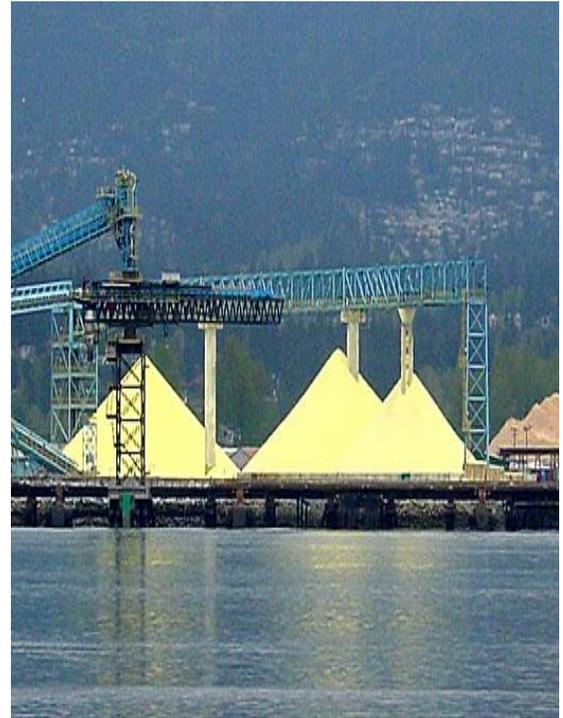


## Voluntary Pollution Prevention and Waste Minimization (P2/WM) Initiatives for Petroleum Refineries in Region VIII



Wyoming Department of Environmental Quality (WY DEQ), Solid and Hazardous Waste Division (SHWD) January, 2007 Update  
(Original Issue August, 2004)

# **Voluntary Pollution Prevention and Waste Minimization (P2/WM) Initiatives for Petroleum Refineries in Region VIII**

## **PREFACE**

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For further information, please contact:

Robert W. Breuer  
Wyoming Department of Environmental Quality (WY DEQ)  
Solid and Hazardous Waste Division (SHWD)  
152 N. Durbin, Suite 100  
Casper, Wyoming 82601

Phone: 307-473-3450

Ben Bents, Mailcode:8P-HW  
US EPA, Region VIII  
1595 Wynkoop Street  
Denver, Colorado 80202-1129

Phone: 303-312-6435

## **DISCLAIMER**

This document is intended as advisory guidance only in developing approaches to pollution prevention. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

# Voluntary Pollution Prevention and Waste Minimization (P2/WM) Initiatives for Petroleum Refineries in Region VIII

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*(Individual descriptions of Pollution Prevention and Waste Minimization (P2/WM) initiatives)*

**Attachment A:** Minimum voluntary initiatives evaluated at refineries (designated as A1 – A10 with updated figures in this 2006 report)

**Attachment B:** Potentially newer or innovative initiatives evaluated at refineries during 2003 – 2004 (designated as B1 – B21 with updated figures in this 2006 report)

**Attachment C:** Potentially newer or innovative initiatives evaluated at refineries during 2005 (designated as C1 – C13 and newly added in this 2006 report)

**Attachment D:** Summary Table of voluntary initiatives documented from this effort to date (as of January, 2007)

## **1.0 Executive Summary – Voluntary Pollution Prevention and Waste Minimization (P2/WM) Initiatives for Petroleum Refineries in Region VIII**

This effort by the WY DEQ and U.S. EPA Region 8 evaluated several petroleum refineries in Region 8 to assess and update the industry's voluntary initiatives to implement energy conservation and Pollution Prevention/Waste Minimization (P2/WM) projects. This work progressed on a part-time basis over a several year period with an initial report issued in August 2004. Additional refineries were evaluated through 2006 and previous P2/WM initiatives in the 2004 report were updated to better define environmental benefits. There was initial emphasis on Persistent, Bio-accumulative and Toxic (PBT) contaminants. Subsequently, additional consideration was given to numerous P2/WM initiatives yielding significant environmental benefits from reductions in energy use, water consumption and conventional pollutants discharged to air, water and land.

A focus on energy use evolved because it became evident energy-related P2/WM initiatives offered multiple environmental benefits, compared to other initiatives. Minimizing the use of fuel gas, liquid fuels and natural gas in refineries achieves benefits beyond energy conservation. This is due to the significant energy consumption, wastes, air emissions and water discharges normally associated with processing the fuels before they are ever consumed.

The report also attempts to summarize significant trends in the refining industry because such trends and their recognition offer significant P2/WM opportunities. These trends include: (1) a trend toward heavier, higher-sulfur crude oil to refineries; (2) changes in fuel sulfur standards; (3) changes to accommodate market demands for higher yields of transportation fuels from crude oil sources not historically able to meet these demands; (4) trends toward more utilization of so-called "conversion" process units such as hydrocracking and coking and; (5) significant, mandated increased use of ethanol as a gasoline additive. This recognition of significant changes in the refining industry can provide more insight into what affects decisions made by refiners. This can then allow more productive discussions involving enforcement cases, Supplemental Environmental Project (SEP) negotiations and/or general regulatory-industry coordination to assure maximum benefit from P2/WM opportunities.

With this 2007 report, initiatives for reduction of energy use, water consumption and Greenhouse Gas (GHG) emissions were more thoroughly evaluated. The initiatives yielded significant benefits from new refinery evaluations and re-calculating previously identified initiatives. This effort identified over 300,000 tons per year of voluntary GHG reductions for Region VIII petroleum refineries. Many of these initiatives involved energy savings incentives but also provided significant, additional environmental benefits. With growing concerns for water shortages (particularly in the western U.S.), the 2006 update also included evaluations of water savings. The findings and analysis confirmed that, beyond conserving a resource, saving water is also saving energy and reducing waste. This is due to the energy use, chemicals and waste generated from treating water and wastewater as discussed in Section 3.5. These evaluations yielded an encouraging, cumulative water conservation of approximately 500,000 gallons per day (gpd) for the refineries evaluated in EPA Region VIII.

A total of nine (9) refineries were evaluated, yielding 44 significant P2/WM initiatives in the 2007 update. The report categorizes these P2/WM initiatives into two groups: (1) those reasonably considered to be "minimum", conventional efforts that have been voluntarily "self-imposed" by most refiners in the industry (designated as A1 through A10 in Appendix A) and; (2) those initiatives which appeared to be more innovative and site-specific (designated as B1 – B21 and C1 – C13 in Appendix B and C). Appendix D summarizes all initiatives in a spreadsheet form. In addition to the GHG reductions discussed above, evidence is provided which indicates these initiatives yielded a benefit of approximately 17,000 tons per year (tpy) in voluntary reductions of combined air emissions, water effluents and waste generation. These benefits are expected to continue for the operating life of these facilities. Emphasis was placed on photo documentation of the actual refinery activities and equipment involved. Reasonable attempts were also made to calculate/document the actual contaminant reductions for each initiative in a conservative manner to avoid over-estimating any benefits.

Finally, since petroleum refiners themselves usually know more about their own P2/WM opportunities, the report is not intended as a guide for the refining industry. It is more an effort to provide information and a different view of refineries for regulators to help improve any coordination on P2/WM efforts they may have with refiners.

## 2.0 Introduction

Grant Proposal No. 8.3-02 to evaluate and document Pollution Prevention and Waste Minimization (P2/WM) initiatives for petroleum refineries was submitted through the Region 8 Chemical Initiative Coordinator's office and subsequently approved through U.S. EPA headquarters in September, 2002 (Grant X988725-01 PBT). The corresponding, approved work plan was sent to Region 8 offices on August 20, 2002.

Petroleum refineries consistently rank among the top ten facilities for Toxic Release Inventory (TRI) emissions and hazardous waste generation in most states in Region 8, as documented by TRI and RCRA Biennial Report System (BRS) records. With the exception of the Tesoro refinery in Mandan, ND, most regional refineries are also between one-half to three miles distance to population or commercial centers with the consequent potential to impact their neighbors. These impacts can also pose environmental risks due to unintentional releases of contaminants from complex operations involving the necessary processing of hundreds of hazardous chemicals. Refinery P2/WM initiatives, which go beyond regulatory requirements, offer more progressive and efficient methods for a refiner to reduce impacts or risks to the public.

The introduction of stringent RCRA waste management regulations, Clean Air Act (CAA) and Clean Water Act (CWA) updates in the 1980 to 1990 period provided significant incentives for petroleum refiners to reduce their waste generation and releases to air, water and land. There are indications these incentives are still present but may have ebbed somewhat due to extensive capital needs and efforts for low sulfur fuel requirements that may have distracted some refiners from continuing intense P2/WM developments. One of the objectives of this grant project is to re-establish more direct communication between refiners and regulators regarding P2/WM initiatives and evaluate new initiatives that may have been developed. **This is not stating refiners have been negligent but, in the view of many, they have had to apply their resources elsewhere in recent years.**

This evaluation also emphasizes two categories for the P2/WM initiatives: (1) those reasonably considered to be "minimum", conventional efforts that have been voluntarily "self-imposed" by most refiners in the industry (in Appendix A) and; (2) those initiatives which appeared to be more "innovative" and case-specific (in Appendix B and C). All initiatives are summarized with a table in Appendix D.

### 2.1 Grant Objectives

The objectives of the project were to document at least six (6) P2/WM projects most petroleum refiners should, at a minimum, be implementing. This objective was achieved with ten (10) "Minimum" P2/WM initiatives documented for the project. The term "minimum" is used because most or all of the refineries evaluated had implemented these basic P2/WM initiatives. A second main objective was to outline at least three (3) potential "new" P2/WM initiatives refiners could implement beyond the "minimum" P2/WM gains thus far achieved. At the time of this writing, an additional 34 innovative P2/WM initiatives were identified and documented. Although these initiatives may not be described as innovative by all refiners, they were more site-specific and less common among their peers. Evidence collected and documented by this effort estimates the P2/WM benefits approach 20,000 tpy of reductions in combined air emissions, water effluents and solid waste generation.

The project included coordination among Wyoming, Montana, Colorado and EPA Region 8 waste management program offices to provide an opportunity for other states to access the information obtained on P2/WM activities for refineries in their region.

Analysis of "life cycle" benefits of the P2/WM projects indicated the air emission, water effluent and waste reductions for each initiative exceeded the energy and general resource requirements to implement the projects. A clear example is the initiative designated as B11, reducing catalyst carryover into fuel oils and hazardous wastes from the Fluid Catalytic Cracking Unit (FCCU) in a Wyoming refinery. This P2/WM

initiative required capital and some minor resource consumption in the form of steel and energy for fabrication. However, improvements in this process unit operation has provided continuous benefits of cleaner fuel oils and reduced Clarified Slurry Oil (CSO) hazardous wastes (designated as U.S. EPA and WY DEQ waste code K170).

### 3.0 Petroleum Refinery Trends & Background Information Affecting P2/WM Opportunities

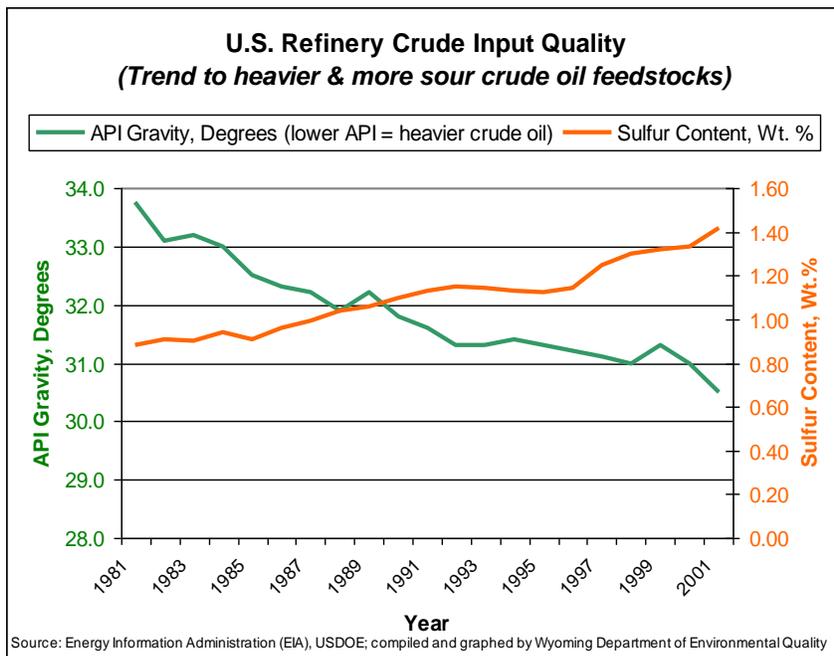
#### 3.1 Refinery Industry General Trends

It is important to consider significant trends in the refining industry to increase the understanding of incentives and decisions facing refiners and to better assess P2/WM opportunities. Some of the more significant trends with higher potential to impact P2/WM initiatives at refineries included those listed below. These trends have been observed at the regional level and, to some extent, at the national and international levels in this industry.

1. Trend toward higher-sulfur, heavier crude oil feed stock (light/sweet vs. heavy/sour crudes)
2. Changes in fuel sulfur standards (sulfur in gasoline and diesel)
3. Changes in product yields from crude oils and market demands
4. Process unit configuration trends to meet changing factors above
5. Increased ethanol use in gasoline

**Trend toward higher-sulfur, heavier crude oils** - According to the International Energy Agency (IEA), the U.S. Energy Department's Energy Information Administration (EIA), industry associations and regional observations; refiners are processing crude oils which are increasingly higher in sulfur and heavier or more viscous. This is shown graphically in Figures 3.1.1 and 3.1.2 below. Numerous conventions have been published for designating crude oils as sweet or sour in terms of sulfur content and as light or heavy in terms of specific gravity. The convention most commonly encountered during preparation of this report is that sweet crudes contain less than 0.5 % sulfur (sour crude > 0.5% sulfur).

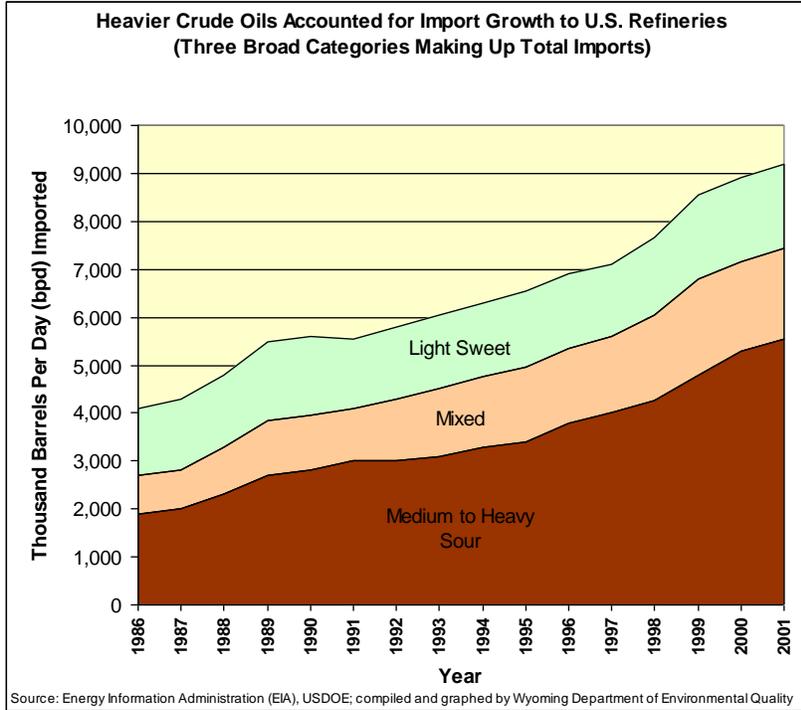
**Figure 3.1.1**



gravities below 26.9.

The designation for heavy vs. light crude oils is based on the API gravity scale. API gravity is a scale to designate the relative density of liquid petroleum materials. The scale was jointly devised by the American Petroleum Institute and the National Bureau of Standards. The scale is in degrees "API" with the lower number on the API scale, the heavier the crude oil (in terms of density). Conversely, crude oils with higher API designations are lighter, less viscous crudes. Convention varies within the industry but "light" crudes are normally considered those with an API gravity exceeding 34. "Intermediate" crudes are normally in the range of 27 – 33.9 API and "Heavy" crudes as those with API

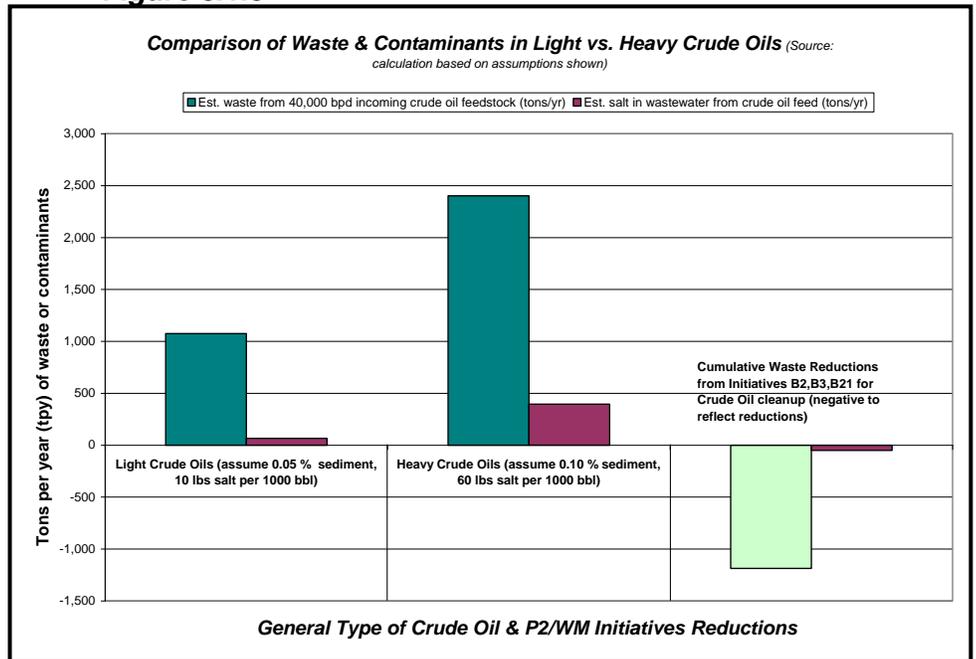
**Figure 3.1.2**



Among other things, the trend toward heavier crude oil to refineries increases the amount of wastes, air emissions and wastewater discharges. Heavy crude oils normally contain more contaminants in the form of Bottom Sediment & Water (BS&W), salts, particulates, sulfur, nitrogen and metal contaminants. These contaminants must be removed by refineries to the extent possible. They accumulate in the bottom of storage tanks as crude oil tank bottom waste and are also generated as wastes from crude oil desalter units. Contaminants not removed from incoming crude oil result in waste generation, resource and energy losses due to corrosion and accumulation in processing equipment. The additional waste generated from heavier, sour crude oil

input to refineries is estimated in Figure 3.1.3.

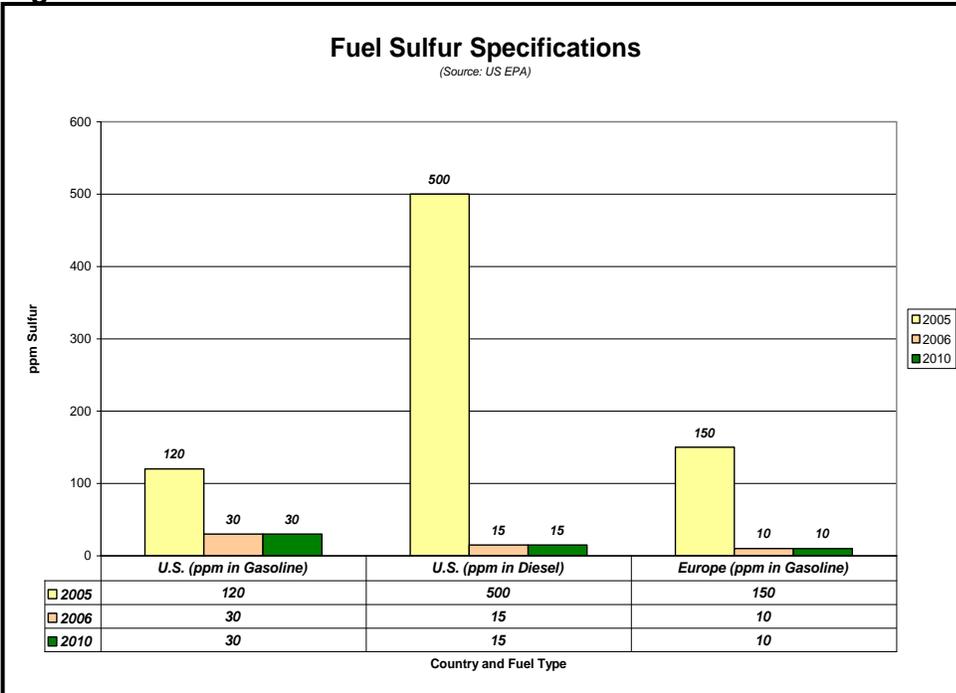
**Figure 3.1.3**



Three (3) P2/WM initiatives were evaluated which provided significant waste reduction benefits by removing contaminants in crude oil feedstock. These are designated as initiatives B2, B3 and B21 in Appendix B. Initiative B2 improved crude oil desalter operations with equipment to monitor the crude oil-water interface and improve crude washing. B3 added an additional vessel to further clean crude oil feed. B21 added a second-stage crude oil desalter to improve contaminant removal efficiency. These initiatives provided a combined benefit of approximately 1,200 tons/yr in hydrocarbon recovery and waste reductions and are also depicted in Figure 3.1.3.

**Changes in fuel sulfur standards** - De-sulfurization of fuels continues to be an important trend with significant potential for P2/WM opportunities. Figure 3.1.4 shows the new requirements for low-sulfur fuels in the U.S. and Europe.

**Figure 3.1.4**

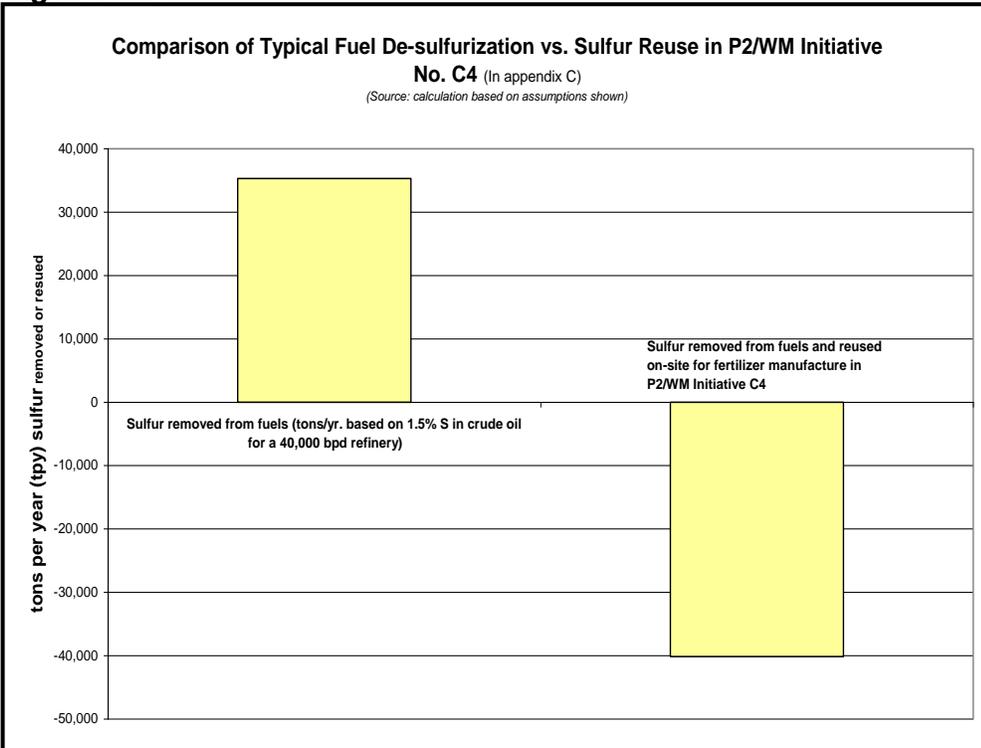


Following de-sulfurization of fuels, the sulfur produced as a by-product has to go somewhere. The market for sulfur fluctuates and is often weak. Consequently, refiners often encounter difficulty establishing a consistent, viable outlet for the sulfur by-product.

In addition, it requires energy and other resources to transport and implement productive uses for sulfur. Manufacture of sulfuric acid and fertilizers represent primary uses for elemental sulfur but are often located far from the

refinery source.

**Figure 3.1.5**



One of the Montana refineries in this evaluation resolved this impediment by establishing a fertilizer manufacturing facility adjacent to the refinery. Sulfur and other by-product materials from the refinery are feed stocks to the fertilizer plant. This results in a significant savings of energy and resources and is evaluated as Initiative C4 in Appendix C. An estimate of typical amounts of sulfur removed from fuels in a 40,000 bpd refinery is compared to the amount re-used at this Montana facility and is shown in Figure 3.1.5.

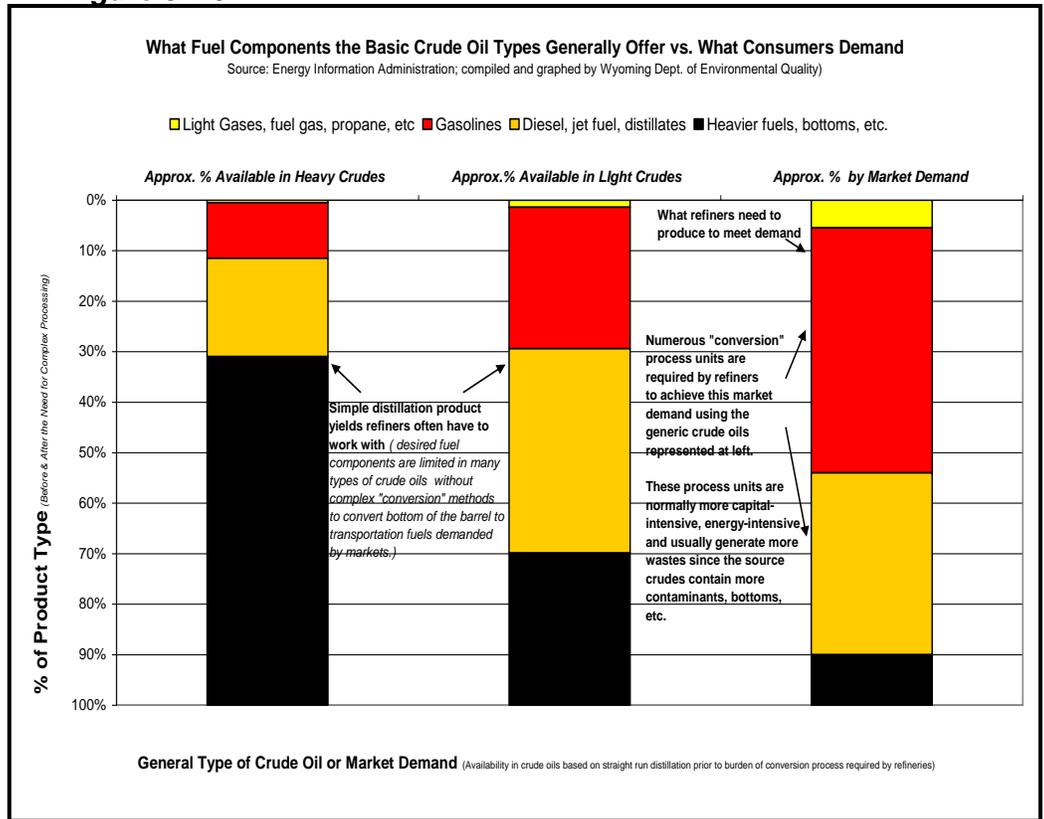
**Changes in product yields from general crude oil types and market demand -**

Another significant change or trend in the refining industry which presents P2/WM opportunities is the increased demand for transportation fuels such as gasoline, diesel and jet fuels. At the same time there has been a decrease in demand for heavier distillates and fuel oils. This has been an inconvenient trend for refiners for a couple of reasons.

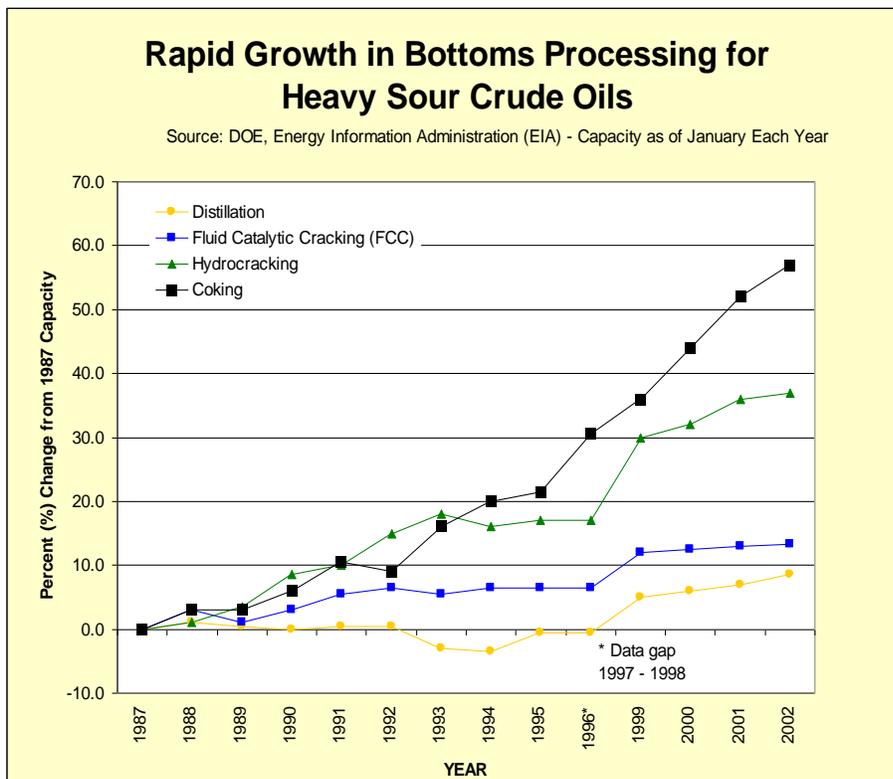
First, as discussed in the beginning of this

section, the trend in crude oil supply/input to U.S. refineries has been toward heavier crudes containing more sulfur. The distillation yields of gasoline, diesel and jet fuels are lower in heavier, sour crudes and there are sulfur removal requirements discussed above. These lower yields are depicted in Figure 3.1.6.

**Figure 3.1.6**



**Figure 3.1.7**



The second factor is that producing more transportation fuels has historically required a proportional increase in the volume of crude oil processed. A past consequence of processing more crude oil would be to have an associated, proportional increase in the undesirable, co-production of additional, heavier products for which the market is weak or non-existent. Consequently, if a refiner chooses to simply process more crude oil to meet transportation fuel demand, they are often faced with the dilemma of accumulating heavier products which are difficult to market and involve

considerable costs to carry in inventory.

A major part of the solution has been a trend by refiners to incorporate improvements in process units which achieve more “conversion” of bottom of the barrel materials (or “bottoms processing”) into petroleum intermediates more suited for transportation fuels (gasoline, diesel and jet fuels). In simple terms, these type process units normally involve sulfur removal, adding hydrogen and cracking larger hydrocarbons into smaller, lower-boiling range molecules. Unit expansions, new construction and increased utilization of advances in petroleum coking, hydrocracking and Fluid Catalytic Cracking (FCC) are dominant examples of this trend. Increased capacities for these categories of refinery process units are seen in Figure 3.1.7 as they compare to the more flat growth in overall crude oil distillation capacity. In summary, refineries are making the adjustment to produce more light transportation fuels from heavier, sour crude oils while minimizing the co-production of less marketable heavier products by utilizing, expanding and improving coking, FCC and hydrocracking operations. Future evaluations of P2/WM opportunities should consider this trend since bottoms processing usually generates higher waste volumes than light crude oils.

**Increased ethanol use in gasoline** - A final refining industry trend covered in this section is the significant increased ethanol use in gasolines required by the Energy Policy Act of 2005. This is considered an industry trend worth recognizing due to wholesale replacement of Methyl Tertiary Butyl Ether (MTBE) with ethanol. Ethanol, as a replacement gasoline additive for MTBE, could comprise over 10 % of the gasoline sold in the U.S. There are indications this change has significant potential to impact P2/WM initiatives both inside and outside refinery gates. This is due to how MTBE and ethanol differ in numerous ways such as in their chemical & physical properties; how they are produced; how they are shipped; how they are blended into gasolines and; differences in resources needed to produce and use these two additives. MTBE had been a historical preference for refiners for several reasons. Among those reasons included the lower volatility of MTBE vs. ethanol (to meet warm season gasoline volatility requirements), its oxygen content and ability to blend MTBE within a refinery for pipeline shipment compared to more costly blending of ethanol downstream of product pipelines.

**Figure 3.1.8**

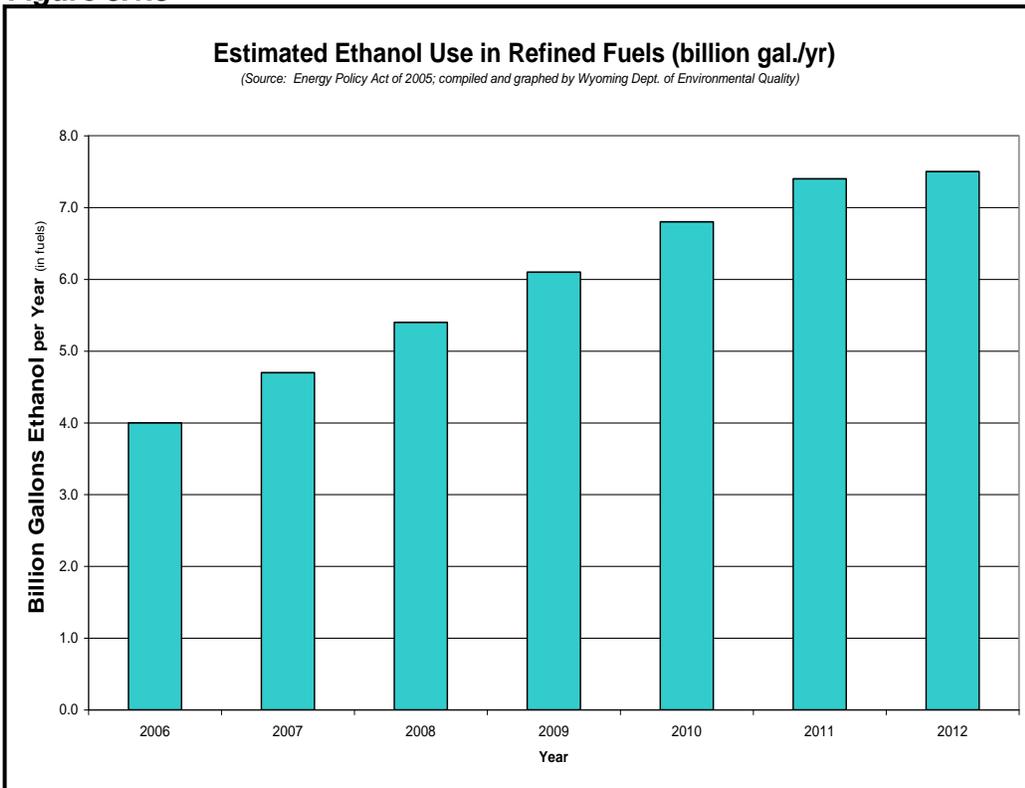


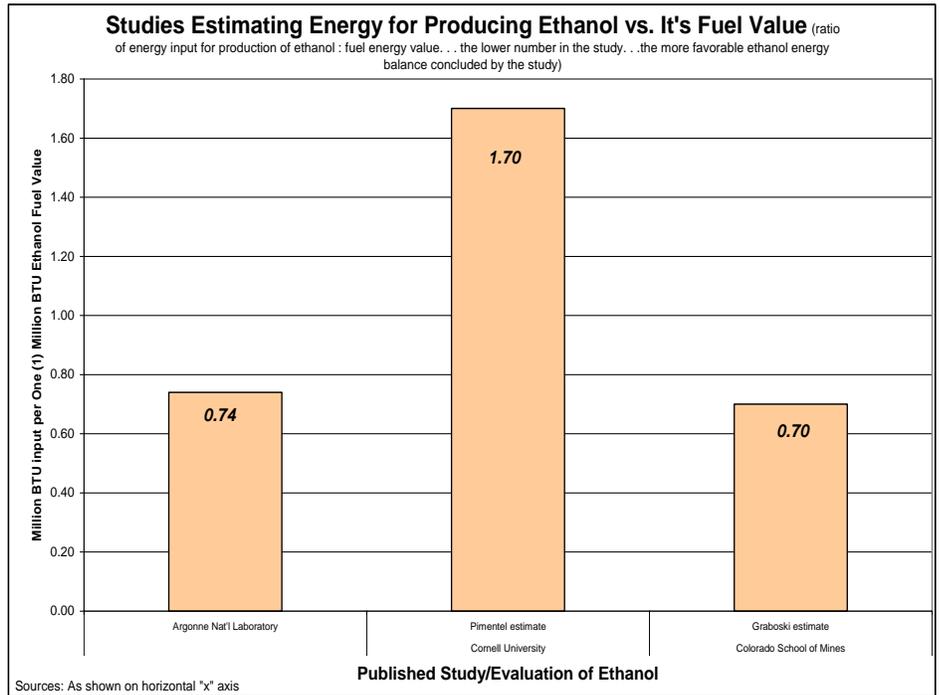
Figure 3.1.8 estimates the ethanol volumes to be blended into gasolines over the next few years. There are numerous, published evaluations of environmental and energy incentives for and against increased use of ethanol in gasolines.

The net energy gain (or loss) with use of ethanol in fuels is one of the contested factors. The estimated amount of energy used in the production of ethanol compared to its energy yield as a fuel has varied widely. Some of these

estimates are shown graphically in Figure 3.1.9.

**Figure 3.1.9**

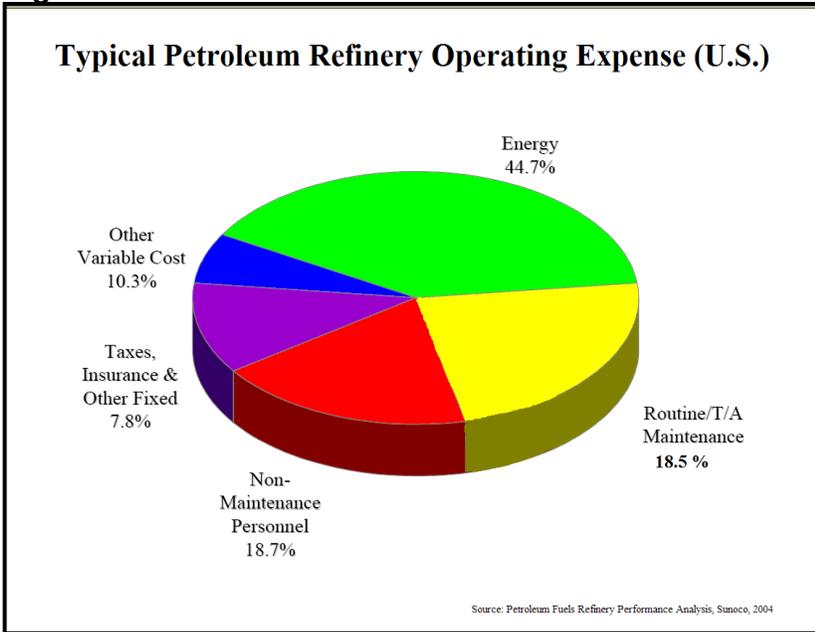
This report is not intended to support a case one way or another. However, it is reasonable to identify some of these factors since the information has the potential to better indicate the more beneficial P2/WM opportunities regarding use of ethanol. One example is addressing the tendency of ethanol-gasoline mixtures to undergo “phase separation” where the ethanol in the fuel absorbs water to the extent where a water/ethanol layer can separate from the gasoline. This is due to ethanol’s affinity for water in vapor or liquid form. Fuels containing moisture are more corrosive to steel pipelines and tanks than dry fuels. Beyond the fuel quality and energy loss concerns, this can lead to significant quantities of wastes generated from corrosion of equipment for shipping, storage and transfer of fuels containing ethanol. Recognition of this factor increases the potential for implementing P2/WM initiatives to resolve the concern. This is also one of the reasons pipeline operators reject transport of gasoline-ethanol blends in their pipelines. Consequently, ethanol has to be shipped separately by rail or truck and blended near the point of sale. Unfortunately, truck and rail transport generally require more energy and resources compared to pipelines.



### 3.2 Energy Use a Primary Consideration for P2/WM in Refineries

According to statistics from the US Department of Energy (DOE), petroleum refining is the most energy-intensive manufacturing industry in the U.S. Most refineries were built when energy was relatively cheap. This section summarizes general, statistical information for the facilities evaluated in this project as well as some peer comparisons within the refining industry and with other energy consumers outside the industry. Preparing some of these comparisons and summaries in advance of this project work provided better discussions with participating refiners and improved focus on more productive initiatives. The summaries and comparisons in this and the following sections should also aid the reader in identifying and understanding how the more promising areas of P2/WM can be pursued at a particular facility. Minimizing the use of electric power clearly saves energy and achieves GHG emission reductions. Minimizing fuel gas, liquid fuels and natural gas use in refineries achieves benefits beyond energy conservation. This is due to the significant amounts of energy use, air emissions, water discharges, chemical use and waste resulting from processing of these fuels. Therefore, reducing energy use results in lower waste generation, air emissions, water discharges, water usage and provides overall, cascading benefits. To further highlight the point, according to the DOE, the Oil & Gas Journal (O&GJ) and refineries evaluated in this project, the average energy consumption range for a US refinery is approximately 500,000 – 700,000 BTU per bbl of crude oil processed. With this energy consumption range, for every 118,000 bbl of fuels delivered from an average refinery, approximately 10,000 – 14,000 bbl of crude oil equivalent are consumed to process the fuels (at 5,810,000 BTU in each bbl of crude oil).

**Figure 3.2.1**



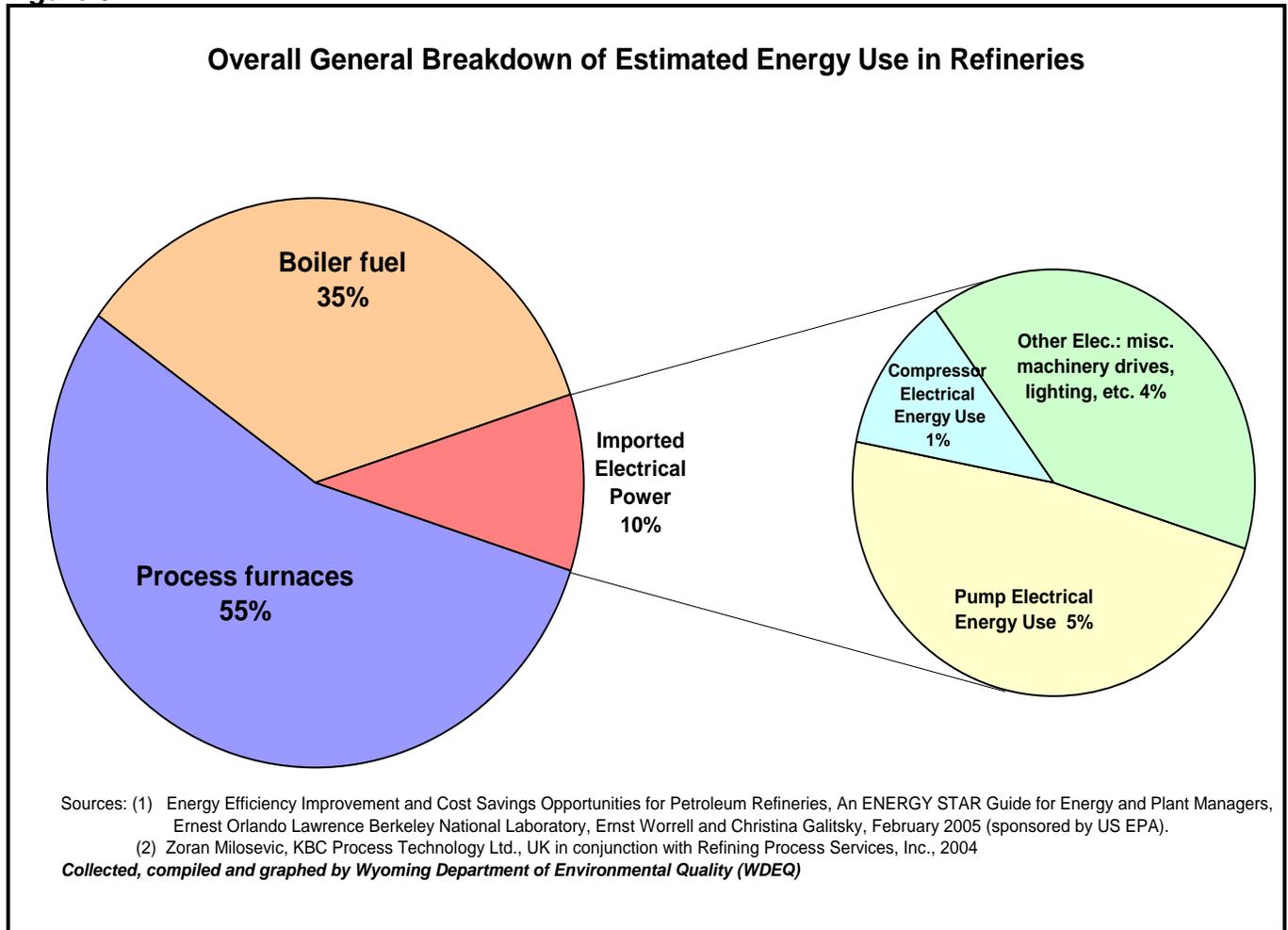
It is helpful to understand some of the more important factors affecting a refiner's incentive for P2/WM projects and, specifically, which types of P2/WM projects are more likely to be implemented. Aside from safety, among the most important issues to a refinery include operating expense control, capital investment allocation and controlling impacts from emissions, effluents and wastes. Operating expenses clearly vary from one refinery to the next but a representative allotment of these expenses is shown in Figure 3.2.1. It is frequently the case that energy is the largest single operation cost in a refinery. From this simple representation, energy projects should stand a much better chance of

implementation than many others candidates. Energy costs include fuel for furnaces to heat raw materials and intermediates for further processing and separation, steam generation, imported electrical power costs, etc.

A developing convention for measuring energy efficiency at petroleum refineries is referred to as "**Energy Intensity Index**" (EII) and it is becoming an accepted measure of efficiency in the industry. Among the reasons for development of the EII was to account for varying refinery types/configurations and allow comparisons among refineries with different process units, sizes, etc. The EII is an unbiased, relative measure of energy efficiency with built-in ability to perform statistical analysis and comparisons with common industry benchmarks established by performance consultants such as Solomon Associates. This analysis can help compare energy use per barrel processed and identify improvements which are still obtainable. These improvements are often available due to past construction of "stand-alone" process units or expansions which were not efficiently heat-integrated with older units on the same refinery. This EII should not be confused with the US DOE Energy Intensity (EI) which is based on a ratio of energy use to economic value of production. It may be helpful to go a step further to estimate the breakdown of energy use in most refineries. This is an estimate which can vary from one refinery to another but Figure 3.2.2 indicates a common breakdown for most refineries.

It is evident in Figure 3.2.2 that most refiners should continue some focus on process furnace and boiler efficiency. For electrical energy use, emphasis should be on pumps using large amounts of electrical power such as crude oil charge pumps, hydrotreater charge pumps and other pumps in large-volume service. Some of these pumps can exceed 5,000 hp and have considerable room for efficiency improvements.

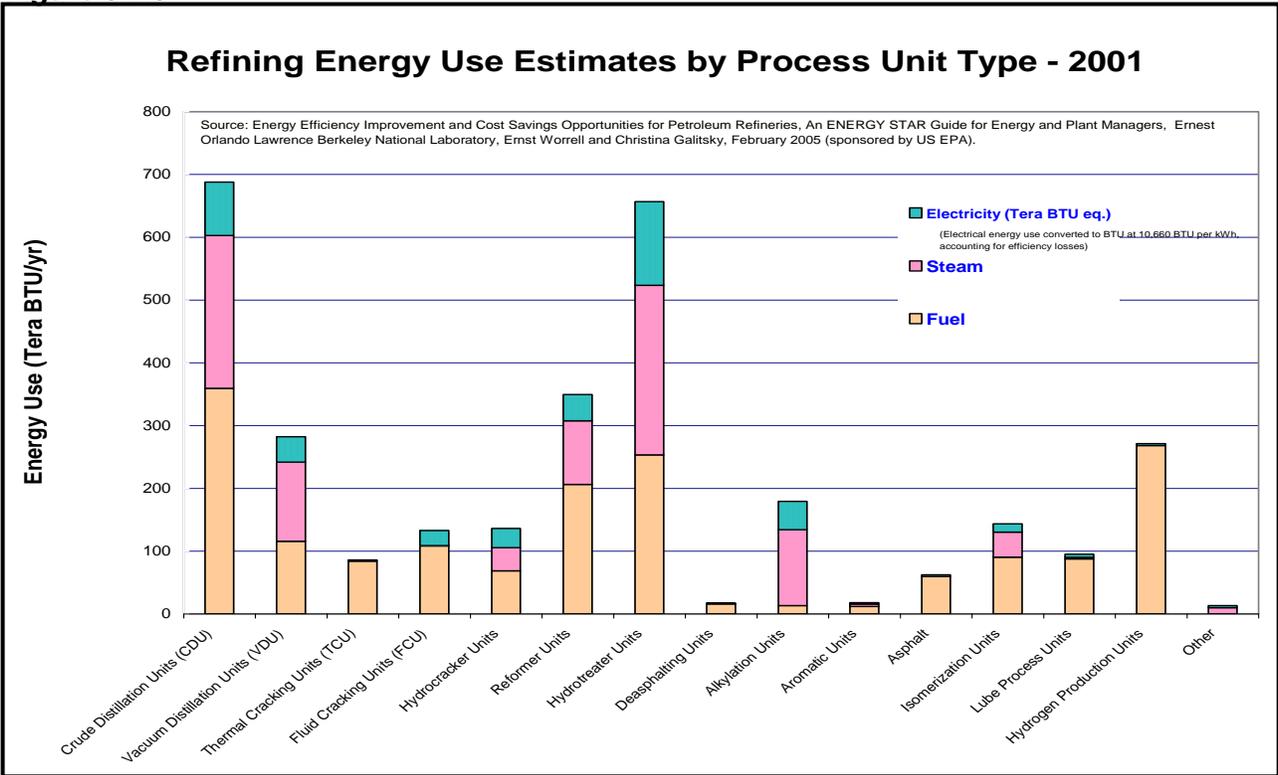
**Figure 3.2.2**



Taking this one step further, an estimate of which individual process units in a refinery use more energy provides clarification on where energy-saving initiatives are likely to be more beneficial. Figure 3.2.3 indicates crude oil distillation and hydrotreating units are more likely to offer higher energy conservation initiatives since they consume more energy than other process units.

If one were to consider process units with more potential to exhibit the highest energy losses, Fluid Catalytic Cracking Units (FCC) would more likely be in this category. This is mainly due to their high-flow, high-temperature flue gas stream releasing large amounts of heat energy to the atmosphere compared to other process units. However, according to DOE/EIA, the industry has made significant energy improvements. During the past 20 years, the refining industry has improved energy efficiency by over 30 %.

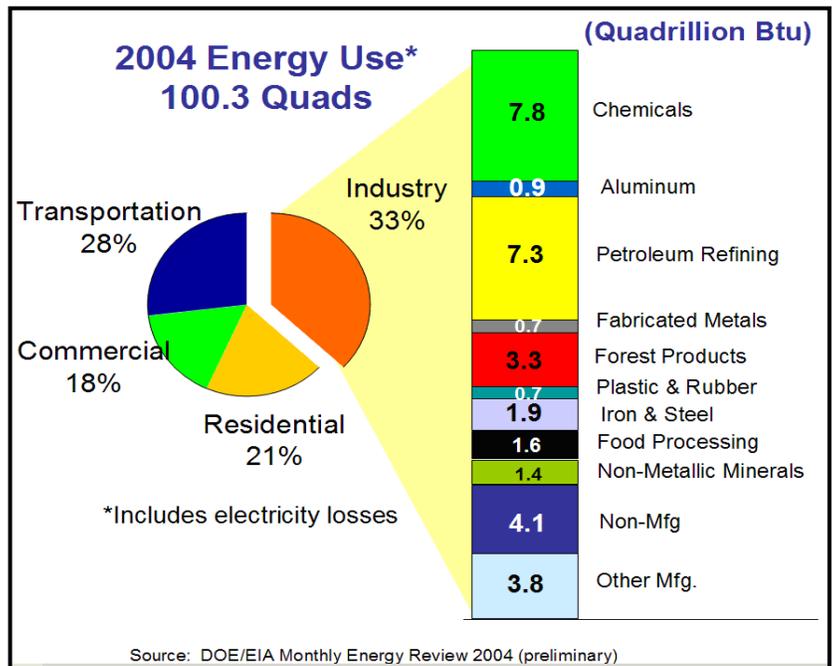
**Figure 3.2.3**



An additional comparison of how the refining industry compares with other manufacturing industries is shown in Figure 3.2.4. This further illustrates how energy-intensive the petroleum refining industry is.

The following sections present a series of comparisons of refining industry electrical energy use, natural gas use, water use and GreenHouse Gas (GHG) emissions. These were compiled from numerous sources by the Wyoming Department of Environmental Quality (WY DEQ) and US EPA Region VIII. These comparisons are intended to indicate the most resource-intensive industrial activities and illustrate incentives for conservation in areas of highest potential benefits. Comparisons of facility resource consumption with P2/WM initiative reductions in this project are also shown.

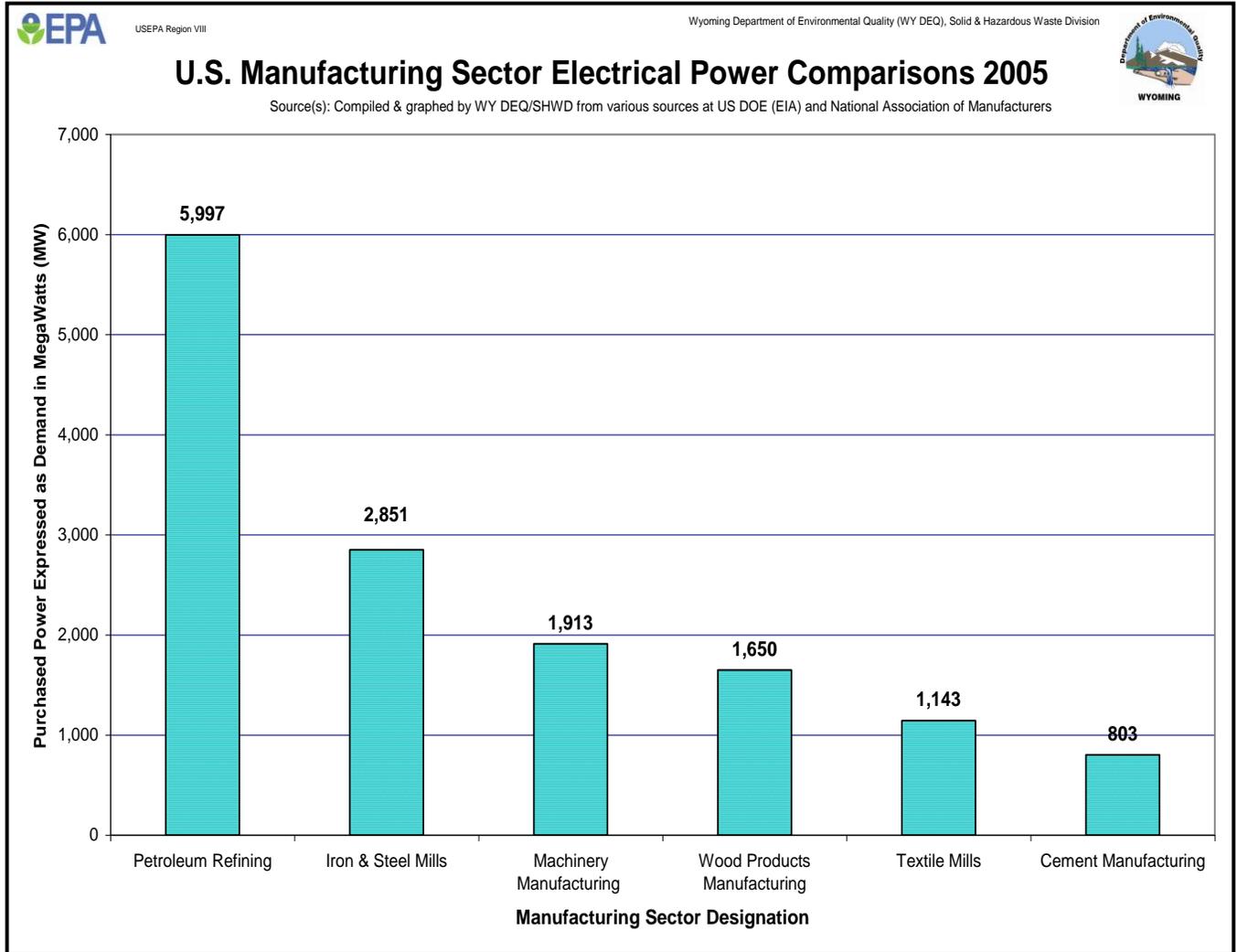
**Figure 3.2.4**



### 3.3 Electrical Power Demand in Refineries and Comparisons to Other Power Users

According to the U.S. Department of Energy (DOE), the petroleum industry is one of the largest consumers of electric energy in the U.S., compared to other industries in the manufacturing sector. This comparison is shown in Figure 3.3.1 below. An average U.S. refinery running over 100,000 bpd requires approximately 42 MegaWatts (MW) of electrical power, primarily for hundreds of large pumps, compressors and other process unit equipment with electric drives.

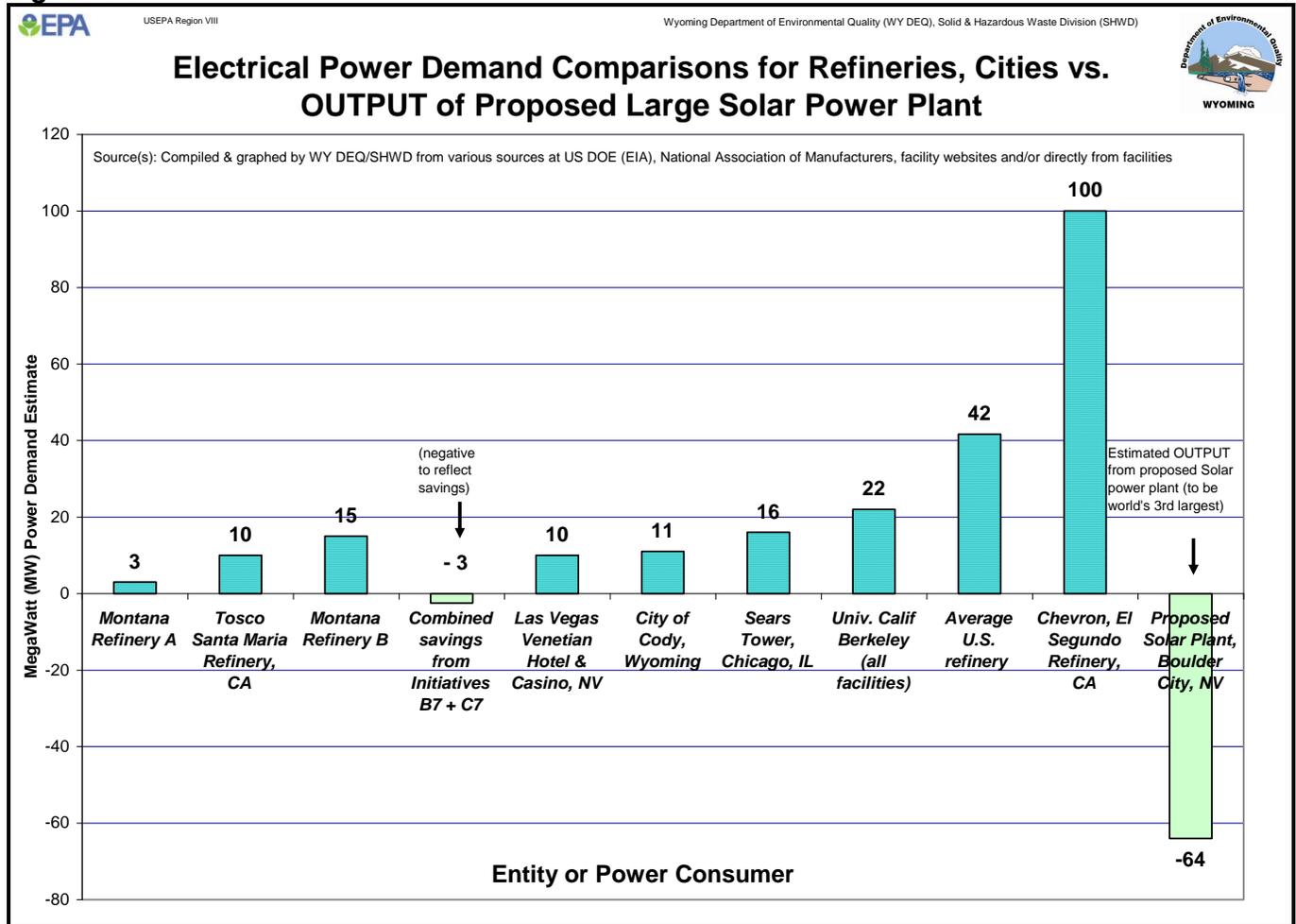
Figure 3.3.1



Heavy industries have extensive electrical demands, from running numerous pumps in refineries to electric arc furnaces in steel production and sizable looms in the textile industry. The refining industry has also begun to install electrical power stations on-site (referred to as “co-generation”), allowing reduced electrical power imports. There has also been a general trend among refiners to convert steam-driven pumps, compressors and other rotating equipment to electrical power because of the lower cost to operate electrical equipment vs. steam driven. This is attributed to high fuel and labor costs to operate steam boilers. Many refineries have two or more boilers dedicated to steam production. A frequent goal has been to reduce steam demands from steam-driven equipment to the point where one or more boilers can be shutdown. When this steam reduction threshold is reached, a refiner can reap the benefit of the lower cost electrical equipment and realize savings in labor and fuel with shutdown of one or more boilers.

Figure 3.3.2 shows a comparison of some refineries among their peers and with other electric power users. Electric power savings from P2/WM Initiatives B7 and C7 (Appendices B and C) are also shown.

**Figure 3.3.2**



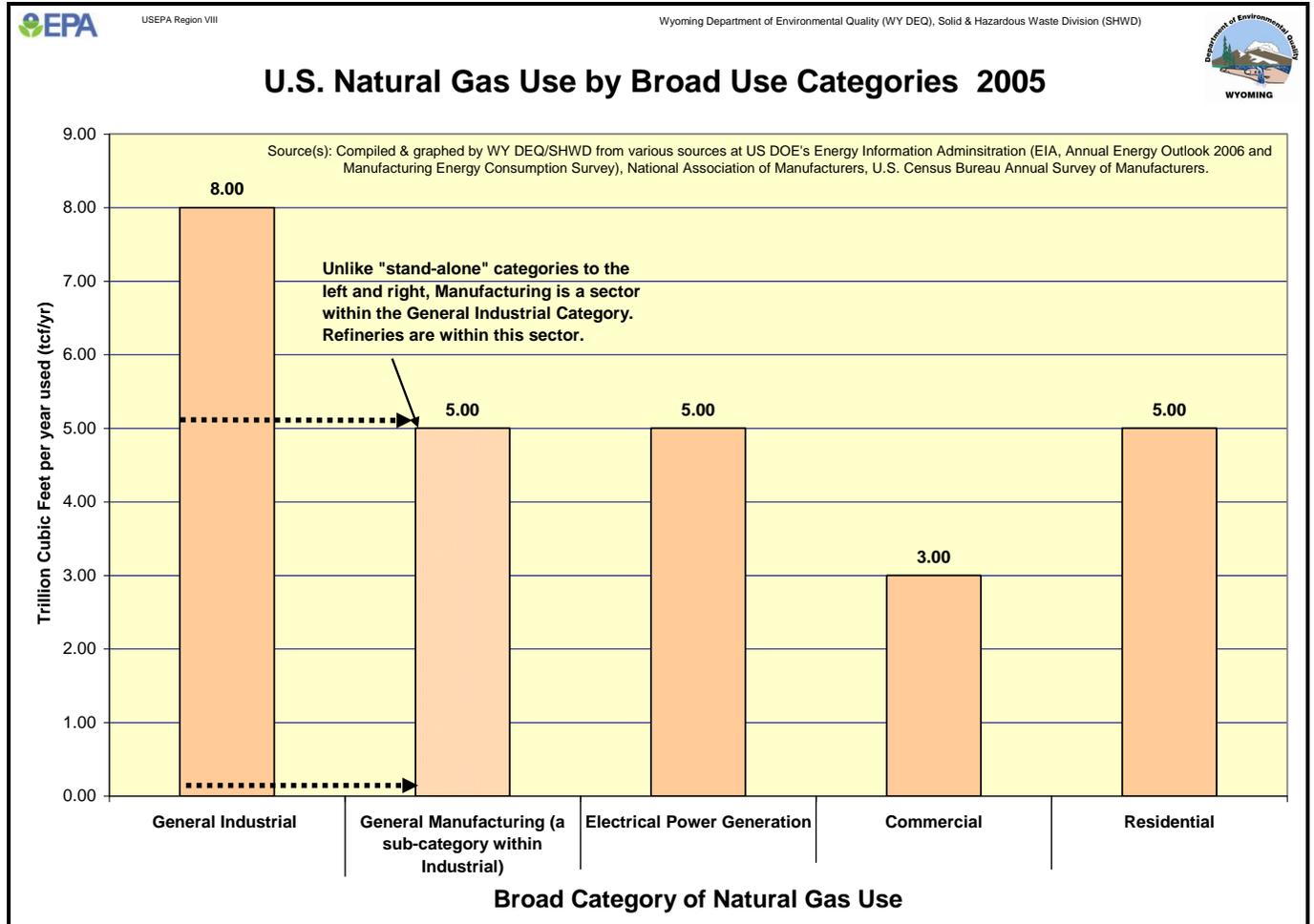
The initiatives B7 in Appendix B and C7 in Appendix C provide good examples of electrical power conservation. Initiative B7 installed a Variable Frequency Drive (VFD) control system for one of the larger electrical compressors in a Montana refinery. This allows the electric drive for the compressor to operate at the minimum power level required for the volume of gas processed at a given time. Initiative C7 installed heat recovery at the Fluid Cracking Unit (FCU) stack for co-generation of approximately 1.5 MW of electrical power. Although the savings are small when compared to larger facilities, the cumulative reduction is near the total power demand for one of the small Montana refineries.

Reducing electrical power demand results in cascading environmental benefits. These include reducing the impacts to produce the fuel for power generation (coal, fuel oil, uranium or gas), electrical transmission line losses, large volumes of water required for power plants and large quantities of chemicals required to treat boiler and cooling water. In addition much of the power in the U.S. is produced at 30 – 35 % efficiency so any conservation also decreases the 65 – 70 % efficiency loss associated with each unit of electrical power delivered.

### 3.4 Natural Gas Use in Refineries and Comparisons to Other Gas Consumers

Within the General Industrial category of natural gas users, the Manufacturing Sector represents the largest consumer of natural gas. This is shown in Figure 3.4.1 below.

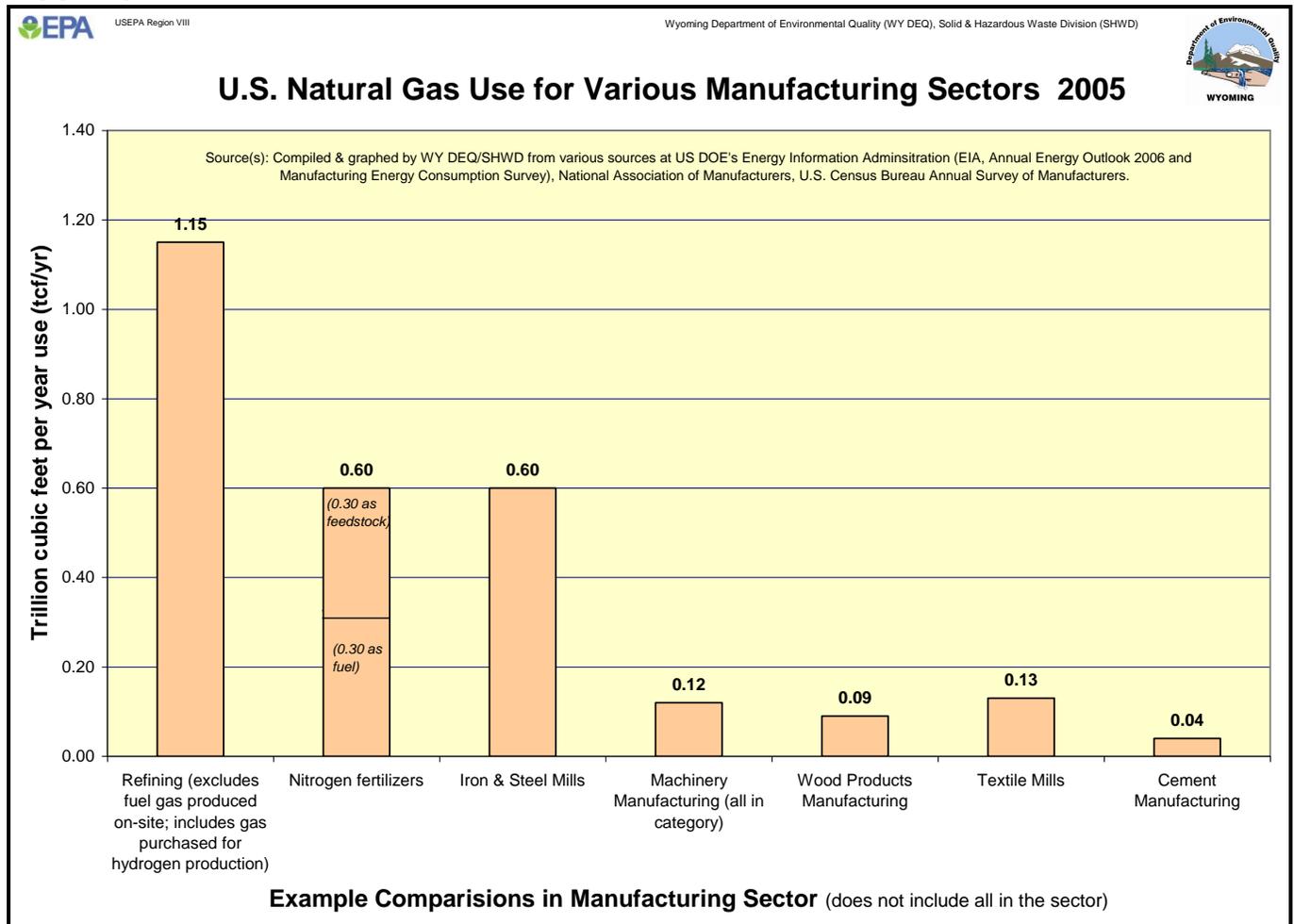
**FIGURE 3.4.1**



The General Industrial category of natural gas use significantly exceeds the other three categories of Electrical Power Generation, Commercial (large office buildings, etc.) and Residential. Within the General Industrial category, manufacturing represents the largest consumers of gas. Among other reasons, the manufacturing sector is a heavy consumer of natural gas since much of the processing in the sector is heat-intensive. Examples include large, gas-fired heaters/furnaces to vaporize billions of pounds of oil in refineries each day, large kilns at temperatures above 1500 degrees in cement manufacturing and the heat needed in textile mills for dyeing, washing and drying. Some of these facilities also depend heavily on other fuels such as coal and/or coke for cement kilns. These manufacturing facilities also often have large space heating requirements due to the high square footage and tall profile of the large buildings or factories they occupy.

Figure 3.4.2 clearly indicates the petroleum refining industry is a large consumer of natural gas when compared to many other well-established industries in the manufacturing sector. These figures are for imported or purchased natural gas and do not include use of any fuel gas produced on-site.

**FIGURE 3.4.2**

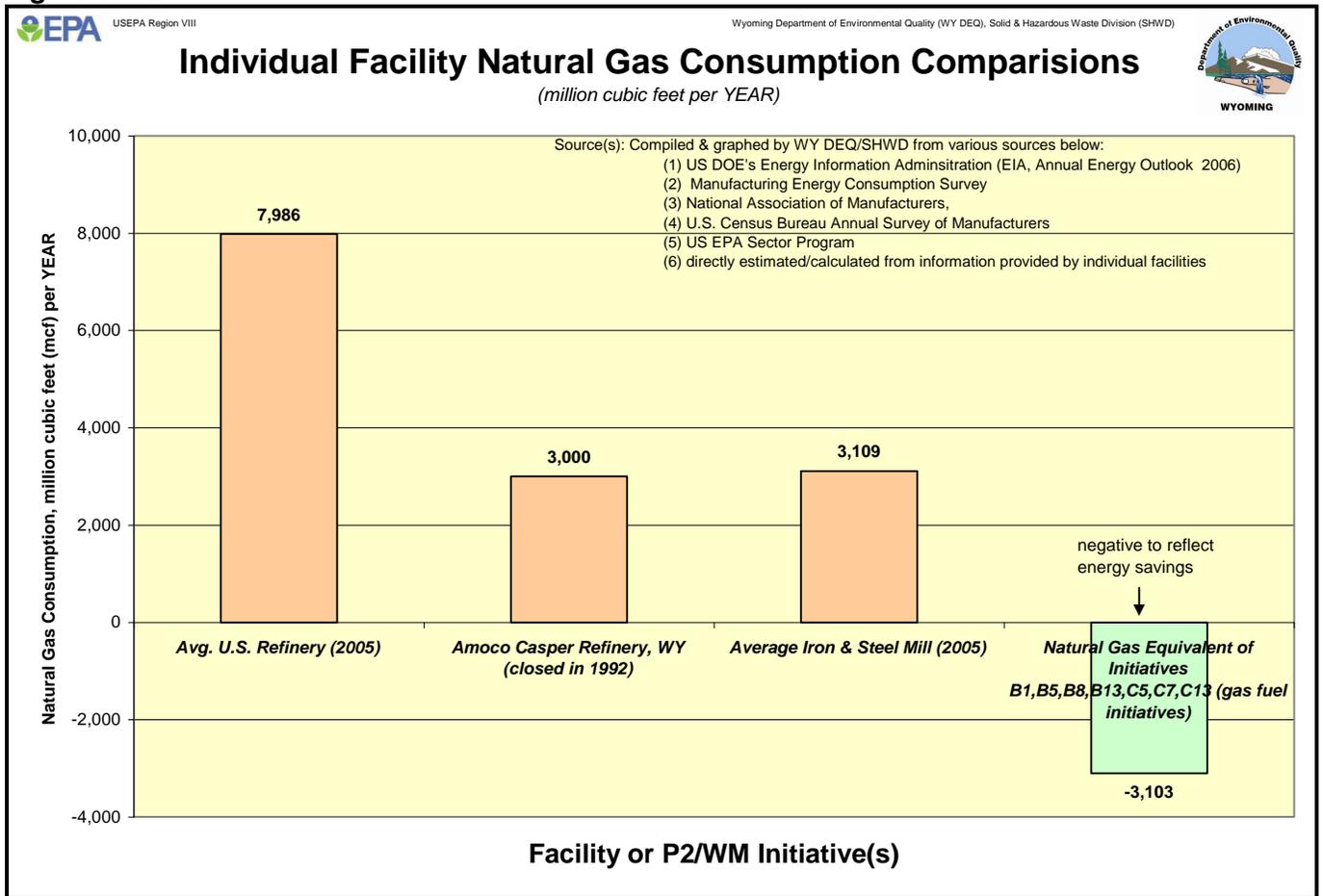


There is the heat-intensive nature of many manufacturing process units. With the U.S. refining industry running over 16,000,000 barrels per day (bpd), the industry must heat most of this 5.2 billion pounds of oil to vaporizing temperature every day (at approximately 325 lbs. per barrel). This is just for crude oil distillation and every barrel of crude oil input goes through the distillation process. Additional portions of the distilled intermediates frequently have to be heated again to similar temperatures for the various process unit reactions such as Fluid Cracking Units (FCU), Catalytic Reforming Units, Hydrotreaters, Hydrocrackers, etc.

Although refiners provide much of their own fuel gas, there is a considerable need for imported natural gas to heaters/furnaces. Added to the heating needs, there is natural gas required to make hydrogen, the hydrogen is then used to remove sulfur in hydrotreaters. Hydrogen demand has been rapidly increasing due to the need for hydrotreating to meet fuel sulfur standards. Refiners obtain some hydrogen from Reformer Unit off-gas but most hydrogen for refining is produced from natural gas.

Figure 3.4.3 below compares natural gas consumption among various individual facilities and with the estimated savings total from initiatives B1, B5, B8, B13, C5, C7 and C13. These initiatives all involved reductions in consumption of gaseous fuels, either as fuel gas, flare gas or the equivalent energy as natural gas to generate electrical power. The energy savings from these initiatives were totaled and converted to approximate volumes of natural gas equivalents.

**Figure 3.4.3**



Initiatives B1, C5 and C13 implemented flare gas recovery systems to reduce unnecessary flaring of refinery fuel and flare gas. This conserved the equivalent volume of natural gas by capturing and using the otherwise wasted flare gas for fuel or products. B5 instituted flare gas flow metering which significantly reduced flare gas combustion. Metering or measuring flare gas volume is essential to gas savings since conservation of the resource can not be achieved without first having knowledge to correlate gas flow rates with times and activities within the refinery. The refinery accomplished the savings by recognizing unnecessary flaring of gas upon correlating the flow rates with activities in the refinery which could be controlled, minimized or the flare gas diverted to process use. Initiative B13 involved gasification of oily refinery wastes at a gasification plant in North Dakota. This conserved the equivalent volume of natural gas by converting the waste hydrocarbons to a useful gas product. Initiative C7 captured waste heat from a Fluid Catalytic Cracking (FCC) flue stack, generating steam and electric power from otherwise wasted energy. This resulted in an equivalent savings of natural gas since natural gas is often used to generate electrical power. It can be seen the combined savings were roughly equivalent to natural gas use in a Wyoming refinery and an average iron & steel mill.

### 3.5 Water Use in Refineries and Comparisons to Other Water Users

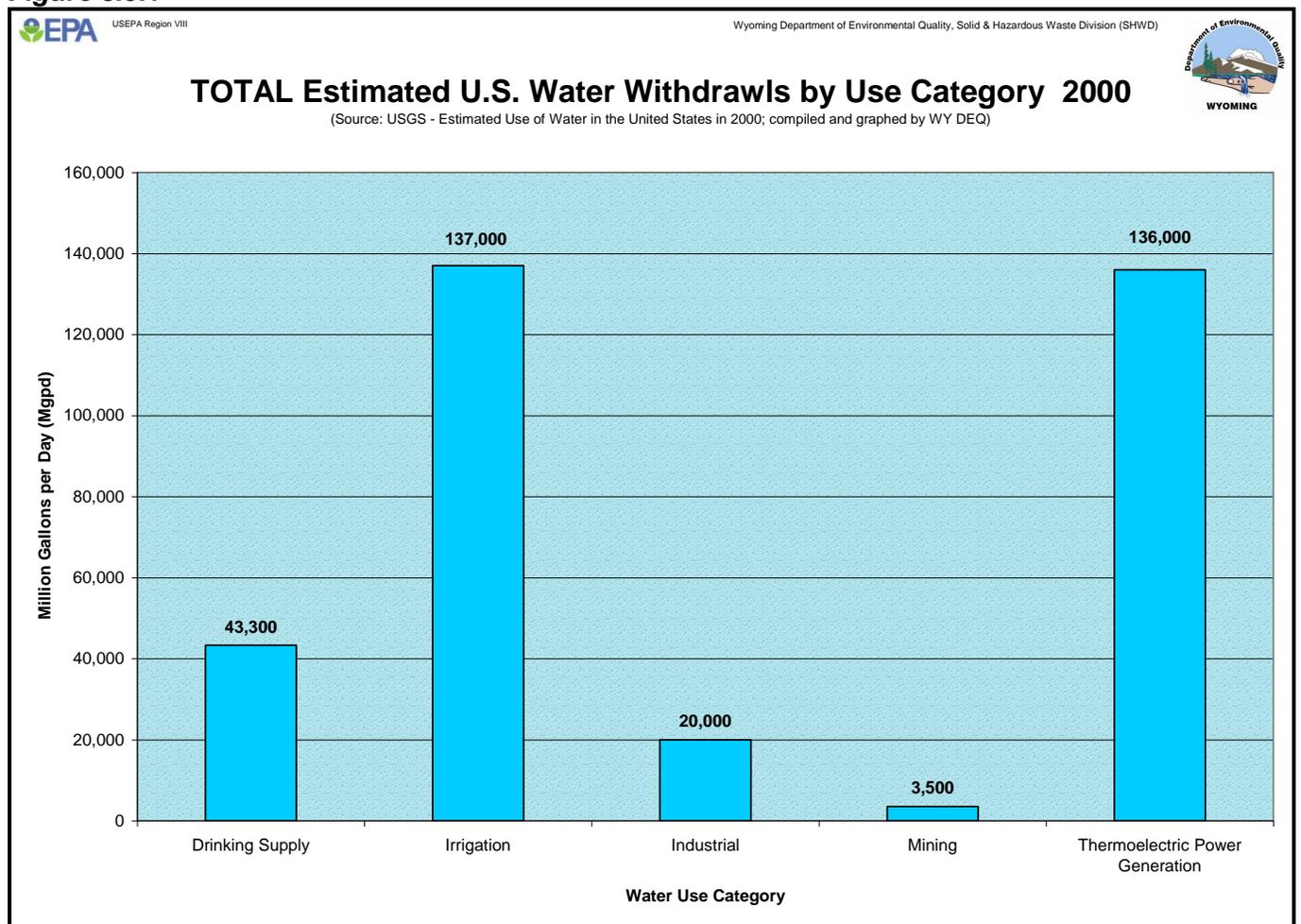
When an industry or other entity uses water, it is also consuming the energy and chemicals required to withdraw, pump/transfer and treat the water. The City of Austin, Texas estimates the total energy costs for water treatment, pumping and wastewater treatment at approximately 4 kilowatt hours (kWh) per 1000 gallons of water delivered. This estimate is probably higher for large volumes of boiler feed water which must be treated beyond drinking water quality to minimize corrosion in the high-temperature environments of an industrial boiler. These energy estimates do not include the energy required to produce the thousands of tons of water treatment chemicals in the U.S. each year. The City of Austin estimates the chemical costs of water and wastewater treatment at \$0.09 per 1000 gallons. A partial list of chemicals used in water and wastewater treatment is shown below in TABLE 3.5.1, (examples include domestic and industrial use).

**TABLE 3.5.1**

Acrylamide	Chlorine	Filming amines	Lime
Aluminum sulfate	Chlorine dioxide	Hexafluorosilicic acid	Phosphoric acid
Aluminum chloride	Copper sulfate	Hydrochloric acid	Sodium sulfite
Benzalkonium chloride	Ferric chloride	Hydroquinone	Sulfuric acid

The list of chemicals used in water and wastewater treatment is more extensive but the information above provides some idea of the resources needed to use water of the appropriate quality for domestic and industrial use. The Figure 3.5.1 below provides estimates from the U.S. Geological Survey (USGS) on fresh water withdrawals by broad categories of use.

**Figure 3.5.1**



Thermoelectric power generation is only second to irrigation in volume of water use. According to DOE's Energy Information Administration (EIA), there are approximately 11,000 thermoelectric generators in the U.S., including coal-fired, gas-fired, fuel oil and nuclear. There are approximately 1,500 coal-fired power plants in the U.S. compared to roughly 150 petroleum refineries. As small as it seems compared to other users of water, the industrial category uses over 20 billion gallons per day (bgpd) of fresh water.

Industrial facilities use water for cooling, boilers/steam production, raw material washing, quenching, chemical process reactions, etc. The primary use in many heavy industries such as petroleum refining or chemical production is for cooling and steam production. The Texas Water Development Board estimates approximately 900,000,000 gallons are evaporated in Texas each day for cooling (including thermoelectric power generation). Estimates from US DOE, The American Institute of Chemical Engineers (AIChE) and the World Bank indicate water use in the average petroleum refinery ranges from approximately 42 - 90 gallons per bbl of crude oil processed. The average petroleum refinery is estimated to process 118,000 bpd. At the low end of this estimate (42 gal water per bbl), the average refinery would use approximately 5,000,000 gallons of water per day. The high end of this estimate could result in some refineries using as much as 10,600,000 gallons per day. Figure 3.5.2 compares water withdrawals by specific industrial facilities and other users.

**Figure 3.5.2**

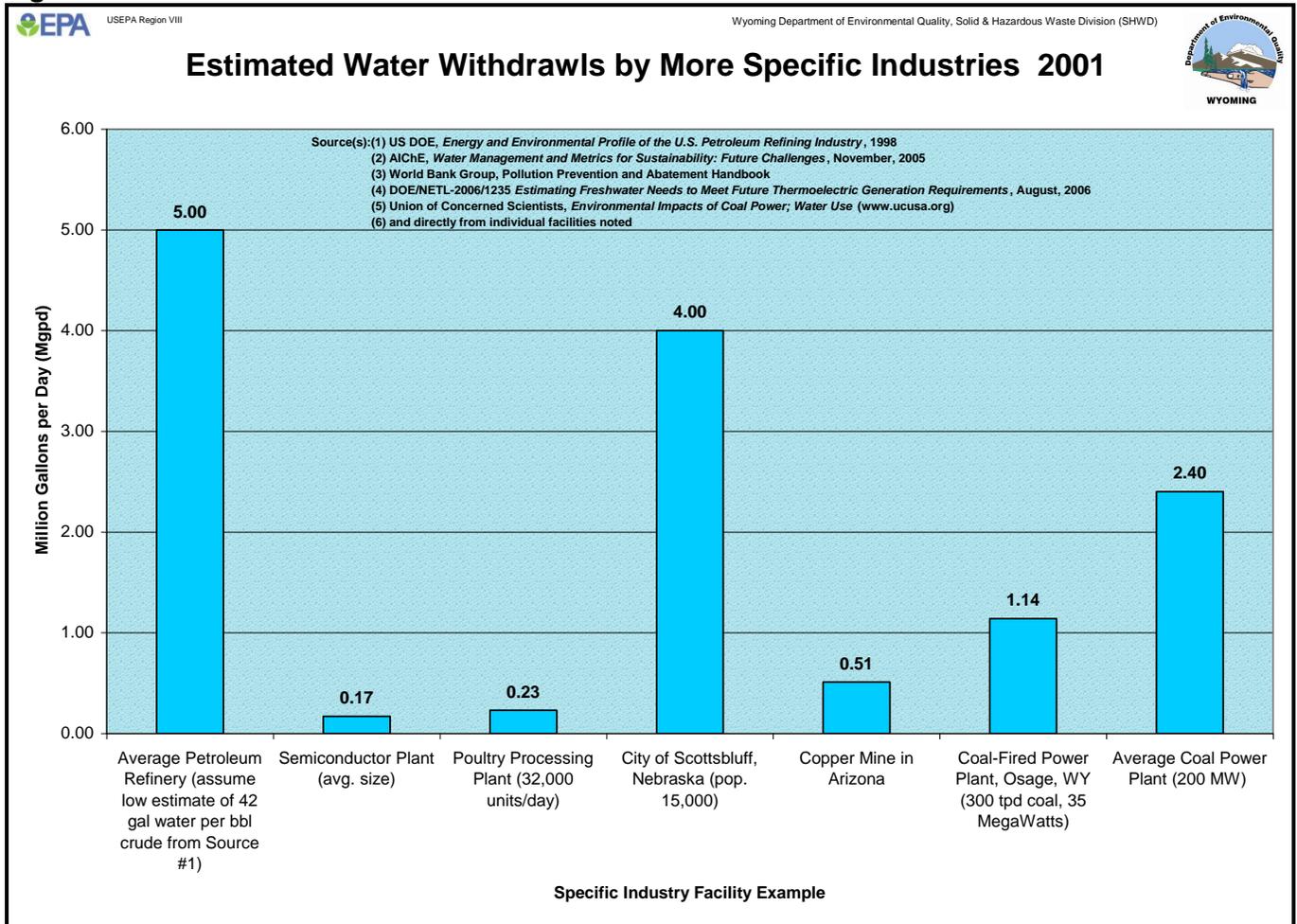
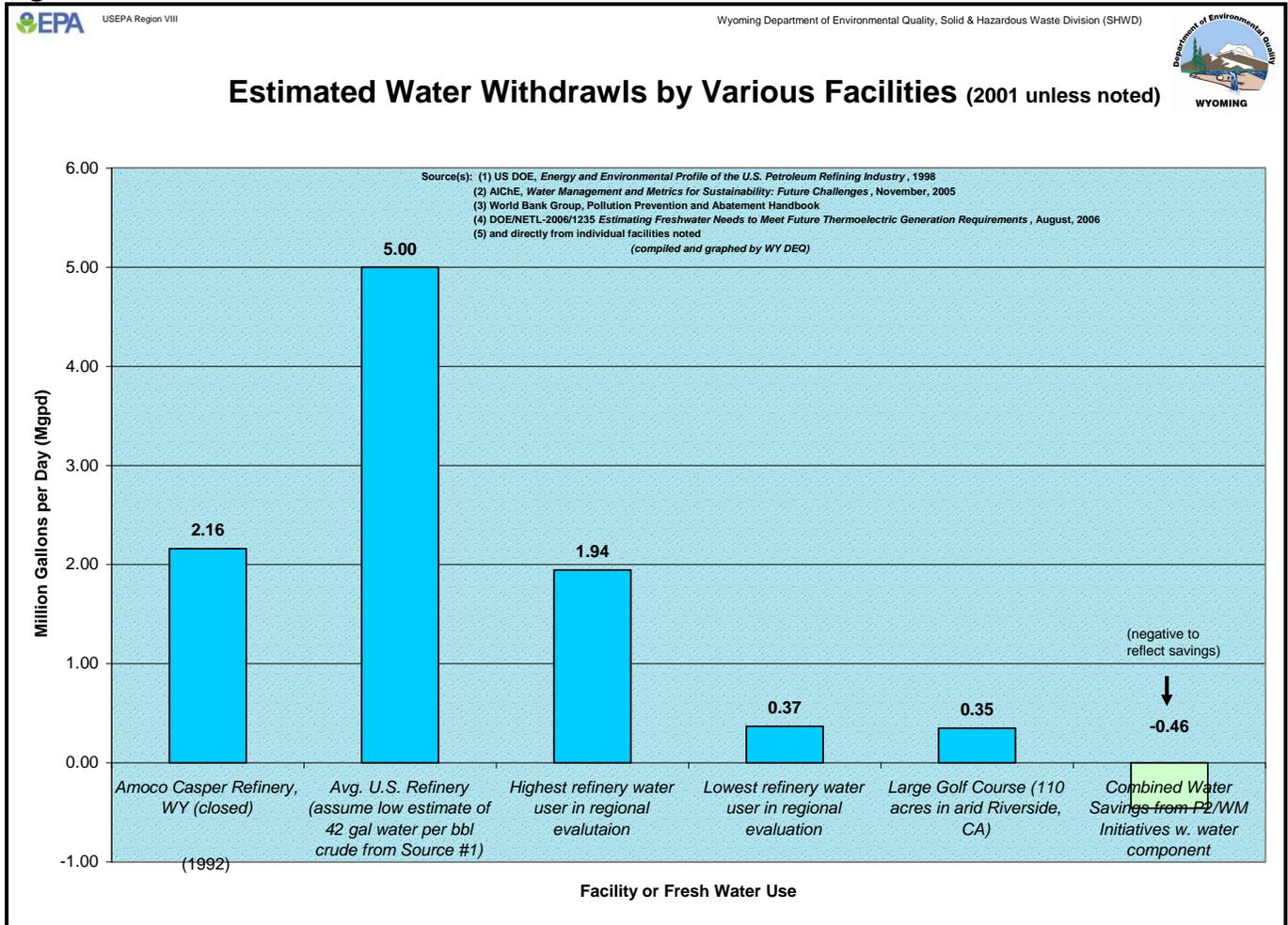


Figure 3.5.3 provides additional examples of water use among several peer refineries and a large golf course in Riverside, California for another point of comparison. Golf courses are large consumers of fresh water due to their irrigation-intensive nature and large acreage. The golf course example in Riverside, CA also represents an arid part of the country where water demand and the evaporation-transpiration rate is particularly high. The combined water use reductions from Initiatives A2,B6,B10,B20,C1,C2,C3,C6 and C10 (in Appendices A,B & C) are also shown.

**Figure 3.5.3**



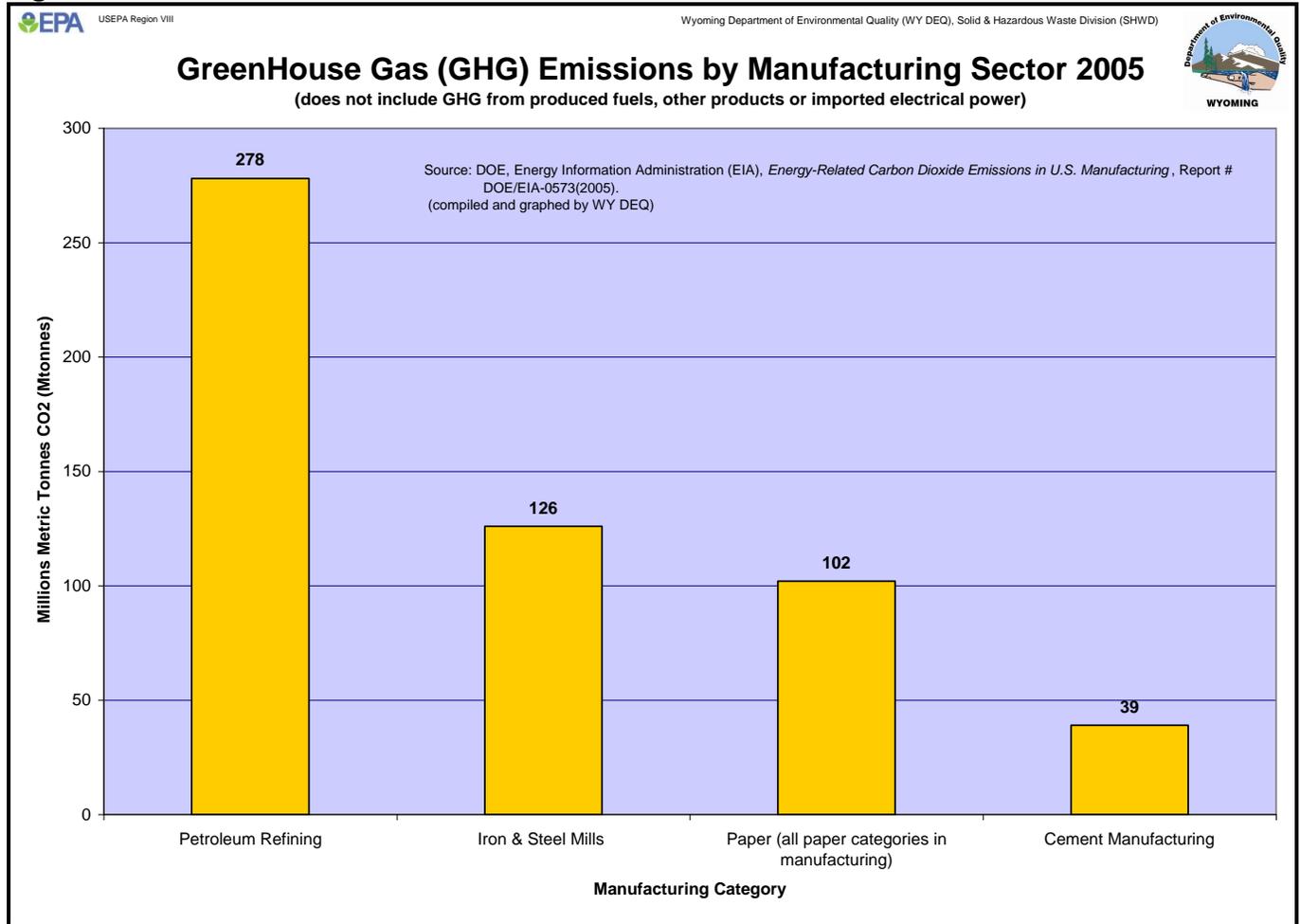
The combined water savings from these P2/WM initiatives appear small in comparison with the average US refinery but they more than offset the total use of one refinery in the P2/WM evaluation. The initiatives included hydrocarbon loss minimization (conserves water used for re-processing recovered oil), use of spent caustic for manufacture of sodium hydrosulfide, installation of air coolers in place of heat exchangers in cooling water service and wastewater reuse.

### 3.6 Green House Gases (GHG) from Petroleum Refineries and Comparisons to Other Sources

GHG emissions are directly related to energy use. Any heavy industry, particularly those with heat and power requirements will have significant GHG emissions. The manufacturing sector often represents the largest emissions of GHG in the broad industrial category, similar to the case of this sector's consumption of electrical power and natural gas or other hydrocarbon fuels. Due to the inherent

demand for heat and power, the petroleum refining industry ranks near the top for GHG emissions in the manufacturing sector, as seen in Figure 3.6.1.

**Figure 3.6.1**

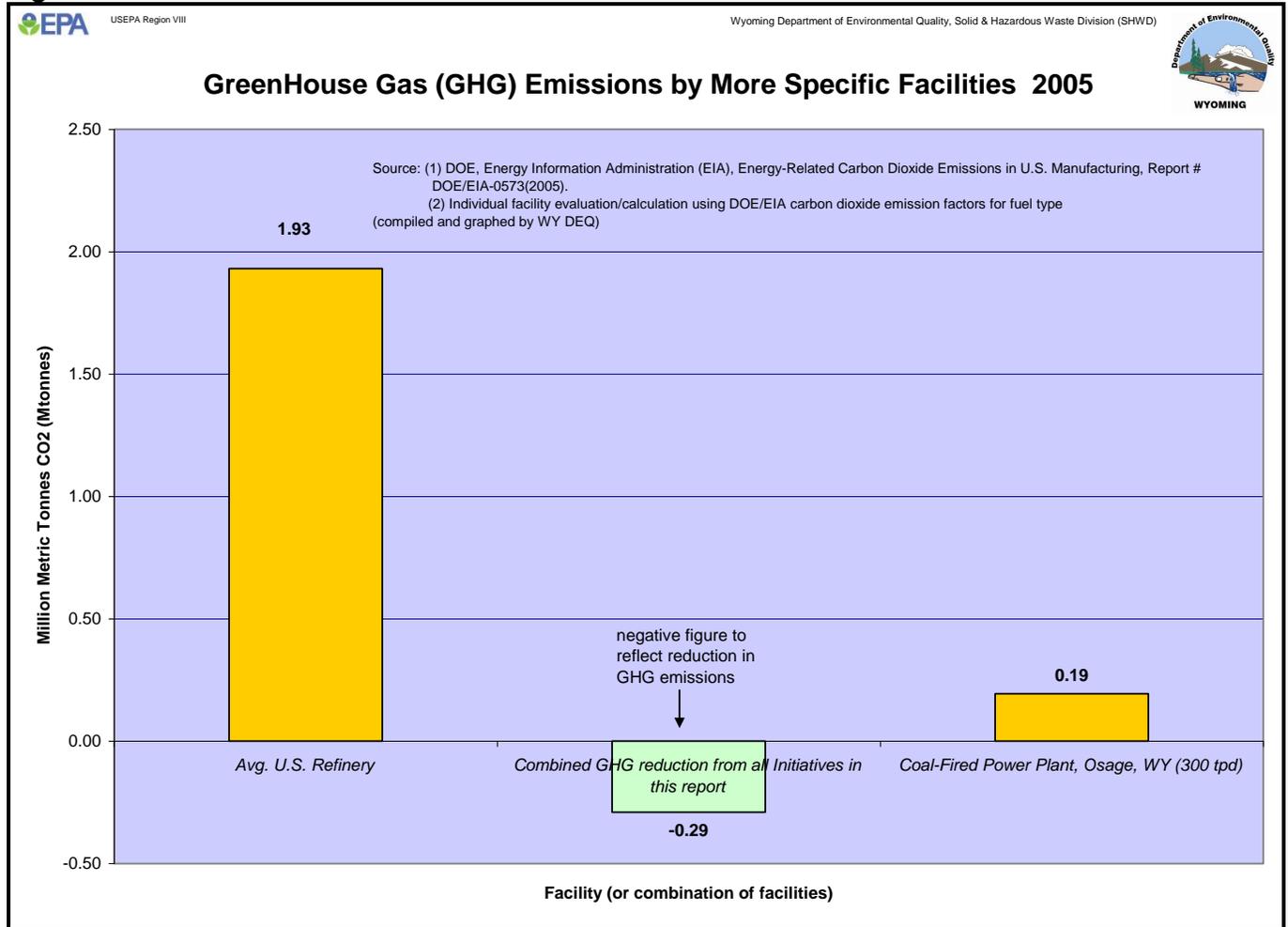


In addition, the industry trends toward heavier crude oil feed to refineries and the recent fuel sulfur standards require more energy and associated increase in GHG emissions, regardless of efficiencies gained over the past two decades. Heavier crude oils have more components with higher boiling points. Higher boiling-point hydrocarbons require more energy to reach vaporized conditions for reactions to occur in various process units. Higher sulfur levels require additional hydrogen (from natural gas) for hydrotreating/desulfurization since it is hydrogen replacing the sulfur removed from hydrocarbons. As discussed in previous sections, heavier/sour crude oils require additional process units or expansions to achieve the “conversion” of heavier crude components into lighter intermediates for transportation fuels (gasoline, diesel and jet fuels). Additional process units and/or expansions for Fluid Catalytic Cracking (FCC), hydrocracking, hydrogen supply and coking will emit more GHG because they use more energy.

This higher energy use increases GHG emissions since most of the energy used in petroleum refineries is in the form of fuel gas (from process unit reactions) and from purchased natural gas. However, the process unit additions or expansions discussed above are more modern installations and more likely to be “heat integrated” with other parts of a given refinery. On the positive side, this consideration, along with refiners efforts to improve efficiency is more likely to result in less energy used per bbl processed, compared to historical consumption. One final consideration on this point is: with these gains already achieved due to newer unit installations, etc; further reductions in GHG emissions (per bbl processed) will likely become more difficult in the future.

The combined GHG initiatives for this evaluation yielded approximately 319,000 short tons per year (290,000 metric tonnes) of GHG reductions. There were over 30 voluntary initiatives which contributed to the GHG reductions but Initiatives B8, C4, C5 and C7 in Appendices B and C represented the highest gains. As expected, these initiatives involved conserving fuel that would otherwise be combusted. Initiative B8 covered installation of oxygen analyzers in large fired heaters to conserve fuel by monitoring and limiting excess combustion air. Intake of more combustion air than is needed to fire a heater wastes energy by acting as a medium for heat loss through the flue stack. Initiative C7 provided significant GHG reductions by capturing large amounts of heat loss through the Fluid Catalytic Cracking (FCC) unit flue stack. Prior to recovery of this heat energy for steam and electric power, the flue stack temperatures exceeded 540 degrees Fahrenheit, representing significant energy losses. Combined GHG reductions from these and other initiatives are shown in Figure 3.6.2, along with comparisons of an average US refinery and a coal-fired power plant in Osage, Wyoming.

**Figure 3.6.2**



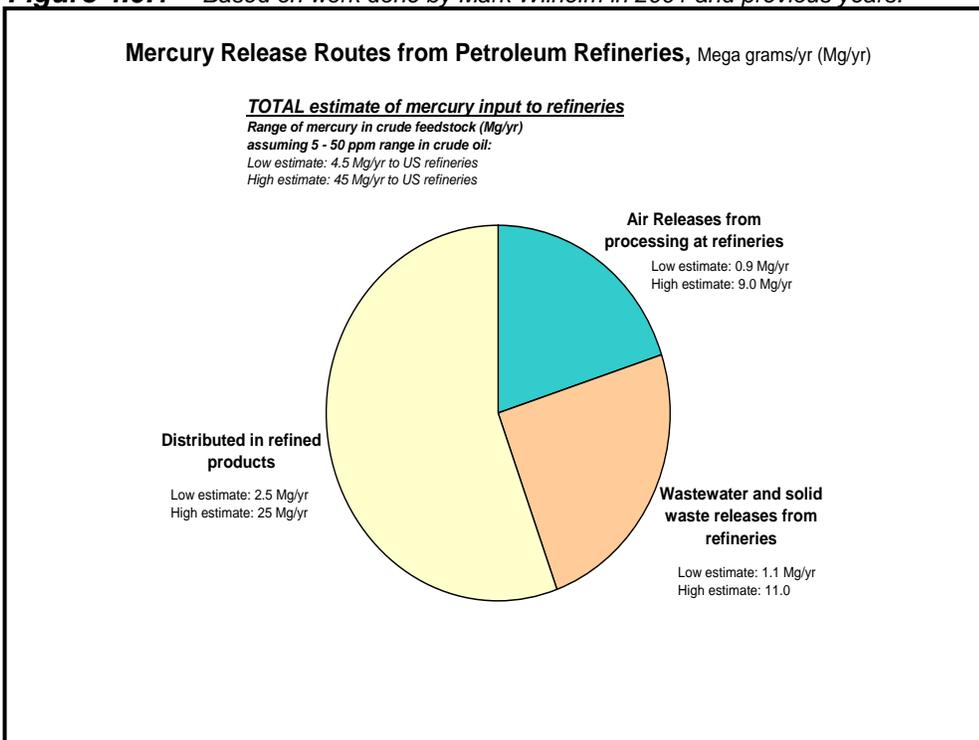
As shown in Figure 3.6.2, the GHG reductions identified in this project more than offset the emissions from a coal-fired power plant in Wyoming.

#### 4.0 Persistent, Bio-accumulative and Toxic (PBT) Compounds in Refineries

**Mercury** - A significant source of mercury release to the environment is from electricity generated at coal-fired power plants. Mercury is emitted to the atmosphere from combustion and release of mercury in the coal. Refiners reduce emissions of mercury by lowering their consumption of electricity from coal-fired power plants. This project identified several initiatives where this was accomplished by conservation or by refiners generating their own electricity using refinery-derived fuel instead of coal. Any previously emitted or wasted hydrocarbons that are used to cogenerate electricity at a refinery offset mercury emissions at coal-fired power plants. These factors may also be used for simplified comparisons to obtain electrical power equivalents of hydrocarbons, which can then be used to estimate mercury or other emission reductions by use of the EPA [eGRID Database Version 2.01](#) calculators.

Mercury is also present in crude oils and natural gas condensates at varying levels. Most of the information in this report is from EPA research document No. EPA-600R/-01-066; from the *EPA Mercury Report to Congress published* in 1997 and; an excellent summary of mercury’s environmental fate by the Florida Department of Environmental Protection (FL DEP). The Florida DEP document is *Trends of Mercury Flow over the US with Emphasis on Florida* (FL DEP PO#S3700 303975). Each of these documents frequently refers to work done by Mark Wilhelm at Mercury Technologies Services in Texas. EPA research documents mercury in natural gas reservoirs but the mercury is thought to partition into the gas condensate liquid phase at gas treating plants with little carried over into the product gas. Natural gas condensates are often mixed in with crude oil feed to refineries so the mercury carried over with condensates would enter the refining process. Although at relatively low concentrations and variable in different crudes, most sources put mercury in crude oil within the range of 5 – 50 ppb. Some samples have exceeded 30,000 ppb (or 30 ppm) but most concentrations are relatively low. Mercury can be released to the environment during the refining process. Figure 4.0.1 estimates the impacted media and sources of mercury releases to the environment when considering both the low 5 ppm and the high 50 ppm range of mercury input to refineries from crude oil.

**Figure 4.0.1** – Based on work done by Mark Wilhelm in 2001 and previous years.



Information is not yet conclusive but the petroleum products accumulating higher levels of mercury appear to be heavier, residual fuels, fuel oils and petroleum coke.

Assuming the low end of 4.5 Mg/yr from all refineries for mercury releases, an average, annual mercury release from a typical refinery would be about 0.03 Mg/yr or roughly 70 lbs/yr. (assuming 144 operating refineries in the US).

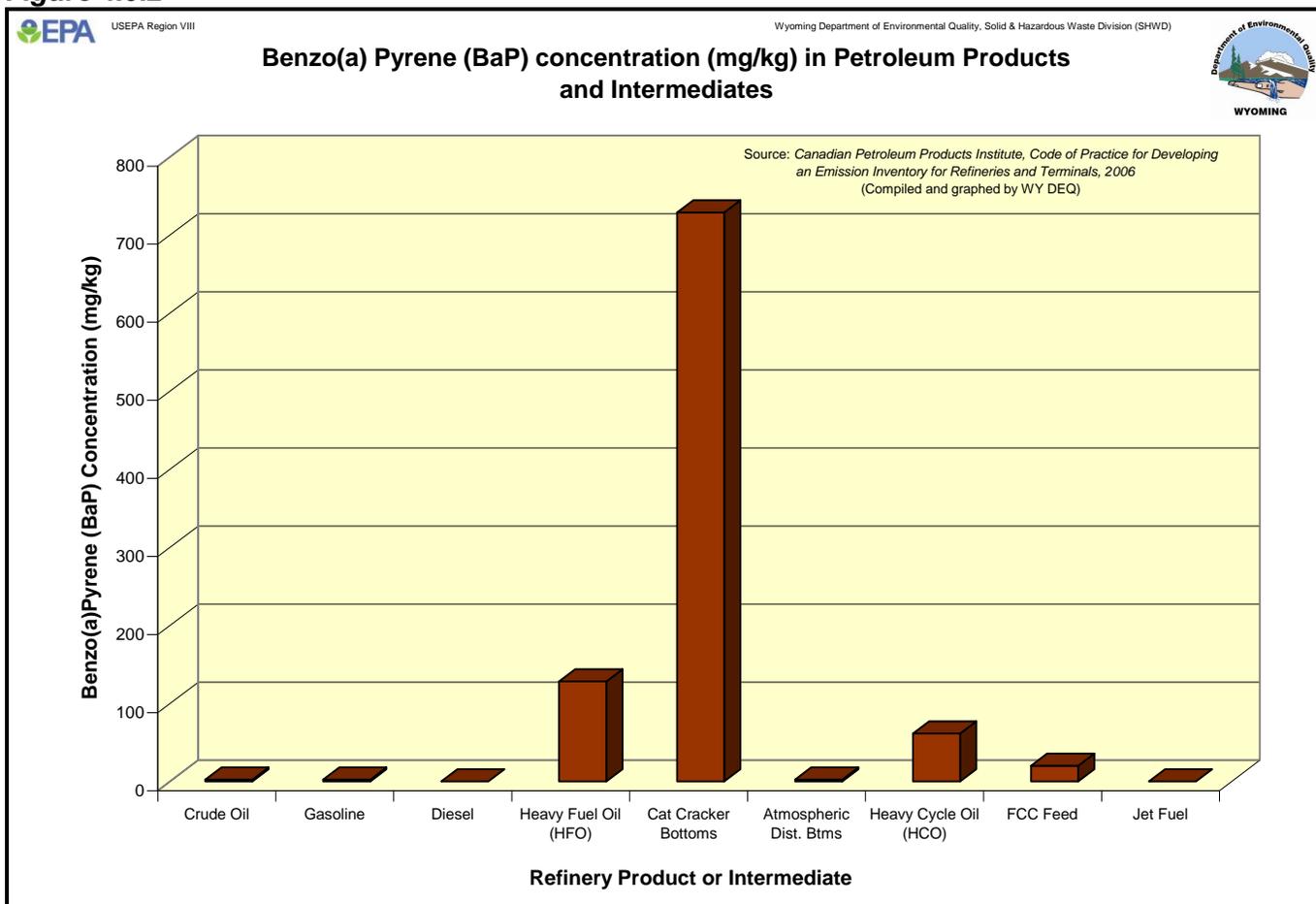
Initiative A9 documented significant reductions in mercury

releases from a different source; mercury used in flow measurement instruments. These instruments typically contained over 20 lbs. mercury per unit with as many as 50 units on refineries. There was

typically a failure rate of 10 % for many of these instruments with significant amounts of mercury released during failure or maintenance. Replacing mercury instruments over the past two decades has reduced mercury releases from the nine (9) refineries evaluated in this project by an estimated 100 lbs/yr per refinery.

***Polycyclic Aromatic Hydrocarbons (PAH)*** - Benzo (a) pyrene (BaP) and other PAH compounds have been considered on EPA’s PBT list in the recent past. PAH compounds in refineries are usually more concentrated in heavier petroleum intermediates and products in refineries. These hydrocarbons include intermediates such as bottoms and heavier fuel oil blending components from Fluid Catalytic Cracking (FCC) units. They are often referred to as “CC bottoms”, Heavy Fuel Oils (HFO) and Heavy Cycle Oils (HCO). Higher accumulation of the PAH Benzo(a)Pyrene in these intermediates is seen in Figure 4.0.2 as compared to other refinery intermediates and products.

**Figure 4.0.2**



Other significant sources of PAH compound releases are solids and sludges generated from contaminated soils and refinery wastewaters containing the heavier petroleum intermediates such as heavy fuel oils, cat cracker bottoms or clarified slurry oils (CSO. . . a listed hazardous waste, EPA code K170). One of the reasons for this is suspended solids in refinery wastewaters often become coated with these heavier, more viscous hydrocarbons. These more viscous hydrocarbons have more of an affinity for adhering to suspended solids and their density is closer to that of water than lighter hydrocarbons. The oily suspended solids then settle out as sludges in API separators and other equipment to be managed as wastes; frequently as listed hazardous wastes. Initiative B13 achieved significant reductions in BaP releases by sending much of this waste to a gasification plant in North Dakota. Initiative B14 achieved similar results by minimizing water carryover in heavy fuel oil and other streams

treated in a sweetening plant. This was done by installing salt towers to remove moisture from incoming feed prior to processing in the sweetening plant.

BaP and other PAH compounds are also combustion by-products, particularly when combustion occurs in open air with hydrocarbons heavier than methane. Although refinery flare gases contain significant amounts of methane, hydrogen and inerts (such as carbon dioxide, nitrogen), they can often contain heavier hydrocarbons such as butane, pentane and other heavier compounds, resulting from process upsets, etc. Open air combustion of hydrocarbons containing significant amounts of these heavier flare stream components generate higher levels of PAH compounds than combustion of methane and hydrogen by themselves. Although refinery flares have typically become more efficient over the past 20 years, higher volumes of flare gas and continuous flaring can be a significant source of PAH pollutants. Initiatives B1, C5 and C13 implemented flare gas recovery systems to reduce unnecessary flaring of refinery fuel and flare gas. These initiatives resulted in an estimated 700 lb/yr in PAH reductions.

## 5.0 Participating Refinery Profiles

Table 5.0.1 provides a general description of each refinery evaluated. In general, refineries in the Rocky Mountain area are smaller with many plants under 50,000 barrels per day (bpd). All refineries in the region are well below 100,000 bpd capacities. This is evident from the information presented in Table 5.0.1. By contrast, many refineries in the Gulf Coast, East Coast and West Coast regions exceed 200,000 bpd and have what may be termed the “economy of scale” advantage. Their size generally allows them to implement larger P2/WM projects with added potential for higher rates of return on the investments.

**TABLE 5.0.1 – General Profile of Petroleum Refineries Evaluated**

<b>Refinery</b>	<b>Location</b>	<b>Capacity (bpd)</b>
1. Sinclair Oil Corp.	Casper, WY	22,500
2. Sinclair Oil Corp.	Sinclair, WY	66,000
3. Montana Refining Co.	Great Falls, MT	10,000
4. Tesoro	Mandan, ND	60,000
5. Valero (now Suncor)	Commerce City, CO	28,000
6. ConocoPhillips (now Suncor)	Commerce City, CO	58,000
7. Wyoming Refining Co.	Newcastle, WY	12,500
8. CHS, Inc.	Laurel, MT	59,600
9. ConocoPhillips	Billings, MT	58,000

## 6.0 Individual Summaries of P2/WM Initiatives

Appendix A provides individual summaries for “minimum” initiatives encountered at most or all the refineries evaluated (designated as A1 through A10). Appendix B summarizes initiatives considered more innovative and site-specific steps by refiners in the region (designated as B1 through B21). Appendix C provides an additional set of innovative initiatives evaluated in a third phase of this project (designated as C1 through C 13). Appendix D is a table summary of each individual initiative with columns for various categories of pollutants. These columns include hazardous waste constituents such as benzene, lead and chromium; the PBT chemicals Benzo (a) pyrene and mercury (Hg), solid wastes, conventional air pollutants, GHG and others in a spreadsheet layout.

# **Appendix A**

## **Individual P2/WM Projects**

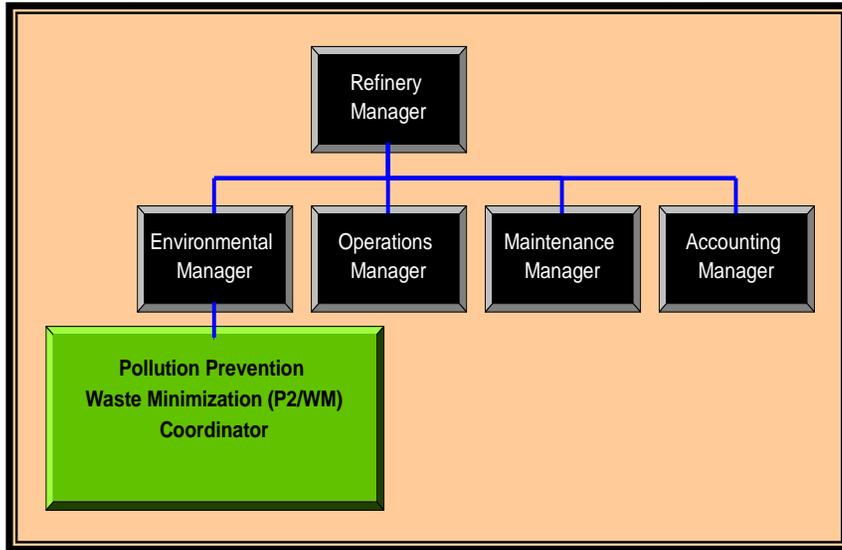
P2/WM Initiatives Designated as "Minimum" voluntary efforts most refineries in the evaluation have implemented.

### **Designated as A1 through A10**

(Note: there may be additional, minimum initiatives many refineries in the Region 8 have implemented but were not included in this document)

Pollution Prevention and Waste Minimization (P2/WM) Profiles Emphasizing PBT\*  
Chemical Reductions for Petroleum Refineries  
\*(Persistent, Bioaccumulative and Toxic)

**Summary of MINIMUM Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



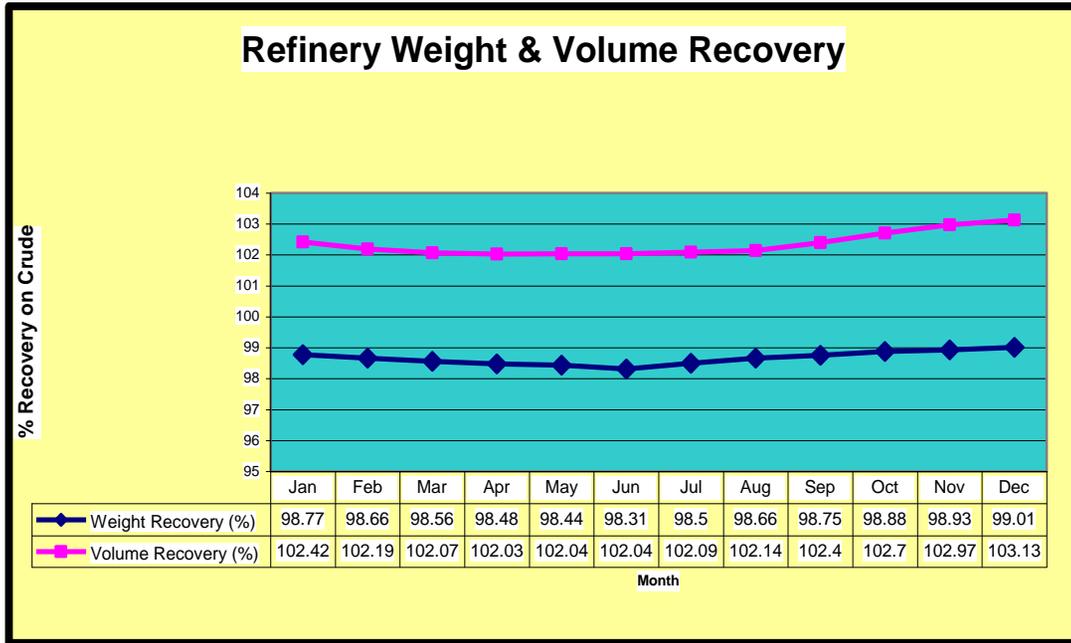
All refineries in the evaluation had designated a Pollution Prevention or Waste Minimization (P2/WM) Coordinator. Generally, this position provides the advantage of a single point of contact accountable for measurement, reporting and follow through of P2/WM initiatives.

**P2 Initiative Description**

**A1. Designate a Waste Minimization and/or Pollution Prevention (WM/P2) Coordinator (procedure modifications)** : Designating a specific person or position enhances WM/P2 prospects since at least one person becomes accountable to assess P2 opportunities and measure gains.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
benzo (a) pyrene Mercury (Hg) PCBs			Significant benefits evident but not practicably quantifiable for this project.

**Summary of MINIMUM Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Source: example calculations only and not necessarily representative of any refinery in the evaluation.

Refiners may choose and implement differing methods of gauging recovery or "yield" of products on crude oil input. Achieving a degree of accuracy can be tedious for many of the figures but the regular tracking of this recovery is often crucial for minimizing hydrocarbon loss. Volume figures can typically exceed 100 % recovery on crude because of normal volume gains during cracking and similar processing.

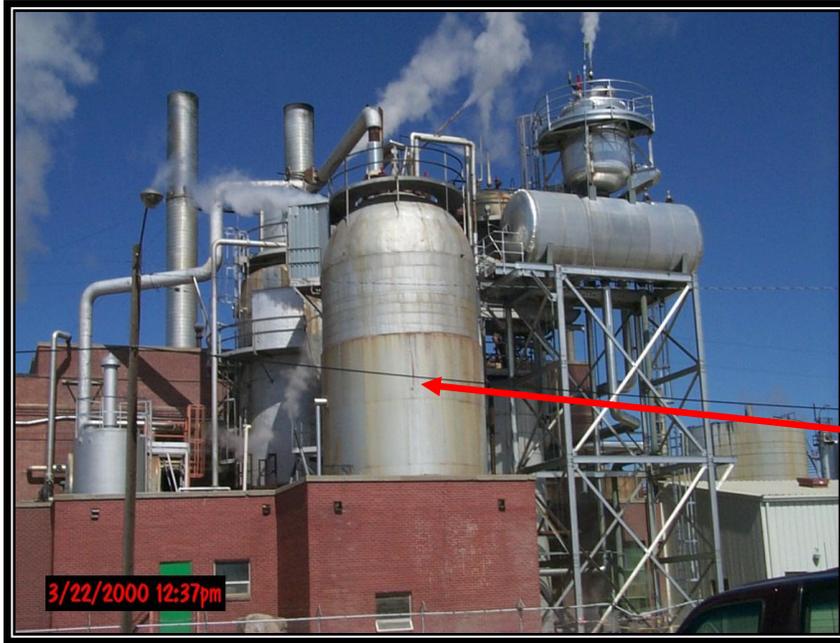
**P2 Initiative Description**

**A2. Regular evaluation of weight yield/volume yield (or "recovery) (procedure modifications)** : Regular assessment of hydrocarbon loss is crucial to P2 efforts since a seemingly insignificant 0.01 % weight loss translates into approximately 40,000 - 50,000 lbs. hydrocarbon loss per month for a relatively small 50,000 BPD refinery. It is very difficult to reduce hydrocarbon losses to the environment if the refinery weight yield is not regularly completed to attempt quantification of the loss.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo (a) pyrene	119	TPH	2,372,500
Mercury (Hg)	1.19	Benzene	5,931

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>3,793</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>395,417</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>929</b>

**Summary of MINIMUM Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Depending on raw water hardness and refinery size, segregating lime softener wastes can reduce hazardous waste generation by 300 - 500 tons per year (tpy) for regional refineries.

This can be done with separate, non-oily conveyance systems, with sedimentation basins or other methods. Whatever the method, the main objective is to avoid contact of these wastes with oily process sewers. Wastes such as lime softener sludges also have the potential for beneficial use if they are not contaminated with oily wastes.

"Hot process" lime softener vessel with non-oily wastes in conical bottom managed separately from oily wastes (conical bottom behind brick wall)

**P2 Initiative Description**

**A3. Segregation of oily from non-oily wastes (procedure modifications)** : Segregation of these wastes significantly reduces total oily waste generation by avoiding contact of non-oily wastes with oily process sewers. Examples of non-oily process wastes to segregate from oily process wastewater systems include water softener sludges generated from lime softening for boiler water (& some cooling waters), boiler blowdown solids, etc.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo (a) pyrene	54	F037 haz. wastes TPH (oil) Nitrogen Oxides Sulfur Oxides	5,400,000 270,000 2,121 6,056
<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.) =</b>			<b>432</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year) =</b>			<b>38,571</b>
<b>Water Savings Estimate (gallons/day) =</b>			<b>NA</b>

**Summary of MINIMUM Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Wastewater management areas open to windblown particulate, storm silt, etc. can surprisingly add to oily waste generation with accumulation of these solids in units.



Wastewater management areas designed to minimize storm silt inflow. Slats in fence can reduce added waste volumes by a surprising 20 - 30 % in areas such as Wyoming.

**P2 Initiative Description**

**A4.**

**Significant control of stormwater and windblown solids entering oily wastewater system (equip. & technology modifications, procedure modifications, housekeeping, maintenance, training):** Successful, significant control of non-contaminated storm solids can avoid generation of hundreds of tons of oily waste by avoiding flow through oily wastewater system. These solids become coated with oil in process sewers and are subsequently deposited as waste in downstream separators, etc. Controls included fencing or covering of oily wastewater management structures (ex: ABTU's, equalization basins), curbing & paving earthen areas which could drain to oily wastewater system, sediment retention at oily sewer grates, re-routing stormwater, etc.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
		TPH	90,000
		Nitrogen Oxides	6,364
		Sulfur Oxides	18,167

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.) =</b>	<b>1,295</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>135,000</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

**Summary of MINIMUM Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Spent/used drums often contain several pounds of residual chemicals. Minimizing use of drums significantly reduces the volume and toxicity of wastes from the combined residues in several hundred drums of chemicals consumed in a year. The photo to the right is an example of a portable chemical container which is normally refilled with no residual waste.

**P2 Initiative Description**

**A5.**

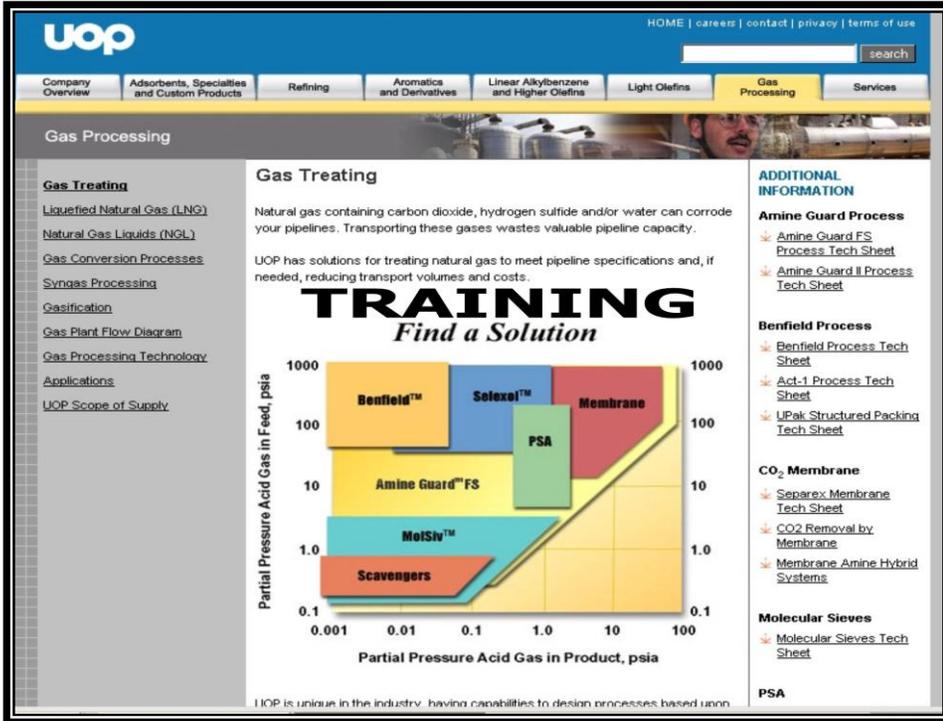
**Minimize use of drums for chemical additives**

**(procedure modification):** Minimizing use of drums prevents pollution by reducing the wasted residual which is not recovered from each chemical additive drum (normally > 1 gal. or 8 lbs.). Since it is not unusual for even a small refinery to use over 200 different chemical additives and potentially over 500 - 1,000 drums in a year, this effort yields significant P2 benefits. Methods normally consisted of requiring chemical vendors to supply chemicals in refillable, "PORT A FEED" or similar containers supplied by vendors.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
benzo (a) pyrene	0.18	TPH	2,800
Mercury (Hg)	0.50		

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>NA</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>400</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

**Summary of MINIMUM Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
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**P2 Initiative Description**

**A6. Personnel training (training):** Regular and pertinent training for management and operating personnel is one of the most significant WM/P2 initiatives since it is the properly motivated and knowledgeable worker who must implement WM/P2 initiatives.

PBT Constituent(s)	Significant benefits evident but not practicably quantifiable for this project.
benzo (a) pyrene Mercury (Hg) PCBs	

**Summary of MINIMUM Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Chromates can be released in cooling tower "drift" (the mist seen emanating from cooling towers) and from accumulations in cooling tower basin sludges and in wastewaters.

To a certain extent, cooling tower drift can contain whatever contaminants/chemicals are in the cooling water system since the drift can be in aerosol form vs. simple water vapor from evaporation. In addition, reducing toxicity of chemicals in cooling water system minimizes releases to land and water in the form of cooling tower basin sludges and blowdown wastewaters.

**P2 Initiative Description**

**A7. Eliminate use of chromate corrosion inhibitors and pentachlorophenol biocides in cooling tower system (technology modification):** WM/P2 is achieved since the relatively large volumes of cooling tower basin wastes will not contain these hazardous constituents. Most common P2 practice was to convert to phosphate corrosion inhibitors and to chlorine and or bromine-based biocides.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
		Chromium	197,258
		Pentachlorophenol	118,355

**Summary of MINIMUM Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



**P2 Initiative Description**

**A8. Eliminate use of Poly Chlorinated Biphenyls (PCBs) in electric transformers (material substitution):**

In most cases, this was achieved by: (1) draining PCB dielectric oil from transformers; (2) adding non PCB oil; (3) placing transformer back in service for at least the TSCA regulatory requirement of 90 days and; (4) testing the dielectric oil for PCB content < 50 parts per million (ppm). IF necessary, the process was repeated until the PCB content < 50 ppm. Some refiners changed out whole transformers. Both initiatives reduced PCB pollution from future transformer leaks, accidents, etc.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
PCBs	13,500		

**Summary of MINIMUM Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**

**Mercury-Containing Flow Meters**



**Description:**

Flow meters are used for measuring water flows and steam pressure at larger plants, such as water and sewage plants, power stations and heating plants.

**How to Identify:**

A variety of different sizes and shapes can be found. Ask the personnel at the plant for help and ask how much they know about the equipment. If the equipment has been replaced and or repaired, check drains located nearby for possible contamination.

**Amount of Mercury:**

Always assume that the flow meter does contain mercury until you can find the facts about the manufacturer and the model. Some models do contain large quantities of mercury - 5 kilograms and more.

**Safe Removal:**

If the device is small enough to be contained in a airtight package, consult a mercury recycler about how to ship properly to avoid spillage.

If the device is too large to be shipped in an airtight container (such as the devices pictured above), the mercury will need to be poured out of the device into a separate container. Given the potential for spills, such operations require that you are prepared to contain possible spills, that you have appropriate airtight, unbreakable containers for the mercury, that you have personal protective equipment on hand, that you provide adequate ventilation, and that [Occupational Health and Safety regulations](#) are followed. Thus, the typical demolition contractor should

inform the building owner when such a device is encountered, so that a contractor with the necessary equipment and experience can remove the device.

**Safe Disposal:**

The mercury drained from the device, as well as the parts of the meter that have been in contact with mercury should be regarded as mercury waste and properly disposed of with a mercury recycler.

Refiners have eliminated the use of mercury in numerous instrument applications such as steam and gas metering equipment (similar to the one at left). They have also discontinued use of mercury in larger volume applications with large storage tank vacuum breakers, etc.

**P2 Initiative Description**

**A9. Eliminate use of mercury in instruments and other equipment (material substitution, technology modification):** This initiative results in significant P2 by removing instruments, storage tank vacuum "breakers" and other equipment containing mercury and significantly reduce the release of mercury into the environment from equipment leaks, accidents, fires and other mishaps. This was normally achieved by replacement of mercury-containing equipment with digital instruments.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Mercury (Hg)	900		

**Summary of MINIMUM Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Valuable P2/WM initiatives can be "low tech" and still provide significant benefits. The dewatering pad in the figure to the left provides a readily available area with adequate maneuvering space for heavy equipment. Wastes are placed on the pad and water/oil/fluids allowed to drain to the sloped, collection portion of the pad (left of center). The need for such dewatering can occur on a daily basis during some refinery maintenance activities. The fluids can then be collected and managed in the facilities' wastewater treatment system with significant reduction in the volume and toxicity of remaining solids.

However, such pads can be relatively expensive with special design features such as sloping, reinforcement, liners, etc. Depending on size and other design features, the cost for these areas can range from \$100.00 -

Liquids drain to one corner by

Remaining solids significantly dryer without cost and energy requirement of more elaborate equipment.

**P2 Initiative Description**

**A10. Maximize de-oiling/de-watering of oily wastes wherever practicable and as soon in the process as practicable (process modification):** Results in significant P2 with recovery of hydrocarbons (HC) and avoids environmental costs of shipping water with wastes and saves energy with less water in wastes going to fuels programs, etc.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo(a)pyrene	18	TPH	3,600,000

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>NA</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>600,000</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

<b><u>Appendix A Reference Calculations:</u></b>	
<b>A2</b>	
BaP reduction estimate = 50ppm BaP in hydrocarbon x 10 <sup>-6</sup> x 0.0005 (0.5%) HC loss improvement factor x 0.40,000 bpd x 300 lb/bbl x 365 days/yr	118.63
Hg reduction estimate = 0.5 ppm Hg in hydrocarbon x 10 <sup>-6</sup> x 0.0005 (0.05 %) HC loss improvement factor x 40,000 bpd x 325 lb/bbl x 365 days/yr	1.19
Total Petroleum Hydrocarbon (TPH) or HC loss reduction = 40,000 bpd x 365 days/yr x 325 lb/bbl x 0.0005 HC loss improvement factor	2,372,500
Benzene reduction estimate = 0.0025 benzene crude fraction (0.25%) x 40,000 bpd x 325 lb/bbl x 365 days/yr x 0.0005 HC loss improvement factor	5,931
GHG estimate = 2,372,500 lb/yr oil x 1 gal/7 lbs x 22.38 lbs CO <sub>2</sub> /gal oil burned/incinerated x 1 ton CO <sub>2</sub> /2,000 lbs	3,793
Energy estimate = 2,372,500 lb/yr oil x 1 gal/6 lbs	395,417
Water estimate = 2,372,500 lb/yr oil x 1 yr/365 days x 1 gal oil/7 lbs x 1 bbl/42 gal x 42 gal water/bbl crude processed	929
<b>A3</b>	
BaP estimate = 10ppm BaP in waste/10 <sup>6</sup> x 300 tpy lime waste to F037 x 2,000 lb/ton x 9 refineries	54
F037 haz. wastes estimate = 300 tpy lime sludges contaminated by oily process sewer x 2000 lb/ton x 9 refineries (or plants)	5,400,000
TPH estimate = 300 tpy oily waste (lime mixed with oily residuals) x 0.05 unrecoverable oil fraction x 2000 lb/ton x 9 plants	270,000
NOx estimate = 300 tpy oiled lime wastes x 0.05 unrecoverable oil fraction x 2000 lbs/ton x 1 gal/7 lbs x 55 lbs NOx/1,000 gal oil burned/incinerated x 9 plants	2,121
SOx estimate = 300 tpy oiled lime wastes x 0.05 unrecoverable oil fraction x 2000 lbs/ton x 1 gal/7 lbs x 157 lbs SOx/1,000 gal oil burned/incinerated x 9 plants	6,056
GHG estimate = 300 tpy oiled lime wastes x 2,000 lbs/ton x 0.05 unrecoverable oil fraction x 1 gal/7 lbs x 22.38 lbs CO <sub>2</sub> /gal oil x 1 ton CO <sub>2</sub> /2,000 lbs x 9 plants	432
Energy estimate = 300 tpy oiled lime wastes x 2,000 lbs/ton x 0.05 unrecoverable oil fraction x 1 gal/7 lbs x 9 plants	38,571
<b>A4</b>	
F037 haz. waste estimate = 1000 tpy avg. oil sludge generation x 0.1 reduction factor w. initiative x 2,000 lbs/ton x 9 plants = 1,800,000 lbs/yr oily wastes/sludges	1,800,000
TPH estimate = 1000 tpy avg. oil sludge generation x 0.1 reduction factor w. initiative x 0.05 unrecoverable oil fraction x 2000 lb/ton x 9 plants = 90,000 lb oil (TPH)/yr	90,000
NOx estimate = 90,000 lbs oil/yr x 1 gal/7 lbs x 55 lbs NOx/1,000 gal oil burned/incinerated x 9 plants = 6,364 lbs. NOx	6,364
SOx estimate = 90,000 lbs oil/yr x 1 gal/7 lbs x 157 lbs SOx/1,000 gal oil burned/incinerated x 9 plants = 18,167 lbs. SOx	18,167
GHG estimate = 90,000 lb/yr oil x 1 gal/7 lbs x 22.38 lbs CO <sub>2</sub> /gal oil burned/incinerated x 1 ton CO <sub>2</sub> /2,000 lbs x 9 plants = 1,295 tons CO <sub>2</sub> /yr	1,295
Energy savings estimate = 90,000 lb/yr x 1 gal/6 lbs x 9 plants = 135,000 gal gasoline	135,000

<b>A5</b>	
BaP estimate = 200 (of 500 chemical drums with BaP component) x 10 lbs residual/drum x 10 ppm BaP in residual/10 <sup>6</sup> x 9 plants	0.18
Hg estimate = 10 of 500 chemical drum containing 0.05 lbs each of Hg as polymer, grout or coating catalyst component	0.5
TPH estimate = 200 of 500 drums with TPH component x 2 gal TPH residual x 6 lb/gal	2,800
Energy savings est. = 200 of 500 drums with TPH (hydrocarbon) x 2 gal/drum	400
<b>A7</b>	
Cr reduction estimate = 200 gpm (blowdown + drift) x 8.34 lb/gal x 1440 min/day x 365 days/yr x 25 ppm Cr residual / 10E6 x 9 plants = 197,258 lbs/yr chromium	197,258
PCP reduction estimate = 200 gpm (blowdown + drift) x 8.34 lb/gal x 1440 min/day x 365 days/yr x 15 ppm PCP residual / 10E6 x 9 plants = 118,355 lbs/yr pentachlorophenol	118,355
<b>A8</b>	
PCB reduction estimate = 100 gallons/transformer x 15 lb/gal x 100 transformers x 0.5 (assume 50 % PCB content) x 0.02 fraction leak rate/yr x 9 plants = 13,500 lb/yr PCBs	13,500
<b>A9</b>	
Hg reduction estimate = 50 Hg metering units x 20 lb Hg/unit x 0.1 (10 % failure or Hg loss rate each yr.) x 9 plants = 900 lbs. Hg/yr	900
<b>A10</b>	
BaP reduction estimate = 1000 tpy oily wastes x 2000 lb/ton x 5 ppm BaP in oil component / 10 <sup>6</sup> x 0.2 (20 % oil) x 9 plants = 18 lbs/yr BaP	18
TPH reduction estimate = 1000 tpy x 2000 lbs/ton x 0.2 (20 % oil component) x 9 plants = 3,600,000 lbs/yr TPH hydrocarbons	3,600,000
Energy savings estimate = 1000 tpy x 2000 lbs/ton x 0.2 (20 % oil component) x 1 gal./6 lbs x 9 plants = 600,000 gal. gasoling eq/yr	600,000

# **Appendix B**

## **Individual P2/WM Projects**

P2/WM Initiatives designated as potentially newer or innovative, voluntary efforts initiated by petroleum refineries in the evaluation.

Designated as B1 through B21

(Note: there are likely additional, P2/WM innovations many refineries in the region have implemented that were not included in this document)

Pollution Prevention and Waste Minimization (P2/WM) Profiles Emphasizing PBT\* Chemical Reductions for Petroleum Refineries  
\*(Persistent, Bioaccumulative and Toxic)

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Flares are a necessity at most refineries. They provide a safe outlet for gases which can not be used/consumed to make products at a given time. Within limits, flaring rates can be controlled but the flare must remain an available relief device. This refinery has installed a adsorption/refrigeration unit to cool, condense and recover much of the hydrocarbons that would otherwise be flared.

This process reduces hydrocarbon losses by approximately 2,000,000 gallons per year of light petroleum gases and gasoline-range materials.

Ammonia adsorption refrigeration unit

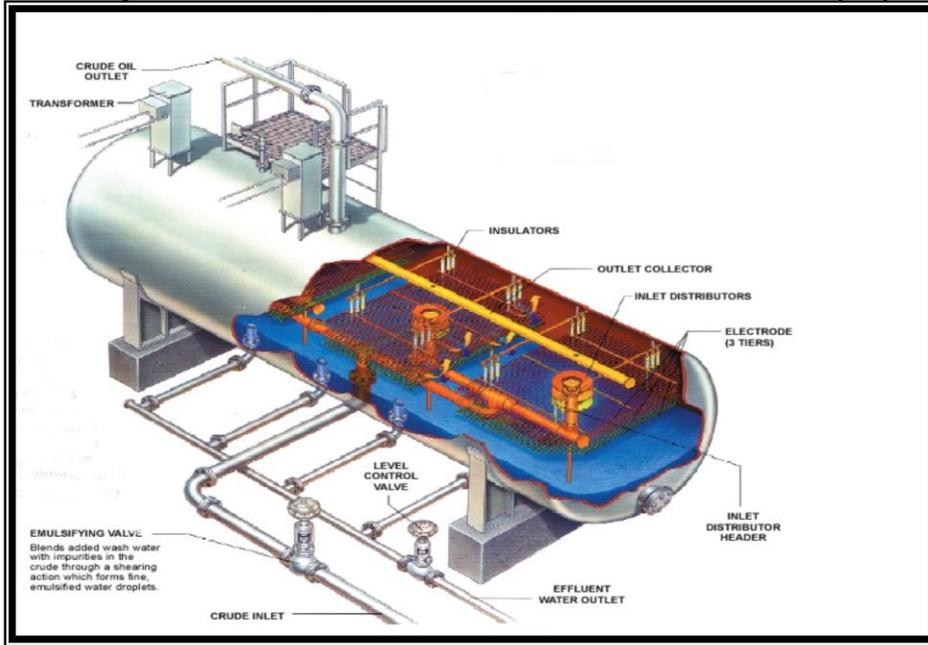
**P2 Initiative Description**

**B1. Flare gas recovery (technology modification, energy efficiency/conservation):** Refinery gases normally flared to atmosphere and lost are recovered by novel refrigeration/adsorption process for sales or use in refinery.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo (a) pyrene	204	Nitrogen Oxides	9,928
Mercury (Hg)	2	Sulfur Oxides	146,000

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>10,366</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>2,168,000</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



One of the first opportunities for P2/WM in a refinery would be with crude oil, the raw material. A refiner running 50,000 barrels per day (bpd) is processing approximately 15,000,000 lbs. of material each day. If only an added 0.01 % (0.0001) of the crude oil feed is contaminants, it could lead to as much as 500,000 lbs. (250 tons) of additional waste each year.

Efficient contaminant removal is very dependent on frequent and reliable information for the exact location (level) of the oil-brine (oil-water) interface in the desalter vessel. This vessel is utilized to remove contaminants from incoming crude oil. This continuous level indication provides better control of make-up water volumes and other parameters for more efficient desalter operation. Upgrading the desalter monitoring system with an interface probe better accomplishes the desalting objectives by providing continuous information on this interface and other operating parameters. The result is fewer contaminants in crude oil with a consequent reduction in downstream corrosion and other waste generation. An added P2/WM benefit is reduced hydrocarbon losses in the brine, desalter effluent.

**P2 Initiative Description**

**B2. Oil/water interface probe installed in crude oil desalter unit (equipment modification):** Continuous level detection of oil-water interface with Agar probe significantly reduces oil losses to brine effluent of desalter unit and reduces corrosive contaminants in crude oil leading to downstream generation of hazardous wastes in fractionating towers, heat exchangers, etc..

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo (a) pyrene	0.02	TPH	237,250
Mercury (Hg)	0.02	037 haz. wastes	23,725

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>38</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>3,954</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



As discussed in the previous "# N2" case, improved treatment of incoming crude oil results in P2/WM benefits by removing, segregating and treating the contaminants before they generate corrosion and wastes in downstream process units.

This refiner has provided additional crude oil processing & treating equipment to provide further P2/WM benefits upstream of the crude desalter.

Additional crude oil treating vessel to improve crude feed quality and reduce associated wastes.

**P2 Initiative Description**

**B3. Additional crude treating/ conditioning vessels upstream of crude oil desalter (equipment modification):** Additional vessel installed upstream of crude oil desalter units to improve desalter performance with more gentle waterwash (avoiding tight emulsions), more residence time for sediment removal. This results in less hazardous waste generation and hydrocarbon loss to brine wastewaters. Improved removal of sediments upstream of desalter reduces plugging in the desalter brine draws consequently reducing concerns such as "vortexing" which leads to oil loss with brine wastewater.

Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
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PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo (a) pyrene	0.002	TPH	23,725
Mercury (Hg)	0.002	037 haz. wastes	2,375

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>4</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>395</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Relief valves (RV) are often utilized in petroleum and chemical process industries to “relieve” pressure in vessels when the pressure exceeds a threshold considered dangerous or otherwise ill-advised. These valves are designed to open or “relieve” at a certain pressure and close or “re-seat” when the pressure returns to below the design threshold. The idea is for these valves to only sporadically open when absolutely necessary and release vapors or fluids that are often hazardous such as benzene, vinyl chloride, ethylene oxide and other materials utilized in these and other industries. Relief valves should be periodically maintained and tested to assure they open and close at the proper pressures. If the valves are not properly maintained, corrosion, scale and other deterioration can prevent them from fully closing, allowing continued, unnecessary release/waste of hazardous process materials.

Large relieve valves (RV) releasing contaminants when open

**P2 Initiative Description**

**B4. Acoustic meters for large Relief Valves (RV) (equipment modification):** Acoustic meters installed on larger relief valves offers better detection of relief valve operation, reseating (closing), etc. This significantly

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo (a) pyrene	0.22	VOC emissions	438,000
Mercury (Hg)	0.08		

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>700</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>73,000</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Low-emission flare tip

**P2 Initiative Description**

**B5. Mass flow meters in flare system (equipment modification):** Measuring flare gas flowrates is crucial step to reducing unnecessary hydrocarbon gas losses to refinery flare system. Mass flow measurement are often an innovative, significant improvement over volume flow measurements which are more vulnerable to erroneous fluctuations, corrosion, etc.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo (a) pyrene	10.07	Nitrogen Oxides	489
Mercury (Hg)	0.083	Sulfur Oxides	719

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>674</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>118,625</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

## Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries

**P2 Initiative Description**

**B6. Manufacture of sodium hydro- sulfide from spent caustic(material purification, energy conservation, process modification):** Spent caustic solutions are recovered and purified to manufacture sodium hydrosulfide, a valuable component in metals refining & pharmaceutical production.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Mercury (Hg)	0.10	Spent Caustic Soda	2,400,000
		Nitrogen Oxides	648
		Sulfur Oxides	1,296

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.) =</b>	<b>150</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>5,897</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>6,904</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**

**P2 Initiative Description**

**B7. Large volume gas compressor speed control (energy conservation, equipment modification):**

Saved over 25% electrical usage for one of the largest compressors in the refinery by trimming speed and amperage use of compressor in proportion to gas flow rates. Energy use is more in line with compressor duty at any given time.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Mercury (Hg)	0.75	Nitrogen Oxides Sulfur Oxides	75,000 150,000

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.) =</b>	<b>17,400</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>682,500</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**

**P2 Initiative Description**

**B8. Oxygen analyzers installed in flue gas stacks (equipment modification):** Significant energy savings achieved with control of excess air/oxygen to furnaces (don't have to invest energy to preheat much more incoming air). Higher efficiency heater installed at Alkylolation Unit (AU) and direct-fired asphalt tank heaters.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Mercury (Hg)	10	Nitrogen Oxides Sulfur Oxides	79,424 116,800

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.) =</b>	<b>82,928</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>9,344,000</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**

**P2 Initiative Description**

**B9. Vacuum distillation unit eductors equipped with surface condensers & gas routed to crude unit furnaces (equipment modification, energy conservation):** Eductors lower pressure in vacuum towers to lower distillation temperature requirements. They also function to recover overhead vapors from distillation. Hydrocarbon loss significantly reduced with improved heat exchange system to condense vacuum tower overhead vapors. Fuel gas formerly lost now goes to distillation unit furnaces to lower energy demands.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo(a)Pyrene	27	TPH	1,977,083
		Nitrogen Oxides	185
		Sulfur Oxides	2,725
<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>			<b>421</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>			<b>329,514</b>
<b>Water Savings Estimate (gallons/day) =</b>			<b>NA</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**

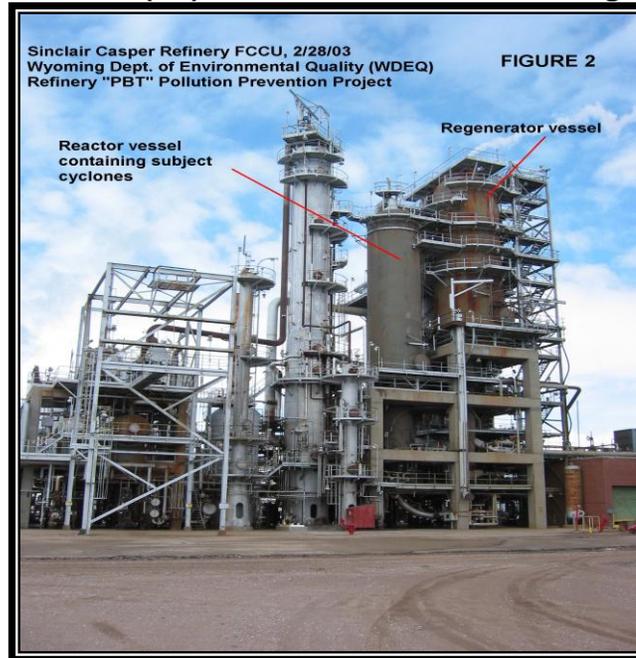
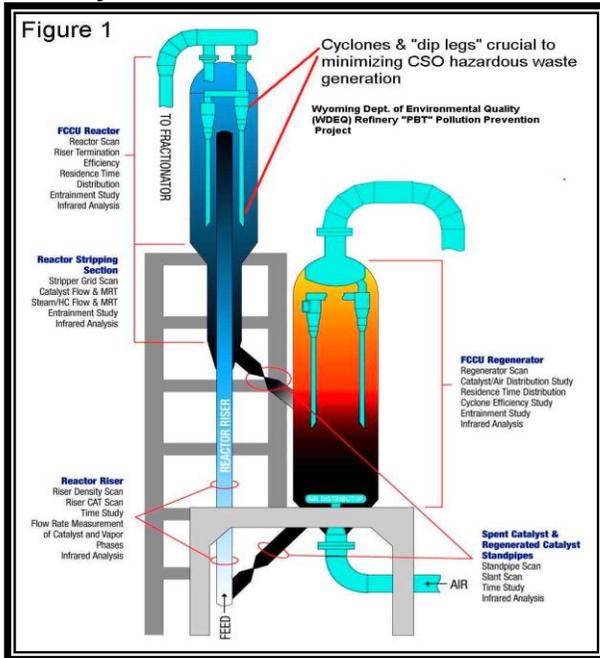
**P2 Initiative Description**

**B10. Air cooler at Hydrodesulfurizer (HDS) unit (equipment modification, energy conservation):**

Hazardous waste generated from conventional cooling water loop heat exchanger bundles is avoided and energy conservation achieved with reduced use of cooling water pumps and chemicals with use of air coolers/heat exchangers in place of cooling water.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo(a)Pyrene	0.67	Nitrogen Oxides Sulfur Oxides	741 957
<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>			<b>175</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>			<b>21,914</b>
<b>Water Savings Estimate (gallons/day) =</b>			<b>192,000</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



The original cyclone design had extended dip legs . This was thought to have resulted in significantly reduced cyclone efficiency due to catalyst deposits plugging dip legs and bottom flap valves. These dip legs and valves must discharge captured catalyst for cyclone to work properly. Efficient operation of these dip legs and valves is crucial to assure recovery and recycle of FCCU catalyst.

**P2 Initiative Description**

**B11. Fluid Catalytic Cracking Unit (FCCU) cyclone modifications (technology modification):** Cyclone equipment used to separate fine catalyst particulates from clarified slurry oils ("CSO" or heavy fuel oils) modified to

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo(a)Pyrene	73	TPH	72,727
Mercury (Hg)	0.73	K170 listed haz. waste	727,273
		Nitrogen Oxides	571
		Sulfur Oxides	1,631

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.) =</b>	<b>116</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year) =</b>	<b>12,121</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Large-volume storage tanks may contain numerous contaminants in the layer of water normally accumulating in the bottom of the tank. These contaminants can include rust/scale, hydrocarbons, dissolved chemicals (from additives, etc.) and emulsions. Installation of additional separation and treatment significantly reduces these contaminants.

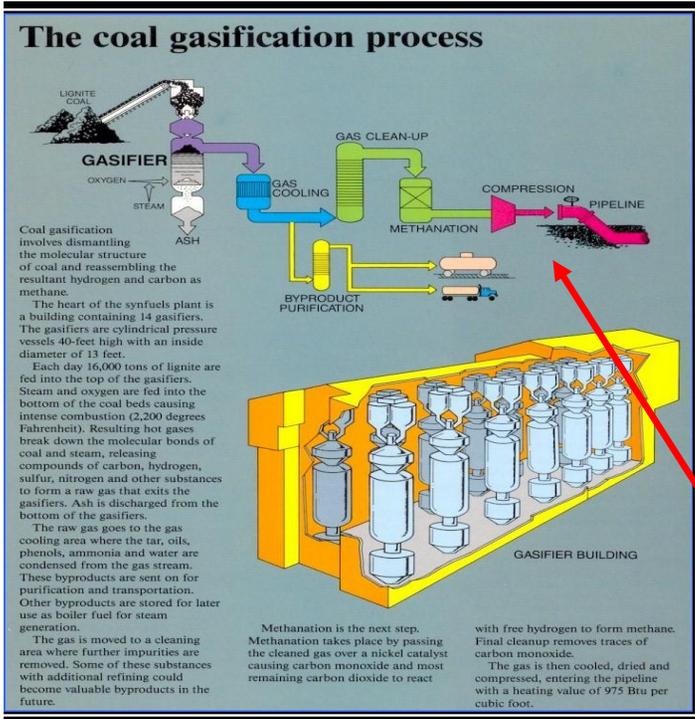
**P2 Initiative Description**

**B12. Pretreatment of large-volume storage tank water draws (technology modification):** Additional, modified oil/water/solids separator in place for storage tank field water draws. This significantly reduces oil contamination of wastewater and improves oil recovery.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo(a)Pyrene	3	TPH	593,125

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>NA</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year) =</b>	<b>76,650</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Preparation/loadout of Clarified Slurry Oil (CSO) hazardous waste for shipment to DGC plant

Simplified diagram of Dakota Gasification Co. (DGC) process for coal and selected refinery hazardous wastes

**P2 Initiative Description**

**B13. Gasification of (Clarified Slurry Oil (CSO) listed hazardous wastes, crude oil tank bottoms and other wastes (reformulation of products, substitution of raw materials):** Wastes are sent to gasification plant to produce clean, on-specification gas and liquid fuels instead of incineration.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo(a)Pyrene	20	listed haz. waste	400,000
Mercury (Hg)	0.40	Nitrogen Oxides	629
		Sulfur Oxides	1,794

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>128</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>133,333</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Salt towers are utilized to dry heater oil and other feed to "Doctor Plant". This Doctor process uses lead and caustic soda to sweeten (remove or transform undesirable sulfur compounds) the feed to the unit for producing heater oil and other blending stocks. The salt towers were added to reduce moisture present in some of the feedstock. This moisture in feed often increased the rate of lead and caustic treating chemical usage and, consequently, increased the amount of wastes generated in the process.

The additional equipment installed at this unit also included provisions for using steam condensate near the end of the process (where water is utilized to remove contaminants from the processed intermediate) and filters to reduce solids, sulfur and lead released to process sewers.

**P2 Initiative Description**

**B14. Salt tower treaters, filter systems and steam condensate use improves fuel oil sweetening process which uses lead and caustic soda (equipment modifications):** Process enhancements significantly reduces volume of treating solution required, resulting in energy savings and reduced contaminant/waste generation.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo(a)Pyrene	22	Lead (Pb)	300
Mercury (Hg)	2	Spent caustic	10,000

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>NA</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year) =</b>	<b>NA</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Efficient heat transfer is crucial in many process units for **either adding or removing heat** from process streams. Heat exchanger (HETX) systems at the alkylation unit are used to cool process streams to remove hydrofluoric (HF) acid and hydrocarbons for further use and/or processing. Alkylation units produce high octane alkylate for gasoline blending and the process reactions normally favor cooler temperatures.

Piping, control valves and an additional control loop were added to maximize heat transfer/cooling by automatically routing process streams through the heat exchangers offering the more efficient heat transfer (based on temperature measurements in the control loop). The improved HETX significantly reduced HF & hydrocarbon emissions and returned more of these components to the process for recycle and/or sales.

**P2 Initiative Description**

**B15. Improved heat exchanger control (equipment modifications):** Added control equipment for more efficient routing of alkylation vent gas through Heat Exchangers (HETX) to reduce hydrofluoric Acid (HF) venting and improve overall gas (primarily propane) recovery at unit.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
		Hydrofluoric acid (HF)	1,825
		TPH (as VOC)	18,250

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.) =</b>	<b>NA</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>3,042</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Heater burner/inlet assembly modified for Acid Soluble Oil (ASO) combustion. ASO is a unique and complex mixture of waste oils generated during the alkylation process. ASO has significant Btu value but is an undesirable component in refinery intermediates or finished products.

**P2 Initiative Description**

**B16. Convert furnace burner to use Acid Soluble Oil (ASO) (equipment modifications):** recover BTU value of ASO instead of offsite waste shipment.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
		TPH	54,750
<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>			<b>NA</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>			<b>9,125</b>
<b>Water Savings Estimate (gallons/day) =</b>			<b>NA</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Chloride guard beds for hydrogen-rich gas stream to Distillate Desulfurizer (DDS)

**P2 Initiative Description**

**B17. Chloride guard beds for H<sub>2</sub>-rich gas compressor (technology modification):** adsorption beds installed to remove chlorides & other corrosive material in hydrogen-rich feed to compressor for distillate desulfurizer unit (DDU) achieving P2 with reduced contaminants/waste and less compressor downtime, etc.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Mercury (Hg)	0.03		
<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>			<b>6,097</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>			<b>239,148</b>
<b>Water Savings Estimate (gallons/day) =</b>			<b>NA</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



New tank mixer on slop tank helps assure effective use of de-emulsifying chemicals and other agents which are often needed for refinery slop tank operating efficiency. Due to the variety of sources of slop oils and their complex makeup, slop oil tanks often require more attention to control emulsions which significantly contribute to hazardous waste generation.

**P2 Initiative Description**

**B18. Improved slop oil recovery with mixer for chemical addition (equipment modification);** tank mixer added to improve efficiency of de-emulsifying agent in slop oil "rag layer") for P2 with less slop oil going to wastewater and/or hazardous waste.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo(a)Pyrene	6	K049 listed Haz. waste	118,625
Mercury (Hg)	0.12	TPH	118,625
		Nitrogen Oxides	932
		Sulfur Oxides	2,661

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.) =</b>	<b>190</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>19,771</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Additional piping added to utilize hydrogen-rich gas produced by one unit ("Ultraformer") and needed by another (Distillate Desulfurizer-DDU). Previously, the hydrogen content of this gas was not utilized and sometimes lost to flaring.

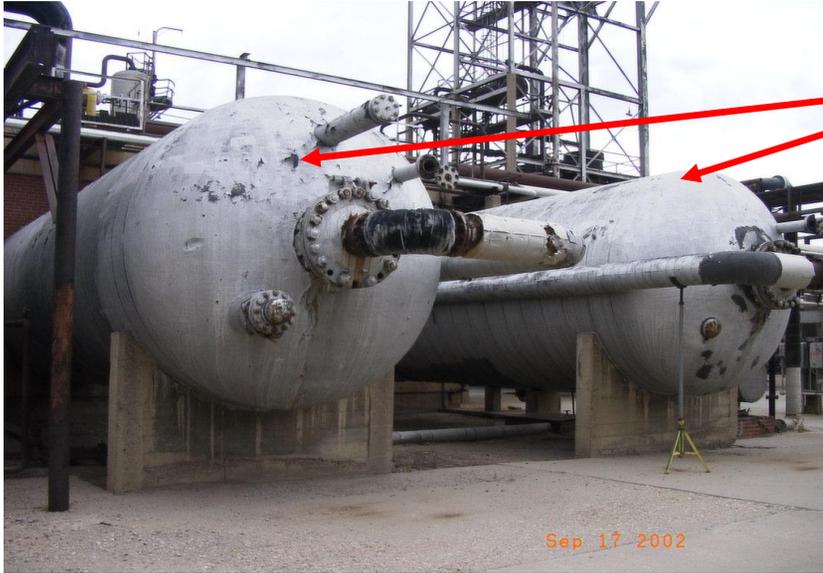
Installation of piping to recover this process stream significantly reduced flaring and provided hydrogen for the DDU process. This also provided significant P2/WM since the production of hydrogen is a very resource and energy intensive process.

**P2 Initiative Description**

**B19. Energy and resource recovery with added piping to use hydrogen-rich gas from ultraformer to Distillate Desulfurizer (DDU) for process use (equipment modification, process modification):** This stream was more or less "wasted" in flare system or inefficiently used as fuel gas where hydrogen-rich gas was not needed.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
		TPH	3,650
		Nitrogen Oxides	9
		Sulfur Oxides	129
<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>			<b>9</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>			<b>2,129</b>
<b>Water Savings Estimate (gallons/day) =</b>			<b>NA</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Vessels for segregation, storage & loadout of various types of spent caustic. Several types of spent caustic are generated by a variety of treating processes in refineries. Spent caustic is one of highest volume wastes generated by many refiners.

**P2 Initiative Description**

**B20. Segregation & recovery of spent caustic for cresylic acid manufacture (procedure modification, substitution of raw materials):** Different types of spent caustic are segregated, collected and used for making cresylic acid instead of treated and disposed.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo(a)Pyrene	6	Spent caustic	1,149,750
Mercury (Hg)	0.046	Nitrogen Oxides	310
		Sulfur Oxides	621

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>72</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>2,825</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>3,308</b>

**Summary of NEWER/INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Additional 2nd stage crude oil desalter to improve crude oil feedstock, reduce hydrocarbon losses, oily waste generation, etc.

Original, 1st stage desalter

**P2 Initiative Description**

**B21. Crude oil desalter upgrade (equipment modifications):** Desalter equipment upgraded to more efficiently remove salt and other impurities from crude oil, resulting in significantly reduced oil loss to wastewater and reduced generation of corrosion-derived hazardous waste in equipment downstream of the desalter (distillation/fractionating tower trays, overhead systems, etc.).

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo (a) pyrene	0.19	TPH	1,898,000
Mercury (Hg)	0.19	037 haz. wastes	189,800

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>303</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year) =</b>	<b>31,633</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

<b><u>Appendix B Reference Calculations:</u></b>	
<b>B1</b>	
BaP estimate = 0.50 MMscf/day x 800 btu/scf x 365 days/yr x 0.014 lbs Total PAH/MMbtu x 0.1 fraction BaP	204
Hg estimate = 12,000,000 lbs hydrocarbon/yr x 20,000 btu/lb x 1 MWh/3,412,000 btu x 0.00003 lb Hg/MWh/yr x 0.8 (20% energy savings deduction for power to refrigeration unit) (this also assumes savings based on energy content of recovered hydrocarbons to generate electrical power)	2
NOx estimate = 0.068 lbs NOx/MM btu x 500000scf/day x 800 btu/scf x 1 MMbtu/1,000,000 btu x 365 days/yr	9,928
SOx estimate = 0.0008 lbs SOx/scf x 0.50 MM scf/day x 365 days/yr	146,000
GHG estimate = 0.50 MMscf/day x 1,000,000 scf/MMscf x 800 btu/scf x 142 lbs CO2/MMbtu x 365 days x 1 ton CO2/2000 lbs	10,366
Energy estimate = [0.50 MMscf/day x 1,000,000 scf/MMscf x 800 btu/scf x 8 gal. gasoline/1,000,000 btu x 365 days/yr] + 1,000,000 gal. liquids recovery	2,168,000
<b>B2</b>	
BaP estimate = 23,725 lbs/yr F037oily waste x 1 ppm BaP oily waste content / 10 <sup>6</sup>	0.02
Hg estimate = 23,725 lbs/yr F037 oily waste x 1 ppm Hg oily waste content / 10 <sup>6</sup>	0.02
TPH estimate = 2 bbl/day improved oil recovery from brine x 325 lbs/bbl x 365 days/yr	237,250
F037 estimate = assume 10 % of above oil recovery would have ended up in F037 sludges; 237,250 lbs/yr x 0.10 fraction to F037	23,725
GHG estimate = 23,725 lb/yr oil x 1 gal/7 lbs x 22.38 lbs CO2/gal oil burned or incinerated x 1 ton CO2/2,000 lbs	38
Energy estimate = 23,725 lb/yr x 1 gal/6 lbs	3,954
<b>B3</b>	
all reduction estimates above are assuming 10 % of previous case # B2 (further 10 % improvement/reduction in crude feed contaminants)	
<b>B4</b>	
BaP estimate = 10 leaking RVs x 5 lb/hr leak rate x 8,760 hrs/yr x 0.5 ppm BaP/ 10 <sup>6</sup>	0.22
Hg estimate = 438,000 lbs TPH x 20,000 Btu/lb x 1 MWh/3,412,000 Btu x 0.00003 lb Hg/MWh/yr x (assuming approx. electrical power energy equivalent of hydrocarbon loss)	0.08
Volatile Organic Carbon (VOC) emissions estimate = 10 leaking RVs x 5 lb / hr leak rate x 8,760 hrs/yr	438,000
GHG estimate = 438,000 lb/yr oil x 1 gal/7 lbs x 22.38 lbs CO2/gal oil burned or incinerated x 1 ton CO2/2,000 lbs	700
Energy estimate = 438,000 lb/yr x 1 gal/6 lbs	73,000

<b>B5</b>	
BaP estimate = 474,500 lbs flare gas/yr x 1 lb mole/20 lbs x 379 scf/lb mole x 800 btu/scf x 0.014 lb Total PAH/MMbtu x 0.10 fraction BaP	10.07
Hg estimate = 474,500 lbs TPH x 20,000 Btu/lb x 1 MWh/3,412,000 Btu x 0.00003 lb Hg/MWh/yr (assuming approx. electrical power energy equivalent of hydrocarbon loss)	0.083
Hydrocarbon recovery estimate = 40,000 bpd x 325 lb/bbl x 0.0001 (0.01 %) HC loss improvement factor w. better flare gas monitoring x 365 days/yr	474,500
NOx estimate = 474500 lbs/yr flare gas x 1 lb mole/20 lbs x 379 scf/lb mole x 800 btu/scf x 0.068 lbs NOx/MM btu flare gas	489
SOx estimate = 474500 lbs/yr flare gas x 1 lb mole/20 lbs x 379 scf/lb mole x 0.0008 lbs SOx/scf flare gas	719
GHG estimate = 474500 lbs/yr x 20000 btu/lb x 142 lbs CO2/MMbtu x 1 ton CO2/2000 lbs	674
Energy estimate = 474500 lbs/yr x 1 gal gasoline/6 lbs	118,625
<b>B6</b>	
Note: Casutic soda is very energy intensive to produce; this is estimate of energy use & Hg emissions for producing this amount of caustic. Electrical use estimates from caustic producers association and Chemlink Consultants.	
Hg estimate = 360,000 lbs NaOH x 0.03/0.50 (spent:fresh strength ratio) x 1 ton/2000 lbs x 0.6 g Hg/ton NaOH x 1 lb/454 g	0.10
Note: chloro-alkali process for NaOH production uses Hg with international standard being approximately 0.6 g Hg/ton NaOH produced	
Spent NaOH estimate = 3000 gal/month x 10 lb/gal x 12 mo/yr	2,400,000
NOx estimate = 360,000 lbs NaOH/yr. x 0.03/0.5 (spent:fresh strength ratio) x 1 ton/2000 lbs x 3 MW hr/ton NaOH x 3.0 lbs NOx/MW hr (nat'l avg.)	648
SOx estimate = 360,000 lbs NaOH/yr. x 0.03/0.50 (spent:fresh strenght ratio) x 1 ton/2000 lbs x 3 MW hr/ton NaOH x 6.0 lbs SOx/MW hr (nat'l avg.)	1,296
GHG estimate = 360,000 lb NaOH/yr x 0.03/0.50 (spent: fresh strength ratio) x 1 ton/2,000 lb x 3Mwhr/ton NaOH produced x 1392 lbs CO2/Mwhr x 1 ton CO2/2000 lbs	150
Energy estimate = 3 Mwhr/ton NaOH produced x 360000 lb NaOH/yr x 0.03/0.5 (spent:fresh strength ratio) x 1 ton/2000 lb x 27.3 gal. gasoline/Mwhr	5,897
Water estimate = 360,000 lb NaOH/yr x 1yr/365 days x 1 ton/2000 lb x 2100 gal water/ton NaOH produced	6,904
<b>B7</b>	
Hg estimate = 15,000 MW hr power usage for compressor x 0.25 (25 % savings) x 0.00003 lb Hg/MWh/yr	0.75
NOX estimate = 15,000 MW hr power usage x 0.25 (25 % savings) x 3 lb NOx /MWh	75,000
SOx estimate = 15,000 MW hr power usage x 0.25 (25 % savings) x 6 lb SOx /MWh	150,000
GHG estimate = 15,000 MW hr x 0.25 (25% power savings) x 1392 lbs CO2/Mwhr x 1 ton CO2/2000 lbs	17,400
Energy savings estimate = 15,000 MW hr x 0.25 (25% power savings) x 27.3 gal. gasoline/Mwh	682,500

<b>B8</b>	
Hg estimate = 20,000,000 Btu/hr. savings x 8760 hrs/yr x 1 MWh/3,413,000 Btu x 0.00003 lb Hg/MWh (energy savings. converted to approx. electrical power energy equivalent)	10
NOx estimate = 0.068 lbs NOx/MM btu x 20MM btu/hr savings x 24 hrs/day x 365 days/yr	79,424
SOx estimate = 0.0008 lbs SOx/scf x 1scf/800 btu x 20,000,000 btu/hr savings x 24 hrs/day x 365 days/yr	116,800
GHG estimate = 20 MM btu/hr savings x 142 lbs CO2/MMbtu x 24 hrs/day x 365 days x 1 ton CO2/2000 lbs	82,928
Energy estimate = 20 MM btu/hr savings x 8 gal. gasoline/MMbtu x 24 hrs/day x 365 days/yr	9,344,000
<b>B9</b>	
BaP estimate = 5 bbl/day HC recovery x 365 days/yr x 325 lb/bbl x 10 ppm BaP (in overhead vacuum stream) x 1/10 <sup>6</sup> (estimating 5 bpd HC loss prior to condenser installation)	40
TPH estimate = 5 bpd HC recovery x 0.50 (50 % lost to barometric sump vent + flare) x 365 days/yr x 325 lb/bbl	1,977,083
NOx estimate = 59,313 lbs/yr flare gas (assume 20 % loss to flare) x 1 lb mole/44 lbs x 379 scf/lb mole x 800 btu/scf x 0.068 lbs NOx/MM btu flare gas	185
SOx estimate = 59,313 lbs/yr flare gas x 1 lb mole/44 lbs x 379 scf/lb mole x 0.0008 lbs SOx/scf flare gas	2,725
GHG estimate = 59,313 lbs/yr (assume 20 % of TPH loss to flare) x 15,000 btu/lb x 142 lbs CO2/MMbtu x 1 ton CO2/2000 lbs	421
Energy estimate = 296,563 lbs/yr x 1 gal gasoline/6 lbs	329,514
<b>B10</b>	
BaP estimate = 10 tpy HETX & Ctwr sludges x 2000 lb/ton x 5 ppm BaP / 10 <sup>6</sup> x 40/6 (ratio to convert to 40,000 bpd basis)	0.67
NOX estimate = 4.8 g/1000 gal x 20 gpm cooling water loss x 1440 min/day x 365 days/yr x 1 lb/454 g x 40/6 (ratio to convert to 40,000 bpd basis)	741
SO2 estimate = 6.2 g/1000 gal x 20 gpm cooling water loss x 1440 min/day x 365 days/yr x 1 lb/454 g x 40/6 (ratio to convert to 40,000 bpd basis)	957
GHG estimate = 5 lb. CO2/1000 gal. water x 1 ton CO2/2000 lbs x 20 gpm cooling water loss x 1440 min/day x 365 days/yr x 40/6 (ratio to convert to 40,000 bpd basis)	175
Energy estimate = 3.94kWhr/1000 gal x 20 gpm loss x 1440 min/day x 365 days/yr x 1 gal gasoline/36 kWhr x 1/0.35 elect. pwr. eff. factor (35 % from coal) x 40/6 (ratio to convert to 40,000 bpd basis)	21,914
Water estimate = 20 gpm cooling water loss x 1440 min/day x 40/6 (ratio to convert to 40,000 bpd basis)	192,000

<b>B11</b>	
BaP estimate = 727,273 lbs/yr reduction x 100 ppm BaP component x 1/10 <sup>6</sup> (K170 CSO waste is high in PAH compounds)	73
Hg estimate = 727,273 lbs/yr reduction x 1 ppm Hg component x 1/10 <sup>6</sup>	0.73
K170 listed haz. waste reduction estimate provided by refinery and converted to approx. 40,000 bpd basis (200 tpy x 40,000 bpd/22,000 bpd)	727,273
TPH estimate = 727,273 lbs/yr oily K170 waste x 0.10 unrecoverable oil fraction	72,727
NOx estimate = 727,273 lbs/yr oily K170 waste x 0.10 unrecoverable oil fraction x 1 gal/7 lbs x 55 lbs NOx/1,000 gal oil burned/incinerated	571
SOx estimate = 727,273 lbs/yr oily K170 waste x 0.10 unrecoverable oil fraction x 1 gal/7 lbs x 157 lbs SOx/1,000 gal oil burned/incinerated	1,631
GHG estimate = 727,273 lbs/yr oily K170 waste x 0.10 unrecoverable oil fraction x 1 gal/7 lbs x 22.38 lbs CO <sub>2</sub> /gal oil x 1 ton CO <sub>2</sub> /2,000 lbs	116
Energy estimate = 727,273 lbs/yr oily K170 waste x 0.10 unrecoverable oil fraction x 1 gal/6 lbs	12,121
<b>B12</b>	
BaP estimate = 5 bpd oil loss recovery estimate x 365 days/yr x 325 lbs/bbl x 5 ppm BaP x 1/10 <sup>6</sup>	3
TPH estimate = 5 bpd oil loss recovery estimate x 365 days/yr x 325 lbs/bbl (assume approx. 5 bpd additional oil recovery rate for vessel in combination with conventional separator, etc.)	593,125
Energy estimate = 5 bpd oil loss recovery estimate x 365 days/yr x 42 gal/bbl	76,650
<b>B13</b>	
BaP estimate = 400,000 lbs/yr to gasification x 50 ppm BaP component x 1/10 <sup>6</sup>	20.00
Hg estimate = 400,000 lbs/yr reduction x 1 ppm Hg component x 1/10 <sup>6</sup>	0.40
K170 listed haz. waste reduction estimate of 200 tons x 2000 lb/ton (estimated by refinery based on shipments to DGC plant)	400,000
TPH estimate = 400,000 lbs/yr oily K170 waste x 0.20 (20%) oil fraction recovered/gasified	80,000
NOx estimate = 400,000 lbs/yr oily K170 waste x 0.20 (20%) oil fraction recovered/gasified x 1 gal/7 lbs x 55 lbs NOx/1,000 gal oil burned/incinerated	629
SOx estimate = 400,000 lbs/yr oily K170 waste x 0.20 (20%) oil fraction recovered/gasified x 1 gal/7 lbs x 157 lbs SOx/1,000 gal oil burned/incinerated	1,794
GHG estimate = 400,000 lbs/yr oily K170 waste x 0.20 (20%) oil fraction recovered/gasified (not incinerated) x 1 gal/7 lbs x 22.38 lbs CO <sub>2</sub> /gal oil x 1 ton CO <sub>2</sub> /2,000 lbs	128
Energy estimate = 400,000 lbs/yr oily K170 waste x 0.20 (20%) oil fraction recovered/gasified x 1 gal/6 lbs	133,333
<b>B14</b>	
BaP estimate = 5 gpm water contaminant reduction x 1440 min/day x 365 days/yr x 8.34 lb/gal x 1 ppm BaP (in oily TSS)	22
Hg estimate = 5 gpm water contaminant reduction x 1440 min/day x 365 days/yr x 8.34 lb/gal x 0.1 ppm Hg (in oily TSS)	2
Pb estimate = 10,000 lb caustic solution reduction x 0.03 (approx. 3% or greater Pb)	300
Caustic soda estimate = assume approx. 10,000 lb/yr caustic waste reduction	10,000

<b>B15</b>	
HFestimate = assume 5 lbs/day HF recovery x 365 days/yr	1,825
VOC (as TPH) estimate = assume 50 lb/day propane recovery x 365 days/yr.	18,250
energy savings = 18,250 lbs/yr recovered hydrocarbon x 1 gal/6 lbs gasoline eq.	3,042
<b>B16</b>	
TPH estimate = 0.5 bpd x 365 days/yr x 300 lb/bbl	54,750
energy savings = 54,750 lbs x 1 gal/6 lbs gasoline	9,125
<b>B17</b>	
Hg estimate = 1 MWhr power load savings w. compressor x 24 x 365 x 0.00003 lb Hg/MWh	0.03
energy estimate = 1 MWhr power load savings w. compressor x 24 x 365 x 27.3 gal gasoline eq./MWhr	239,148
GHG estimate = 1 MWhr x 24 hrs/day x 365 days/yr x 1392 lbs CO2/Mwhr x 1 ton CO2/2000 lbs	6,097
<b>B18</b>	
BaP estimate = 118,625 lbs/yr slop waste reduction x 50 ppm BaP component x 1/10 <sup>6</sup>	5.93
Hg estimate = 118,625 lbs/yr slop waste reduction x 1 ppm Hg component x 1/10 <sup>6</sup>	0.12
K049 waste estimate = 1 bpd additional slop separation/recovery x 365 days/yr x 325 lb/bbl (oil contaminants not going to waste layer)	118,625
TPH estimate = 1 bpd additional slop oil recovery x 365 days/yr x 325 lb/bbl (oil recovered vs. disposed/incinerated w. haz. wastes)	118,625
NOx estimate = 118,625 lbs/yr oil x 1 gal/7 lbs x 55 lbs NOx/1,000 gal oil burned/incinerated	932
SOx estimate = 118,625 lbs/yr oil x 1 gal/7 lbs x 157 lbs SOx/1,000 gal oil burned/incinerated	2,661
GHG estimate = 118,625 lbs/yr oil x 1 gal/7 lbs x 22.38 lbs CO2/gal oil x 1 ton CO2/2,000 lbs	190
Energy estimate = 118,625 lbs/yr oil x 1 gal/6 lbs	19,771
<b>B19</b>	
TPH estimate = assume approximately 10 lbs/day liquids recovery in knock out drum x 365 days/yr	3,650
NOx estimate = 12,774 lbs/yr (flare gas + flare liquids recovery) x 1 lb mole/30 lbs x 379 scf/lb mole x 800 btu/scf x 0.068 lbs NOx/MM btu flare gas	9
SOx estimate = 12,774 lbs/yr (flare gas + flare liquids recovery) x 1 lb mole/30 lbs x 379 scf/lb mole x 0.0008 lbs SOx/scf flare gas	129
GHG estimate = 12,774 lbs/yr (flare gas + flare liquids recovery) x 1 lb mole/30 lbs x 379 scf/lb mole x 800 btu/scf x 142 lbs CO2/MMbtu flare gas x 1 ton CO2/2000 lbs	9
energy estimate = [25 lbs/day recovered from flare gas x 365 days/yr] + [3650 lbs/yr liquids recovery] x 1 gal. gasoline eq./6 lbs	2,129

<b>B20</b>	
BaP estimate = 1,149,750 lbs/yr spent caustic x 5 ppm BaP component (avg.) x 1/10 <sup>6</sup>	6
Hg estimate = 1,149.750 lbs NaOH x 0.03/0.50 (spent:fresh strength ratio) x 1 ton/2000 lbs x 0.6 g Hg/ton NaOH x 1 lb/454 g	0.05
Note: chloro-alkali process for NaOH production uses Hg with international standard being approximately 0.6 g Hg/ton NaOH produced	
Spent caustic estimate = 315 gpd x 10 lb./gal x 365 days/yr (Notes: Casutic soda is very energy intensive to produce; this is estimate of energy use & Hg emissions for producing this amount of caustic. Electrical use estimates from caustic producers association and Chemlink Consultants.)	1,149,750
NOx estimate = 1,149,750 lbs NaOH/yr. x 0.03/0.5 (spent:fresh strength ratio) x 1 ton/2000 lbs x 3 MWhr/ton NaOH x 3.0 lbs NOx/MWhr (nat'l avg.)	310
SOx estimate = 1,149,750 lbs NaOH/yr. x 0.03/0.50 (spent:fresh strenght ratio) x 1 ton/2000 lbs x 3 MWhr/ton NaOH x 6.0 lbs SOx/MWhr (nat'l avg.)	621
GHG estimate = 1,149,750 lb NaOH/yr x 0.03/0.50 (spent: fresh strength ratio) x 1 ton/2,000 lb x 3Mwhr/ton NaOH produced x 1392 lbs CO2/Mwhr x 1 ton CO2/2000 lbs	72
Energy estimate = 3 Mwhr/ton NaOH produced x 1149750 lb NaOH/yr x 0.03/0.5 (spent:fresh strength ratio) x 1 ton/2000 lb x 27.3 gal. gasoline/Mwhr	2,825
Water estimate = 1,149,750 lb NaOH/yr x 1yr/365 days x 1 ton/2000 lb x 2100 gal water/ton NaOH produced	3,308
<b>B21</b>	
BaP estimate = 189,800 lbs/yr F037oily waste x 1 ppm BaP oily waste content / 10 <sup>6</sup>	0.19
Hg estimate = 189,800 lbs/yr F037 oily waste x 1 ppm Hg oily waste content / 10 <sup>6</sup>	0.19
TPH estimate = 5 bbl/day improved oil recovery from brine x 325 lbs/bbl x 365 days/yr x 40.0/12.5 (refinery size ratio for 40,000 bpd basis)	1,898,000
F037 estimate = assume 10 % of above oil recovery would have ended up in F037 sludges; 1,898,000 lbs/yr x 0.10 fraction to F037	189,800
GHG estimate = 189,800 lb/yr oil x 1 gal/7 lbs x 22.38 lbs CO2/gal oil burned or incinerated x 1 ton CO2/2,000 lbs	303
Energy estimate = 189,800 lb/yr x 1 gal/6 lbs	31,633

# **Appendix C**

## **Individual P2/WM Projects**

P2/WM Initiatives designated as potentially newer or innovative, voluntary efforts initiated by petroleum refineries in the evaluation

Designated as  
**C1 through C13**

(Note: there are likely additional, P2/WM innovations many refineries in the region have implemented that were not included in this document)

Pollution Prevention and Waste Minimization (P2/WM) Profiles Emphasizing PBT\* Chemical Reductions for Petroleum Refineries  
\*(Persistent, Bioaccumulative and Toxic)

**Summary of INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Wastewater from this final polishing pond in the wastewater treatment system is reused within the refinery. This conserves approximately 60,000 - 70,000 gallons per day (gpd). This reduces the energy, emissions and chemicals otherwise used to pump and treat the large volumes of water used. The minor limitation on its use is unsuitability for cooling water makeup due to its higher dissolved solids content.

**P2 Initiative Description**

**C1. Wastewater reuse (recycling/reuse, equipment modifications):** More efficient treatment of wastewater and minimizing dissolved contaminants going to process sewers leads to increased capacity to reuse wastewater within the refinery.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
		Nitrogen Oxides	232
		Sulfur Oxides	299

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>55</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>6,848</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>60,000</b>

**Summary of INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Calcium Fluoride (CaF) waste is generated from operation of Hydrofluoroic acid (HF) alkylation units. An alkylation unit is one of the more crucial units for producing the high-octane blending components of gasoline. CaF is generated from use of potassium hydroxide(KOH) and lime (Ca(OH)<sub>2</sub>) for neutralization of HF carried over from the alkylation process.

The CaF waste contains significant quantities of high strength KOH which can be removed (centrifuged or filter-pressed) from the CaF sludge and reused for neutralization. The collection system in this photo processes CaF waste for centrifuging to recover and reuse this KOH solution. Conserving the KOH solution conserves the energy required to produce replacement KOH and minimizes KOH discharge to process sewers where it would contribute to hazardous waste generation by precipitation of oily solids due to increased pH.

Generation of CaF is related to HF acid consumption in the Alkylation Unit. Acid consumption can vary with the type of unit and control of the unit. Alkylation units using sulfuric acid as the catalyst can consume 10 - 30 lbs. acid per barrel of alkylate produced. Units using HF acid as the catalyst normally consume much less acid and are often in the range of 0.5 - 1.5 lbs. per barrel of alkylate.

**P2 Initiative Description**

**C2.Potassium Hydroxide (KOH) reuse (recycling/reuse, equipment modifications):** KOH solution is recovered from CaF sludges generated at HF alkylation units with segregated collection and centrifuging or filter-pressing the CaF waste. The estimated 2,000 gal. per month KOH solution recovered can then be reused to neutralize the normal amounts of HF acid carried over into the high octane alkylate produced in the alkylation unit.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Hg	0.19	Spent KOH Nitrogen Oxides Sulfur Oxides	288,000 1,296 2,592
<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.) =</b>			<b>301</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>			<b>11,794</b>
<b>Water Savings Estimate (gallons/day) =</b>			<b>840</b>

Summary of INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries



Drilling gantry above coker unit drums

Oily materials from wastewater treatment and other operations are processed and fed to this Montana refinery's coker. This represents Pollution Prevention by recovery and reuse of hydrocarbons in the oily materials. One minor disadvantage of the process is it lowers conventional charge to the coker by an estimated 50 - 60 barrels per day (bpd) but does offer savings with a significant reduction in hazardous waste generation, shipment and disposal requirements.

Much of this material is from Dissolved Air Floatation (DAF) unit, oil-water-solids separators, slop oil tanks and similar high-oil content materials.

This photo shows the storage tank for the coker feed and the pump for transferring material to the coker unit in the background.

**P2 Initiative Description**

**C3. Recovery / reuse of oily residues in coker unit:** (equipment modifications, reuse/recycling): Coker unit modified with feed systems for processing oily residues to minimize generation, shipment and disposal of oily hazardous wastes.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo (a) pyrene		1 TPH	50,000
		Nitrogen Oxides	393
		Sulfur Oxides	1,121

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.) =</b>	<b>80</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>8,333</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>15</b>

**Summary of INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Most refiners produce varying grades of sulfur from Sulfur Recovery Units (SRU) which remove sulfur compounds from numerous sour gas streams in the refinery. Sales markets for the sulfur can often be marginal with some sulfur actually going unused or stockpiled for long periods of time and, in some cases, disposed.

This Montana refinery made the investments to process the sulfur into ammonium thiosulfate fertilizer at a plant constructed adjacent to the refinery. This provides an efficient, valuable outlet for the sulfur and represents Pollution Prevention through savings in transportation and energy required to process the raw materials and otherwise manufacture the fertilizer.

**P2 Initiative Description**

**C4. Use of sulfur from Sulfur Recovery Unit (SRU) & other by-products to produce fertilizer (recycling/reuse, equipment modifications):** Sulfur from the refinery SRU is utilized to produce Ammonium thiosulfate fertilizer instead of shipped as molten sulfur. This conserves much of the energy to otherwise process and ship the raw materials and manufacture the fertilizer.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
		Nitrogen Oxides	115,533
		Sulfur Oxides	231,067

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.) =</b>	<b>26,804</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>3,587,220</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>108,000</b>

**Summary of INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



A flare gas recovery system was installed at this Montana refinery to recover approximately 1 million standard cubic feet (scf) per day of light hydrocarbons which would otherwise be wasted by flaring. Although the original project was a Supplemental Environmental Project (SEP) as part of a settlement, the refiner spent more than 3 times the value of the SEP to install the system. The system provides significant Pollution Prevention benefits through energy recovery with captured hydrocarbons used as fuel gas for fired heaters and other fuel needs in the refinery. Flared gas represents a significant energy loss if steps are not taken to control flaring. However, the flare must remain available as a relief system or safe outlet for light hydrocarbons which can not be normally processed at a give time. Depending on the refinery configuration, flare losses can range from 0.10 - 0.40 % of crude run.

It can often be difficult for a refinery to achieve "fuel gas balance" where the amount of fuel gas produced by various process units is more consistently balanced with fuel demands throughout the refinery. This is difficult to achieve due to a number of factors which can change the amount of fuel demand or supply at a given time. These factors can include % utilization of process units, variations in crude feed, seasonal changes in product slate & operating conditions, etc. Installation of this process equipment along with constant attention and response to process generators and users of fuel gas led to this refinery being more successful with fuel gas balance and ranks high in energy efficiency among U.S. refiners.

This photo shows the compressor building for the flare gas recovery system and associated piping with a fractionating tower in front of the building.

**P2 Initiative Description**

**C5. Flare gas recovery (recycling/reuse, equipment modifications):** Flare gas losses represent a significant loss of energy and resources. Flare systems are a necessity for refiners but steps can be taken to minimize emissions & hydrocarbon losses if investments in equipment and operating changes are made. Flare gas recovery systems are an innovative way to capture and reuse hydrocarbons that would otherwise be lost to flaring.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
BaP	409	Nitrogen Oxides Sulfur Oxides	19,856 292,000

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>59,564</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year) =</b>	<b>2,336,000</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

**Summary of INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



An additional water conservation effort at this Montana Refinery is realized with reuse of wastewater from the sour water stripper in this photo. The sour water stripper bottoms are routed to the crude unit desalter to replace fresh water used for removing salts from incoming crude oil. This measure conserves an estimated 43,000 - 72,000 gallons per day (gpd) of water.

Another P2 initiative with the sour water stripper is reuse of some of the refinery's spent caustic solutions to adjust the pH of this unit effluent. This reduces management of spent caustic as a waste and conserves the energy and resources associated with producing caustic. At a rate of 1 gpm spent caustic reuse, this process would reduce waste caustic solution generation by over 2,000 tons per year (tpy).

**P2 Initiative Description**

**C6. Wastewater reuse in crude oil desalter (recycling/reuse, equipment modifications):**

Incoming crude oil contains salts and other contaminants which must be removed prior to distillation to minimize corrosion of downstream equipment. Since the quality of water used for desalters is normally not crucial, sour water stripper bottoms can be used for this purpose if the refinery invests in the piping and other equipment modifications.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
		Spent caustic	4,000,000
		Nitrogen Oxides	278
		Sulfur Oxides	359

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.) =</b>	<b>66</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year) =</b>	<b>8,218</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>72,000</b>

**Summary of INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Additional recovery of heat/energy from the FCCU regnerator stack should result in high-pressure steam and electrical power generation at approximately 1.5 MegaWatts (MW) or about 15 - 20 % of the plants power needs. This heat energy is currently lost with stack temperatures exceeding 540 degrees F.

This energy conservations significantly reduces emissions and wastes that would otherwise be associated coal-fired generation of 1.5 MW of electrical power.

**P2 Initiative Description**

**C7. Heat recovery system at Fluid Catalytic Cracking Unit (FCCU) (energy conservation, equipment modifications):** The regenerator vessel at FCCU operates at high temperatures (often over 1,300 F) to regenerate catalyst by burning off petroleum coke which collects on the catalyst. This results in very high stack temperatures and a significant energy loss. This Montana refinery plans to increase heat/energy recovery from this process, including installation of a 600 lb. steam boiler for energy recovery and production of approx. 1.5 MW of electrical power.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Mercury (Hg)	16	Nitrogen Oxides Sulfur Oxides	394,200 788,400

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>91,454</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year) =</b>	<b>10,146,718</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

Summary of INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries



Hydrocarbon losses and emissions from opening coke drums at the end of a coke cycle are minimized with a closed coker blowdown system which routes the overhead hydrocarbon stream to a wet gas compressor. This significantly reduces the pollutant release and conserves hydrocarbons for use as intermediates or fuel in the refinery.

Assuming capture of approximately 100 lbs. of overhead hydrocarbons for each coking cycle, an emission reduction of 70,000 lbs. or more could be realized each year.

Coke drum blowdown piping to compressor located below gantry structure.

**P2 Initiative Description**

**C8. Coker unit blowdown system routed to wet gas compressor for reduced hydrocarbon losses**

**(recycling/reuse, equipment modifications):** Opening or "unheading" a coker unit at the end of a coking cycle can result in significantly increased emissions if adequate systems & procedures are not in place to capture this overhead hydrocarbon stream. This refinery minimizes these emissions with a closed system to route these hydrocarbons to a wet gas compressor for use in refinery intermediates or as a fuel.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo (a) pyrene	1		

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>579</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>22,720</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

**Summary of INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



These raised, isolated process sewer drain systems replace conventional, drains which are flush with the process deck. These systems significantly reduce the amount of sediment and other undesirable materials which would otherwise be continuously flushed into the oily wastewater system. This reduces hazardous waste generation and allows the process sewer system to more efficiently serve its purpose - to collect wastewater and recover oil for reprocessing.

The system in the photo to the left has 2 connections to the raised drain system which serves the large pump base in upper right of photo and a process line in upper portion of photo. The photo below shows a raised drain for a smaller pump base.



**P2 Initiative Description**

C9. Isolation of oily process sewer drains (source reduction, equipment modifications): Dozens or even hundreds of individual process sewer drains results in high volumes of sediment and other undesired materials flushed into process sewers which end up as oily waste in separators and other downstream equipment. Replacement of flush-mounted process sewer drains with raised or isolated drain systems reduces the undesirable collection of sediments and other materials which only add to oily, hazardous waste generation. The benefit is significant when multiple drains are replaced and eliminate the continuous flushing of undesirable materials into the wastewater and slop oil collection system.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo (a) pyrene	1	TPH	50,000
Mercury (Hg)	1		

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>NA</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>8,333</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

**Summary of INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



Significant Pollution Prevention (P2) benefits are realized with reuse of spent caustic solution for control of overhead corrosion at refinery distillation unit. Far left photo shows injection quill for adding spent caustic to distillation unit. Bottom left photo shows spent caustic tank and bottom right shows pump and piping for transferring caustic to distillation unit. At 1 gpm, this would reduce spent caustic waste generation by an estimated 2,000 tons per year (tpy).



**P2 Initiative Description**

**C10. Spent caustic reuse for overhead corrosion control (recycling/reuse, equipment modifications):**

Spent caustic solutions are often a troublesome, high-volume waste stream. However, these solutions can often have significant caustic or neutralization value if a refinery undertakes the necessary efforts. In this case, the caustic is reused to neutralize corrosive overhead streams at the distillation unit. This significantly reduces waste generation, chemical oxygen demand (COD) of wastewater and conserves the resources used for production of fresh caustic and/or substitute corrosion chemicals otherwise needed.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Hg		2 Spent caustic	2,000,000
		Nitrogen Oxides	1,080
		Sulfur Oxides	2,160

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.) =</b>	<b>251</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year) =</b>	<b>9,828</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>11,507</b>

**Summary of INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



This photo shows a separate process sewer system for high-solids wastewater streams which normally do not contain significant quantities of oil (compared to normal, oily process sewers). Segregating these streams from oily process water collection systems significantly reduces the volumes of oily hazardous waste (HW) that would otherwise be generated if the streams were routed to the same process water collection system.

This effort also reduces hydrocarbon losses because hydrocarbons in wastewater normally coat solids in the wastewater stream and are lost as oily sludges instead of captured in the oil layer of separators. Reductions of 500 - 1,000 tons per year (tpy) of oily wastes are achievable with this efficient segregation of wastewater streams. Assuming a oil content of 5 % in the resulting sludges, a 1,000 ton reduction would allow recovery and reuse of as much as 50 tons per year (tpy) of oil or approximately 300 barrels (bbl.).

**P2 Initiative Description**

**C11. Separate "high-solids" wastewater collection (equipment modifications):** This refiner has exceeded most refinery efforts at segregating non-oily, high-solids wastewater from oily process wastewaters. This significantly reduces EPA "F037" hazardous waste (HW) generation by keeping non-hazardous solids out of oil process water streams. It also allows more efficient wastewater treatment by separate collection and treatment of wastewater streams which normally do not contain significant quantities of oil (boiler & cooling tower blowdown, raw water treatment solids, etc.)

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo (a) pyrene		1 F037 - hazardous waste	500,000
Mercury (Hg)		1 TPH	50,000

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>NA</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>8,333</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

**Summary of INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries**



This photo shows an additional aeration unit upstream of the Dissolved Air Flootation (DAF) unit. The less conventional, supplemental aeration improves treatment/removal of heavier hydrocarbon contaminants from refinery wastewater and consequently lowers mass discharge of these contaminants into waters receiving the plant discharge.

**P2 Initiative Description**

**C12. Enhanced wastewater aeration (equipment modifications):** Increased aeration of refinery wastewater generally leads to more efficient treatment/degradation of organic contaminants, particularly heavier hydrocarbon pollutants which are more resistant to biotreatment. At a flow rate of 500 gallons per minute (gpm) and 5 ppm reduction in higher molecular weight contaminants, enhanced aeration would lower organic contaminants in the refinery's discharge by 10,000 lbs/yr.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
Benzo (a) pyrene	0.50	TPH	10,959

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.)</b>	<b>NA</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year ) =</b>	<b>NA</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

Summary of INNOVATIVE Pollution Prevention (P2) Initiatives Evaluated at Region VIII Petroleum Refineries



The compressor system to the left allows for recovery and reuse of significant hydrocarbon streams which would normally be lost to flare emissions.

**P2 Initiative Description**

**C13. Low-pressure flare gas system and vapor recovery system (recycling/reuse, equipment modifications):** Many refiners have a single flare system only. This Montana refinery has invested in a second, lower pressure flare gas collection system to allow collection and recovery of additional, lower pressure gas streams for reuse in the plant. A flare gas recovery system has also been installed to further improve hydrocarbon recovery and reduce flare emissions.

PBT Constituent(s)	Estimate of PBT constituent eliminated from emissions, wastes, or effluent (lbs./yr., 40,000 bpd basis)	Non-PBT waste and/or Constituent(s)	Estimate of Non-PBT constituent eliminated from emissions, wastes, or effluents (lbs./yr., 40,000 bpd basis)
BaP	102	Nitrogen Oxides	5,585
		Sulfur Oxides	73,000

<b>Greenhouse Gas (GHG) Emissions Reduction Estimate (tons/yr.) =</b>	<b>15,000</b>
<b>Energy Savings Estimate (gal. gasoline equivalent / year) =</b>	<b>580,000</b>
<b>Water Savings Estimate (gallons/day) =</b>	<b>NA</b>

<b><u>Appendix C Reference Calculations:</u></b>	
<b>C1</b>	
NOX estimate = 4.8 g/1000 gal x 60,000 gal/day x 365 days/yr x 1 lb/454 g	232
SO2 estimate = 6.2 g/1000 gal x 60,000 gal/day x 365 days/yr x 1 lb/454 g	299
GHG estimate = 5 lb. CO2/1000 gal. water x 60,000 gpd x 365 days/year x 1 ton/2000 lbs	55
Energy estimate = 3.94kWhr/1000 gal x 60,000 gpd x 365 days x 1 gal gasoline/36 kWhr x 1/0.35 e;ect. pwr. eff. factor (35 % for power from coal)	6,848
<b>C2</b>	
Hg estimate = 288,000 lbs KOH x 1 ton/2000 lbs x 0.6 g Hg/ton KOH x 1 lb/454 g (NOTE: chloro-alkali process for KOH production uses Hg with international standard being approximately 0.6 g Hg/tonne KOH produced)	0.19
Spent KOH estimate = 2000 gal/month x 12 lb/gal x 12 mo/yr.	288,000
NOx estimate = 288,000 lbs KOH/yr. x 1 ton/2000 lbs x 3 MWhr/ton KOH x 3.0 lbs NOx/MWhr (nat'l avg.)	1,296
SOx estimate = 288,000 lbs KOH/yr. x 1 ton/2000 lbs x 3 MWhr/ton KOH x 6.0 lbs SOx/MWhr (nat'l avg.)	2,592
GHG estimate = 2000 gal. KOH/month x 12 months/yr x 12 lb/gal x 1 ton/2000 lb x 3Mwhr/ton KOH produced x 1392 lbs CO2/Mwhr x 1 ton CO2/2000 lbs	301
Energy estimate = 3Mwhr/ton KOH produced x 144 tons/yr x 27.3 gal. gasoline/Mwhr	11,794
Water estimate = 2000 gal KOH/mo x 12 lb/gal x 1 ton/2000 lb x 2100 gal water/ton KOH produced x 1 month/30 days	840
<b>C3</b>	
BaP estimate = 250 tons/yr to coker x 2000 lbs/ton x 2 ppm BaP = 1 lb BaP/yr	1
NOx estimate = 50,000 lbs oil x 1 gal/7 lbs x 55 lbs NOx/1,000 gal oil burned/incinerated	393
SOx estimate = 50,000 lbs oil x 1 gal/7 lbs x 157 lbs SOx/1,000 gal oil burned/incinerated	1,121
TPH estimate = 250 tons oily waste/yr x 2000 lb/1 ton x 0.1 fraction oil in oily waste content	50,000
GHG estimate = 50,000 lb/yr oil x 1 gal/7 lbs x 22.38 lbs CO2/gal oil burned/incinerated x 1 ton CO2/2,000 lbs = 80 tons CO2/yr	80
Energy estimate = 50,000 lb/yr x 1 gal/6 lbs	8,333
Water estimate = 50,000 lbs oil/yr x 1 yr/365 days x 1 gal oil/7 lbs x 1 bbl/42 gal x 33 gal water/bbl crude processed	15
<b>C4</b>	
NOx estimate = 120 tons sulfur production/day x 3,000,000 btu/ton x 1 Mwh/3,412,000 btu x 3 lbs NOx/MWhr x 365 days/yr	115,533
SOx estimate = 120 tons sulfur production/day x 3,000,000 btu/ton x 1 Mwh/3,412,000 btu x 6 lbs SOx/MWhr x 365 days/yr	231,067
GHG estimate = 120 tons sulfur production/day x 3,000,000 btu/ton x 1 Mwh/3,412,000 btu x 1,392 lbs CO2/Mwhr x 1 ton CO2/2,000 lbs x 365 days/yr	26,804
Energy estimate = 120 tons sulfur production/day x 3,000,000 btu/ton sulfur x 1 Mwhr/1,000,000 btu x 27.3 gal. gasoline/Mwhr x 365 days/yr	3,587,220
Water estimate = 75 gpm water consumption for 120 tpd fertilizer production x 1440 min/day	108,000

<b>C5</b>	
BaP estimate = 1.0 MMscf/day x 800 btu/scf x 365 days/yr x 0.014 lbs Total PAH/MMbtu x 0.1 fraction BaP	409
NOx estimate = 0.068 lbs NOx/MM btu flare gas x 1MM scf/day x 800 btu/scf flare gas x 365 days/yr	19,856
SOx estimate = 0.0008 lbs SOx/scf flare gas x 1MM scf/day x 365 days/yr	292,000
GHG estimate=1 MMscf/day flare gas x 1,000,000 scf/MMscf x 800 btu/scf x 1 MWhr/3,412,000 btu x 1,392 lbs CO2/Mwhr x 1 ton CO2/2,000 lbs x 365 days/yr	59,564
Energy estimate = 1 MMscf/day x 1,000,000 scf/MM scf x 800 btu/scf x 8 gal. gasoline/1,000,000 btu x 365 days/yr	2,336,000
<b>C6</b>	
spent caustic hazardous waste estimate = 2,000 tpy x 2000 lbs/ton	4,000,000
NOX estimate = 4.8 g/1000 gal x 72,000 gal/day x 365 days/yr x 1 lb/454 g	278
SO2 estimate = 6.2 g/1000 gal x 72,000 gal/day x 365 days/yr x 1 lb/454 g	359
GHG estimate = 5 lb. CO2/1000 gal. water x 72,000 gpd x 365 days/year x 1 ton/2000 lbs = 66 tons CO2/yr.	66
Energy estimate = 3.94kWhr/1000 gal x 72,000 gpd x 365 days x 1 gal gasoline/36 kWhr x 1/0.35 electrical power efficiency factor (35 % for elec pwr from coal)	8,218
Water estimate = 72,000 gpd (refinery estimate)	72,000
<b>C7</b>	
Hg estimate = 15 MW power usage for compressor x 24 hrs/day x 365 days/yr x 0.25 (25 % savings) x 0.00003 lb Hg/MWh/yr	15.77
NOx estimate = 15 MW x 3 lbs NOx / MWhr x 24 hr/day x 365 days/year	394,200
SOx estimate = 15 MW x 6 lbs NOx / MWhr x 24 hr/day x 365 days/year	788,400
GHG estimate = 15 MW x 1,392 lbs CO2/MWhr x 1 ton/2,000 lbs x 24 hr/day x 365 days/year	91,454
Energy estimate = 15 MWhr x 24 hrs/day x 365 days/yr x 1 gal gasoline/37 kWhr x 1000 kwhr/MWhr x 1/0.35 electrical power efficiency factor	10,146,718
<b>C8</b>	
BaP estimate = 100 lbs. hydrocarbon released per coking cycle x 2 coke drums x 2 coke cycles/drum (per day) x 355 days run time/yr x 5 ppm BaP content x 1ppm/10 <sup>6</sup>	1
GHG estimate = 100 lb per coke cycle x 2 coke cycles/day x 355 days x 2 coke drums x 20,000 btu/lb x 1 MWhr/3,412,000 btu x 1392 lbs CO2/MWhr x 1 ton/2000 lbs	579
Energy estimate = 100 lb per coke cycle x 2 coke cycles/day x 355 days x 2 coke drums x 20,000 btu/lb x 1 gal gasoline/125,000 btu	22,720
<b>C9</b>	
BaP estimate = 250 tons oily waste x 2000 lb/1 ton x 1 ppm BaP oily waste content / 10 <sup>6</sup>	1
Hg estimate = 250 tons oily waste x 2000 lb/1 ton x 1.0 ppm Hg oily waste content / 10 <sup>6</sup>	1
TPH estimate = 250 tons oily waste x 2000 lb/1 ton x 0.1 fraction oil in oily waste content	50,000
Energy estimate = 50,000 lbs hydrocarbon x 1 gal. gasoline eq./6 lbs	8,333

<b>C10</b>	
Hg estimate = 2,000 tons/yr caustic soln (NaOH) x 0.03/0.50 (spent: fresh strength ratio) x 0.8 g Hg/ton NaOH x 1 lb/454 g ( NOTE: NaOH production uses Hg with intl. std. being approx. 0.9 g Hg/tonne NaOH produced)	2
GHG estimate=2000 tons/yr caustic reduction x 0.03/0.50 (spent: fresh strength ratio) x 3Mwhr/ton caustic produced x 1392 lbs CO2/Mwhr x 1 ton CO2/2000 lbs	251
Energy estimate = 2000 tons caustic x 3 MWhr/ton caustic produced x 27.3 gal gasoline/MWhr x 0.03/0.50 (spent: fresh strength ratio)	9,828
Water estimate = 2000 tons caustic production reduced/yr x 2100 gal water/ton caustic produced x 1yr/365 days	11,507
NOx estimate = 2,000 tons caustic/yr x 3 % strength/50 % std (0.06) x 3 MWhr/ton NaOH x 3.0 lbs NOx/MWhr (nat'l avg.)	1,080
SOx estimate = 2,000 tons caustic/yr x 0.03/0.50 (spent: fresh strength ratio) x 3 MWhr/ton NaOH x 6.0 lbs SOx/MWhr (nat'l avg.)	2,160
<b>C11</b>	
F037 haz. waste estimate = 250 tons waste segregated x 2000 lbs/ton	500,000
BaP estimate = 250 tons oily waste x 2000 lb/1 ton x 1 ppm BaP oily waste content / 10 <sup>6</sup>	1
Hg estimate = 250 tons oily waste x 2000 lb/1 ton x 1.0 ppm Hg oily waste content / 10 <sup>6</sup>	1
TPH estimate = 250 tons oily waste x 2000 lb/1 ton x 0.1 fraction oil in oily waste content = 50000 lbs TPH hydrocarbon	50,000
Energy estimate = 50,000 lbs hydrocarbon x 1 gal. gasoline eq./6 lbs	8,333
<b>C12</b>	
BaP estimate = 10,000 lbs/yr organics x 50 ppm BaP oily waste content / 10 <sup>6</sup> = 0.01 lbs B(a)P	0.50
TPH estimate = 500 gal/min x 1440 min/day x 365 days/yr x 8.34 lbs/gal x 5 ppm organics reduction/10 <sup>6</sup>	10,959
<b>C13</b>	
BaP estimate = 0.25 MMscf/day x 800 btu/scf x 365 days/yr x 0.014 lbs Total PAH/MMbtu x 0.1 fraction BaP	102
NOx estimate = 0.068 lbs NOx/MM btu x 0.25MM scf/day x 900 btu/scf x 365 days/yr	5,585
SOx estimate = 0.0008 lbs SOx/scf x 0.25MM scf/day x 365 days/yr = 73,000 lbs SOx/yr	73,000
GHG estimate = 0.25 MMscf/day x 1,000,000 scf/MMscf x 800 btu/scf x 1 MWhr/3,412,000 btu x 1392 lbs CO2/Mwhr x 1 ton CO2/2000 lbs x 365 days/yr	14,891
Energy estimate = 0.25 MMscf/day x 1,000,000 scf/MMscf x 800 btu/scf x 8 gal. gasoline/1,000,000 btu x 365 days/yr	584,000

# **Attachment D: Summary Table of Voluntary Initiatives documented from this effort to date**

(March 2007)



APPENDIX D: Summary Table - Petroleum Refinery Voluntary Pollution Prevention/Waste Minimization (P2/WM) Initiatives



OP= Operation Modification Init EQ= Equipment Modification Subtotals/Totals

Initiative Description		BaP lbs/yr	Hg lbs/yr	Pb lbs/yr	Benzene lbs/yr	Cr lbs/yr	Listed HW lbs/yr	Characteristic HW lbs/yr	TPH lbs/yr	Nitrogen Oxides (NOx) lbs/yr	Sulfur Oxides (SOx) lbs/yr	Greenhouse Gas (GHC) tons/yr	Energy Conservation gal. gasoline equivalent/yr.	Water Conservation gal/day	TOTAL (lb/yr) Reduction for PBT Constituents (Columns D to J)	TOTAL (lb/yr) Reduction for RCRA constituents (Columns G & H)	TOTAL (lb/yr) Reduction for Hazardous Wastes (Columns I & J)	TOTAL (lb/yr) Reduction for Conventional Pollutants (Columns K to M)	TOTAL (lb/yr) P2/WM Reduction for Specific Initiative (Columns D to M; excludes D to M)
A1. WM Coordinator	OP														0.00	0.00	0	0	0
A2. Weight & Volume Recovery	OP	119	1.19		5,931				2,372,500			3,793	395,417	730	120.19	5,931.00	0	2,372,500	2,378,551
A3. Segregate non-oily wastes	OP	54					5,400,000		270,000	2,121	6,056	432	38,571		54.00	0.00	5,400,000	278,177	5,678,231
A4. Stormwater & blowstand control	EQ						1,800,000		90,000	6,364	18,167	1,295	135,000		0.00	0.00	1,800,000	114,531	1,914,531
A5. Drums - minimize use	OP	0.18	0.5						2,800					400	0.68	0.00	0	2,800	2,801
A6. Training for WM	OP														0.00	0.00	0	0	0
A7. Chromates - eliminate	OP							197,258							0.00	197,258.00	0	0	197,258
A8. PCBs - eliminate	OP														0.00	0.00	0	0	0
A9. Hg Instruments - eliminate	EQ		900												900.00	0	0	0	900
A10. De-water & De-oil all wastes	EQ	18							3,600,000						18.00	0	0	3,600,000	3,600,018
<b>SubTotal (A1 - A10)</b>		<b>191</b>	<b>902</b>	<b>0</b>	<b>5,931</b>	<b>197,258</b>	<b>7,200,000</b>	<b>0</b>	<b>6,335,300</b>	<b>8,485</b>	<b>24,223</b>	<b>5,520</b>	<b>1,169,388</b>	<b>730</b>	<b>1,092.87</b>	<b>7,200,000</b>	<b>6,368,008</b>	<b>13,772,290</b>	
B1. Flare gas recovery	EQ	204	2							9,928	146,000	10,366	2,168,000		206.00	0	0	155,928	156,134
B2. Desalter interface monitoring	EQ	0.02	0.02				23,725		237,250			38	3,954		0.04		23,725	237,250	260,975
B3. Additional crude cleaning	EQ	0.002	0.002				2,375		23,725			4	395		0.00		2,375	23,725	26,100
B4. Acoustic meter for large RVs	EQ	0.22	0.08						438,000			700	73,000		0.30	0	0	438,000	438,000
B5. Flare mass flow metering	EQ	10.07	0.083						5,475	489	719	674	118,625		10.15	0	0	6,683	6,693
B6. Sodium hydro-sulfide mfg.	EQ		0.1				2,400,000		648	1,296	150	5,897	6,904		0.10	2,400,000	2,401,944	2,401,944	
B7. VFD for large compressors	EQ		0.75						90	75,000	150,000	17,400	682,500		0.75	0	0	225,090	225,091
B8. Oxygen analyzer for flue gas	EQ		10						79,424	116,800	82,928	9,344,000		10.00	0	0	196,224	196,234	
B9. Vacuum unit eductor condensers	EQ	27							1,977,083	185	2,725	421	329,514		27.00	0	0	1,979,993	1,980,020
B10. Air coolers for HDS (vs. cooling H2O)	EQ	0.67							741	957	175	21,914	192,000		0.67	0	0	1,698	1,699
B11. FCCU cyclone revamp (CSO)	EQ	73	0.73				727,273		72,727	571	1,631	116	12,121	192,000	73.73	0	727,273	74,929	802,276
B12. Pre-treat tank water draws	EQ	3							593,125						3.00	0	0	593,125	593,128
B13. Gasification of oily wastes	OP	20	0.4				400,000		400,000	629	1,794	128	133,333		20.40	0.00	400,000	402,423	802,443
B14. Salt tower treaters/filters for Dr. treaters	EQ	22	2	300				10,000							324.00	0	10,000	0	10,324
B15. HETX control for efficient HETX	EQ								18,250				3,042		0.00	0	0	18,250	18,250
B16. ASO burner modifications	EQ								54,750				9,125		0.00	0	0	54,750	54,750
B17. Chloride guard beds for H2-rich compressor	EQ		0.03									6,097	239,148		0.03	0	0	0	0
B18. Improved slop oil recovery w. tank mixer	EQ	6	0.12				118,625		118,625	932	2,661	190	19,771		6.12	118,625	122,218	240,849	
B19. H2-rich gas piping for DDU	EQ								3,650	9	129	9	2,129		0.00	0	0	3,788	3,788
B20. Segregate & recycle spent caustic for cresylic acid	OP	6	0.046					1,149,750		310	621	72	2,825	3,308	6.05	0.00	1,149,750	931	1,150,687
B21. Desalter upgrade (2nd stage)	EQ	0.19	0.19				189,800		1,898,000			303	31,633		0.38	0	189,800	1,898,000	2,087,800
<b>SubTotal (B1 - B21)</b>		<b>372</b>	<b>17</b>	<b>300</b>	<b>0</b>	<b>0</b>	<b>1,461,798</b>	<b>3,559,750</b>	<b>5,840,750</b>	<b>168,866</b>	<b>425,333</b>	<b>119,771</b>	<b>13,277,576</b>	<b>202,212</b>	<b>688.72</b>	<b>5,021,548</b>	<b>8,834,949</b>	<b>11,457,186</b>	
C1. Wastewater reuse (from final polishing pond)	OP									232	299	55	6,848	60,000	0.00	0.00	0	531	531
C2. KOH recovery/reuse	EQ		0.19					288,000		1,296	2,592	301	11,794	840	0.19	288,000	3,888	291,888	
C3. Coking oily residues	OP	1							50,000	393	1,121	80	8,333	15	1.00	0.00	0	51,514	51,515
C4. Sulfur from SRU to Ammonium thiosulfate fertilizer	EQ									115,533	231,067	26,804	3,587,220	108,000	0.00	0	0	346,600	346,600
C5. Flare gas recovery	EQ	409								19,856	292,000	59,564	2,336,000		409.00	0	0	311,856	312,265
C6. Sour water stripper wastewater recycled to desalter	OP						4,000,000		278	359	66	8,218	72,000		0.00	0.00	4,000,000	637	4,000,637
C7. FCCU regenerator stack co-generation	EQ		16						394,200	788,400	91,454	10,146,718		16.00	0.00	0	1,182,600	1,182,616	
C8. Coker unit blowdown recovery	EQ	1										579	22,720		1.00	0	0	0	1
C9. Raised/isolated oily sewer drains/inlets	EQ	1	1				500,000		50,000				8,333		2.00	500,000	50,000	550,002	
C10. Spent caustic for corrosion control in crude OH	OP		2					2,000,000		1,080	2,160	251	9,828	11,507	2.00	0.00	2,000,000	3,240	2,003,242
C11. Separate "HIGH SOLIDS" sewer system	EQ	1	1				500,000		50,000				8,333		2.00	500,000	50,000	550,002	
C12. Enhanced wastewater aeration	EQ	0.5	0.01						10,959						0.51	0	0	10,959	10,960
C13. Low pressure flare gas recovery	EQ	102	0.1							5,600	73,000	15,000	580,000		102.10	0	0	78,600	78,702
<b>SubTotal (C1 - C13)</b>		<b>516</b>	<b>20</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1,000,000</b>	<b>6,288,000</b>	<b>160,959</b>	<b>538,468</b>	<b>1,390,998</b>	<b>194,154</b>	<b>16,734,345</b>	<b>252,362</b>	<b>535.80</b>	<b>7,288,000</b>	<b>2,090,425</b>	<b>9,378,961</b>	
<b>Grand TOTAL</b>		<b>1,079</b>	<b>939</b>	<b>300</b>	<b>5,931</b>	<b>197,258</b>	<b>9,661,798</b>	<b>9,847,750</b>	<b>12,337,009</b>	<b>715,819</b>	<b>1,840,554</b>	<b>319,445</b>	<b>31,181,309</b>	<b>455,304</b>	<b>2,317.39</b>	<b>19,509,548</b>	<b>17,293,382</b>	<b>34,608,436</b>	
<b>Refinery Capacity (bpd)</b>																			
Sinclair, Casper WY		22,000	73.00	0.73	0	0	727,273	0	72,727	571	1,631	116	12,121	0	73.73	727,273	74,929	802,276	
Sinclair, Sinclair WY		65,000	6.00	0.05	0	0	0	1,149,750	0	310	621	72	2,825	3,308	6.05	1,149,750	931	1,150,687	
Tesoro, Mandan ND		60,000	51.00	2.55	300	0	518,625	10,000	1,188,400	1,570	4,584	6,424	483,198	0	353.55	528,625	1,194,554	1,723,533	
Valero, Denver CO		28,000	204.02	2.02	0	0	26,100	0	260,975	9,928	146,000	10,408	2,172,349	0	206.04	26,100	416,903	443,209	
Conoco, Denver CO		58,000	10.29	0.16	0	0	0	0	443,475	489	719	1,374	191,625	0	10.45	0	444,683	444,693	
WRC, Newcastle WY		12,500	0.19	0.19	0	0	189,800	0	1,898,000	0	0	303	31,633	0	0.38	189,800	1,898,000	2,087,800	
CHS, Billings MT		56,000	511.50	2.11	0	0	0	2,000,000	10,959	26,536	367,160	74,815	2,925,828	11,507	513.61	2,000,000	404,655	2,405,169	
Conoco, Billings MT		58,000	412.00	17.19	0	0	500,000	4,288,000	100,000	531,788	1,315,838	178,903	16,136,184	240,855	429.19	4,788,000	1,947,626	6,736,055	
MRC, Great Falls MT		8,200	27.67	10.85	0	0	0	2,400,000	1,977,173	155,998	271,778	101,074	10,383,825	198,904	38.52	2,400,000	2,404,949	4,804,988	
TOTAL		367,700																	
AVG.		40,856																	
<b>No. of Initiatives in each category</b>																			
Equipment Modifications (EQ)																			
Operation Modifications (OP)																			
<b>TOTALS by P2 Category (A,B,C series initiatives)</b>																			
Pollutant reduction figures as Equipment Modifications (EQ)		879	934	300	0	0	3,861,798	2,698,000	9,241,709	710,776	1,828,144	314,568	30,577,536	307,744	2,113.08	6,559,798	11,780,629	18,342,540	
Pollutant reductions as Operation Modifications (OP)		200	4																