BAY AREA AIR QUALITY MANAGEMENT DISTRICT

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BAAQMD TBARCT WORKBOOK

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BAY AREA AIR QUALITY MANAGEMENT DISTRICT
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BAAQMD TBARCT WORKBOOK

1. INTRODUCTION

The Air District's Regulation 11, Rule 18, Reduction of Risk from Air Toxic Emissions at Existing Facilities, requires existing facilities to reduce health risks below the risk action levels specified in Section 11-18-218. Facilities subject to this rule must submit and implement a risk reduction plan, pursuant to Section 11-18-301 and 11-18-404, within the time frames specified in Sections 11-18-403 and 11-18-405.

As indicated in Section 11-18-404.6.3, a subject facility that cannot feasibly reduce health impacts below the risk action levels shall demonstrate that best available retrofit control technology for toxics, or TBARCT, has been or will be installed on all significant sources. This document describes the procedures the Air District will follow to identify TBARCT for a source.

Facilities that need to install new equipment, modify or alter existing equipment, and/or revise permit conditions to meet TBARCT requirements must apply for and obtain permits from the Air District and any other necessary agencies prior to implementing these facility improvements.

1.1 Background

Rule 11-18 is a health risk-based rule that will require an updated health risk assessment (HRA) for a facility based on the facility’s most recent toxic air contaminant emission inventory, the toxicity of the materials emitted, the proximity of the facility to nearby receptors, and the resulting prioritization score for the site. Sections 11-18-103 and 11-18-104 identify two types of facilities - sites with only emergency-use diesel engines and retail gasoline dispensing facilities - that will not be subject to this rule provided the facility prioritization score is less than 250.

The Air District will notify a facility when the facility’s toxic emissions trigger a facility-wide HRA. Section 11-18-401 requires a facility to submit any information that the Air District needs to complete the HRA for that facility.

Facility-wide HRAs for Rule 11-18 will be conducted in accordance with the Air District’s December 2016 HRA Guidelines, which are published on the Air District’s web site:

http://www.baaqmd.gov/~/media/files/planning-and-research/permit-modeling/hra_guidelines_12_7_2016_clean-pdf.pdf?la=en

The Air District will notify the facility if the APCO-approved HRA results exceed a Rule 11-18 risk action level. As defined in Section 11-18-218.1, the initial risk action levels are: a cancer risk of 25 per million, a chronic hazard index of 2.5, and an acute hazard index of 2.5, effective upon the adoption date of Rule 11-18. As defined in Section 11-18-218.2 and effective January 1, 2020, these risk action levels are reduced to: a cancer risk of 10 per million, a chronic hazard index of 1.0, and an acute hazard index of 1.0.

Some facilities may not be able to achieve these risk action levels, even when the facility is employing stringent emission control technologies. Therefore, the Air District is allowing facilities the alternative to employ TBARCT on all significant sources of health risks in lieu of achieving health risks for the maximally exposed individual that are less than the risk action levels.

The TBARCT compliance criteria are described in the risk reduction plan requirements in Section 11-18-404.6.3. The facility must demonstrate that it is not feasible for the facility to reduce the health risks below all risk action levels. The facility must also demonstrate, to the satisfaction of the APCO, that all significant sources of health risks currently have TBARCT or that TBARCT will be installed within the deadlines specified in Section 404.6.3.2. The Air District will identify significant sources for a facility based on the APCO-approved HRA, if the facility proposes to demonstrate compliance with this regulation pursuant to Section 11-18-404.6.3.

1.2 Definitions

Best available retrofit control technology for toxics, or TBARCT, is defined in Section 11-18-204 as follows:

> For any existing source of toxic air contaminants, except cargo carriers, the most stringent of the following retrofit emission controls, provided that under no circumstances shall the controls be less stringent than the emission control required by any applicable provision of federal, state or district laws, rules, regulations or requirements:
>
> - The most effective retrofit emission control device or technique that has been successfully utilized for the type of equipment comprising such a source; or
> - The most stringent emission limitation achieved by a retrofit emission control device or technique for the type of equipment comprising such a source; or
> - Any retrofit control device or technique or any emission limitation that the APCO has determined to be technologically feasible for the type of equipment comprising such a source, while taking into consideration the cost of achieving health risk reductions, any non-air quality health and environmental impacts, and energy requirements; or
> - The most stringent retrofit emission control for a source type or category specified as MACT by U.S. EPA, or specified in an ATCM by CARB.

A significant source of health risks is defined in Section 11-18-222 as follows:

> A source of toxic air contaminants or health risk that poses a risk equal to or greater than a significant risk threshold at any MEI location at which all sources at the facility, taken together, pose a health risk equal to or greater than a risk action level.

A source commonly means an individual piece of equipment, but a source may also include “related groupings” of devices as defined in Section 11-18-223.

The significant risk thresholds for a source are a cancer risk of 1.0 per million, a chronic hazard index of 0.2, or an acute hazard index of 0.2, as defined in Section 11-18-221. Based on the results of the Air District approved HRA for the facility, the Air District will review all sources that result in health risks that are equal to or greater than the significant risk thresholds and that contribute to facility-wide health risks that exceed the risk action levels. Based on this review, the Air District will identify the significant sources that would need to meet TBARCT.

2. Purpose of the TBARCT Workbook

The purpose of the TBARCT Workbook document is to specify the TBARCT requirements for commonly permitted sources in the Bay Area Air Quality Management District. It is intended to be used as a guide by BAAQMD staff engineers, the regulated community, and interested public in determining the specific emission limits, emission control devices, or risk reduction techniques needed to meet the TBARCT requirements of Rule 11-18.

In many cases, TBARCT will be as stringent as BACT or TBACT emission control levels described in BAAQMD’s BACT/TBACT Workbook. However, TBARCT may also include less effective risk reduction measures that reduce the public’s exposure to toxic air contaminants, pollution prevention measures, process modifications, material substitutions, work practice standards, operating restrictions, or other reasonable actions that result in reductions in health risks for the exposed individuals. Where possible, the Air District prefers methods that reduce or prevent the creation of toxic emissions, as opposed to "end-of-stack" treatment. TBARCT shall not be any less stringent than the emission controls required by any applicable provision of federal, state or district laws, rules, regulations or requirements for the source under evaluation.

Source-specific TBARCT measures for commonly permitted sources are described in Attachment A. Whenever possible, source-specific TBARCT determinations shall be consistent with the risk reduction measures described in Attachment A.

However, the Air District recognizes that the applicability, efficiency, performance, effectiveness at reducing health risks, and cost of controls are dependent on many different source-specific and site-specific factors. Thus, TBARCT determinations may need to be made or confirmed on a case-by-case basis. The following sections of this

TBARCT Workbook describe the procedures that the Air District will follow when making case-by-case TBARCT determinations.

3. Case-By-Case TBARCT Determinations

The Air District may make case-by-case TBARCT determinations under the following circumstances:

- If there are no applicable source-specific TBARCT measures identified in Attachment A for the type of source under evaluation;
- If the TBARCT measures identified in Attachment A are not technologically feasible for a particular source or facility due to source-specific or site-specific constraints;
- If the TBARCT measures identified in Attachment A would, due to source-specific or site-specific factors, result in costs to the facility that are demonstrated to be unreasonably high.

Case-by-case TBARCT determinations shall be guided by the following criteria, which are included in the Rule 11-18 definition of TBARCT.

- The most effective retrofit emission control device or technique that has been successfully utilized for the type of equipment comprising such a source; or
- The most stringent emission limitation achieved by a retrofit emission control device or technique for the type of equipment comprising such a source; or
- Any retrofit control device or technique or any emission limitation that the APCO has determined to be technologically feasible for the type of equipment comprising such a source, while taking into consideration the cost of achieving health risk reductions, any non-air quality health and environmental impacts, and energy requirements; or
- The most stringent retrofit emission control for a source type or category specified as MACT by U.S. EPA, or specified in an ATCM by CARB.

In addition, the Air District will consider the magnitude of the health risks from the source, the contribution of the source health risks to the facility wide risks that exceed the risk action levels, the feasibility of risk reduction measures, and the potential impacts on health risks of risk reduction measures.

Case-by-case TBARCT determinations will also consider site-specific costs of risk reduction measures and emission controls. These costs will be compared to emission control costs for similar toxic compounds and similar source types that have been identified in Attachment A, the staff report for Rule 11-18 or for other toxic emission reduction rules or regulations, or to costs in other appropriate documentation. The Air District may also consider additional factors when determining the reasonableness of TBARCT costs such as: the type of business (non-profit business or public agency), size of the facility (small business), and location of the facility (disadvantaged areas).

3.1 Streamlined Case-by-Case TBARCT Determinations

For many situations, a case-by-case TBARCT determination can be made using a streamlined procedure that does not involve a cost analysis. Any emission control methods proposed by the facility that meet the Air District's TBACT requirements, as identified in the Air District's BACT/TBACT Workbook, shall constitute TBARCT for the source under evaluation. A facility may also employ sufficient emissions or risk reduction measures to reduce health impacts from a source to less than the significant risk thresholds. As a minimum, TBARCT must include compliance with all district, state, and federal regulations that apply to a source. This streamlined procedure includes this minimum compliance assessment. The procedures for a streamlined TBARCT determination are discussed below.

- Identify all toxic air contaminant emission controls and emission limits that are in existence or that have been proposed by the facility in the Rule 11-18 TBARCT plan for the source under evaluation.
- Compare these existing and proposed toxic emission control measures to the applicable BACT and TBACT control measures identified in the Air District's BACT/TBACT Workbook for the source under evaluation. If the proposed controls include use of abatement devices or toxic air contaminant emission limits that would satisfy the Air District's current BACT or TBACT criteria for the source type under evaluation, the proposed controls will be considered TBARCT, provided that no unabated emissions shall be deemed TBARCT using this procedure. Examples of TBACT controls that would also constitute TBARCT include:
  - Full enclosure and capture of all organic emissions and venting of captured emissions to an incinerator achieving at least 98% control of individual TACs.
  - Full enclosure of particulate emission sources and venting of captured emissions to a baghouse meeting an outlet grain loading limit of 0.0013 grains/dscf.
- Identify the source emission reductions that would be necessary to reduce source impacts to less than the significant risk thresholds and, if possible, to reduce the site-wide health impacts to less than the risk action levels.
- Evaluate the potential health impacts of inexpensive risk reduction measures to determine if these measures could achieve the health impact reductions above. Inexpensive risk reduction measures may include source alterations such as increasing stack heights, reducing stack diameter, changing stack orientation, relocating the source, or accepting operating time restrictions.
- Identify other usually low-cost source alterations or modifications that would reduce TAC emissions, such as limiting throughput or operating rates, reducing emission limitations, using alternative fuels, or substituting materials.
- Evaluate residual health impacts after implementation of the source alterations above.
- Discuss the feasibility of the above risk reduction measures and potential source alterations with the facility. Identify any measures that are feasible and that the facility would be willing to implement without undergoing a detailed cost analysis.

If the facility rejects any of the Air District's suggested control measures due to site-specific constraints or high costs, the TBARCT determination for the source shall be evaluated using the detailed case-by-case TBARCT determination procedures described later in this document.

- Identify all applicable district, state, and federal regulations that apply to the source, including any future effective requirements.
- Confirm that the source is complying with all applicable requirements including future effective requirements.
- At a minimum, TBARCT would include any combination of the above risk reduction measures and source alterations that are: (a) proposed by the facility and acceptable to the Air District, (b) suggested by the Air District as feasible low-cost measures and that are acceptable to the facility, and (c) that result in:
  - the highest possible health risk reductions from the source, or
  - sufficient risk reductions from the source such that the source would no longer be deemed a significant source after TBARCT is implemented, or
  - sufficient facility-wide risk reductions such that the facility-wide health impacts will be less than the risk action levels after TBARCT is implemented.

3.2 Detailed Case-by-Case TBARCT Determinations

If site-specific feasibility or cost constraints must be considered, the Air District will follow the detailed case-by-case TBARCT determination procedures presented below, which shall include feasibility and cost considerations. All detailed TBARCT determinations shall be reviewed and approved by the Air District's TBARCT review panel. The TBARCT review panel will consist of senior staff from the Air District's Engineering Division. The panel will be convened as needed to review and approve detailed case-by-case TBARCT determinations.

3.2.1 Feasibility Considerations

- Identify all controls, emission limits, and risk reduction measures proposed by the facility for this source or source type in their Rule 11-18 TBARCT plan.
- Identify any potentially feasible and more stringent risk reduction techniques, emission controls, or emission limitations for the source type under evaluation. To identify potentially feasible controls or limits, consult the following:
  - District regulatory requirements, state ATCMs, federal NSPS and NESHAP requirements for similar or related sources;
  - District BACT determinations, state and federal BACT clearinghouses, and MACT standards for similar or related sources;
  - Rules or regulations that are under development that would apply to this source or a similar source type;
  - Permit applications for similar or related sources;
  - Rule 11-18 risk reduction or TBARCT plans for other facilities;

  - Other types of approved or proposed plans for this facility, such as CEQA plans, emission control plans submitted to other agencies, or modernization plans;
- Identify any source-specific or site-specific factors that resulted in this analysis being subject to these detailed TBARCT determination procedures.
- Evaluate the feasibility of the more stringent control measures identified above while giving appropriate consideration to the source or site specific constraints identified by the facility for this source. Using best engineering judgement, eliminate any of the more stringent emission control measures that are not feasible for this specific source and facility in light of site-specific factors.
- If the facility and the Air District have reached agreement on the feasibility of all control measures proposed by the facility or deemed feasible by the Air District and the facility has agreed to implement all feasible control measures, the agreed upon control measures shall be deemed TBARCT.
- If there are any remaining emission control measures or emission limitations that are deemed to be feasible by the Air District that the facility has not agreed to implement due to cost considerations, the Air District shall conduct a TBARCT cost effectiveness analysis using the procedures described below.

3.2.2 Cost Considerations

- For any TBARCT abatement project that is subject to a TBARCT cost effectiveness analysis, determine the Total Annualized Project Cost = (Annualized Installed Costs + Annual Operating Costs)X(Tax+Ins+Other Factors) for the TBARCT abatement project in accordance with the BACT project cost calculation procedures described in the Policy and Implementation Procedures section of the Air District's BACT/TBACT Workbook, which is located on the Air District's web site at: http://www.baaqmd.gov/~/media/files/engineering/bact-tbact-workshop/bact-tbact-policy-and-implementation/policy-and-implementation-procedure.pdf?la=en
- Using good engineering practices, calculate the annual emission reductions that would be achieved by the TBARCT abatement project for each toxic air contaminant emitted by the source or sources under evaluation.
- Calculate the total toxicity weighted emission reductions for the project using the following procedures:
  - Identify the type(s) of health impacts that are triggering the TBARCT requirement: cancer risk if the source risk exceeds 1.0 in a million, chronic hazard index if the source risk exceeds 0.2 chronic HI, or acute hazard index if the source risk exceeds 0.2 acute HI. In most cases, cancer risk will be the only type of health impact that is triggering this TBARCT requirement. If more than one type of health risk is triggering TBARCT, determine the driving type of health impact by comparing the source risk to the significant risk threshold. The health impact type with the highest ratio is the driving health impact type.
  - Calculate the toxicity weighted emission reduction for each TAC that would be controlled by the TBARCT abatement project using the procedures

identified in Section 2-5-604 and sum for all TACs to determine the total toxicity weighted emission reductions for the project. Cancer risk and chronic HI toxicity weighted emission reductions should be based on annual emission reductions. If acute health impacts are the driving health impact type, use the toxicity weighted calculation procedure for chronic HI. An example is provided below for a hypothetical abatement project where cancer risk is the driving health risk type:

TBARCT Emission Reductions:

Benzene:	50 pounds/year of emission reductions
Formaldehyde:	200 pounds/year of emission reductions

CP Weighting Factor from Column 6 of Table 2-5-1:

Benzene:	1.0 E-1
Formaldehyde:	2.1 E-2

Toxicity Weighted Emission Reductions:

Benzene:	(50 lbs/yr)*(1.0E-1)	=	5.0 lbs/yr
Formaldehyde	(200 lbs/yr)*(2.1E-2)	=	4.2 lbs/yr
Total:		=	9.2 lbs/yr

- Calculate the cost effectiveness of the TBARCT abatement project by dividing the Total Annualized Project Cost by the Total Toxicity Weighted Emission Reductions.

  For a Total Annualized Project Cost of $10,000/year and the toxicity weighted emission reductions above, the TBARCT cost effectiveness would be:
  $10,000/year / 9.2 pounds/year =
  $1,087/pound of toxicity weighted emission reductions

- Compare the TBARCT project cost effectiveness to any available cost effectiveness data for the most similar source type listed in Appendix A.
- Compare the TBARCT project cost effectiveness to cost effectiveness values for regulations that control similar pollutants.
- Consider the type, size, and location of the business.
- Using good engineering judgment, determine if the cost effectiveness of the TBARCT project is reasonable.
- Submit TBARCT recommendation to TBARCT review panel for final review and approval of cost related TBARCT decisions.

APPENDIX A

Standard TBARCT Determinations

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
All	Combustion	Internal Combustion Engine	Diesel Particulate Matter	Electrify where possible or use other alternative technologies that emit no TACs	BACT/TBACT	Variable	Variable	
All	Combustion	Internal Combustion Engine	Diesel Particulate Matter	Use alternative technologies or alternative fuels that emit less toxic pollutants	Good engineering practice	Variable	Variable	
All	Combustion	Internal Combustion Engine	Diesel Particulate Matter	Reduce Operation Hours	TBACT	$ 0	$ 0	
All	Combustion	Internal Combustion Engine	Diesel Particulate Matter	Relocate device	TBACT	$ 9,900	$ 0	Cost may be higher if relocating the engine would involve building structural changes
All	Combustion	Internal Combustion Engine	Diesel Particulate Matter	Adjust Stack Height	TBACT	$ 7,820	$ 0	
All	Combustion	Internal Combustion Engine	Diesel Particulate Matter	Diesel Particulate Filter	TBACT	$ 11,010	$ 2,348	The costs at left are averages. The cost range is $5000-$15,000. EPA-420-F-10-029, May 2010
All	Combustion	Internal Combustion Engine	Diesel Particulate Matter	Active Diesel Particulate Filter	TBACT	$ 55,000	$ 6,458	The costs at left are averages. EPA-420-F-10-029, May 2010
All	Combustion	Internal Combustion Engine	Diesel Particulate Matter	Oxidation Catalyst	TBACT	$ 1,431	$ 305	Range of $600-$2000. EPA-420-F-10-031, May 2010
Cement Manufacturing	Combustion	Kiln	Chromium (hexavalent)	Baghouse, Filterable PM≤0.006 gr/sdcf for Temperature > 150˚F		Not Yet Available	Not Yet Available	Not Yet Available

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Cement Manufacturing	Combustion	Kiln	Chromium (hexavalent)	Wet Scrubber, Venturi	Venturi Scrubber can remove up to 90%	$1,680,000	$2,100,000	EPA Cost Manual Cost does not include the waste water treatment unit, which will be required because hexavalent chromium is soluble in water.
Cement Manufacturing	Combustion	Kiln	Chromium (hexavalent)	Wet Scrubber, Amine	Amine scrubber is once through non-regenerative	$20,600,000	$5,400,000	Vendor Quote in 2014 (540,960 acfm) Cost does not include the waste water treatment unit, which will be required because hexavalent chromium is soluble in water.
Cement Manufacturing	Cement Handling	Silos, Bins, Mills, Crushing Operations	Chrominum (hexavalent)	Baghouse, Filterable Particulate Matter ≤ 0.0013 gr/sdcf Temperature <150˚F		26.543(ACFM)+18,909	6.2537(ACFM)+138,044	1. Vendor quote in 2008: 2,400 acfm with $79,000 installation cost & $152,000 annual operating cost 2. EPA Cost Manual Procedure, Chapter 6.1, Pulse-Jet: 15,000 acfm with $421,000 installation cost & $233,000 annual operating cost EPA Cost Manual Procedure, Chapter 6.1, Pulse-Jet: 150,000 acfm with $4,000,000 installation cost & $1,076,000 annual operating costs
Cement and Recycling	Concrete Block & Brick Manufacturing	Kiln	Hydrogen Fluoride	Packed Bed Scrubber (99% efficiency)		$125,000 - $200,000	$21,280 - $34,050	5% interest; 20 year life CRF=(0.05*(1.05)^20)/(-1+(1.05)^20)=0.08 annualized cost = =TC*(0.01+0.01+0.02+0.05+CRF)=TC* 0.17

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Chemical Plant			Carbon Tetrachloride	Use Thermal Oxidizers to control collected gas streams. Minimize fugitive emissions by using double mechanical seals and magnetic drive pumps where feasible.	Reg 8-18, 8-22, SIP 8-25; MACT Subpart H Fugitive Monitoring Subpart EEEE; Reg 8-5; vapor tight vapor balance systems for loading operations	none if already installed, which is common, some costs may be incurred to replace pumps with more efficient controls		
Chemical Plant	Inorganic Acid Manufacturing	Reactors, Storage Tanks, Loading Stations	Hydrochloric Acid	Wet Scrubbers (97% control) - often this is an existing control	BAAQMD permit applications			
Chemical Plant	Combustion	Engine	Formaldehyde	Oxidation Catalyst (60%-80% efficiency)	Vendor quotes	$13,800 - $34,800	$2350 - $5930	5% interest; 20 year life CRF=(0.05*(1.05)^20)/(-1+(1.05)^20)=0.08 annualized cost = =TC*(0.01+0.01+0.02+0.05+CRF)=TC*0.17
Chemical Plant	Chemical Manufacturing	Sulfuric Acid Plants	Sulfuric Acid Mist	Wet Electrostatic Precipitators and mist eliminator	Engineering knowledge			
Chrome Plating	Hard chrome plating	Bath with anode & cathode	Chromium (hexavalent)	Increase Stack Height or Install HEPA Filter. Also, scrubber, mesh pads, and chemical fume suppressant. One scrubber/mesh pad, and fume suppressant system demonstrated: 99.4% control. Adding a HEPA filter could increase control efficiency to 99.97%.	ATCM Limit is 0.0015 mg/amp-hr; Current Control = 0.00046 mg/amp-hr, potential rate with HEPA filter = 2.3E-5 mg/amp-hr			

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Coating		Surface Coating - very large items	Ethylbenzene	Thermal Oxidizer	The cost effectiveness to prepare very large items for abatement is $19,499/ton and Thermal Oxidizer cost per ton is $8,594/ton. Size of thermal oxidizer depends on the size of containment.	Cost will include Thermal Oxidizer, Containment, Duct system, and labor	Total Cost Effectiveness: $28,000/ton to $30,000/ton	BAAQMD permit application - system was not installed because it was deemed to be not cost effective for VOC control
Coating		Surface Coating	Methylene diphenyl isocyanate	Scrubber				
Crematory	Miscellaneous Process	Crematory Retort	Chromium (hexavalent)	Increase stack height and prohibit two retorts from operating concurrently.	HRA results for multiple facilities	Not Yet Available	$ 0	
Crematory	Miscellaneous Process	Crematory Retort	Chromium (hexavalent)	Require the following: minimum exhaust temperature of 400 degrees C, a stack diameter of 0.46 meters, a minimum exit velocity of 15 meters/second, and a minimum stack height of 10 meters.	Operating recommendations provided by the Brisbane City Council in Australia for crematories.	$ 0	$ 0	

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Crematory	Miscellaneous Process	Crematory Retort	Chromium (hexavalent)	One or more of the following controls: • Co-flow filter • Gas scrubber • Honeycomb catalytic adsorber • Sodium bicarbonate & activated carbon control systems • Solid-bed filters using absorbents such as cokes or zeolites	Control technologies suggested in the following document: http://www.ejnet.org/crematoria/reindl.pdf	$500,000 - $750,000		Vendor Quote for an abatement system involving an activated carbon and sodium bicarbonate bed and bag filters with up to three cremators abated by a single filter system.
Crematory	Miscellaneous Process	Crematory Retort	Mercury	Increase stack height and prohibit two retorts from operating concurrently.	HRA results for multiple facilities	Not Yet Available	$ 0	
Crematory	Miscellaneous Process	Crematory Retort	Mercury	Require the following: minimum exhaust temperature of 400 degrees C, a stack diameter of 0.46 meters, a minimum exit velocity of 15 meters/second, and a minimum stack height of 10 meters.	Operating recommendations provided by the Brisbane City Council in Australia for crematories.	$ 0	$ 0	

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Crematory	Miscellaneous Process	Crematory Retort	Mercury	One or more of the following controls: • Co-flow filter • Gas scrubber • Honeycomb catalytic adsorber • Sodium bicarbonate & activated carbon control systems • Solid-bed filters using absorbents such as cokes or zeolites	Control technologies suggested in the following document: http://www.ejnet.org/crematoria/reindl.pdf	$500,000 - $750,000		Vendor Quote for an abatement system involving an activated carbon and sodium bicarbonate bed and bag filters with up to three cremators abated by a single filter system.
Engines and Other Sources	Combustion	Engine	Formaldehyde	Oxidation Catalyst (60%-80% efficiency)	Vendor quotes	$13,800 - $34,800	$2350 - $5930	5% interest; 20 year life CRF=(0.05*(1.05)^20)/(-1+(1.05)^20)=0.08 annualized cost = =TC*(0.01+0.01+0.02+0.05+CRF)=TC*0.17
Metal Melting	Metallurgical Process	Secondary Metal Process (Chrome Plating)	Chromium (hexavalent)	1. Electrostatic Precipitator (ESP), 2. High Efficiency Wet Scrubber and 3. Plating bath covers & mesh pad mist eliminators	Use Scrubber and meet California ACTM standards	Not Yet Available	Not Yet Available	

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Metal Melting	Metallurgical Process	Secondary Metal Furnace (Electric Arc Furnace)	Chromium (hexavalent)	**Prevention:** Metal management program (identify and reduce chromium in source metal) Control carbon content of metal (carbon-chromium equilibrium, less carbon = less chromium retained in metal, more chromium emissions) Reduce chromium content of mold material **Mitigation:** Total furnace enclosure & high efficiency cartridge filtration/baghouse Direct evacuation control (DEC), hood, and baghouse (99.00 % control efficiency) Direct-shell evacuation control system with adjustable air gap and water-cooled elbow and duct to baghouse Baghouse followed by dry/semi-dry scrubber Baghouses equipped with broken bag detectors	EPA - "Locating and Estimating Air Emissions from Sources of Chromium" EPA RACT/BACT/LAER Clearinghouse IFC - Environmental, Health, and Safety Guidelines for Foundries	26.543(ACFM)+18,909	6.2537(ACFM)+138,044	1. Vendor quote in 2008: 2,400 acfm with $79,000 installation cost & $152,000 annual operating cost 2. EPA Cost Manual Procedure, Chapter 6.1, Pulse-Jet: 15,000 acfm with $421,000 installation cost & $233,000 annual operating cost 3. EPA Cost Manual Procedure, Chapter 6.1, Pulse-Jet: 150,000 acfm with $4,000,000 installation cost & $1,076,000 annual operating costs

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Metal Melting			Dioxins	Use clean scrap for melting Inject additive powders (e.g. activated carbons) into the gas stream to adsorb dioxins Post combustion of furnace off-gas at a temperature > 1200 deg. C and maximizing residence time, complete with rapid quenching to minimize time in the dioxin reformation temperature window	IFC - Environmental, Health, and Safety Guidelines for Foundries	NA		
Metal Melting			Manganese	**Mitigation:** Total furnace enclosure & high efficiency cartridge filtration/baghouse Direct evacuation control (DEC), hood, and baghouse (99.00 % control efficiency) Direct-shell evacuation control system with adjustable air gap and water-cooled elbow and duct to baghouse Baghouse followed by wet scrubber Baghouses equipped with broken bag detectors	EPA - "Locating and Estimating Air Emissions from Sources of Manganese" EPA-450/4-84-007h EPA RACT/BACT/LAER Clearinghouse IFC - Environmental, Health, and Safety Guidelines for Foundries	26.543(ACFM)+18,909	6.2537(ACFM)+138,044	1. Vendor quote in 2008: 2,400 acfm with $79,000 installation cost & $152,000 annual operating cost 2. EPA Cost Manual Procedure, Chapter 6.1, Pulse-Jet: 15,000 acfm with $421,000 installation cost & $233,000 annual operating cost 3. EPA Cost Manual Procedure, Chapter 6.1, Pulse-Jet: 150,000 acfm with $4,000,000 installation cost & $1,076,000 annual operating costs

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Landfill: Closed	Landfill	closed landfill	Acrylonitrile	Enhanced monitoring per CARB Landfill methane control rule - lower leak standards and integrated surface monitoring limits in addition to instantaneous surface leak limit.	State Methane Rule for control of Greenhouse Gas Emissions	N/A		
Landfill: Closed with Compost Facility	Composting	Windrows	Ammonia	Switch from uncontrolled windrow method composting to covered Aerated Static Piles (CASP) with biofilter		$ 100 per ton/year capacity	not included	2008 study titled “Measuring and Controlling Composting Emissions” by Bob Horowitz of the California Integrated Waste Management Board
Landfill	Landfill	Active and closed	Benzene	Same as other organic controls for closed and active landfills				
Landfill	Diesel Engines	Portable Engines, waste tippers, pumps, compressors	Diesel Particulate Matter	Electrify, Use Alternative fuels (CNG, propane), Limit Operating Time	Rule 2-5 compliance options used at various sites	max = to engine replacement costs		
Landfill: Active	Main Emissions: Landfill, Minor from LFG Combustion	Active Landfill	Ethylbenzene	Compliance with Rules (8-34 and state landfill methane control rule). All active landfills are currently subject to the enhanced monitoring in the state rule. Possible additional measures: add synthetic covers to improve capture, faster collection system installation in new fill areas, enhanced monitoring.				

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Landfill	Landfill	Active Landfill	Hydrogen Sulfide: main source of H2S is fugitive surface emissions; small amounts of residual post combustion emissions due to burning collected landfill gas are not expected to trigger TBARCT	Same as organic controls for closed and active landfills				
Landfill:	Landfill	Active and closed	Toluene	Same as other organic controls for closed and active landfills				
Landfill	Landfill	Active and closed	Vinyl Chloride	Same as other organic controls for closed and active landfills				
Landfill gas combustion			Formaldehyde	Oxidation catalyst	BACT for Biogas Fired IC Engines	With LFG Treatment: $2.933 MM Installed Cost (2009 dollars) for 11.4 MW System, Without LFG Treatment: $ 362,250 Installed Cost (2009 dollars for 11.4 MWs)	$ 229,660 / year (2009) (excluding estimated SCR costs)	

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Power Plant			Ammonia	Optimize ammonia distribution and mixing to reduce ammonia slip; use extruded homogeneous SCR catalyst instead of wash coated catalyst	http://www.powermag.com/improving-scr-performance-on-simple-cycle-combustion-turbines/?printmode=1			
Power Plant			Benzene	Oxidation catalyst (70%-90% control efficiency)		$40,000 to $750,000, depending on system size	$6,520 to $122,250, depending on turbine size	
Power Plant			Diesel Particulate Matter	Diesel Particulate Filter/DOC - up to 85% control efficiency	CARB verified DPFs/DOCs. https://www.arb.ca.gov/diesel/verdev/verdev.htm	use ICE resource info	use ICE resource info	use ICE resource info
Power Plant			Formaldehyde	Oxidation catalyst (70%-90% control efficiency)	http://www.jmsec.com/Library/Brochures/jm_sec_data_gas_turbine_033012m.pdf http://www.deq.state.ms.us/MDEQ.nsf/pdf/epd_EPAMemorelatedtoHAPs/$File/EPAMemoHAPs.pdf?OpenElement	$40,000 to $750,000, depending on system size	$6,520 to $122,250, depending on turbine size	4% interest; 10 year life CRF=(0.04*(1.04)^10)/(-1+(1.04)^10)=0.123 annualized cost = =TC*(0.01+0.01+0.02+CRF)=TC* 0.163
Sewage Treatment	Combustion	Incinerator	• Chromium (hexavalent) • Cadmium • Mercury	1. Increase Stack Height 2. Oxidation Catalyst	Control by afterburners and scrubbers - Possibly increase stack heights			
Sewage Treatment			Hydrogen Sulfide	1. Covering the headworks 2. Injecting ferric chloride 3. Injecting peroxide		$1,000,000	$1.5 million for ferric chloride $4.75/ gallon of peroxide + monthly rental $1000	

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Sewage Treatment			Formaldehyde	Oxidation catalyst	For 49.5 MM BTU/hr natural gas engine	$300,000	Minimal	
Metal Melting	Metallurgical Process	Secondary Metal Process (Chrome Plating)	Chromium (hexavalent)	ESP & High Efficiency Wet Scrubber Install plating bath covers and meshpad mist eliminators	Use Scrubber + Meet CA ATCM requirements			

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Metal Melting	Metallurgical Process	Secondary Metal Furnace (Electric Arc Furnace)	Chromium (hexavalent)	**Prevention:** Metal management program (identify and reduce chromium in source metal) Control carbon content of metal (carbon-chromium equilibrium, less carbon = less chromium retained in metal, more chromium emissions) Reduce chromium content of mold material **Mitigation:** Total furnace enclosure & high efficiency cartridge filtration/baghouse Direct evacuation control (DEC), hood, and baghouse (99.00 % control efficiency) Direct-shell evacuation control system with adjustable air gap and water-cooled elbow and duct to baghouse Baghouse followed by dry/semi-dry scrubber Baghouses equipped with broken bag detectors	EPA - "Locating and Estimating Air Emissions from Sources of Chromium" EPA RACT/BACT/LAER Clearinghouse IFC - Environmental, Health, and Safety Guidelines for Foundries	26.543(ACFM)+18,909	6.2537(ACFM)+138,044	1. Vendor quote in 2008: 2,400 acfm with $79,000 installation cost & $152,000 annual operating cost 2. EPA Cost Manual Procedure, Chapter 6.1, Pulse-Jet: 15,000 acfm with $421,000 installation cost & $233,000 annual operating cost 3. EPA Cost Manual Procedure, Chapter 6.1, Pulse-Jet: 150,000 acfm with $4,000,000 installation cost & $1,076,000 annual operating costs

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Metal Melting			Dioxins	Use clean scrap for melting Inject additive powders (e.g. activated carbons) into the gas stream to adsorb dioxins Post combustion of furnace off-gas at a temperature > 1200 deg. C and maximizing residence time, complete with rapid quenching to minimize time in the dioxin reformation temperature window	IFC - Environmental, Health, and Safety Guidelines for Foundries	NA		
Metal Melting			Manganese	**Mitigation:** Total furnace enclosure & high efficiency cartridge filtration/baghouse Direct evacuation control (DEC), hood, and baghouse (99.00 % control efficiency) Direct-shell evacuation control system with adjustable air gap and water-cooled elbow and duct to baghouse Baghouse followed by wet scrubber Baghouses equipped with broken bag detectors	EPA - "Locating and Estimating Air Emissions from Sources of Manganese" EPA-450/4-84-007h EPA RACT/BACT/LAER Clearinghouse IFC - Environmental, Health, and Safety Guidelines for Foundries	26.543(ACFM)+18,909	6.2537(ACFM)+138,044	1. Vendor quote in 2008: 2,400 acfm with $79,000 installation cost & $152,000 annual operating cost 2. EPA Cost Manual Procedure, Chapter 6.1, Pulse-Jet: 15,000 acfm with $421,000 installation cost & $233,000 annual operating cost 3. EPA Cost Manual Procedure, Chapter 6.1, Pulse-Jet: 150,000 acfm with $4,000,000 installation cost & $1,076,000 annual operating costs
Miscellaneous Manufacturing	Batch Mix Asphalt Plant	Aggregate dryer and Batch Mix Plant	benzene	recirculate exhaust to aggregate dryer	BACT for POC			

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Miscellaneous Manufacturing	Combustion/ Misc. Process	Turbine/Dryer	Formaldehyde	Oxidation Catalyst	EPA Memo Dated 8-21-2001	$360,000-$4,800,000	$140,000-$1,400,000	http://www.deq.state.ms.us/MDEQ.nsf/pdf/epd_EPAMemorelatedtoHAPs/$File/EPAMemoHAPs.pdf?OpenElement
Miscellaneous Manufacturing			Chromium (hexavalent)	**Prevention:** None **Mitigation:** Baghouses equipped with broken bag detectors followed by wet scrubber Baghouses equipped with broken bag detectors Wet ESP Wet scrubber		$825,000 (Wet Scrubber followed by Wet ESP)	Annualized Cost = $322,526	
Miscellaneous Manufacturing			Formaldehyde	**Prevention:** Replace phenol-formaldehyde-based binder with starch-based binder. Already implemented by the facility. **Mitigation:** Thermal Oxidation Catalytic Oxidation Carbon Adsorption		**Mitigation:** Thermal Oxidation: RTO: Total Capital Cost = $1,571,121 - $3,211,950 for 67,263 scfm exhaust flow with total 9.1 tpy VOC emissions Catalytic Oxidation Carbon Adsorption: Total Capital Cost = $115,630 (+/- 30%) for 5,000 acfm exhaust flow with 5.17 lb/hr of VOC emissions; $1,365,538 for 67,263 scfm exhaust flow with total 9.1 tpy VOC emissions	**Mitigation:** Thermal Oxidation: RTO: Annualized Cost = $335,106 - $685,080 for 67,263 scfm exhaust flow with total 9.1 tpy VOC emissions Catalytic Oxidation Carbon Adsorption: Annualized Cost = $26,132 for 5,000 acfm exhaust flow with 5.17 lb/hr of VOC emissions; $291,257 for 67,263 scfm exhaust flow with total 9.1 tpy VOC emissions	Capital Cost from Vendors

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Miscellaneous Manufacturing	LED Manufacturing	Acid Treatment Tank	Sulfuric Acid Mist	Emission factors have been corrected. Tank is currently abated with a wet scrubber, deemed TBARCT. Next highest risk driver - emissions of arsine are also currently meeting greater than TBARCT control with a combination of oxidation/baghouse/wet scrubber.	Acid mist already being controlled to TBARCT levels. Arsine emissions already being controlled to TBARCT levels.			
Miscellaneous Manufacturing	Metal Container Coating	Coating Oven	Diethanolamine (DEA or DEOA)	Material Substitution: dimethyl ethanol amine (DMEA) for diethanolamine (DEA).	Use of DMEA, which not a TAC, instead of DEA.			

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Miscellaneous Manufacturing	Metal Container Coating	Coating Oven	Diethanolamine (DEA or DEOA)	Regenerative Thermal Oxidizer (RTO)	RTO abates POC emissions, which includes DEA	$51.78 To $207.13 per SCFM (2017, Assuming CPI=2.6, T=15 Years)	$5.92 To $14.80 Per SCFM (2017, Assuming CPI=2.6, T=15 Years)	EPA cost estimates obtained from https://www3.epa.gov/ttncatc1/dir1/fregen.pdf EPA Estimates that a RTO initial cost is equal to $35 to $140 per scfm and a RTO annual O & M cost is equal to $4 to $10 per scfm (2002 Dollars).
Miscellaneous Manufacturing	Particulate Emitters	Dryer, Kiln, Silos, Misc. Material Handling	Nickel	Baghouses, Nickel Limits (currently limited to 3% nickel in their product)	BACT and Permit Limits: Dryer, Kilns and Misc. handling limited to 0.005 gr/dscf from baghouses; Silo Baghouses limited to 0.006 gr/dscf			
Miscellaneous Manufacturing	Foam Manufacturing	Foam Machines	Toluene diisocyanates	Wet scrubbers, incineration, and carbon adsorption are all feasible control options. Also, replacing the process equipment - see 1996 EPA document regarding emission reduction technologies.	Due to the high flowrates and low organic concentration, carbon adsorption is likely the most cost effective choice. Note that the existing process is not fully enclosed, but there are partially enclosed segments with existing vents that could be diverted to a control device.	No installation costs available for full enclosure with fixed carbon adsorption	Maintenance (carbon changeout and disposal) $20,000 every 18 months, achieving estimated emission reductions of 0.25 tpy based on 98% control. Equates to $53,000/ton reduced just in material maintenance costs.	Review of EPA literature shows wide range of costs for C adsorption depending on VOC inlet concentration, exhaust flowrate, type of C system. For low VOC concentration streams, cited examples range from $5,000 to $86,000/ton reduced for non-regenerable, regenerable, and rotary concentrator systems.

Operating Type	**Source Category**	**Source Type**	**Pollutant**	**Potential Risk Reduction Measure**	**Risk Reduction Basis**	**Installation Cost**	**Annual Operating Cost**	**Cost References or Comments**
Printing			Methylene Chloride	**Prevention:** Use non-methylene chloride-containing inks, fountain solutions, and solvents **Mitigation:** Permanent total enclosure around one or more presses w/ thermal oxidation Permanent total enclosure around one or more presses w/ catalytic oxidation Permanent total enclosure around one or more presses w/ carbon adsorption		Mitigation: Thermal Oxidation: RTO: Total Capital Cost = $1,571,121 - $3,211,950 for 67,263 scfm exhaust flow with total 9.1 tpy VOC emissions Catalytic Oxidation Carbon Adsorption: Total Capital Cost = $115,630 (+/- 30%) for 5,000 acfm exhaust flow with 5.17 lb/hr of VOC emissions; $1,365,538 for 67,263 scfm exhaust flow with total 9.1 tpy VOC emissions	Mitigation: Thermal Oxidation: RTO: Annualized Cost = $335,106 - $685,080 for 67,263 scfm exhaust flow with total 9.1 tpy VOC emissions Catalytic Oxidation Carbon Adsorption: Annualized Cost = $26,132 for 5,000 acfm exhaust flow with 5.17 lb/hr of VOC emissions; $291,257 for 67,263 scfm exhaust flow with total 9.1 tpy VOC emissions	Site used prevention methods and removed methylene chloride. Cost data for controls are from vendor quotes
Soil Vapor Extraction		TAC and VOC Emissions	Benzene	Increase stack height when possible, carbon adsorption, electric catalytic thermal oxidizer	Catalytic Thermal Oxidizer: Carbon Adsorption; Increase stack height;	Regenerative catalytic oxidizer (RCO): Capital & Installation cost: $75/scfm; Regenerative Thermal oxidizer (RTO): Capital & Installation cost: $75/scfm; Activated Carbon Canister System: $48/scfm; Cost of stack height increase: Most practical application if the city allows the stack height increase.	O&M cost: RCO: $7/scf; RTO: $12/scf; O&M annualized cost: $18/million cft;	

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Petroleum Refining		Delayed Coker (delayed coking unit steam vent)	• Benzene • PAHs	Rule based: Depressurize each coke drum to a closed blowdown system until the coke drum vessel pressure or temperature measured at the top of the coke drum or in the overhead line of the coke drum as near as practical to the coke drum meets applicable coke drum vessel pressure or coke drum vessel temperature requirements for existing and new delayed coking units in MACT CC (63.657) prior to venting to the atmosphere, draining, or deheading the coke drum at the end of the cooling cycle.	1. Recover hydrocarbon laden liquids in blowdown system. 2. Route hydrocarbon laden gases to flare, flare gas recovery system, or gas plant for further processing and recovery.			

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Petroleum Refining	Wastewater Treatment		Benzene	**Leak Monitoring:** 1) Lower leak limit (e.g. from 500 ppm to 100 ppm) 2) Increased leak monitoring frequency (e.g. from semi-annual to quarterly or monthly) **Technology:** 1) Install water seals or equivalent technology on vents and drains open to atmosphere 2) Collect and vent emissions to a control device (e.g. carbon adsorption or thermal oxidizer) 3) Enclose open weirs and lines with direct piping	ARB/BAAQMD - Draft Technical Assessment Document: Potential Control Strategies to Reduce Emissions from Refinery Wastewater Collection and Treatment Systems	Component Leak Monitoring (All Component Types): 1) Update LDAR databases (~ 2 hours of time, ~$25/hour) 2) Update LDAR databases (~ 2 hours of time, ~ $25/hour)	Component Leak Monitoring (All Component Types): 1) $3,000 - $6,000 (assumptions: repair time of leaks ~ 1 hours @ ~$30/hr, ~100 - 200 additional leaking components, 100% of wastewater streams may contain benzene) 2) Quarterly: ~$8,000 - $16,000 (assumptions: $4/inspection, 1,000 - 2,000 components, 100% of wastewater streams may contain benzene) Monthly: ~$40,000 - $80,000 (assumptions: $4/inspection, 1,000 -2,000 components, 100% of wastewater streams may contain benzene)	

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Petroleum Refining	Wastewater Treatment		Naphthalene	**Leak Monitoring:** 1) Lower leak limit (e.g. from 500 ppm to 100 ppm) 2) Increased leak monitoring frequency (e.g. from semi-annual to quarterly or monthly) **Technology:** 1) Install water seals or equivalent technology on vents and drains open to atmosphere 2) Collect and vent emissions to a control device (e.g. carbon adsorption or thermal oxidizer) 3) Enclose open weirs and lines with direct piping	ARB/BAAQMD - Draft Technical Assessment Document: Potential Control Strategies to Reduce Emissions from Refinery Wastewater Collection and Treatment Systems	Component Leak Monitoring (All Component Types): 1) Update LDAR databases (~ 2 hours of time, ~$25/hour) 2) Update LDAR databases (~ 2 hours of time, ~ $25/hour)	Component Leak Monitoring (All Component Types): 1) $3,000 - $6,000 (assumptions: repair time of leaks ~ 1 hours @ ~$30/hr, ~100 - 200 additional leaking components, 100% of wastewater streams may contain naphthalene) 2) Quarterly: ~$8,000 - $16,000 (assumptions: $4/inspection, 1,000 - 2,000 components, 100% of wastewater streams may contain naphthalene) Monthly: ~$40,000 - $80,000 (assumptions: $4/inspection, 1,000 -2,000 components, 100% of wastewater streams may contain naphthalene)	BAAQMD Staff Report - Refinery Strategy - Appendix C Reg. 8-18 & supporting Excel workbook CA Energy - "Estimating Natural Gas Burner Tip Prices for California and the Western United States - Final Project Report", November 2014 (http://www.energy.ca.gov/2014publications/CEC-200-2014-008/)
Petroleum Refining	Combustion	Furnace	Chromium (hexavalent)	Potential: 1. Treat Raw Materials (Crude and Intermediates) to remove Chromium 2. Treat Fuel Gas to remove Chromium 3. Treat Flue Gas to remove Chromium	1. Non-catalytic supercritical water treatment 2. Scrubbers, catalysts 3. Scrubbers, Filters (used in chrome plating industry), carbon	Not Yet Available	Not Yet Available	

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Petroleum Refining	Combustion	Furnace	PAHs	Potential: 1. Combustion Optimization 2. Treat Flue Gas	1. Optimize Firebox temperature, preheat combustion air, flue gas recirculation 2. Catalytic Filters	Not Yet Available	Not Yet Available	
Petroleum Refining	Combustion	Heaters	Chromium (hexavalent)	Potential: 1. Treat Raw Materials (Crude and Intermediates) to remove Chromium 2. Treat Fuel Gas to remove Chromium 3. Treat Flue Gas to remove Chromium	1. Non-catalytic supercritical water treatment 2. Scrubbers, catalysts 3. Scrubbers, Filters (used in chrome plating industry), carbon	Not Yet Available	Not Yet Available	
Petroleum Refining	FCCU		Chromium (hexavalent)	Potential: 1. Treat Raw Materials (Crude and Intermediates) to remove Chromium 2. Treat FCCU Feed to remove Chromium 3. Treat Regenerator or CO Boiler Flue Gas to remove Chromium	1. Non-catalytic supercritical water treatment 2. Non-catalytic supercritical water treatment 3. Scrubbers, Filters (used in chrome plating industry), carbon	Not Yet Available	Not Yet Available	
Petroleum Refining	FCCU		PAHs	Potential: 1. Regeneration Optimization 2. Treat Flue Gas	1. Optimize regeneration temperature 2. Catalytic Filters	Not Yet Available	Not Yet Available	

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Petroleum Refining	Reformers	Catalytic Reforming Units (CRUs) (Continuous, cyclic & semi-regenerative)	• Benzene • 1,3 Butadiene	Meet the emission limit in Table 15 of MACT UUU (63.1566) during the initial catalyst depressurizing and catalyst purging operations by routing vent emissions to a flare (option 1), or meet the less stringent of a total organic compound (TOC) or nonmethane TOC percent reduction standard (98% by weight) or concentration limit (20 ppmv dry basis as hexane corrected to 3% O2).	MACT UUU (63.1566)			

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Petroleum Refining	Fugitives (pumps, valves, flanges)	All Component Types	• Benzene • Naphthalene	1. Lower leak limit (e.g. from 100 ppm to 50 ppm or 25 ppm) 2. Increased leak monitoring frequency (e.g. from quarterly to monthly or weekly)		1. $400 2. $400	1. $10,000 - $15,000 Monthly: $320,000 - $450,000 Weekly: $1,900,000 - $2,700,000	BAAQMD Staff Report - Refinery Strategy - Appendix C Reg. 8-18 & supporting Excel workbook CA Energy - "Estimating Natural Gas Burner Tip Prices for California and the Western United States - Final Project Report", November 2014 (http://www.energy.ca.gov/2014publications/CEC-200-2014-008/) If component vented to an abatement device, there would be a cost savings of $4/inspection/component since the component would be exempt from Reg. 8-18 monitoring. Installation Cost Assumptions: 1. Update LDAR Database (4 hours of time, $50/hour) 2. Update LDAR Database (4 hours of time, $50/hour) Annual Operating Cost Assumptions: 1. Repair time of leaks ~ 1 hours @ ~$30/hr, ~2000 - 5000 additional leaking components, 20% of components handle naphthalene containing streams 2. $4/inspection, 50,000 to 70,000 components, 20% of components handle naphthalene containing streams 3. $4/inspection, 50,000 to 70,000 components, 20% of components handle naphthalene containing streams

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Petroleum Refining	Fugitives (pumps, valves, flanges)	Valves	• Benzene • Naphthalene	1. Welded bonnet flanges 2. Zero-emission seals and packing (manufacturer guarantee leaks < 10 ppm)		1. $120 per valve 2. $5,000 per valve	1. None 2. None	BAAQMD Staff Report - Refinery Strategy - Appendix C Reg. 8-18 & supporting Excel workbook CA Energy - "Estimating Natural Gas Burner Tip Prices for California and the Western United States - Final Project Report", November 2014 (http://www.energy.ca.gov/2014publications/CEC-200-2014-008/) If component vented to an abatement device, there would be a cost savings of $4/inspection/component since the component would be exempt from Reg. 8-18 monitoring. Installation Costs Assumptions: 1. 4 hrs/installation (locating, welding, etc.) @ $30/hr) 2. $4,000 for valve, 20 hrs/installation (selection, purchasing, locating, installing, etc.) @ $30/hr

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Petroleum Refining	Fugitives (pumps, valves, flanges)	Pumps	• Benzene • Naphthalene	1. Rotating shaft shrouded and vented to a thermal oxidizer or furnace 2. Double-mechanical seals, 3. Zero emission seal packing		1. $50,000 - $300,000 (depending on either venting to existing furnace or new thermal oxidizer and amount of pipe needed) 2. $5,000 - $50,000 (depending on complexity of pump) 3. $1,000 - $5,000 (depending on complexity of pump)	1. None if vented to existing furnace or thermal oxidizer. If new thermal oxidizer installed, natural gas costs are ~$6/MMBtu 2. None 3. None	BAAQMD Staff Report - Refinery Strategy - Appendix C Reg. 8-18 & supporting Excel workbook CA Energy - "Estimating Natural Gas Burner Tip Prices for California and the Western United States - Final Project Report", November 2014 (http://www.energy.ca.gov/2014publications/CEC-200-2014-008/) If component vented to an abatement device, there would be a cost savings of $4/inspection/component since the component would be exempt from Reg. 8-18 monitoring.
Petroleum Refining	Fugitives (pumps, valves, flanges)	Pressure-Relief Valves	• Benzene • Naphthalene	1. Vented to recovery (process, fuel gas, etc.) or to abatement (thermal oxidizer, furnace, etc.) 2. Equip with monitoring device (e.g. rupture disk indicator, magnetic sensor, motion detector on PRD valve stem, flow monitor, or pressure monitor)		1. $10,000 - $300,000 (depending on either venting to existing furnace or new thermal oxidizer and amount of pipe needed) 2. $5,000 - $10,000	1. None if vented to existing furnace or thermal oxidizer. If new thermal oxidizer installed, natural gas costs are ~$6/MMBtu 2. None	BAAQMD Staff Report - Refinery Strategy - Appendix C Reg. 8-18 & supporting Excel workbook CA Energy - "Estimating Natural Gas Burner Tip Prices for California and the Western United States - Final Project Report", November 2014 (http://www.energy.ca.gov/2014publications/CEC-200-2014-008/) If component vented to an abatement device, there would be a cost savings of $4/inspection/component since the component would be exempt from Reg. 8-18 monitoring.

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Petroleum Refining	Fugitives (pumps, valves, flanges)	Connectors	• Benzene • Naphthalene	1. Welded connections 2. Shrouded and vented to abatement (e.g. oxidizer or furnace) 3. Zero emission seals		1. ~$120 per connector (Assumptions: 4 hrs/installation (locating, welding, etc.), $30/hr) 2. $10,000 - $300,000 (depending on either venting to existing furnace or new thermal oxidizer and amount of pipe needed) 3. $500 - $5,000 per connector (depending on material type and location of connecter)	1. None 2. None if vented to existing furnace or thermal oxidizer. If new thermal oxidizer installed, natural gas costs are ~$6/MMBtu 3. None	BAAQMD Staff Report - Refinery Strategy - Appendix C Reg. 8-18 & supporting Excel workbook CA Energy - "Estimating Natural Gas Burner Tip Prices for California and the Western United States - Final Project Report", November 2014 (http://www.energy.ca.gov/2014publications/CEC-200-2014-008/) If component vented to an abatement device, there would be a cost savings of $4/inspection/component since the component would be exempt from Reg. 8-18 monitoring.
Petroleum Refining	Cooling Towers		Benzene	Leak detection, repair and monitoring	Compliance with the leak detection, repair, and monitoring requirements in Reg. 11-10 and MACT CC (Section 63.654: Heat Exchange Systems)	Not Yet Available	Not Yet Available	
Petroleum Refining	Cooling Towers		1,3 Butadiene	Leak detection, repair and monitoring	Compliance with the leak detection, repair, and monitoring requirements in Reg. 11-10 and MACT CC (Section 63.654: Heat Exchange Systems)	Not Yet Available	Not Yet Available	

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Petroleum Refining	Combustion	Heaters	Chromium (hexavalent)	Potential: Non-catalytic supercritical water treatment	Treat Raw Materials (Crude and Intermediates) to remove Chromium (if gas turbine is fired on refinery fuel gas)	Not Yet Available	Not Yet Available	
Petroleum Refining	Combustion	Heaters	Chromium (hexavalent)	Potential: Scrubbers, Catalysts	Treat fuel gas to remove chromium	Not Yet Available	Not Yet Available	
Petroleum Refining	Combustion	Heaters	Chromium (hexavalent)	Potential: Scrubbers, filters (used in chrome plating industry), carbon	Treat fuel gas to remove chromium	Not Yet Available	Not Yet Available	
Petroleum Refining	Combustion	Heaters	PAHs	Potential: Combustion Optimization	Optimize Firebox temperature, preheat combustion air, flue gas recirculation	Not Yet Available	Not Yet Available	
Petroleum Refining	Combustion	Heaters	PAHs	Potential: Catalytic Filters	Treat Flue Gas	Not Yet Available	Not Yet Available	
Petroleum Refining	Combustion	Cogeneration Units	Chromium (hexavalent)	Potential: Non-catalytic supercritical water treatment	Treat Raw Materials (Crude and Intermediates) to remove Chromium (if gas turbine is fired on refinery fuel gas)	Not Yet Available	Not Yet Available	

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Petroleum Refining	Combustion	Cogeneration Units	Chromium (hexavalent)	Potential: Scrubbers, Catalysts	Treat fuel gas to remove chromium	Not Yet Available	Not Yet Available	
Petroleum Refining	Combustion	Cogeneration Units	Chromium (hexavalent)	Potential: Scrubbers, filters (used in chrome plating industry), carbon	Treat fuel gas to remove chromium	Not Yet Available	Not Yet Available	
Petroleum Refining	Hydrogen Generation		Chromium (hexavalent)	Potential: Non-catalytic supercritical water treatment	Treat Raw Materials (Crude and Intermediates) to remove Chromium (if gas turbine is fired on refinery fuel gas)	Not Yet Available	Not Yet Available	
Petroleum Refining	Hydrogen Generation		Chromium (hexavalent)	Potential: Scrubbers, Catalysts	Treat fuel gas to remove chromium	Not Yet Available	Not Yet Available	

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Petroleum Refining	Hydrogen Generation		Chromium (hexavalent)	Potential: Scrubbers, filters (used in chrome plating industry), carbon	Treat fuel gas to remove chromium	Not Yet Available	Not Yet Available	
Petroleum Refining	Storage Tanks		Benzene	• Vapor recovery to an oxidizer and/or scrubber • Dome external floating roof tanks • Reduce number of roof fittings (e.g. remove rim vents, etc.) • Re-paint tank • Increased gap seal monitoring frequency • Decreased seal gap allowance (e.g. from 1/8" to 1/16", etc.) • Reduce number of roof fittings		Dome: $350,000 - $1,000,000 (depending on the age of the tank) Align dome installation with API inspection frequency or scheduled tank turnarounds to minimize logistical challenges, extra degassing costs, and other cost overruns		Estimate of installation costs does not include the following: • ≥$10,000 – structural evaluation (required by city planning departments) • ≥$100,000 to $500,000 – structural upgrades (such as shell courses, wind girders on the rim of the EFR tank and any additional work identified by city planners) • ≥$100,000 if wind girders are required • ≥$700,000 – redo foam system (fire prevention measure)

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Petroleum Refining	Storage Tanks	Fixed Roof Tanks	• 1,3 Butadiene • Naphthalene	• Internal floating roof and seals (60%-99% control) • Vapor balancing (90%-98% percent control) • Vapor recovery to process, oxidizer and/or scrubber (90%-98% control) • Maintain the insulation of heavy fuel storage tanks in good condition (reduces storage loss) • Reduce generation of dissolved gases by eliminating pressure drop in tank fill line • Reduce number of roof fittings • Re-paint tank	EPA AP-42 Section 7.1 (November 2006) IFC - Environmental, Health, and Safety Guidelines - Petroleum Refining (November 17, 2016) IFC - Environmental, Health, and Safety Guidelines - Crude Oil and Petroleum Product Terminals (April 30, 2007)			
Petroleum Refining	Storage Tanks	Floating Roof Tanks	• 1,3 Butadiene • Naphthalene	• Vapor recovery to an oxidizer and/or scrubber • Dome external floating roof tanks • Reduce number of roof fittings • Re-paint tank • Increased gap seal monitoring frequency • Decreased seal gap allowance (e.g. from 1/8" to 1/16", etc.)				

Operating Type	Source Category	Source Type	Pollutant	Potential Risk Reduction Measure	Risk Reduction Basis	Installation Cost	Annual Operating Cost	Cost References or Comments
Petroleum Refining	Storage Tanks	Pressurized Tanks	• 1,3 Butadiene • Naphthalene	• Lower maximum allowable leak limit (e.g., from 500 ppm to 100 ppm) for pressure vacuum valves • Increase leak monitoring frequency				