude origin	Result	Crude origin	Result	(factor)
Arsenic[a]	ng/g	Louisiana	46.400	California	1,110.00	24 times
Chromium[a]	ng/g	Louisiana	1.560	California	17.50	11 times
Mercury[a]	ng/g	Louisiana	22.500	California	29,700.00	1,300 times
Mercury[b]	ng/g	Not reported	0.420	Not reported	15,200.00	36,000 times
Selenium[a]	µg/g	Louisiana	0.026	California	1.40	54 times
Sulfur[c]	%	Texas	0.110	Texas	3.34	30 times
Sulfur[d]	%	San Joaquin Valley	0.200	San Joaquin Valley	1.20	6 times
Uranium[a]	ng/g	Louisiana	4.000	California	434.00	109 times

Low and high U.S. samples from: [a] Shah et al., 1970. [b] Willhelm and Bloom, 2000. [c] Pillay et al., 1969. [d] Purvin & Gertz, 1992.

Cracked hydrocarbons are then “reformed” or “alkylated” to boost the octane rating of motor fuels, in *reforming* or *alkylation* processes. *Hydrogen plants* are often needed to make hydrogen for a refinery’s expanded hydrotreating and hydrocracking. These eight processes, among others, are typically expanded by refineries to make motor fuel from heavy, sour crude.

Refining heavy, sour crude has been linked to increasing refinery pollutant releases for more than ten years. (CBE, 1994.) Both the dirtier oil input and the more intensive processing needed to refine it increase pollution. Selenium discharge to San Francisco Bay increased more than the selenium content of refiners’ crude slates because of this more intensive processing. (Id.)

Figure 4. Approximate distillation yields for four types of crude oil, in percent volume.



Computed average yields from U.S. Dept. of Energy Analysis as reported by Purvin & Gertz, 1992.

Dirty crude refining can increase flare pollution in similar ways. It produces more gases from the expanded catalytic cracking, hydrocracking and coking that make vehicle fuels from the increased volumes of gas oil and heavy ends. This is because of the increased volumes cracked in these processes and because cracking reactions produce gases as well as fuel-sized hydrocarbons. Dirty crude may also produce more gases from distillation. See Figure 4. The bigger gas volumes will have higher concentrations of sulfur and other pollutants. See Table 13. Dirtier processes will flare more, and dirtier, unless more gases are recovered and reused.

Refining cheaper crude could make the dirtiest processes flare more, and dirtier, unless refiners expand their gas handling systems.

Chevron and ConocoPhillips propose major new steps in more than a decade of intertwined process expansions that amount to a fundamental shift in their fuel refining technology. One or both refiners has expanded or plans to expand the capacity of each process that the evidence above links to dirty crude refining. See Table 14. Chevron has expanded actual capacities of at least five of the processes that are

Table 14. Approximate completion dates for some expansions of processes linked to dirty crude refining.

	Completed Expansions		Planned Expansions	
	Richmond	Rodeo	Richmond	Rodeo
Alkylation			2007-2008	
Catalytic Cracking	1996		2007	
Coking		2004		
Distillation	1991	2004-2005		
Hydrocracking	1995		2007-2010	2008
Hydrogen plants	1994	1996	2008	2008
Hydrotreating	1995	2005	2007	2008
Reforming			2009	2008

Examples include process expansions, and increases in actual process capacity through de-bottlenecking for purposes other than hydrogen supply, at the Richmond (Chevron) and Rodeo (ConocoPhillips and other owners in previous years) refineries. Data from Chevron FMP at 7; ConocoPhillips 3/13/05 Cause Report; Cal. Env. Quality Act documents for SCH Nos. 92113007, 93121027, 2002122017, 2005072117, 2005092028; and AQMD permit applications. See text for process/crude source link.

associated with dirty crude refining and plans to expand or further expand at least six of them between 2007 and 2010. ConocoPhillips has expanded at least four since 1996 and plans to expand another four between 2007 and 2009. Both refiners' current expansion proposals seek to further increase the amounts of heavy gas oil and high-sulfur crude converted into gasoline, diesel and/or jet fuel. (CEQA documents for SCH# 2005072117; SCH# 2005092028.)

Chevron has not proposed any detailed plan or firm commitment to install dedicated backup flare gas recovery capacity or adequate recovery/reuse capacity to prevent non-emergency flaring with its new expansion. (SCH# 2005072117; FMP at 20-42.) Instead of adding backup capacity sized to its existing flare gas recovery compressor, ConocoPhillips proposes the same scheme that has already failed at Chevron–using a smaller compressor that primarily serves a different purpose in dual use as a *partial* backup for flare gas recovery. (FMP at 3-13, 3-16, 4-25.)

Shell installed its DCU flare gas recovery compressors among other equipment that expanded its gas recovery/reuse capacity when it built a major expansion of its dirty crude refining capacity in the mid-1990s. (AQMD App. 8407; Per. Com. 9/20/04 AQMD staff; SCH# 92093028; FMP.) This equipment has proven effective, with more recent measures, in largely eliminating episodic flaring from dirtier-flaring processes since 2004.

In contrast, Chevron and ConocoPhillips have inadequate equipment capacity for reliable flare gas recovery *today*. Monitoring was too poor twenty years ago to know whether their gas handling systems were adequate before the shift to dirty crude began, but current data show that they are not adequate now. There is a need to upgrade them to prevent flaring, even without the potentially large increase in high-pollutant gases that would result in flaring from their new expansion proposals. This feasible prevention measure would avoid a significant potential impact.

Total impacts from a full-blown shift to dirty crude refining–on workers and working class communities of color, regional environmental health, green energy, green jobs and the pace of energy transition to stop global warming–reach far beyond flaring and demand an urgent search for better alternatives. This review of flaring prevention measures identifies an aspect of these better alternatives that is needed and feasible now. Refinery upgrades should be designed, built and operated to prevent non-emergency flaring.

Closing

Measures to greatly reduce serious pollution from refinery flares are demonstrated in practice. This information supports community demands to stop the pollution, and government requirements to protect our environmental health. In the Bay Area, communities can act to ensure that our Air District will require these measures in "flare minimization" plans that are due for public comment in April-May 2007. Contact information for some of the responsible officials is listed on the last page of this report. In every refinery town, neighbors and workers can act to ensure that refiners commit to these measures before public officials permit expansions of low-cost crude oil refining–which otherwise threaten to further increase pollution from flares.

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Appendix 1: Flare gas quality analysis for refining processes

Different refineries flare from different processes that produce gases of different quality. The purpose of this analysis is to quantify these “process factors” at Bay Area refineries for hydrogen sulfide (H_2S) and the major gases from the processes that these plants flare from frequently: C2- hydrocarbon,[1] C3-5 hydrocarbon,[2] hydrogen (H_2) and nitrogen (N_2). The data available for this analysis are limited by industry self-monitoring. Consistent process source and gas quality reporting began only after November 2003, when Rule 12-11 began to require standardized monitoring and reporting. Further, after 2003, refiners often report incomplete flare gas source or quality data, and generally fail to report hourly flare gas composition. However, the refiners flare frequently, so many flaring episodes are reported.

For 130 episodes from December 2003 through August 2006, data are adequate to identify a primary process source of gases flared and quantify at least one of the five gases targeted in at least four episodes with the same type of process source. These represent 73% of the flaring episodes reported in this period, and include eight types of refining processes. Data from these 130 events are presented in Table A-4 at the end of this appendix, and are summarized in Table A-1 below. Review of Table A-1 shows that each refinery flares from a different mix of processes. This is consistent with their different equipment and different flaring prevention measures, such as Shell’s measures to prevent episodic flaring from its catalytic cracking, distillation, delayed coking and hydrocracking processes. (See e.g., Table 4.)

Table A-1. Counts of flaring episodes reported by refinery, process, and gas.

	Chevron Refinery					**ConocoPhillips**					**Shell Refinery**					**Tesoro Refinery**					**Valero Refinery**				
	C2-	C3-5	H2S	H2	N2	C2-	C3-5	H2S	H2	N2	C2-	C3-5	H2S	H2	N2	C2-	C3-5	H2S	H2	N2	C2-	C3-5	H2S	H2	N2
Cat. Cracking	6	6	6	6	6	No Cat. Cracking					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coking	No Coking					4	4	4	4	4	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
Distillation	4	4	4	4	4	1	1	1	1	1	0	0	0	0	0	0	0	1	2	2	0	0	0	0	0
Hydrocracking	15	15	15	15	15	3	3	3	3	3	0	0	0	0	0	4	2	5	7	7	1	1	3	3	3
Hydrogen plts.	0	0	0	0	0	5	5	5	5	5	0	0	0	0	0	7	7	12	11	11	2	2	2	2	2
Hydrotreating	4	4	4	4	4	2	2	2	2	2	0	0	0	0	0	5	5	6	6	6	6	6	15	15	15
Reforming	1	1	1	1	1	2	2	2	2	2	0	0	0	0	0	0	0	0	2	2	1	1	2	2	2
Shell Flexigas	No Flexigas					No Flexigas					20	20	30	30	30	No Flexigas					No Flexigas				

Gas quality and source data reported by Bay Area refineries for 130 flaring events in Table A-4. Totals from this table do not sum to the total number of events analyzed (130) because different gases were reported for different events in some cases.

The expected gas quality pattern is observed among these processes. Flare gases from catalytic cracking, coking, distillation and hydrocracking have the highest hydrocarbon and/or H_2S content, and those from hydrogen plants have the highest hydrogen content. See Table A-2 below. Median hydrocarbon and H_2S content in gases from the dirtiest-flaring process is always at least 30 times that from the lowest-flaring process. Hydrogen plants flare gases with 12 times higher H_2 content than catalytic cracking.

These differences in gas quality were assessed for statistical significance in paired comparisons (e.g., catalytic cracking v. coking for C2-, cat-cracking v. distillation for H_2S, etc.) using a nonparametric test (Mann-Whitney U). Many of these comparisons between the eight processes for the five gases (57 of 140) indicate significant differences in gas quality (two-tailed $p < 0.01$).

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[1] C2- is hydrocarbon with two or less carbon atoms per molecule: methane, ethane and ethylene.

[2] C3-5 is hydrocarbon in the propane–pentane range, with 3-5 carbon atoms per molecule.

Table A-2. Median flare gas concentrations by volume for eight processes.

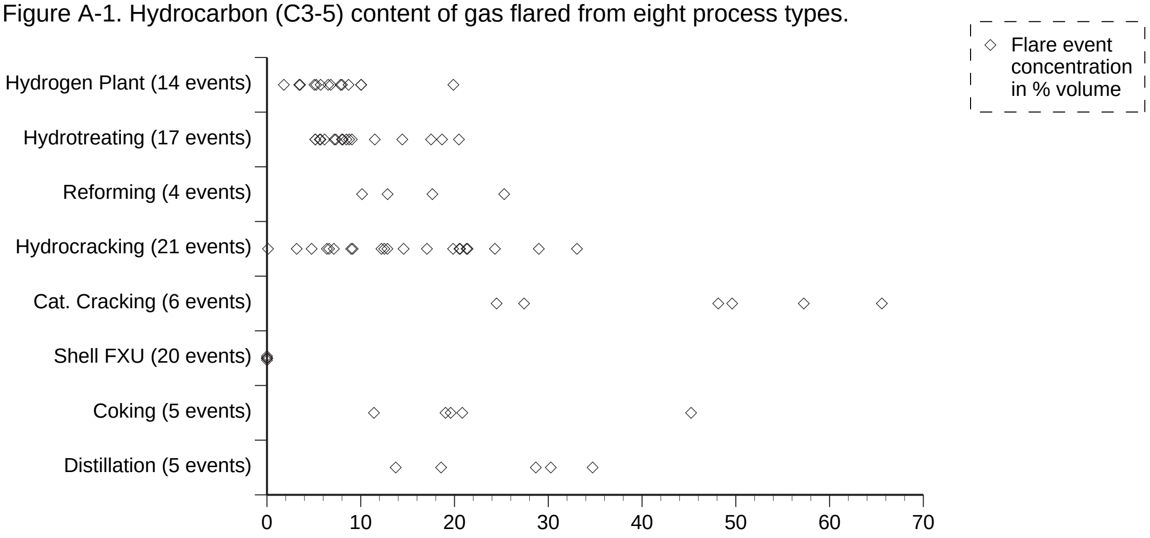
	C2-	C3-5	H_2S	H_2	N_2
Cat. Cracking	41.9 %	48.9 %	0.11 %	4.3 %	12.1 %
Coking	36.4 %	19.6 %	0.78 %	21.0 %	11.9 %
Distillation	13.1 %	28.7 %	1.52 %	28.7 %	7.3 %
Hydrocracking	19.0 %	12.8 %	1.05 %	42.8 %	14.3 %
Hydrogen plants	18.3 %	6.7 %	0.14 %	50.7 %	11.5 %
Hydrotreating	20.6 %	8.1 %	0.14 %	32.7 %	28.0 %
Reforming	22.3 %	15.3 %	0.98 %	35.2 %	18.6 %
Shell Flexigas (FXU)	1.4 %	< 0.01 %	< 0.01 %	16.9 %	53.0 %
All eight processes[a]	17.7 %	8.59 %	0.13 %	26.8 %	19.4 %

Gas quality and source data reported by Bay Area refineries for 130 events in Table A-4. [a] Median of the total data set for these processes. Process-specific values may not average or sum to this median or 100% of volume because processes have different data distributions, some gases are not reported for some events, and gases not shown are flared (e.g., CO_2).

Each dirtier-flaring process–catalytic cracking, coking, distillation and hydrocracking–flares gases with significantly higher hydrocarbon and/or H_2S content than those from several other processes. This finding holds even if Shell is removed from the comparisons.[3]

For example, several significant differences are apparent in the case of C3-5 hydrocarbon. Figure A-1 plots the C3-5 hydrocarbon content of gases in each flaring event for the eight processes. The lowest flaring event concentration from catalytic cracking exceeds the highest event concentrations from hydrogen plants and hydrotreating. At the same time, the lowest hydrogen plant and hydrotreating event concentrations exceed any from the twenty events reported from the FXU process. Each of these differences, among others,[4] is significant.

Figure A-1. Hydrocarbon (C3-5) content of gas flared from eight process types.



Event concentrations in % volume for 130 flaring events at five refineries shown in Table A-4.

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[3] Counting paired comparisons between processes for each pollutant (C2-, C3-5, H_2S) individually, when Shell is excluded, cat-cracking and coking each have significantly higher concentrations than other processes in four comparisons; hydrocracking is significantly higher in three comparisons, and distillation is significantly higher than other processes in five comparisons (two-tailed $p < 0.01$).

[4] For C3-5 in gases from dirtier-flaring processes: cat-cracking, coking and distillation are significantly higher than hydrogen plants, hydrotreating and FXU; cat-cracking is higher than hydrocracking, and hydrocracking is significantly higher than hydrogen plants and FXU (two-tailed $p < 0.01$).

Table A-3. Median flare gas concentrations by volume for five refineries.

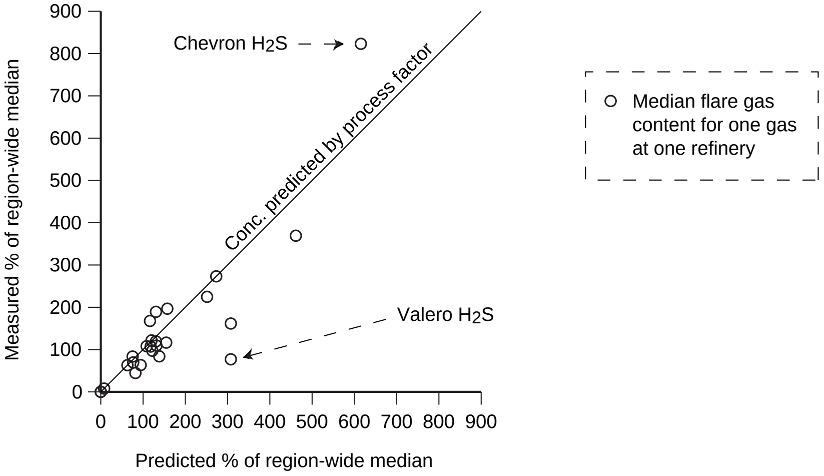
	C2-	C3-5	H_2S	H_2	N_2
Chevron	21.1 %	19.30 %	1.07 %	28.7 %	13.50 %
ConocoPhillips	33.5 %	10.00 %	0.48 %	22.5 %	16.20 %
Shell	1.4 %	< 0.01 %	< 0.01 %	16.9 %	53.00 %
Tesoro	19.1 %	5.44 %	0.21 %	52.7 %	8.64 %
Valero	17.2 %	14.40 %	0.10 %	29.3 %	23.60 %

Gas quality and source data reported by five refineries for 130 flaring events in Table A-4. Values may not sum to 100% because some gases are not reported for some events and gases not shown are flared (e.g., CO_2).

Refiners' flare gas concentrations reflect these different process sources. Flaring from dirtier processes (Table A-1), Chevron and ConocoPhillips flare gases with the highest median hydrocarbon and H_2S content among the five refineries. See Table A-3. Tesoro and Shell do the most hydrogen plant and FXU flaring, and flare gases with the highest H_2 and N_2 content, respectively.

A refinery's process factor is the process-specific median concentration of each gas weighted by the percentage of the refinery's flaring from each process. (See tables A-1 and A-2.) Figure A-2 compares each refinery's process factor for each gas with its refinery-specific median from direct measurements at the refinery in Table A-3. Values for each refinery and gas are shown as percentages of the region-wide median at the bottom of Table A-2. For example, Chevron's measured H_2S content is 820% and Valero's is 77% of the region-wide median.

Figure A-2. Effect of process sources on refinery-specific flare gas content.



Shows observations for five gases (C2-, C3-5, H_2S, H_2 and N_2) at each of five Bay Area refineries. Based on gas quality and source data reported by the refineries for 130 flaring events. Data are shown in Table A-4.

As shown in Figure A-2, there is a good fit between predicted and measured flare gas concentrations. Process factors explain about 80% of the difference in median flare gas quality between refineries for these five gases and 130 flaring episodes (R-squared = 0.79, p = 3E-09). The purpose of this comparison (in Figure A-2) is to gain a more formal understanding of the observations presented in Figure 1 on page 3 of the report. The parametric regression performed on the data shown in Figure A-2[5] further supports the underlying message of Figure 1: The mix of process sources a refinery flares from is a strong predictor of that refinery's flare gas quality.

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[5] A nonparametric regression would be more precise. That excercise is left to future analysis.

Table A-4. Gas quality and process source data for 130 flaring episodes.

Flaring event initiated	Refinery flaring	Initiating condition	Primary flare gas process source	Event mean flare gas content (fraction)				
				C2- by vol.	C3-5 by vol.	H2S by vol.	H2 by vol.	N2 by vol.
12/2/03	Valero	Not reported	Hydrotreating			0.0040	0.2830	0.2993
12/20/03	Valero	Not reported	Hydrotreating			0.0045	0.2530	0.2990
12/30/03	Valero	Not reported	Hydrocracking			0.0135	0.4920	0.1260
1/19/04	Tesoro	Planned Maint.	Hydrogen Plant			0.0027	0.5288	0.1267
1/24/04	Tesoro	Planned Maint.	Hydrogen Plant			0.0031	0.2148	0.3150
1/26/04	Shell	Not reported	Shell FXU			0.0000	0.1740	0.5440
1/31/04	Valero	Not reported	Hydrotreating			0.0010	0.5160	0.1530
2/2/04	Valero	Not reported	Hydrotreating			0.0010	0.6800	0.0780
2/3/04	Valero	Not reported	Hydrotreating			0.0000	0.1460	0.6320
2/7/04	Chevron	Planned Maint.	Hydrocracking	0.1166	0.2431	0.0122	0.5414	0.0573
2/7/04	Tesoro	Not reported	Hydrogen Plant			0.0082	0.3263	0.2484
2/10/04	Shell	Planned Maint.	Shell FXU			0.0000	0.1720	0.5300
2/10/04	Valero	Not reported	Hydrotreating			0.0000	0.4300	0.3200
2/15/04	Chevron	Planned Maint.	Hydrocracking	0.0914	0.1221	0.0010	0.6242	0.1213
3/1/04	Tesoro	Planned Maint.	Hydrocracking			0.0021		
3/4/04	Tesoro	Planned Maint.	Hydrogen Plant			0.0021		
3/28/04	Valero	Not reported	Hydrotreating			0.0010	0.6380	0.0830
4/10/04	Shell	Malfunction	Shell FXU			0.0000	0.1310	0.6600
4/15/04	Tesoro	Malfunction	Hydrotreating			0.0083	0.3454	0.1454
6/12/04	Valero	Not reported	Reforming			0.0040	0.2810	0.3410
7/23/04	ConocoPhillips	Planned Maint.	Hydrocracking	0.3355	0.0011	0.0000	0.0037	0.6596
9/7/04	Shell	Planned Maint.	Shell FXU			0.0000	0.1830	0.5170
9/7/04	Tesoro	Planned Maint.	Distillation			0.0121	0.2464	0.1452
10/5/04	Shell	Malfunction	Shell FXU			0.0000	0.1790	0.5230
10/20/04	ConocoPhillips	Planned Maint.	Hydrocracking	0.1569	0.2139	0.0402	0.3822	0.1199
10/24/04	ConocoPhillips	Planned Maint.	Hydrogen Plant	0.0882	0.0653	0.0020	0.7352	0.0741
10/30/04	Tesoro	Planned Maint.	Distillation				0.2874	0.0732
10/31/04	Chevron	Planned Maint.	Hydrocracking	0.0171	0.0914	0.0010	0.0137	0.8716
11/4/04	Chevron	Planned Maint.	Hydrocracking	0.1760	0.0713	0.0321	0.2875	0.2835
11/23/04	Chevron	Malfunction	Hydrotreating	0.0578	0.0847	0.0030	0.3879	0.4639
11/23/04	Tesoro	Malfunction	Hydrogen Plant			0.0032	0.2847	0.0785
12/3/04	Shell	Malfunction	Shell FXU			0.0000	0.1745	0.5195
12/23/04	Tesoro	Planned Maint.	Hydrocracking				0.6677	0.0636
1/3/05	Shell	Planned Maint.	Shell FXU			0.0000	0.1670	0.5270
1/4/05	ConocoPhillips	Planned Maint.	Hydrogen Plant	0.0278	0.0785	0.0011	0.1621	0.5696
1/6/05	Tesoro	Planned Maint.	Hydrocracking				0.4668	0.2422
1/8/05	Shell	Malfunction	Shell FXU			0.0000	0.1670	0.5270
1/14/05	Shell	Planned Maint.	Shell FXU			0.0000	0.1690	0.5350
2/5/05	Tesoro	Planned Maint.	Reforming				0.6533	0.0576
2/11/05	ConocoPhillips	Planned Maint.	Coking	0.2605	0.4523	0.0048	0.2452	0.0000

Table A-4. Gas quality and process source data for 130 flaring episodes (continued).

				Event mean flare gas content (fraction)				
Flaring event initiated	Refinery flaring	Initiating condition	Primary flare gas process source	C2- by vol.	C3-5 by vol.	H2S by vol.	H2 by vol.	N2 by vol.
2/11/05	Tesoro	Planned Maint.	Reforming				0.4877	0.0474
2/13/05	Tesoro	Planned Maint.	Hydrocracking				0.6037	0.0347
2/19/05	Shell	Malfunction	Shell FXU			0.0000	0.1760	0.5195
2/23/05	Chevron	Planned Maint.	Hydrocracking	0.2357	0.1284	0.0130	0.2863	0.2983
3/3/05	Chevron	Planned Maint.	Hydrocracking	0.3163	0.1457	0.0135	0.0049	0.5180
3/5/05	Chevron	Planned Maint.	Catalytic Cracking	0.1759	0.6558	0.0007	0.0012	0.1633
3/12/05	Chevron	Planned Maint.	Hydrocracking	0.2022	0.3306	0.0501	0.2699	0.1470
3/13/05	ConocoPhillips	Planned Maint.	Hydrogen Plant	0.2092	0.0180	0.0010	0.3826	0.2205
3/14/05	ConocoPhillips	Malfunction	Hydrotreating	0.4081	0.0571	0.0006	0.3030	0.1386
3/15/05	ConocoPhillips	Malfunction	Hydrogen Plant	0.3670	0.0800	0.0010	0.3520	0.0000
3/25/05	Valero	Malfunction	Hydrocracking			0.0020	0.2660	0.2360
3/26/05	Shell	Malfunction	Shell FXU	0.0144	0.0000	0.0000	0.1741	0.5237
3/29/05	Valero	Planned Maint.	Hydrotreating			0.0007	0.2637	0.3193
4/5/05	Tesoro	Malfunction	Hydrogen Plant	0.1815	0.0525	0.0013	0.5259	0.0686
4/7/05	Valero	Planned Maint.	Hydrotreating			0.0090	0.3269	0.2163
4/10/05	ConocoPhillips	Malfunction	Reforming	0.4503	0.1286	0.0149	0.1983	0.1861
4/10/05	Shell	Planned Maint.	Shell FXU	0.0300	0.0000	0.0000	0.1644	0.5517
4/18/05	ConocoPhillips	Malfunction	Coking	0.8276	0.1141	0.0001	0.0042	0.0009
5/3/05	Shell	Malfunction	Shell FXU	0.0140	0.0000	0.0000	0.1942	0.5095
5/23/05	Shell	Planned Maint.	Shell FXU	0.0151	0.0000	0.0000	0.1682	0.5802
6/7/05	Tesoro	Not reported	Hydrogen Plant	0.1849	0.0344	0.0014	0.5031	0.0608
6/21/05	Shell	Not reported	Shell FXU	0.0143	0.0000	0.0000	0.1599	0.5337
7/6/05	Shell	Not reported	Shell FXU	0.0129	0.0001	0.0000	0.1554	0.5377
7/15/05	Shell	Malfunction	Shell FXU	0.0129	0.0001	0.0000	0.1554	0.5377
7/28/05	Tesoro	Not reported	Hydrotreating	0.1572	0.0563	0.0012	0.7559	0.0292
8/14/05	Valero	Malfunction	Hydrogen Plant	0.1723	0.1988	0.0007	0.3755	0.1457
8/21/05	Shell	Malfunction	Shell FXU	0.0078	0.0000	0.0000	0.1539	0.5266
8/26/05	ConocoPhillips	Planned Maint.	Hydrogen Plant	0.4503	0.1003	0.0111	0.1633	0.1737
9/7/05	Tesoro	Malfunction	Hydrocracking	0.1401		0.0058	0.7856	0.0316
9/7/05	Valero	Planned Maint.	Hydrotreating	0.1941	0.0905	0.0003	0.1731	0.5498
9/12/05	Valero	Planned Maint.	Hydrotreating	0.1653	0.1750	0.0000	0.2553	0.3443
9/14/05	Tesoro	Malfunction	Hydrocracking	0.1178		0.0004	0.8157	0.0241
9/16/05	Shell	Malfunction	Shell FXU	0.0125	0.0003	0.0000	0.1639	0.5294
9/18/05	Shell	Malfunction	Shell FXU	0.0083	0.0002	0.0000	0.1604	0.5390
9/22/05	Shell	Malfunction	Shell FXU	0.0083	0.0002	0.0000	0.1604	0.5390
9/26/05	ConocoPhillips	Planned Maint.	Coking	0.4489	0.1959	0.0285	0.1589	0.1185
9/28/05	Chevron	Malfunction	Catalytic Cracking	0.3970	0.4813	0.0011	0.0604	0.0521
10/8/05	ConocoPhillips	Malfunction	Hydrocracking	0.1789	0.0898	0.0086	0.5493	0.1387
10/10/05	Chevron	Planned Maint.	Catalytic Cracking	0.4442	0.4961	0.0011	0.0053	0.1236
10/20/05	Shell	Malfunction	Shell FXU	0.0129	0.0000	0.0000	0.1628	0.5300

Table A-4. Gas quality and process source data for 130 flaring episodes (continued).

Flaring event initiated	Refinery flaring	Initiating condition	Primary flare gas process source	Event mean flare gas content (fraction) C2- by vol.	C3-5 by vol.	H2S by vol.	H2 by vol.	N2 by vol.
10/23/05	Chevron	Planned Maint.	Hydrocracking	0.1821	0.1251	0.0079	0.4885	0.1945
10/26/05	Tesoro	Malfunction	Hydrotreating	0.2128	0.0515	0.0019	0.6540	0.0615
10/28/05	Chevron	Planned Maint.	Hydrotreating	0.2501	0.1867	0.0317	0.2511	0.2804
11/13/05	Valero	Planned Maint.	Hydrotreating	0.2745	0.1443	0.0024	0.1604	0.3613
11/20/05	Valero	Planned Maint.	Hydrotreating	0.2056	0.1150	0.0026	0.2197	0.3810
11/30/05	Chevron	Planned Maint.	Catalytic Cracking	0.4399	0.2742	0.0001	0.0256	0.2545
12/7/05	Tesoro	Malfunction	Hydrocracking	0.1897	0.0317	0.0175	0.4255	0.3298
12/16/05	Chevron	Malfunction	Hydrocracking	0.2883	0.2899	0.1420	0.2539	0.0259
12/31/05	Shell	Malfunction	Shell FXU	0.0112	0.0000	0.0000	0.1745	0.5330
1/6/06	Tesoro	Planned Maint.	Hydrogen Plant	0.1933	0.0353	0.0002	0.6629	0.0637
1/8/06	Tesoro	Planned Maint.	Hydrotreating	0.1966	0.0734	0.0035	0.5603	0.1504
1/13/06	Chevron	Malfunction	Catalytic Cracking	0.2624	0.5725	0.0023	0.1324	0.0196
1/13/06	Chevron	Planned Maint.	Hydrotreating	0.1090	0.0808	0.0059	0.3417	0.4512
1/22/06	ConocoPhillips	Planned Maint.	Reforming	0.3052	0.1764	0.0132	0.2255	0.2244
1/27/06	Tesoro	Planned Maint.	Hydrogen Plant	0.1521	0.0506	0.0007	0.5533	0.1034
1/31/06	Tesoro	Malfunction	Hydrogen Plant	0.2627	0.0572	0.0017	0.5098	0.0576
2/8/06	Tesoro	Malfunction	Hydrogen Plant	0.1995	0.1005	0.0082	0.5466	0.1277
2/13/06	Tesoro	Malfunction	Hydrogen Plant	0.1349	0.0680	0.0008	0.5584	0.1622
2/17/06	Valero	Planned Maint.	Hydrocracking	0.1883	0.2128	0.0016	0.2695	0.1938
2/20/06	Chevron	Malfunction	Hydrocracking	0.1164	0.1985	0.0157	0.6608	0.0086
2/24/06	Chevron	Planned Maint.	Hydrocracking	0.2586	0.2052	0.0500	0.2292	0.2569
3/1/06	ConocoPhillips	Malfunction	Coking	0.3637	0.1904	0.0092	0.2100	0.1689
3/6/06	Valero	Planned Maint.	Reforming	0.0920	0.2530	0.0008	0.3518	0.2177
3/8/06	Chevron	Planned Maint.	Hydrocracking	0.2190	0.0639	0.0317	0.4151	0.1633
3/11/06	ConocoPhillips	Malfunction	Hydrotreating	0.2437	0.0719	0.0001	0.2466	0.3887
3/12/06	Chevron	Malfunction	Hydrotreating	0.3232	0.0799	0.0116	0.5425	0.0422
3/14/06	Chevron	Malfunction	Catalytic Cracking	0.4526	0.2449	0.0059	0.1720	0.1179
3/15/06	Shell	Malfunction	Shell FXU	0.0133	0.0000	0.0000	0.1661	0.5366
4/7/06	Chevron	Planned Maint.	Reforming	0.1408	0.1014	0.0098	0.6853	0.0627
4/21/06	Chevron	Planned Maint.	Hydrocracking	0.2480	0.2060	0.0087	0.2276	0.2963
4/29/06	Shell	Malfunction	Shell FXU	0.0123	0.0000	0.0000	0.1457	0.5215
5/1/06	ConocoPhillips	Malfunction	Distillation	0.4106	0.1373	0.0303	0.1897	0.1620
5/10/06	Chevron	Malfunction	Distillation	0.1462	0.1857	0.0043	0.6398	0.0230
5/18/06	Valero	Malfunction	Hydrogen Plant	0.1645	0.0870	0.0000	0.6439	0.1010
5/20/06	Valero	Planned Maint.	Hydrotreating	0.0969	0.0516	0.0000	0.2929	0.5550
5/27/06	Valero	Planned Maint.	Hydrotreating	0.1401	0.0614	0.0002	0.6485	0.1136
5/31/06	Tesoro	Malfunction	Hydrotreating	0.3546	0.0876	0.0036	0.3933	0.1430
6/5/06	Shell	Malfunction	Shell FXU	0.0142	0.0000	0.0000	0.1727	0.4976
6/16/06	Tesoro	Malfunction	Hydrotreating	0.4813	0.2047	0.0014	0.1983	0.0942
6/19/06	Shell	Malfunction	Shell FXU	0.0141	0.0000	0.0000	0.1715	0.4990

Table A-4. Gas quality and process source data for 130 flaring episodes (continued).

Flaring event initiated	Refinery flaring	Initiating condition	Primary flare gas process source	Event mean flare gas content (fraction) C2- by vol.	C3-5 by vol.	H2S by vol.	H2 by vol.	N2 by vol.
6/25/06	Chevron	Planned Maint.	Hydrocracking	0.3495	0.1706	0.0042	0.4307	0.0412
7/6/06	Tesoro	Malfunction	Hydrocracking	0.2031	0.0476	0.0013	0.6303	0.0948
7/10/06	Shell	Planned Maint.	Shell FXU	0.0141	0.0000	0.0000	0.1740	0.4981
7/11/06	Chevron	Malfunction	Hydrocracking	0.3839	0.0662	0.0636	0.4660	0.0204
7/11/06	Shell	Planned Maint.	Shell FXU	0.0141	0.0000	0.0000	0.1740	0.4981
7/21/06	Chevron	Malfunction	Distillation	0.0942	0.2867	0.0291	0.5674	0.0226
8/2/06	Valero	Malfunction	Coking	0.3633	0.2083	0.0078	0.3053	0.1513
8/9/06	Chevron	Malfunction	Distillation	0.0920	0.3027	0.0122	0.5605	0.0327
8/22/06	Shell	Planned Maint.	Shell FXU	0.0177	0.0000	0.0000	0.1921	0.5433
8/30/06	Chevron	Malfunction	Distillation	0.1314	0.3473	0.0181	0.2730	0.1715

Data from refiners' monthly monitoring reports under AQMD Rule 12-11 and refiners' cause reports under rules 12-11 and 12-12, Condition 7 of ConocoPhillips Land Use Permit, and Shell/EPA consent decree in Civil Action No. H-01-0978.

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The Flare Minimization Plan proposed by each of the five Bay Area refineries is available in April and May, 2007, from the Air District by phone or web:

(415) 749-4999

www.baaqmd.gov/flares