CAL ECO MAPS

UCLA-US EPA TRI University Challenge

Assessing and Communicating the Environmental Impact of TRI Facilities in Los Angeles County

UCLA IoES Senior Practicum Project

Faculty Advisor Magali Delmas
Graduate Advisor Aanchal Kohli

Team Members
Ha Hyun Chung
Carmen Ehlinger
Fannie Hsieh
Leanna Huynh
Larry Lai
Amy Tat
Audrey Vinant-Tang

Published: May 2014

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

UCLA Institute of the Environment and Sustainability

EXECUTIVE SUMMARY

In 2012, more than 21,000 facilities in the United States reported over 3.5 billion pounds of toxic chemical releases into the environment to the United States Environmental Protection Agency (EPA) Toxics Release Inventory (TRI). TRI requires facilities that meet the reporting criteria to submit annual reports on the amount of toxic chemicals released directly into the environment, managed as waste through recycling, energy recovery, and treatment, and transferred from one facility to another.

While TRI has been successful at documenting disposal information for over 650 toxic chemicals across the nation, effective communication of local toxic release trends still remains an issue. The purpose of this project is to facilitate the assessment and comparison of the environmental impact of TRI facilities for key stakeholders in Los Angeles County. To achieve this goal, facilities were scored based on multi-dimensional pollution criteria, or environmental impact indicators and the information was displayed on an interactive website: *Cal EcoMaps*. This project was conducted in collaboration with the US EPA University Challenge.

We focused our analysis on 194 facilities that constitute the top four polluting industries based on the amount of toxic releases directly emitted in the Los Angeles County in 2012 Cumulatively these industries account for nearly seven million pounds, or 89% of Los Angeles County's total toxic releases (8,041,909 pounds). The environmental impact score of each facility was evaluated based on five main environmental impact indicators in each industry:

1. Total Toxic Releases, or the amount of toxic chemicals released directly into the environment, measured in pounds
2. Toxicity of Air Releases (pounds * toxicity), measure of health-related impacts as determined by Risk Screening Environmental Indicators (RSEI)
3. Regional Contribution to Lifetime Cancer Risk from Air Emissions, or the estimated conversion of a facility's toxic air releases to cancers in one million people exposed in the Los Angeles Basin over 70 years of exposure
4. Waste managed through Recycling, Energy Recovery, and Treatment, or the amount of toxic chemicals managed to prevent release into the environment, measured in pounds
5. Toxic Releases per $1000 of Revenue

Cal EcoMaps was created as an interactive map for users to access the EISs of the 194 profiled facilities from the top four Industries. This website allows residents of the Los Angeles County to visualize facility-level TRI information in a user-friendly interactive way. It also provides facilities the opportunity to compare their EISs with other facilities within their respective sectors in Los Angeles County to help them reduce their impact on the environment and public health.

Cal EcoMaps is available at: http://www.environment.ucla.edu/ccep/calecomaps.

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ABSTRACT

The UCLA team developed the *Cal EcoMaps* website for public use to highlight facilities reporting to the Toxics Release Inventory (TRI) in the Los Angeles County. Through an interactive map, users are able to see information and environmental impact scores on profiled facilities from the top four emitting industries based on the amount of toxic releases in Los Angeles County, including facilities in the Primary Metals, Petroleum, Fabricated Metals, and Chemicals Industries. The *Cal EcoMaps Environmental Impact Score* was created based on the percentile rank of each facility within its respective industry for five environmental impact indicators: Total Toxic Releases, Toxic Releases per $1000 of Revenue, Toxicity of Air Releases, Regional Contribution to Lifetime Cancer Risk due to Air Emissions, and Waste Managed Through Recycling, Energy Recovery, and Treatment. These scores are displayed on the website so that facilities have the opportunity to compare their scores with other facilities within their respective sectors in Los Angeles County and learn about best practices to help them reduce their impact on the environment and public health. The main feature of *Cal EcoMaps* displays facility-level information based on the five environmental impact indicators with dynamic charts and graphs to show 2010-2012 facility historical data alongside Los Angeles County and California averages. An industry-level analysis on the top four industries is presented in a separate section on *Cal EcoMaps*. *Cal EcoMaps* is available at: http://www.environment.ucla.edu/ccep/calecomaps.

1. PROJECT OBJECTIVES

The intent of this collaborative research project between UCLA and the EPA is to continue the advancement of knowledge, use, and understanding of the TRI through the use of innovative visualizations. The purpose of the UCLA project is to provide key stakeholders in Los Angeles County a comparative resource that communicates TRI data and trends in conjunction with other datasets to evaluate the environmental impact of TRI facilities.

In order to achieve this goal, this project has met the following objectives:

1. Complemented TRI data with revenue data, Census data, cancer risk estimates, and California Protected Areas to determine trends across industries in the Los Angeles County and in California.
2. Developed a robust methodology to evaluate and rate environmental impact of TRI facilities in Los Angeles County.
3. Shared environmental impact evaluations with TRI facilities to better facilitate intra-industry comparisons of toxic chemical trends and data.
4. Created an interactive map of TRI Facilities in the Los Angeles County to effectively communicate results with the general public.

2. THE TOXICS RELEASE INVENTORY (TRI)

When Congress signed the Emergency Planning and Community Right-to-Know Act (EPCRA) in 1986 in response to fatal chemical accidents, it established the Toxics Release Inventory (TRI) to keep manufacturing sectors and federal facilities accountable for reporting chemicals released and managed at their facilities. The United States Environmental Protection Agency (EPA) became the regulatory body responsible for tracking, reporting, and analyzing TRI information received annually from facilities across the nation. The collected data is publicly available through reports, search tools, and applications so that information on toxic chemical releases and waste management activities can be accessed and used by the general public, government, and industry to encourage responsible choices within communities (*Learn about the Toxics Release Inventory,* US EPA).

The TRI is a national database that tracks facility management of certain toxic chemicals that cause "chronic or acute human health effects," such as cancer, or "significant adverse environmental effects." The EPA mandates manufacturing sectors and federal facilities that meet all three reporting criteria to report information on these chemicals for inclusion in the national TRI database during its annual data collection process. The three criteria for facilities required to report are (*Basics of TRI Reporting,* US EPA):

> "1) in a specific TRI-reportable industry sector such as manufacturing or is federally-owned or operated,
> 2) employs 10 or more full-time equivalent employees, and
> 3) manufactures[1], processes[2], or otherwise uses[3] a TRI-listed chemical in an amount above the TRI reporting threshold during a calendar year (thresholds vary depending upon chemical)."

Meeting these three criteria requires facilities to submit a TRI Form R, which is the more comprehensive form required for TRI reporting. Facilities that report information for the dioxin and dioxin-like compounds category, measured in individual grams of compounds, are also required to complete Form R Schedule 1. These forms must be submitted to the EPA and to state agencies in which the facility is located.

The TRI Form A, which is a shorter form, can substitute Form R if all of the following requirements are met (*Basics of TRI Reporting,* US EPA):

> 1) the chemical reported is not a Persistent, Bioaccumulative, Toxic (PBT) chemical
> 2) the quantity of the chemical being handled and produced is not greater than 1,000,000 pounds, and
> 3) the total waste managed of that chemical is not greater than 500 pounds in a year.

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[1] EPCRA defines *manufacture* as processes that "produce, prepare, compound, or import a chemical"

[2] *Process* "is to prepare a chemical, after its manufacture, for distribution in commerce.

[2] *Process* "is to prepare a chemical, after its manufacture, for distribution in commerce.

[3] *Otherwise use* is an overarching term used to describe "any use of a chemical that is not covered by the terms of manufacture or process."

3. SCOPE OF PROJECT

The TRI program now contains annual release and disposal information of over 650 toxic chemicals from more than 21,000 facilities nationwide who have submitted the TRI reporting forms, Form A and Form R. Because reporting requirements for each Form have expanded over the years to include different industries and chemicals, we use the more comprehensive Form R to ensure measurable comparisons of data and trends across the Los Angeles County, California, and United States.

We also limit our analysis to the 2010 to 2012 reporting years, which at the start of this project was the most currently available data from the TRI. While TRI data from these three years is used to determine trends and averages for individual facilities, only data from 2012 is considered in facility environmental impact scores. The TRI data from 2010-2012 that is used throughout this project is downloaded from TRI.NET, an application developed by the EPA that allows sorting and filtering of TRI data (TRI.NET, US EPA).

In 2012, 21,466 facilities across 26 industries nationwide reported to the TRI. For California and the Los Angeles County that same year, 1,256 and 377 facilities reported to the TRI, respectively. Despite the numerous facilities available for analysis, this project only determined facility environmental impact scores for 172 facilities in Los Angeles County reporting to the TRI in 2012 that belong to the four most polluting sectors in Los Angeles County. Facility environmental impact scores were based on five different variables, or environmental impact indicators, to provide comprehensive evaluation.

While some variables were taken directly from the TRI, other variables were derived by complementing TRI data with external data from additional databases. For example, the "Toxic Releases per $1,000 of Revenue" variable was calculated by complementing TRI data with revenue data obtained from ReferenceUSA, Hoovers, and Orbis. It is important to note that this is the first known project to measure a facility's environmental impact relative to its fiscal performance by comparing facility pounds of toxic releases with annual revenue. Moreover, the regional contribution to overall lifetime cancer risk from air emissions was calculated for each census tract in the Los Angeles County by integrating data from Risk-Screening Environmental Indicators (RSEI), Office of Environmental Health Hazards Assessment (OEHHA), and Scorecard's Toxic Equivalency Potential (TEP).

The UCLA team developed the *Cal EcoMaps* website for public use to display all 377 facilities reporting to the Toxics Release Inventory (TRI) in Los Angeles County in 2012. The main feature of *Cal EcoMaps* is that it displays facility-level information based on the five environmental impact indicators with dynamic charts and graphs to show 2010-2012 facility historical data alongside Los Angeles County and California averages. Through an interactive map, users are able to see information and environmental impact scores on 172 profiled facilities from the top four emitting industries in terms of toxic releases in Los Angeles County, including facilities in the Primary Metals, Petroleum, Fabricated Metals, and Chemicals Industries. An industry-level analysis on the these top four industries is dedicated in a separate section on *Cal EcoMaps*. The

205 facilities in the other 14 industries are also mapped with similar facility information, but were not part of the analysis and not given scores. *Cal EcoMaps* is available at: http://www.environment.ucla.edu/ccep/calecomaps.

4. METHODOLOGY

To better understand toxic releases in Los Angeles County and provide environmental impact evaluations on individual facilities during the 2012-reporting year, we first selected specific industries and facilities to receive scores based on their total amount of toxic releases. We then examined a variety of variables provided by the TRI and other datasets to assign scores which led to the selection of five variables, or environmental impact indicators, that were judged to be the most indicative of environmental impact. The chosen facilities were then assigned scores based on the following five environmental impact indicators: 1) the total amount of toxic releases, 2) toxic releases per $1000 of revenue, 3) toxicity of total releases, 4) regional contribution to lifetime cancer risk due to air emissions, and 5) waste managed through recycling, energy recovery, and treatment. We call this score the *Cal EcoMaps Environmental Impact Score* (*Cal EcoMaps EIS*). Finally, we displayed and communicated the *Cal EcoMaps EIS* along with other facility specific information on an interactive mapping website, *Cal EcoMaps*, for residents and other stakeholders in the Los Angeles County to view TRI-listed facilities in their area. The following section details the methodologies in choosing facilities, selecting variables, and communicating the *Cal EcoMaps EIS* on the interactive website *Cal EcoMaps*.

4.1 Choosing Industries and Facilities in Los Angeles County to Score

We used a top-down level of analysis (illustrated in Figure 1) throughout this project to target the most polluting industries and facilities in Los Angeles County for three purposes. First, by identifying industries with the greatest contribution to the total toxic releases in Los Angeles County, we were able to identify facilities with the greatest contribution to both the total toxic releases in Los Angeles County and within their respective industry sector. Intuitively, the industries with the greatest amount of toxic releases would be expected to also include facilities that have the greatest amount of toxic releases. Second, given proportionate reductions, facilities within these top-polluting industries would have the potential for the greatest overall reduction of the total toxic releases in Los Angeles County compared to other industries or facilities with fewer toxic releases.

To conduct our analysis, we categorized industries and facilities based on the North American Industry Classification System (NAICS) 3 or 4-digit code provided by TRI. Facilities that did not have an NAICS code to classify their industry were not considered for our analysis. In 2012, 377 facilities in 18 industries across Los Angeles County reported to the TRI. Of these 18 industries, we focused our analysis on 194 facilities, belonging to the top four polluting industries based on the amount of total toxic releases, because of their contribution and influence in Los Angeles County. Cumulatively, these facilities accounted for nearly seven million pounds, or 89% of Los Angeles County's total of toxic releases (8,041,909 pounds) that are directly released into the environment. The top four industries from the greatest to least contribution to Los Angeles County's total amount of toxic releases are: Primary Metals (30 facilities contributing 38%), Petroleum (27 facilities contributing 31%), Fabricated Metals (61 facilities contributing 15%), and Chemicals (76 facilities contributing 5%). Throughout this paper, the 194 facilities in these four industries are collectively referred to as "top four industries." The top four industries' total toxic releases contribution to the total toxic releases in Los Angeles County in 2012 are shown in Figure 2.

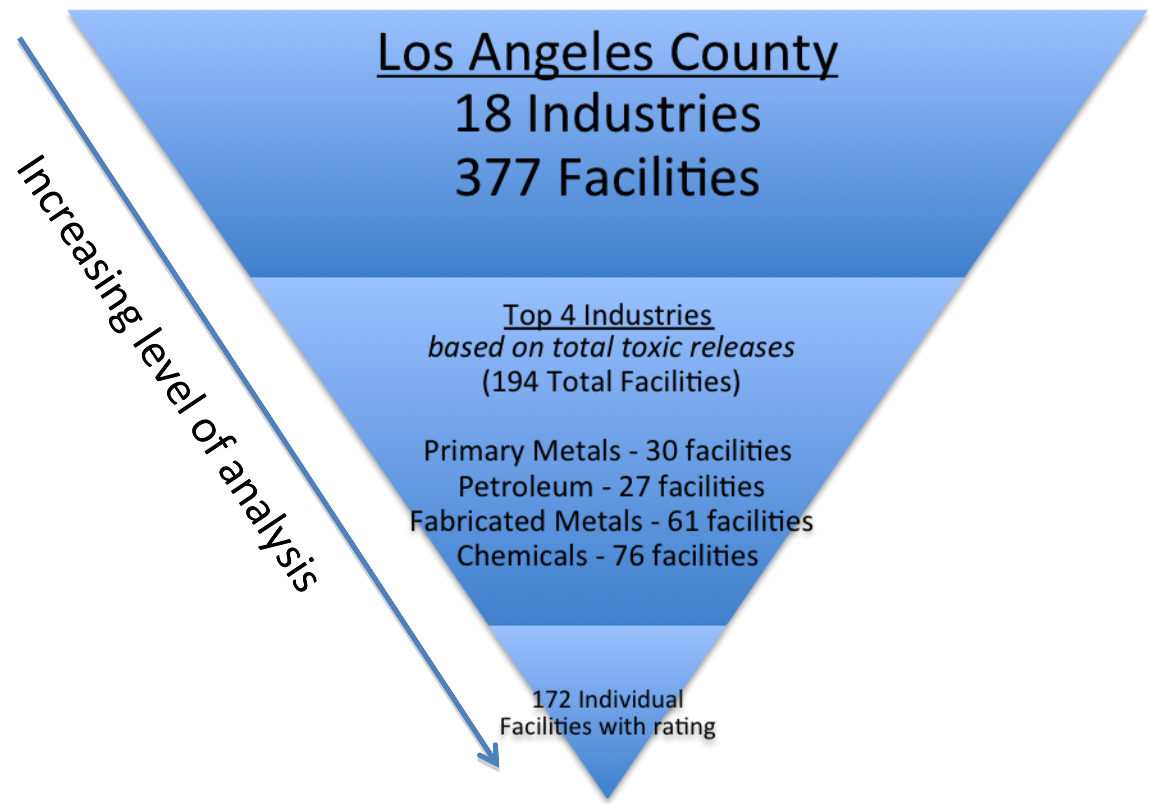

Figure 1 - This project analyzed toxic releases and waste management activities of facilities in the Los Angeles County reporting to the TRI using a top-down approach. Toxic releases and waste management activities were first analyzed for all facilities across the Los Angeles County, then for the top four industries, and finally for individual facilities within those four industries. Of the 194 facilities in the top four industries, only 172 individual facilities had sufficient data to provide ratings.

Within the top four Industries, only 172 out of 194 facilities met the selection criteria for individual environmental impact evaluation and intra-industry analysis. Because facilities within the same industry have more comparable production processes and products, we compare these facilities within their respective industries.

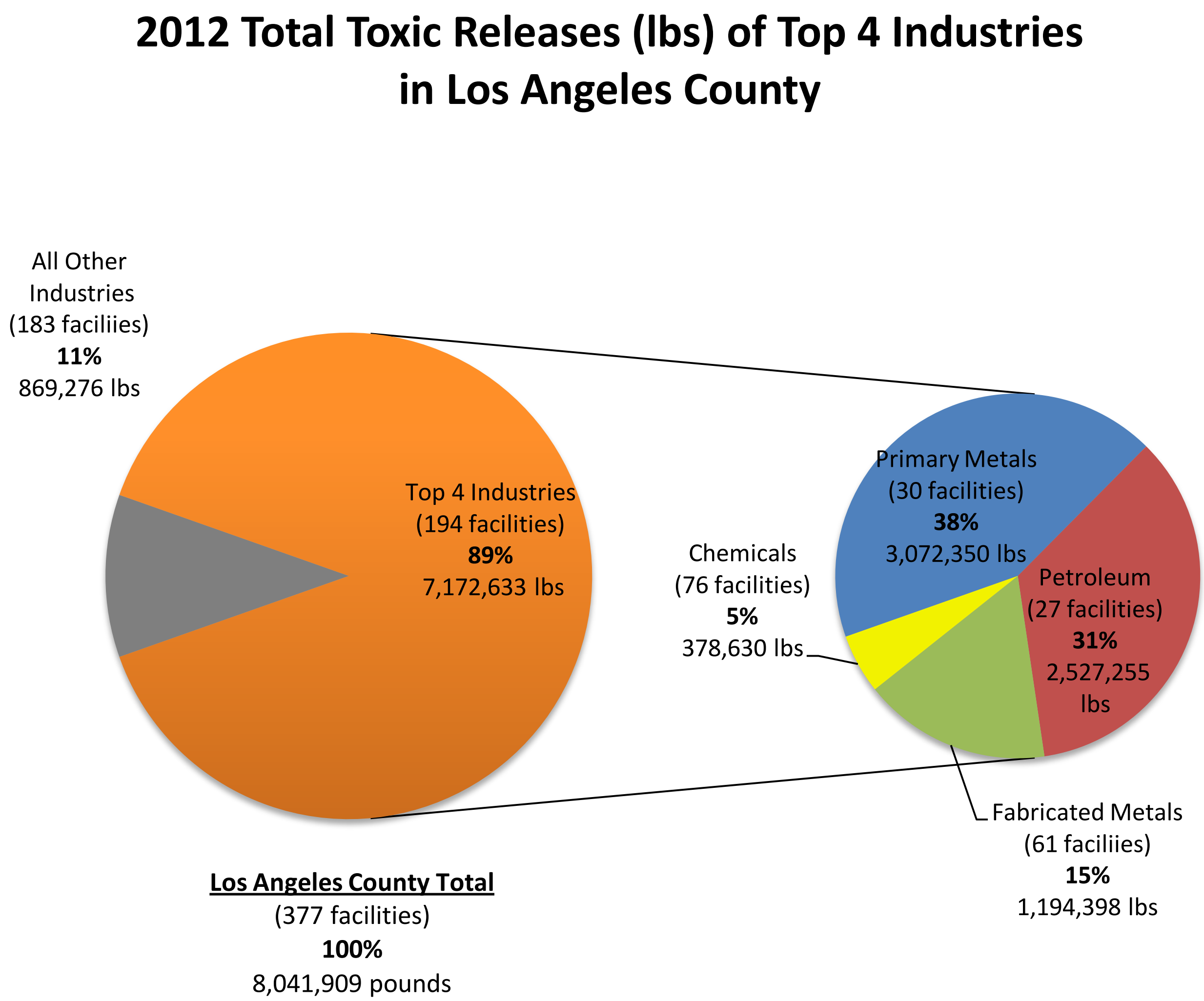

Figure 2 – In 2012, the 377 facilities reporting to the TRI reported 8,041,909 pounds (lbs) of total toxic releases in Los Angeles County. We grouped facilities based on their 3-digit NAICS code and selected the top four industries and facilities within those industries for further analysis because they have the greatest impact on this total. Together, the 194 facilities in the top four industries collectively account for 7,172,633 lbs, or 89% of this total. The figure also shows the following industry-specific values for the Top 4 Industries in 2012: the number of facilities reporting to the TRI, the sum of total toxic releases in pounds (lbs), and the industry's total toxic releases as a calculated percentage of the total releases of Los Angeles County.

4.2 Selection of Variables to determine the *Cal EcoMaps Environmental Impact Score*

The *Cal EcoMaps Environmental Impact Score* (*Cal EcoMaps EIS*) allows facilities that may differ in production scale, manufacturing processes, or the type of chemicals present in emissions to be compared within their respective industries based on a number of variables. We experimented with several variables before selecting five variables or “environmental impact indicators,” which were used to compare the top four industries and to provide intra-industry facility evaluations. Some environmental impact indicators were taken directly from the TRI while others were derived by complementing TRI data with external information such as revenue data. Only 172 out of 194 facilities in the top four Industries had data for all five environmental impact indicators to conduct the analysis. Other variables not used, but considered to determine facility environmental impact are also noted for future research purposes to expand the knowledge of TRI data.

4.2.1 Variables used as Environmental Impact Indicators

Each facility’s *Cal EcoMaps EIS* was based on five environmental impact indicators. *The first four variables* represent negative environmental impact, which should be minimized. The fifth variable represents the facility’s efforts at preventing toxic chemical releases into the environment and should be maximized. A detailed list of variables and their calculations can be found in Appendix A.[4]

1. ***Total Toxic Releases* (lbs)**

To account for the amount of chemicals released into the environment, the *Total Toxic Releases* variable was selected to evaluate facilities because specific toxic releases can have significant environmental and public health effects, especially if they are released in extremely large quantities. This variable includes on- and off-site releases to air, water, land, Class I underground injection wells, Resource Conservation and Recovery Act (RCRA) Subtitle C landfills, other landfills. It excludes toxic releases due to catastrophic, one-time events so that toxic releases related to facility production processes are only considered.

2. ***Toxic Releases per $1000 of Revenue* (lbs/$1000)**

Toxic Releases per $1000 of Revenue represents the facility’s efficiency in generating the least amount of toxic releases for a standardized amount of revenue. For this variable, the facility’s total toxic releases are standardized with respect to $1000 of its annual revenue. This is the first known project to measure a facility’s environmental impact relative to its fiscal performance by

[4] The variable numbers in this report correspond with those found in the Appendix A.

comparing facility pounds of toxic releases with annual revenue. We gathered facility annual revenue data from ReferenceUSA, Hoovers, and Orbis.

3. ***Toxicity of Total Releases*** **(lbs * toxicity)**

Toxicity of Total Releases is provided by the TRI and was used to measure the relative health-related impacts of different facilities. The facility's total toxic releases are multiplied by a specific toxicity factor, specific to each chemical, determined by the EPA's Risk Screening Environmental Indicators (RSEI). Only toxicity of on-site toxic releases were considered for this local analysis of health-related impacts.

4. ***Regional Contribution to Lifetime Cancer Risk from Air Emissions*** **(Number of cancers in one million people exposed in the L.A. Basin over 70 years of exposure due to toxic air emissions by a facility)**

Because *Toxicity of Total Releases* is difficult to comprehend we tried to develop a measure that would be more intuitive for the public. We calculated the facility *Regional Contribution to Lifetime Cancer Risk* to provide a more concrete measure of health-related impacts. Only air releases were considered because inhalation rates could be determined by age and sex to calculate the number of cancers in one million people (*Exposure Factors Handbook*, US EPA). Lifetime cancer was chosen as a health-related impact because it provides an intuitive measure of the disease within a specific population over a long timeframe. Cancer is a disease of environmental exposure and is higher in populations exposed to certain chemicals (*Cancer and the Environment,* National Cancer Institute). This makes cancer easier to calculate over a person's lifetime due to exposure, which would otherwise be more difficult to estimate in other diseases. The TRI provides information about specific chemicals released at certain facilities so carcinogenic chemicals can be analyzed separately from non-carcinogenic chemicals in determining the regional contribution to lifetime cancer risk. Results for this variable are screening-level estimates and suggest that a particular facility may contribute approximately some number of cancers in a million to the overall lifetime risk in the Los Angeles Basin. This estimate does not constitute a risk assessment and should not be used to draw conclusions about individual risk.

5. ***Waste Managed through Recycling, Energy Recovery, and Treatment*** **(lbs)**

This variable represents the facility's efforts at preventing toxic releases into the environment by managing their waste through recycling[5], energy recovery[6], and treatment[7] (*Interpretations*

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[5] *Recycling* is defined as: "(1) the recovery for reuse of a toxic chemical from a gaseous, aerosol, aqueous, liquid, or solid stream; or (2) the reuse, or the recovery for reuse of a toxic chemical that is a Resource Conservation and Recovery Act (RCRA) hazardous waste or is a constituent of a RCRA hazardous waste." (10)

[6] *Energy Recovery* or more specifically, *Combustion for Energy Recovery,* is "the combustion of the toxic chemical that is (1) (i) a RCRA hazardous waste or waste fuel, (ii) a constituent of a RCRA hazardous waste or waste fuel, or (iii) a spent or contaminated "otherwise used" material; and that (2) has a significant heating value (e.g., 5,000 Btu per pound) and is combusted in an 'energy or materials recovery device' (i.e. industrial furnace or boiler)." (4)

of Waste Management Activities: Recycling, Combustion for Energy Recovery, Treatment for Destruction, Waste Stabilization and Release, US EPA). Similar to *Total Toxic Releases*, the quantities managed by these methods exclude catastrophic, one-time events so that values associated with facility production processes are only considered.

4.2.2 Los Angeles County Top 4 Industries Comparison Analysis

NAICS – Industry	Number of Facilities	Sum of Total Toxic Releases (lbs)	Average Total Toxic Releases (lbs)	Average Releases per $1000 of Revenue (lbs/$1000)[8,9]	Average Toxicity of Total Releases (lbs * toxicty)	Average Regional Contribution to Lifetime Cancer Risk Due to Air Emissions (Cancers in 1 million)	Average Percent of Waste Managed through Recycling, Energy Recovery, and Treatment
331 – Primary Metals	**30**	**3,072,350**	**102,411**	**3.32**	**52,228,243**	**465.16, (1.71 without Exide Technologies)[10]**	**88.96%**
331 – Primary Metals	61	3,992,722	65,454	2.25	27,617,641	N/A	88.51%
324 – Petroleum	**27**	**2,527,255**	**93,602**	**8.37**	**8,083,647**	**2.74**	**93.04%**
324 – Petroleum	67	6,067,818	90,564	3.23	12,551,182	N/A	93.14%
332 - Fabricated Metals	**61**	**1,194,348**	**19,580**	**0.80**	**268,556**	**1.85**	**82.60%**
332 - Fabricated Metals	156	1,731,000	11,096	1.22	1,565,375	N/A	89.17%
325 – Chemicals	**76**	**378,630**	**5,186**	**1.41**	**391,235**	**2.99**	**95.52%**
325 – Chemicals	191	1,852,626	9,802	0.53	835,402	N/A	95.29%

7 *Treatment* includes both treatment for destruction and waste stabilization. "Treatment for destruction means the destruction of a toxic chemical in waste such that the substance is no longer the toxic chemical subject to reporting under EPCRA section 313. Treatment for destruction does not include the destruction of a toxic chemical in waste where the toxic chemical has a heat value greater than 5,000 British thermal units and is combusted in any device that is an industrial furnace or boiler [i.e. energy recovery]." (17)

8 LA County averages for this variable are missing revenue data for: 1 facility in Primary Metals, 8 facilities in Petroleum, 3 facilities in Fabricated Metals, 9 facilities in Chemicals, and 59 facilities in other industries.

9 California averages for this variable are missing revenue data for: 5 facilities in Primary Metals, 15 facilities in Petroleum, 33 facilities in Fabricated Metals, and 36 facilities in Chemicals.

10 Exide Technologies contributed 9,270.65 cancers per million, the highest of any facility the Top 4 Industries. It was forced to stop operations in March 2014 by South Coast Air Quality Management District (SCAQMD) for violation of the lead and arsenic air quality standards.

Table 1 – Averages o the five environmental impact indicators for the top 4 industries in Los Angeles County are highlighted in gray. They are shown with California Industry averages (not highlighted).

The top four industries in Los Angeles County were compared using the five *Environmental Impact Indicators*. Intra-industry averages in Los Angeles County and California were determined for each indicator and were used as a reference to compare facilities within each industry. Table 1 shows these averages for the Primary Metals, Petroleum, Fabricated Metals, and Chemicals Industries in Los Angeles County and California.

4.2.2.1 NAICS 331 - Primary Metals Industry

In 2012, the Primary Metal Industry had a total of 30 facilities contributing 3,072,350 lbs or 38% of total toxic releases in Los Angeles County. This made it the top polluting industry with facilities releasing an average of 102,411 lbs. In comparison, all 61 facilities in the Primary Metals Industry in California had a sum of 3,992,722 lbs of total toxic releases and an average of 65,454 lbs. This suggests that the Los Angeles County Primary Metal Industry contributed nearly 77% (3,072,350 lbs / 3,992,722 lbs) of the total toxic releases in the California Primary Metals Industry. Figure 3 shows the 10 facilities in the Primary Metals Industry with highest total toxic releases in 2012 with the Los Angeles and California industry averages.

The Los Angeles County Primary Metals Industry was second-highest after the Petroleum Industry among the top four industries in terms of toxic releases per $1000 of revenue at 3.32 lbs. This was higher than the California industry average at 2.25 lbs.

The average toxicity of total releases for the Primary Metals Industry in Los Angeles County was highest of all industries at 52,228,243 (lbs * toxicity). This was over six times higher than the average toxicity of total releases for the second-highest industry in Los Angeles County, the Petroleum Industry. It was also nearly two times higher than the California industry average.

Correspondingly, the Primary Metals Industry was also highest in regional contribution to lifetime cancer risk due to air emissions at 465.16 average number of cancers in one million. However, this was due to a facility identified as a lead-acid battery recycling plant owned by Exide Technologies (TRIF ID: 90058GNBNC2717S) in the city of Vernon. The plant was forced to stop operations in March 2014 by South Coast Air Quality Management District (SCAQMD) for violation of the lead and arsenic air quality standards [LA Times]. Once removing Exide Technologies, the average number of cancers in one million for the Primary Metals Industry was only 1.71.

At 88.96%, the Los Angeles County industry average for percent of waste managed through recycling, energy recovery, and treatment was second lowest (behind Fabricated Metals). However, this average was close to the California industry average at 88.51%.

Appendix C.1 show the 10 facilities in the Primary Metals Industry with the highest of total toxic releases, toxic releases per $1000 of revenue, toxicity of total releases, regional contribution to lifetime cancer risk due to air emissions, and percent waste managed through recycling, energy recovery, and treatment. Industry averages for California and Los Angeles County are also displayed as a reference.

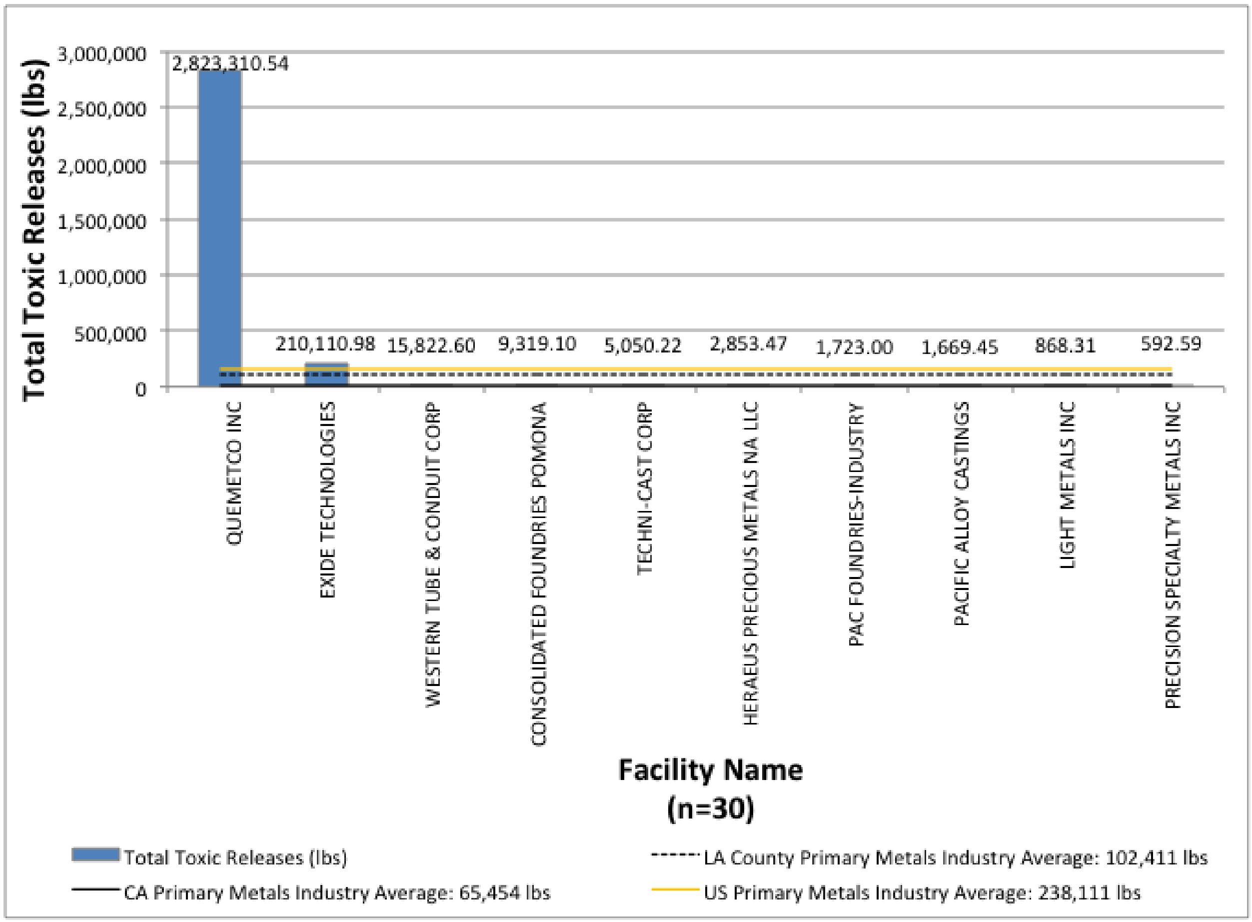


Figure 3 - The 10 Facilities in the Los Angeles County Primary Metals Industry with highest *Total Toxic Releases* in 2012. The Primary Metals Industry in Los Angeles County also had the highest sum and average of Total Toxic Releases.

4.2.2.2 NAICS 324 – Petroleum Industry

In 2012, the Petroleum Industry had 27 facilities contributing 2,527,255 lbs, or 31% of the total toxic releases in Los Angeles County. This made it the second-highest polluting industry. In comparison, all 67 facilities in the Petroleum Industry in California had a sum of 6,067,818 lbs. The Los Angeles County Petroleum Industry average and California average were relatively close with facilities releasing an average of 93,602 lbs and 90,564 lbs, respectively.

The Petroleum Industry in Los Angeles County average releases per $1000 of revenue was highest of all top four industries at 8.37 lbs. The California average in this industry was also highest at 3.23 lbs. Figure 4 shows the 10 facilities in the Petroleum Industry with the highest toxic releases per $1000 of revenue in 2012 with the Los Angeles and California industry averages.

At 8,038,647 (lbs * toxicity), the average toxicity of total releases for the Petroleum Industry in Los Angeles County was second-highest of all top four industries. This was nearly 30 times higher than the average of the next highest industry, Fabricated Metals. However, the Los Angeles County average was lower than the California industry average at 12,551,182 (lbs * toxicity). The Petroleum Industry was also second lowest in regional contribution to lifetime cancer risk due to air emissions behind Fabricated Metals at 2.74 average number of cancers in one million.

The industry average for percent of waste managed through recycling, energy recovery, and treatment was second highest at 93.04% behind the Chemicals Industry. This was close to the California industry average at 93.14%.

Appendix C.2 show the 10 facilities in the Petroleum Industry with the highest total toxic releases, toxic releases per $1000 of revenue, toxicity of total releases, regional contribution to lifetime cancer risk due to air emissions, and percent waste managed through recycling, energy recovery, and treatment. Industry averages for California and Los Angeles County are also displayed as a reference.

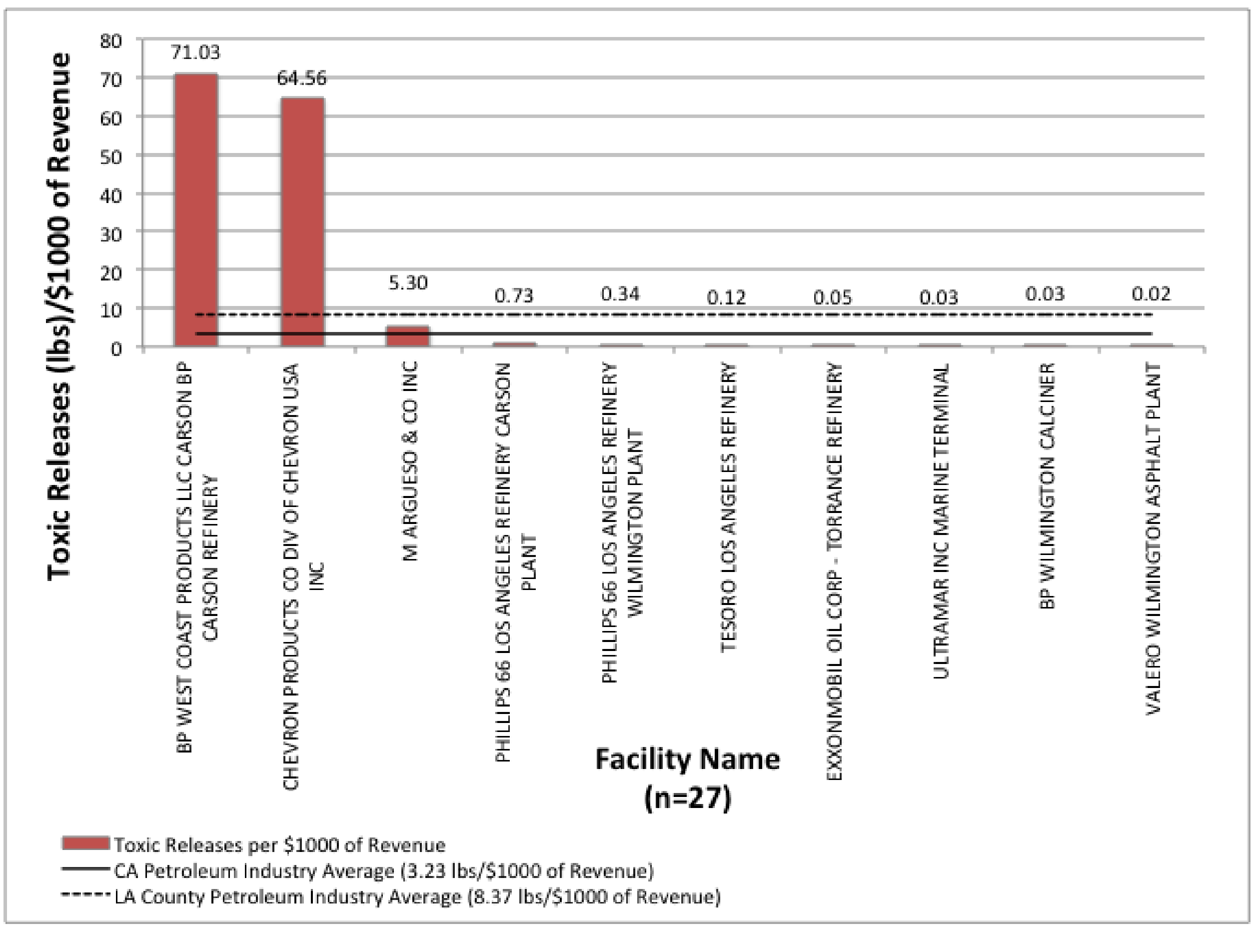


Figure 4 – The 10 Facilities in the Los Angeles County Petroleum Industry with highest *Toxic Releases per $1000 of Revenue* in 2012. The Petroleum Industry in Los Angeles County also had the highest average of Toxic Releases per $1000 of Revenue.

4.2.2.3 NAICS 332 – Fabricated Metals

The 61 facilities in the Fabricated Metals Industry in 2012 rank third highest (or second lowest) among the Top Four Industries in Los Angeles County in terms of total toxic releases at 1,194,398 pounds, accounting for 15% of the Los Angeles County total. In comparison, the 156 facilities in the California industry had a sum of 1,731,000 lbs of total toxic releases with an average of 11,096 lbs. This suggests that the Los Angeles County Fabricated Metals Industry contributes nearly 70% (1,194,398 lbs / 1,731,000 lbs) of the total toxic releases in the California Fabricated Metals Industry.

The average releases per $1000 revenue for the Fabricated Metals Industry in Los Angeles County was lowest at 0.80 lbs. In comparison, the California average for this industry was 1.22 lbs. Figure 5 shows the 10 facilities with highest releases per $1000 revenue for the Fabricated Metals Industry in 2012.

At 268,556 (lbs * toxicity), the Fabricated Metals Industry had the lowest average toxicity of total releases among the Top 4 Industries in Los Angeles County. Correspondingly, it had the lowest average regional contribution to lifetime cancer risk due to air emissions (excluding Primary Metals without Exide Technologies) at 1.85 cancers in one million. Figure 6 shows the 10 Facilities in the Fabricated Metals Industry of Los Angeles County with the highest regional contribution to lifetime cancer risk due to air emissions in 2012 with Los Angeles and California industry averages.

The Fabricated Metals Industry in Los Angeles County on average managed 82.60% of its waste through recycling, energy recovery, and treatment compared to the California industry average at 89.17%.

Appendix C.3 show the 10 facilities in the Fabricated Metals Industry with the highest total toxic releases, toxic releases per $1000 of revenue, regional contribution to lifetime cancer risk due to air emissions, and percent waste managed through recycling, energy recovery, and treatment. Industry averages for California and Los Angeles County are also displayed as a reference.

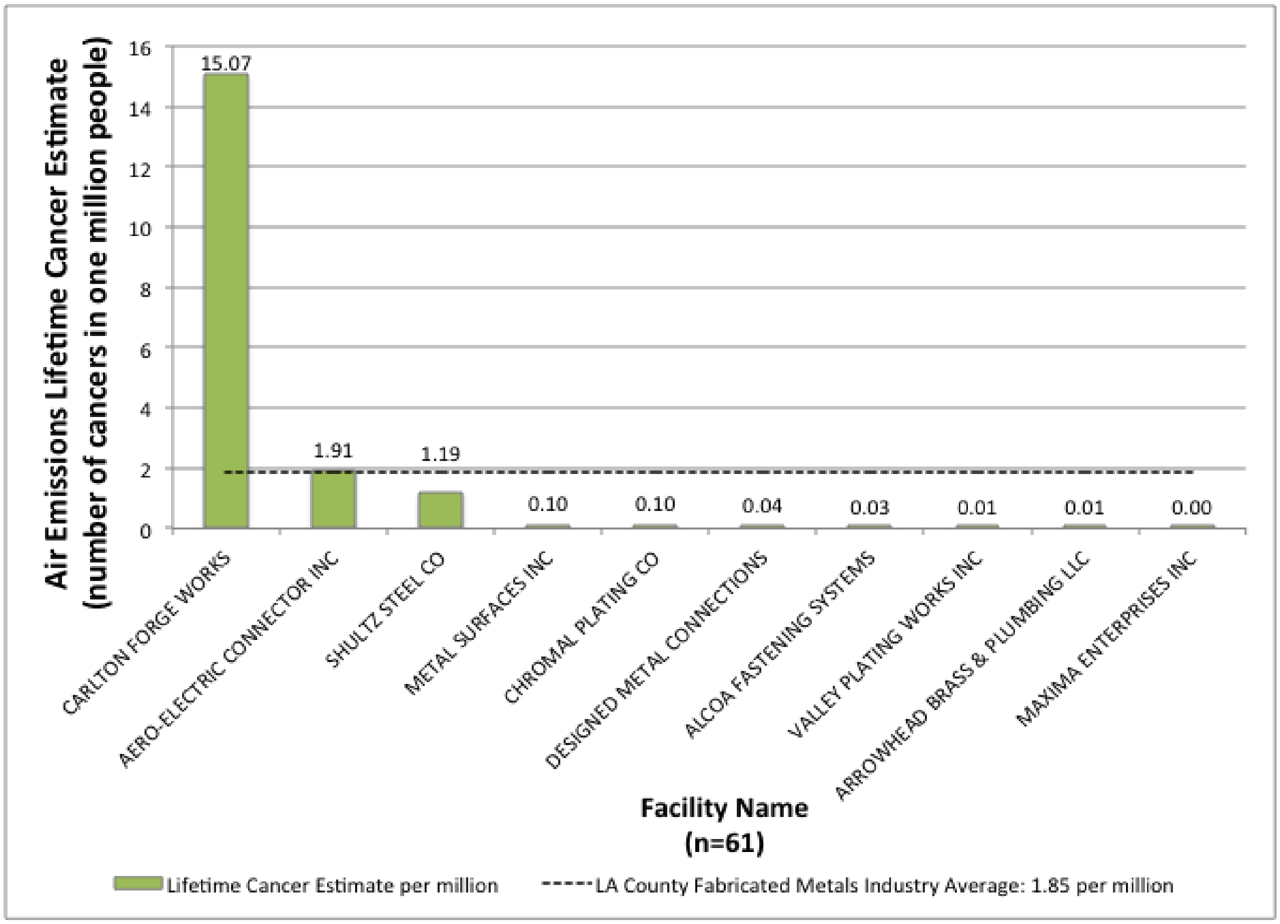


Figure 5 - The 10 Facilities in the Los Angeles County Petroleum Industry with highest *Regional Contribution to the Lifetime Cancer Risk due to Air Emissions* in 2012. The Fabricated Metals Industry in Los Angeles County also had the lowest average of *Regional Contribution to the Lifetime Cancer Risk due to Air Emissions.*

4.2.2.4 NAICS 325 – Chemicals

Of the top four industries in 2012, the Chemicals Industry accounts for the least amount of toxic releases, 378,630 pounds or 5% of all releases in Los Angeles County. The 76 facilities in Los Angeles County generate an average of 5,186 pounds of toxic releases. This is in comparison to the 191 facilities in the California Chemicals Industry who released a sum of 1,852,626 lbs, or an average of 9,802 lbs of toxic chemicals into the environment.

The average releases per $1000 of revenue for the Chemicals Industry in Los Angeles County was the second lowest of the top four industries at 1.41 lbs. The California industry was nearly three times lower at 0.53 lbs.

The average toxicity of total releases for the Chemicals Industry was also second lowest at 391,235 (lbs * toxicity), but the California Chemicals Industry average was lowest at 835,402 (lbs*toxicity). However, the average regional contribution to lifetime cancer risk due to air emissions was highest at nearly 3 cancers per million in the Los Angeles County Chemicals Industry (excluding Primary Metals without Exide Technologies). This suggests the Chemicals Industry release more carcinogenic chemicals into the environment.

The Chemicals Industry in Los Angeles County and California had the highest percent of waste managed through recycling, energy recovery, and treatment among the Top 4 Industries at 95.52% and 95.29%, respectively. Figure 6 shows the 10 Facilities in the Chemicals Industry with the highest percent of waste managed through recycling, energy recovery, and treatment in 2012 with Los Angeles and California industry averages.

Appendix C.4 show the 10 facilities in the Chemicals Industry with the highest total toxic releases, toxic releases per $1000 of revenue, regional contribution to lifetime cancer risk due to air emissions, and percent waste managed through recycling, energy recovery, and treatment. Industry averages for California and Los Angeles County are also displayed as a reference**.**

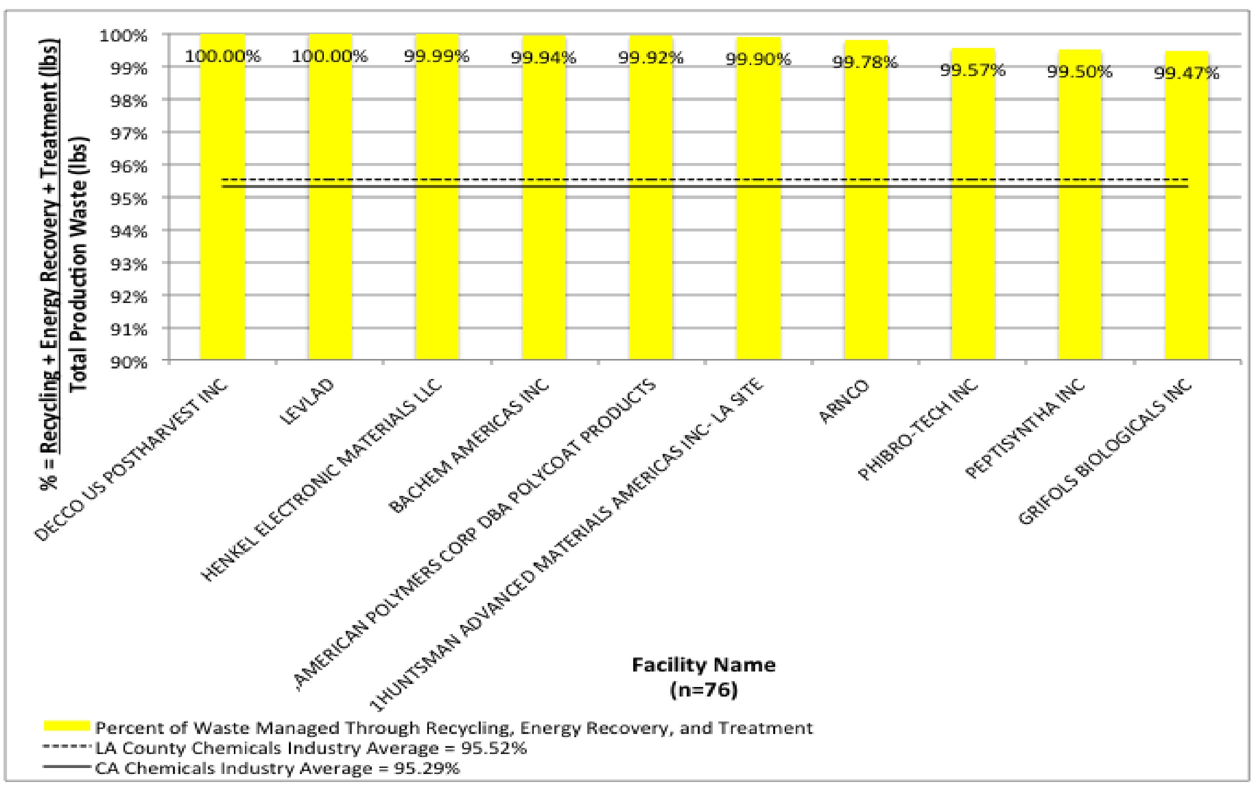


Figure 6 - The 10 Facilities in the Los Angeles County Chemicals Industry with highest Percent of Waste Managed Through Recycling, Energy Recovery, and Treatment in 2012. The Chemicals Industry in Los Angeles County also had the highest average of Percent of Waste Managed Through Recycling, Energy Recovery, and Treatment.

4.2.3 Calculations for Considered Variables

The following section provides calculations for all variables considered in determining facility environmental impact ratings. When multiple variables were considered, justifications are provided for choosing variables as *Environmental Impact Indicators*.

1. *Total Toxic Releases*

To account for the amount of toxic chemicals released, the *Total Toxic Releases* variable was used to evaluate facilities because specific toxic releases can have significant environmental and public health effects, especially if they are released in extremely large quantities. This variable includes on- and off-site releases to air, water, land, Class I underground injection wells, Resource Conservation and Recovery Act (RCRA) Subtitle C landfills, other landfills (*Toxic Release Inventory Basic Data File Format Documentation*, US EPA). It excludes toxic releases due to catastrophic, one-time events so that toxic releases related to facility production processes are only considered (*TRI Search User Guide*, US EPA).

Total Toxic Releases was used to determine key emitting industries and facilities and more specifically, the top 4 Industries in Los Angeles County. Using this variable, we compared each facility's total toxic releases to the intra-industry averages across Los Angeles County, California, and the United States in order to determine the facility's emissions relative to their peers within the same industry.

Under Section 8 of Form R, "Source Reduction and Recycling Activities/ Pollution Prevention," the TRI provides the total amount of on- and off-site releases in units of pounds of emissions (*Toxic Chemical Release Inventory Reporting Forms and Instructions*, US EPA). This value is reported under Section 8.1 and is the summation of the following subcategories:

- (8.1a) Total on-site disposal to Class I Underground Injection Wells, RCRA Subtitle C landfills, and other landfills,
- (8.1b) Total other on-site disposal or other releases,
- (8.1c) Total off-site disposal to Class I Underground Injection Wells, RCRA Subtitle C landfills, and other landfills, and
- (8.1d) Total other off-site disposal or other releases.

Each facility's *Total Toxic Releases* between 2010 and 2012 is displayed as a reference on *Cal EcoMaps*. We also applied *Total Toxic Releases* in other variables including Toxic Releases per $1000 of Revenue and Toxic Releases per Employee.

Database Variable Name From Database	**Calculation**	**Units**
TRI.NET 8.1 Total On- and Off- Site Releases	**Provided by TRI.NET**	**Pounds (lbs)**

Table 2 – Variable database and calculations for *Total Toxic Releases*, an environmental impact indicator

1a) *Share of Total Toxic Releases in Respective Industry in Los Angeles County*

We developed this measure in order to assess each facility's contributing share of toxic releases within its respective industry. A facility's share is calculated as the percentage of its total releases out of the sum of total releases for all facilities in the same industry within Los Angeles County. We intentionally calculated the facility's percentage within its respective industry in Los Angeles County to ensure that this calculated percentage is comparable across similar facilities. For example, the share of total toxic releases for a facility in the petroleum industry was determined by the sum of total toxic releases in the petroleum industry, or 2,527,255 lbs. Table 1 (page 11) shows the Sum of Total Toxic Releases of the top four industries that was used as the denominator to calculate this percentage.

Although it was not used to determine facility environmental impact scores, each facility's share of industry total toxic releases is displayed for reference on *Cal EcoMaps*.

Database Variable Name From Database	**Calculation**	**Units**
TRI.NET 8.1 Total On- and Off- Site Releases	$\frac{\textbf{Individual Facility's Total Toxic Releases (lbs)}}{\textbf{Sum of Total Toxic Releases for all facilities within respective industry in Los Angeles County (lbs)}}$	**% = lbs/lbs**

<u>Table 3</u> – Variable database and calculations for *Facility Contributing Share of Industry Total Toxic Releases*

2. *Toxic Releases per $1000 of Revenue*

Revenue data is often difficult to gather, but with the use of several databases we were able to compile this information for a majority of the facilities in Los Angeles County to determine the *Toxic Releases per $1000 of Revenue* variable. This variable is a standardized value of the facility's total toxic releases with respect to $1000 of its annual revenue. Standardization was done to control for facility size and production scale for comparison within industries. By measuring the facility's environmental impact relative to its economic performance, this variable can serve as a measure of a facility's efficiency.

For our analysis, facility efficiency is generally defined as a facility's ability to reduce its inputs relative to its outputs. In this case, facility efficiency is determined by minimizing the facility's total toxic releases while maximizing its annual revenue. Thus, the *Toxic Releases per $1000 of Revenue* variable can be used as a measure of facility efficiency. Facilities that are more efficient will have fewer toxic releases per $1000 of revenue as compared to less efficient facilities with more toxic releases per $1000 of revenue. This standardized variable allows for comparison of facilities within the same industry, as well as facilities across different industries.

Our primary source of facility revenue data was ReferenceUSA. This database provides extensive information on 24 million businesses across the United States and we are confident that revenue data compiled by ReferenceUSA accurately reflects the facility's annual revenue. ReferenceUSA employs over 700 data specialists to verify that the most accurate data is published. Utilizing over 5,000 public resources and 26,000,000 annual phone calls to build its database, it is the most comprehensive and reliable database of its kind available. If revenue data was not available through ReferenceUSA, then Hoover's and Orbis were used in that order to determine facility annual revenue.

Although ReferenceUSA provides two revenue values, "Location Sales Volume," and "Corporate Sales Volume," only "Location Sales Volume" for a particular facility was used to ensure that values reflected facility-level annual revenue. At the time of data compilation, ReferenceUSA was most recently updated in 2013 so we assumed that reported values reflected 2012 annual revenue. Where revenue data is provided as a range, we selected the highest range value as a "best-case scenario" measure of annual revenue.

ReferenceUSA allows for the filtering and sorting of facilities based on a variety of selection criteria, including name and address. Facility addresses from the TRI were used to find facility revenue data through ReferenceUSA. If both ReferenceUSA and TRI.NET displayed the same facility address but under different facility names, then we assumed that it was the same facility. We confirmed this assumption by entering the addresses into a search engine (i.e. Google) to be certain that facility names had been altered due to changes in reporting and that the facilities were in fact the same facilities based on their address.

When "Location Sales Volume" on ReferenceUSA was not available, we used Hoover's, a subsidiary of Dun & Bradstreet (D&B). Hoover's collects data similar to ReferenceUSA by first researching and contacting the company. Otherwise, it calculates facility revenue estimates using D&B's statistical models and mathematical formulas, which require the following criteria: being in a single location, having an Standard Industrial Classification (SIC) code, and providing an employee count. The D&B formula for creating these estimated values involves grouping facilities with similar characteristics to evaluate predictability. Trends are identified and then used in models to create informed estimates for revenue. If revenue cannot be found by contacting the facility or through D&B estimation models, then this information is not listed on the Hoover's website.

In the case that ReferenceUSA and Hoover's did not provide enough information, Orbis was used. The information on Orbis is direct from the Bureau van Dijk Ownership Database, which includes data that is gathered by a team of specialized researchers working in the Bureau's office in Brussels.

For facilities with annual revenue values, *Toxic Releases per $1000 of Revenue* is displayed on *Cal EcoMaps* as a reference. Production ratio and toxic releases per employee were other variables that were considered to control for the facility's size and production scale. Appendix B discusses these variables.

Database Variable Name From Database	**Calculation**	**Units**
TRI.NET 8.1 Total On- and Off- Site Releases **ReferenceUSA** Location Sales Volume **Hoovers** Revenue **Orbis** Revenue	$\frac{\textit{Total Toxic Releases}}{\frac{\textit{Annual Revenue}}{\$1000}}$	**lbs / $1000**

Table 4 – Variable database and calculations for *Toxic Releases per $1000 of Revenue*, an environmental impact indicator

3. *Toxicity of Total Releases*

In order to account for the level of toxicity of chemicals released, the *Toxicity of Total Releases* variable is used as a measure of toxicity to compare health-related impacts between different facilities. It is provided by the TRI and measured using the facility's toxic releases, in pounds, multiplied by a specific toxicity factor as determined by the EPA's Risk Screening Environmental Indicators (RSEI) model for each chemical released. The toxicity factor was calculated using the RSEI model for both carcinogenic and noncarcinogenic health impacts through oral and inhalation routes. The two major caveats of this variable are that if reported releases were grouped under a chemical category rather than a specific chemical, the most toxic chemical was used and for chemicals without toxicity data, experts extrapolated their toxicity relative to other chemicals. Though this variable is rather holistic, its unitless nature means it can only be communicated as a relative measure of health-related impacts. Given that our results are on a facility-level, we calculated stand-alone values under the *Regional Contribution to Lifetime Cancer Risk from Air Emissions* variable*.* The *Toxicity of Total Releases* variable was still useful in the calculation of a facility score as it considers many additional facets to a facility's toxicity, including noncarcinogenic risk and toxicity of water and land releases.

Database Variable Name From Database	**Calculation**	**Units**
TRI.NET Total On-Site Releases (Toxicity x Pounds)	**Provided by TRI.NET**	**Toxicity * Pounds**

<u>Table 5</u> – Variable database and calculations for *Toxicity of Total Releases*, an environmental impact indicator

4. *Regional Contribution to Lifetime Cancer Risk from Air Emissions*

We calculated the facility's *Regional Contribution to Lifetime Cancer Risk from Air Emissions* to communicate a concrete measure of toxicity that is provided by the *Toxicity of Air Releases* variable from the TRI. The goal of this health risk indicator is to factor in how toxic releases from a point source affect nearby populations. The most tangible units to communicate this indicator is through a cancer risk as opposed to unitless toxicity scores that EPA's TRI and RSEI already provide.

The TRI's variables with the units "lbs x toxicity" is calculated by the release variables in pounds multiplied by a toxicity factor for every chemical released. This toxicity factor only has a relative significance with it being based on the toxic magnitude of the chemical compared to others. This standardized unit allows for the variable to be combined into a single value for each facility rather than broken out by chemical. The main problem with this value is that there is no information on what the toxicity threshold is for residents to identify the health risk of living in close proximity to a facility.

EPA's RSEI tool provides a thorough risk screening methodology that takes into account the fate and transport of pollutants within the environment. The calculations also take into account nearby population demographics, stack height and stack exit velocity. The result is given as a health risk score for each facility. Again, the value is unitless and only significant relatively when comparing multiple facilities. This makes it difficult for use on a facility-level, which is the granularity of our analysis and results.

Our method involves very conservative assumptions and the use of public data to estimate the contribution of a facility's air releases to the overall cancer risk of the Los Angeles Basin, which includes Los Angeles County, San Bernardino County, Orange County, and Riverside County (*About South Coast AQMD,* SCAQMD). The goal of this method is to have a tangible value with a number for the cancers per million people exposed. In order to systematically calculate the cancer risk contribution, each chemical had to be standardized so that the pounds of releases could be converted on a facility-level to a cancer risk. To achieve this, benzene was selected as it is a well-studied carcinogen and assigned a toxic equivalency potential (TEP) of 1 (*Cancer Risk Scores*, Scorecard). Using the Office of Environmental Health Hazards Assessment's (OEHHA) TEP database and RSEI (*Risk Scoring System,* Scorecard), the toxic releases from pounds of a given chemical were converted to pounds of benzene-equivalents.

$$(1)\ TEP\ of\ Chemical = \frac{Pounds\ of\ Released\ Chemical}{Pounds\ of\ Benzene\ for\ same\ relative\ human\ health\ risk}$$

The value in terms of pounds of benzene-equivalents was then converted into a cancer risk by evaluating the amount of benzene in pounds that gives a one in a million cancer risk. The following EPA cancer risk equation was used (*Cancer Risk Calculations,* US EPA):

$$(2.1)\ \begin{matrix} Cancer \\ Risk \end{matrix} = \frac{Chem. Conc. \times Intake\ Rate \times Exposure\ Freq. \times Duration \times Potency}{Body\ Weight\ \times\ Averaging\ Time}$$

First the intake rate and body weight variables are substituted for inhalation rate since EPA provides rates for different age-sex categories in Table 9. An average inhalation rate based on Los Angeles County population distribution from the 2010 US Census was determined to be 0.229 (m^3/kg/day) for any given resident of LA County.

Age-Sex Category	Inhalation Rate (m^3/kg/day)
Male 0 to 17	0.315
Male 18 to 44	0.185
Male 45 to 64	0.173
Male 65 and up	0.159
Female 0 to 17	0.332
Female 18 to 44	0.217
Female 45 to 64	0.201
Female 65 and up	0.187

Table 6 - Exposure Factors for Air Releases[1]

$$(3)\ Inhaltion\ Rate\ (from\ RSEI) = \frac{Intake\ Rate}{Body\ Weight}$$

$$(2.2)\ \frac{Chem.}{Conc.} = \frac{Cancer\ Risk \times Averaging\ Time}{Potency\ Factor \times Inhalation\ Rate \times Exposure\ Freq. \times Duration}$$

$$(2.3)\ Pounds = (Equation\ 1.2)\ \times\ Area\ \times\ Inversion\ Layer\ Height$$

The units for Equation 2.3 are:

$$(2.4)\ lbs = \frac{(1e\text{–}6)\ \times\ day\ \times\ m^2\ \times\ m\ \times\ \frac{lbs}{mg}}{\left(\frac{day \times kg}{mg}\right) \times \left(\frac{\mathrm{m}^3}{kg \times day}\right) \times \left(\frac{day}{yr}\right) \times yr}$$

The following values were used as given:

- *Cancer Risk* = 1 cancer in a million exposed = $1*10^{-6}$
- *Averaging Time* = 70 years for a lifetime assessment = 25,550 days
- *Potency Factor* = 0.054 $(mg/kg*day)^{-1}$ for benzene (*Benzene,* OEHHA).
- *Inhalation Rate* = 0.229 (m^3/kg/day) (*Environmental Factors Handbook*, US EPA).
- *Exposure Frequency* = 365 days/year for local residents
- *Exposure Duration* = 70 years for a lifetime assessment (*Cancer Risk Calculations,* US EPA).
- *Area* = 2,467,843 m^2 for the LA Basin (Mayuga, 160).
- *Inversion Layer Height* = 10.0584 m for the LA Basin (Beer and Leopold, 173).
- *Weight Conversion* = 0.000002204 lbs/mg

The major assumption made is that the Los Angeles Basin is a well-mixed rectangular volume in a constant state of inversion. The LA Basin area was used as it retains air pollution due to the surrounding mountains and land-sea breeze. The inversion layer height was recommended to form the volume by UCLA Professor Dr. Yifang Zhu as the LA Basin tends to be in a state of inversion due to high air temperatures. The well-mixed assumption means that the dispersal of the pollutant is immediate upon release and remains equal over 70 years of air releases across the LA Basin. The use of current data for a lifetime risk assessment inherently assumes that the 2012 TRI emissions are constant over the 70-year period and the 2010 demographics are relevant for the next 70 years in LA County. As seen with the aforementioned given values, the longest period and largest area was selected for analysis making this a very conservative estimate.

Using Equation 2.3, it was determined that the release of 348 pounds of benzene in the LA Basin gives a one in a million lifetime cancer risk for residents of Los Angeles County. This value was then used to convert a facility's air releases in pounds of benzene-equivalents to a one in a million lifetime cancer risk using Equation 4.

$$(4)\ \begin{matrix} Facility's\ Regional\ Contribution\ to \\ Lifetime\ Cancer\ Risk\ from\ Air\ Emissions \end{matrix} = \frac{\text{"Total On–Site Air Releases"}\ \textit{lbs benzene}}{348\ lbs\ benzene/10^{-6}\ cancer\ risk}$$

The resulting variable titled "Facility's Regional Contribution to Lifetime Cancer Risk from Air Emissions" represents the number of cancers in one million people exposed in the Los Angeles Basin over 70 years of exposure due to toxic air emissions by a facility. It can be used to evaluate the facility's contribution to regional cancer risk in the LA Basin, but does not infer any individual risk on a local-level. This provides a useful metric of a facility's health impact without using a health risk assessment while still using units that are easy to communicate. This estimate does not constitute a risk assessment and should not be used to draw conclusions about individual risk. The cancer risk also does not consider exposure to carcinogens in water or land releases.

Using this methodology, the calculated cancer risk for the top four industries in LA County ranged from 0 to 9,270.65 cancers in a million exposed to a lifetime of a facility's air emissions. On average the cancer risk was 48.71 cancers in a million exposed with the one maximum facility being a major outlier. Without this facility the mean drops to 0.93 cancers in a million exposed. This facility was identified as a lead-acid battery recycling plant owned by Exide Technologies (TRIF ID: 90058GNBNC2717S) in the city of Vernon. The plant was forced to stop operations in March 2014 by South Coast Air Quality Management District (SCAQMD) for violation of the lead and arsenic air quality standards (LA Times). All other facilities had cancer risk contribution values that made sense in the context of the regional cancer risk values evaluated by SCAQMD for the LA Air Basin in their 2008 Multiple Air Toxics Exposure Study (MATES) III.

Database Variable Name From Database	**Calculation**	**Units**
TRI.NET Total On-Site Air Releases **Office of Environmental Health Hazards Assessment (OEHHA)** Toxic Equivalency Potential **Risk Screening Environmental Indicators (RSEI)** Inhalation Rates by Sex and Age **American Geophysical Union** Los Angeles Basin dimensions **US Census** LA County Population Count by Sex and Age	$Facility's\ Regional\ Contribution\ to\ Lifetime\ Cancer\ Risk\ from\ Air\ Emissions = \frac{\text{"Total On–Site Air Releases"}\ lbs\ benzene}{348\ lbs\ benzene/10^{-6}\ cancer\ risk}$ *Note: Detailed calculations can be found below in Regional Contribution to Lifetime Cancer Risk from Air Emissions Methodology*	Conversion of facility's air emissions to cancers in a million exposed in LA County over 70 years

Table 7 – Variable database and calculations for *Regional Contribution to Lifetime Cancer Risk from Air Emissions*, an environmental impact indicator

5. *Waste Managed Through Recycling, Energy Recovery, and Treatment*

In order to account for the facility's mitigation strategies at managing toxic waste, we calculated the *Waste Managed Through Recycling, Energy Recovery, and Treatment* variable. While pollution should be prevented at the source, preferred waste management activities can reduce the total amount of toxic chemicals released directly into the environment. Under EPA's Waste Management Hierarchy, preferred waste management activities are preferentially ranked based on the most environmentally sound ways to reduce pollution and toxic releases (*TRI's Pollution Prevention (PS) Data*, US EPA). These activities are listed from most to least preferred by EPA: recycling, energy recovery, and treatment.

Database Variable Name From Database	**Calculation**	**Units**
TRI.NET Energy Recovery, Recycling, Treatment: • Total Energy Recovery (lbs) = 8.2 Energy Recovery On-Site (lbs) + 8.3 Energy Recovery Off-Site (lbs) • Total Recycling = 8.4 Recycling On-Site (lbs) + 8.5 Recycling Off-Site (lbs) • Total Treatment = 8.6 Treatment On-Site (lbs) + 8.7 Treatment Off-Site (lbs)	**Provided by TRI.NET**	**Pounds (lbs)**

Table 8 – Variable database and calculations for *Waste Managed Through Recycling, Energy Recovery, and Treatment*, an environmental impact indicator

5a. *Percent Waste Managed Through Recycling, Energy Recovery, and Treatment*

We also calculated the *Percent of Waste Managed Through Recycling, Energy Recovery, and Treatment* variable to determine the extent of the facility's efforts at managing toxic chemicals and preventing direct releases into the environment. However, it was not used to calculate environmental impact scores because many facilities had similar percentages even though their total waste managed through these activities were completely different. Although this percentage was not used to determine facility environmental impact scores, each facility's percent waste managed through recycling, energy recovery, and treatment between 2010 and 2012 are displayed as a reference on *Cal EcoMaps* to communicate the facility's efforts at managing toxic chemical waste.

This variable is defined by the facility's sum of energy recovery, recycling, and treatment (sum of quantities in Form R Section 8.2 - 8.7) as a calculated percentage of the facility's Total Production-related Waste Managed (Form R Section 8.1 - 8.7). A value of 100% means that the facility manages 100% or all of its waste, while 0% means that the facility manages none of its waste. For the purposes of our analysis, if facility-reported values for Releases and Total Production-related Waste Managed are both 0 (0/0), then the facility is automatically assigned 100% for this variable. This is to account for the fact that the facility is not producing any waste and hence, preventing pollution at the source.

Database Variable Name From Database	**Calculation**	**Units**
TRI.NET Energy Recovery, Recycling, Treatment: • Total Energy Recovery (lbs) = 8.2 Energy Recovery On-Site (lbs) + 8.3 Energy Recovery Off-Site (lbs) • Total Recycling = 8.4 Recycling On-Site (lbs) + 8.5 Recycling Off-Site (lbs) • Total Treatment = 8.6 Treatment On-Site (lbs) + 8.7 Treatment Off-Site (lbs) Total Production-related Waste Managed: • Sum of Releases, Energy Recovery, Recycling, Treatment (Sections 8.1-8.7)	$\frac{Energy\ Recovery\ (lbs) + Recycling(lbs) + Treatment(lbs)}{Total\ Production - related\ Waste\ (lbs)}$ = $\frac{Sections: 8.2 + 8.3 + 8.4 + 8.5 + 8.6 + 8.7}{Sections: 8.1 + 8.2 + 8.3 + 8.4 + 8.5 + 8.6 + 8.7}$	**% = lbs/lbs**

Table 9 – Variable database and calculations for *Percent Waste Managed Through Recycling, Energy Recovery, and Treatment*

4.3 Rating Facility Environmental Impact

Based on the five Environmental Impact Indicators, 172 facilities in the top four industries had sufficient data to assign facility environmental impact ratings. In our first attempt, we used Data Envelopment Analysis (DEA) to assign scores because of its robust methodology in determining facility efficiency for multiple inputs and outputs. However, due to the sensitivity and limitations of DEA, facility environmental impact scores were determined using percentile rank scores instead. Although DEA was not used, DEA methodologies are detailed in Appendix D as a reference for future research purposes.

4.3.1 *Cal EcoMaps Environmental Impact Score*

The *Cal EcoMaps Environmental Impact Score* (*Cal EcoMaps EIS*) was determined by the facility's percentile rank in each of the five environmental impact indicator categories within its respective industry. This percentile rank methodology was adapted from the methodologies used by OEHHA's CalEnviroScreen Version 2.0 in determining CalEnviro Score (*Draft California Communities Environmental Health Screening Tool*, OEHHA). Facilities with lower environmental impact scores are considered to have less impact on the environment and public health and are thus, better performers than their counterparts with higher environmental impact scores.

For each environmental impact indicator, facilities received scores between 0 and 100 based on their percentile rank. Because we wanted to minimize input variables (i.e. *Total Toxic Releases*, *Toxic Releases per $1000 of Revenue, Toxicity of Total Releases*, and *Regional Contribution to Lifetime Cancer Risk due to Air Emissions)*, facilities with lower percentile rank scores were better performers. Conversely, because we wanted to maximize variable (i.e. *Waste Managed Through Recycling, Energy Recovery, and Treatment)*, facilities with higher percentile rank scores were better performers. In order to aggregate the percentile rank scores of all five environmental impact indicators, all percentile score values had to be in the same direction such that facilities with lower scores are better performers. For that reason, we reversed the percentile scores for output variables by subtracting them from 100.

Facility percentile rank scores for each of the five environmental impact indicators were then aggregated with the highest possible total score being 500 (i.e. 100 for each environmental performance indicator). This aggregated score was then divided by 5 so that the *Cal EcoMaps Environmental Impact Score* is on a scale of 100 as opposed to 500. Table 10 shows a sample calculation of a facility's environmental impact score based on its percentile rank in each environmental impact indicator.

A. Total Toxic Releases Percentile	B. Toxic Releases per $1000 of Revenue Percentile	C. Toxicity of Total Releases Percentile	D. Regional Contribution to Lifetime Cancer Risk due to Air Emissions Percentile	E. Waste Managed Through Recycling, Energy Recovery, and Treatment Percentile	F. Waste Managed Through Recycling, Energy Recovery, and Treatment Reversed Percentile	G. Score Out of 500 (A+B+C+D+F)	***Cal EcoMaps* Environmental Impact Score (Out of 100) (G/5)**

Table 10 – Example of *Cal EcoMaps* Environmental *Impact Score* calculation based on percentile rank of each environmental performance indicator.

5. RESULTS

In order to best communicate our results with the public, facilities, and other stakeholders, we created the website, *Cal EcoMaps*. In *Cal EcoMaps*, the name *Cal* is used in reference to California. *EcoMaps* is used to highlight the ecological and economic information that is available for each mapped facility. See Appendix E for more information on how to use the map applet on the *Cal EcoMaps* website at: http://www.environment.ucla.edu/ccep/calecomaps

5.1 *Cal EcoMaps Environmental Impact Score* by Industry

The *Cal EcoMaps Environmental Impact Score* for the 172 facilities in the top four industries were mostly normally distributed within each industry. Figures 7-10 shows the distribution scores for the Primary Metals, Petroleum, Fabricated Metals, and Chemicals industries. Each facility's *Cal EcoMaps EIS* can be viewed on the website by clicking on the facility's marker. A comprehensive list of scores categorized by industry is also available under the "Impact Score" tab on *Cal EcoMaps*.

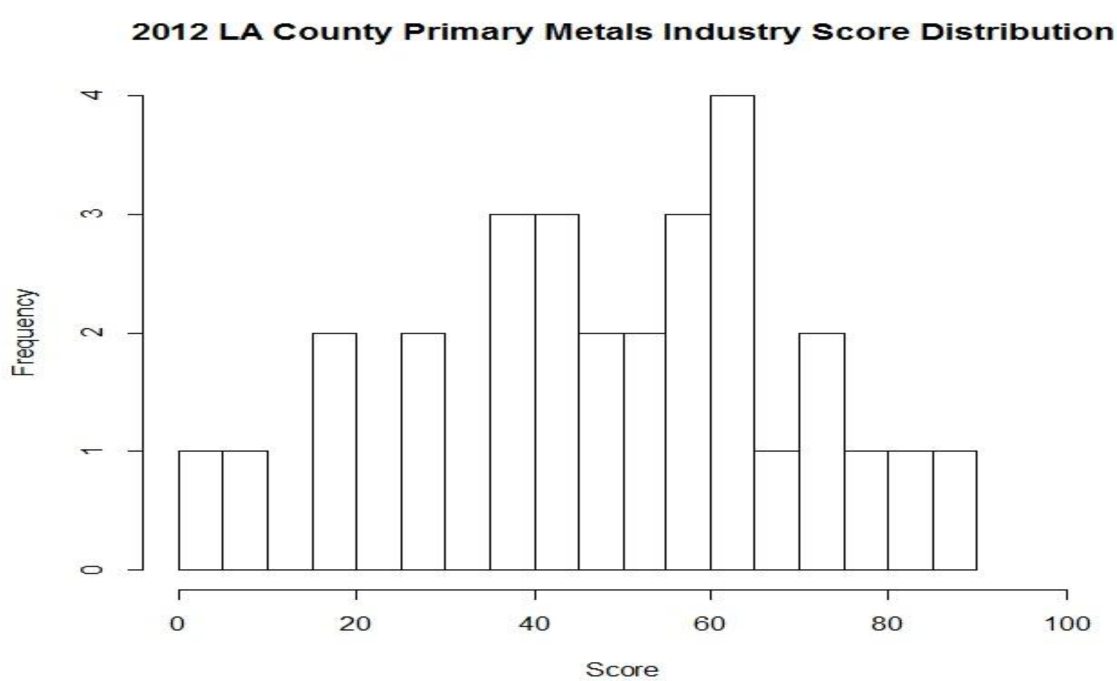


Figure 7 – *Cal EcoMaps Environmental Impact Score* distribution for the Primary Metals Industry in Los Angeles County in 2012

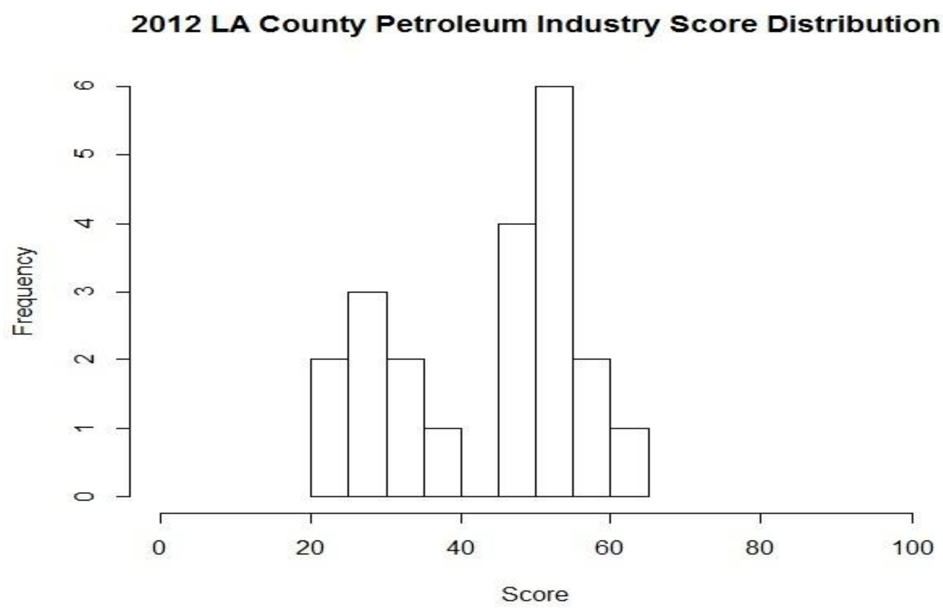


Figure 8- *Cal EcoMaps Environmental Impact Score* distribution for the Petroleum Industry in Los Angeles County in 2012

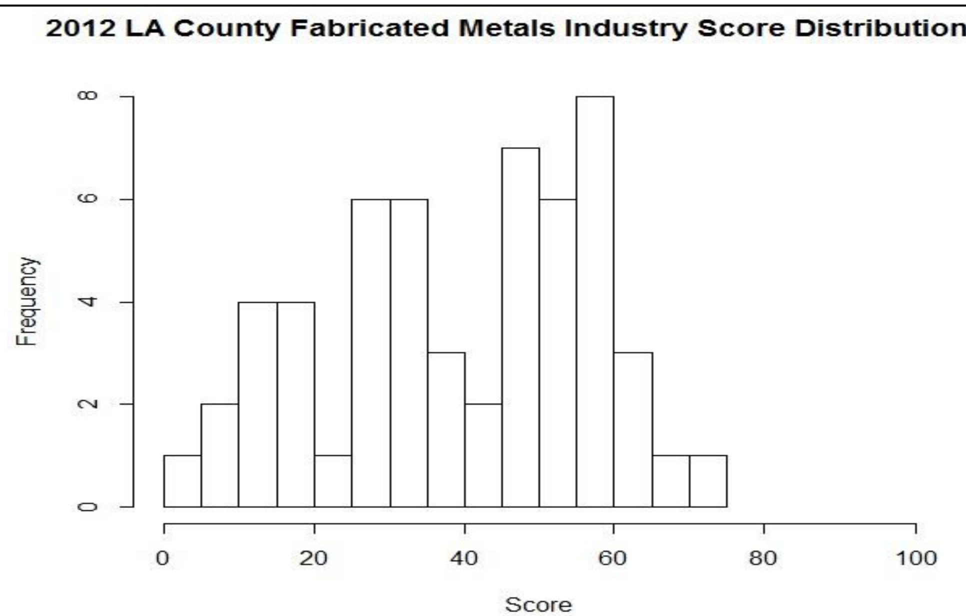


Figure 9 - *Cal EcoMaps Environmental Impact Score* distribution for the Fabricated Metals Industry in Los Angeles County in 2012

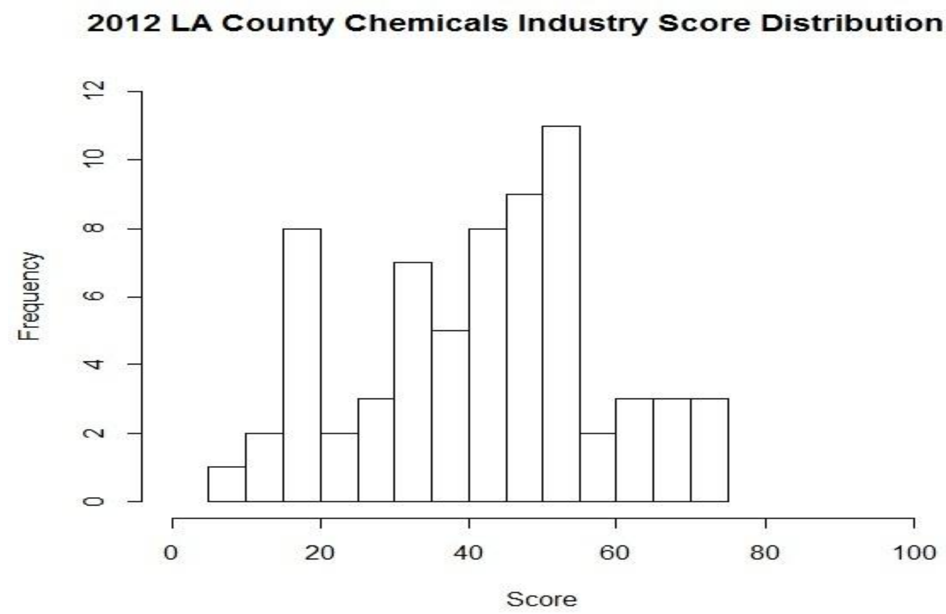


Figure 10 - *Cal EcoMaps Environmental Impact Score* distribution for the Chemicals Industry in Los Angeles County in 2012

5.2 Mapping facilities on interactive website, *Cal EcoMaps*

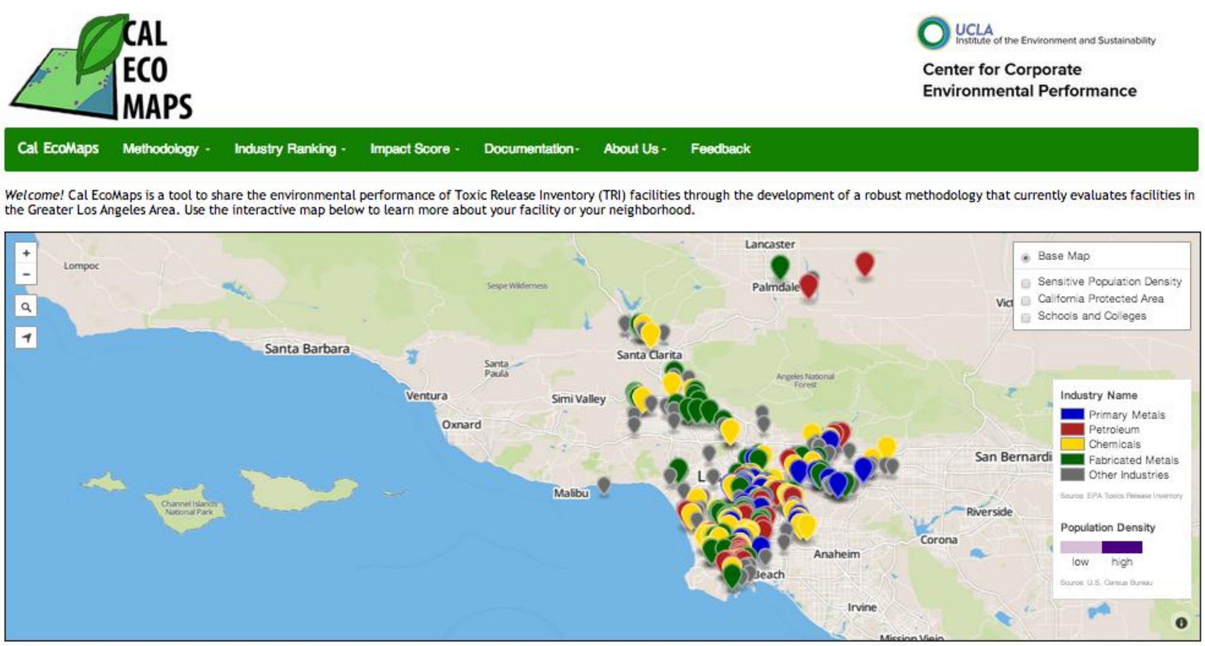


Figure 11 - Picture of *Cal EcoMaps* homepage.

Cal EcoMaps (Figure 11) was created to provide users an interactive way to explore the 194 facilities in the Primary Metals, Petroleum, Fabricated Metals, and Chemicals industries of Los Angeles County. This interactive map is the main feature of *Cal EcoMaps*, which allows residents of LA County to easily find their neighborhoods and local points of interest while interlaying the location of TRI facilities and several other layers.

The interactive map was made using the QGIS layers in conjunction with TileMill, an open-source web Geographic Information Systems (GIS) software, to create the interactive online map layers that are hosted on Mapbox, an open-source web map. Mapbox was used to import the TRI facilities as markers using each facility's latitude and longitude coordinates. These markers have pop-up windows that give a few quick facts about the facility including the five Environmental Performance Indicators (Figure 12– top left) along with a link to a results page with more details. This dynamic link loads interactive charts below the map using Google Charts API based on "TRIF ID". The following charts (Figure 12) are displayed under the map for each individual facility: 1) Share of Total Toxic Releases in Respective Industry in Los Angeles County (top right), 2) Total Toxic Releases between 2010-2012 with Los Angeles County and California Industry Averages (bottom left), and 3) Percent Waste Managed Through Recycling, Energy Recovery, and Treatment between 2010-2012 with Los Angeles County and California Industry Averages (bottom right).

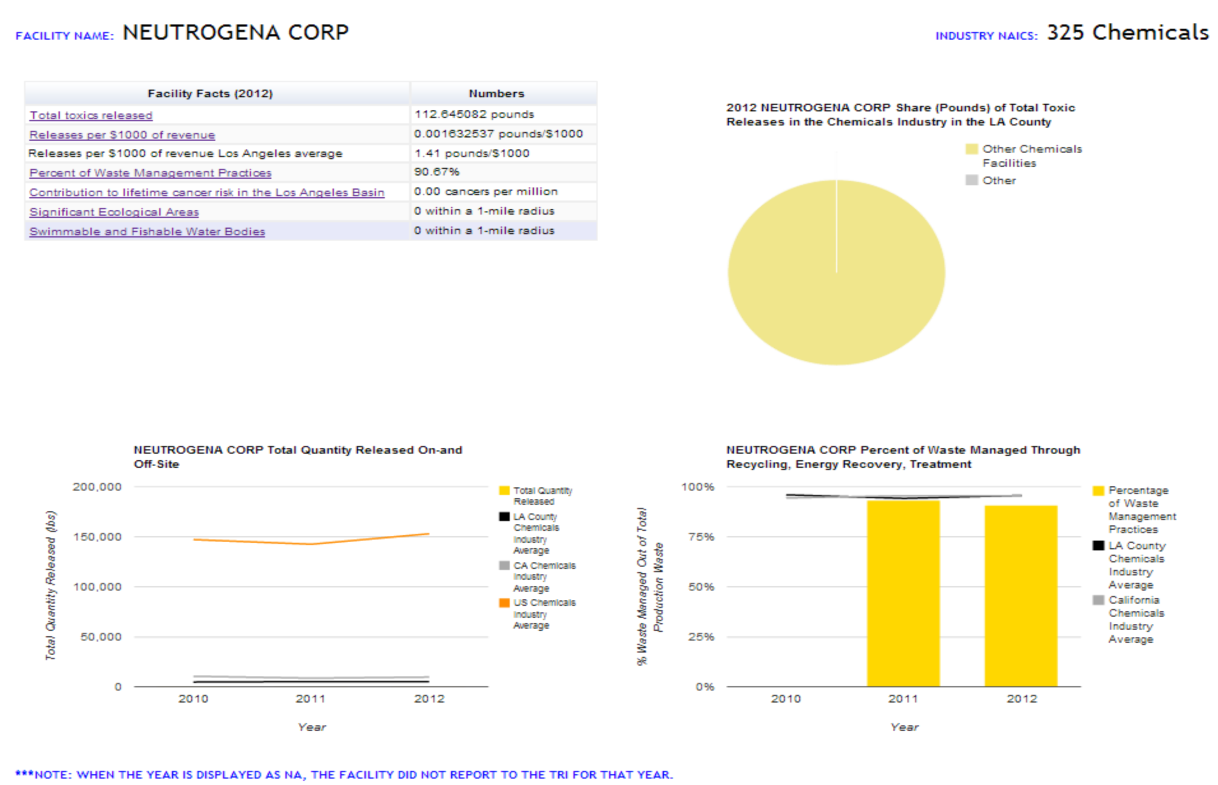


Figure 12 – Example of facility information available on *Cal EcoMaps*: Top left – Facility Facts; Top right –Share of Total Toxic Releases in Respective Industry in Los Angeles County; Bottom left – Total Toxic Releases for 2010-2012; Bottom right – Percent Waste Managed Through Recycling, Energy Recovery, and Treatment for 2010-2012.

The following layers are available and can be toggled on the embedded map:

- "Sensitive Population Density", which is population count by census tract for ages under 17 and over 65 that are defined under the California Environmental Quality Act as inhabitants of sensitive receptors ("Profile of General Population and Housing Characteristics: 2010")
- "California Protected Areas" (CPA), which are open spaces set aside by the state for conservation and preservation due to their ecological significance (California Protected Areas Database)
- "K-12 Schools and Universities", which are private and public schools in Los Angeles County up to the university level.

The aforementioned layers were created in QGIS, an open-source GIS program, to clip the Census, CPA and school shapefiles to the Los Angeles County boundary. The "Sensitive Population Density" layer was created by adding population counts for individuals less than 17 years of age and over 65 within census tracts, and then values were classified into six categories using equal intervals. Buffer analysis was used to create 1-mile buffers around TRI facilities and then select features from the Census, CPA and school layers if they were within the buffers. These selected features were marked as "true" while the inverse was designated as "false". This use of GIS to analyze the spatial relationship between TRI facilities and their surroundings showed that 84% of TRI facilities have CPA within a 1-mile radius and 92% have schools.

The *Cal EcoMaps* website also includes pages that explain our methodology, show rankings of facilities based on industry, provide downloadable data, and allow users to provide feedback including an outlet for facilities to update or correct their data.

6. FUTURE RESEARCH AND NEXT STEPS FOR EXPANSION

We hope that by creating *Cal EcoMaps* that the public, facilities, government, and other stakeholders are not only able to better access information on local toxic release trends, but also able to encourage facilities to reduce their releases. Throughout the process of creating *Cal EcoMaps*, many features were considered to create a more comprehensive and user-friendly map that would communicate information on toxic release and waste management trends from TRI as well as other information from different datasets. Additional areas for expansion are listed below.

6.1 Mapping and Providing Scores for All Facilities

Our analysis focused on the 194 facilities in the Top 4 Industries because of their influence on total toxic releases in Los Angeles County and provided scores to only 172 facilities that had sufficient data to conduct the analysis. *Cal EcoMaps* can expand in the future by mapping and providing scores for all 377 facilities in Los Angeles County that reported toxic releases in 2012.

6.2 Expansion beyond 5 Environmental Impact Indicators

We provided facility environmental performance scores, or *Cal EcoMaps Environmental Impact Score*, based on five environmental impact indicators. Although the *Cal EcoMaps EIS* aggregates the facility percentile rank scores of *Total Toxic Releases*, *Toxic Releases per $1000 of Revenue*, *Toxicity of Total Releases, Regional Contribution to Lifetime Cancer Risk due to Air Emissions, and Waste Managed Through Recycling, Energy Recovery, and Treatment*, other variables can be included in future analysis to provide an even more comprehensive score.

One variable that we examined, but did not use because of limited data available in TRI was *Greenhouse Gas Total Direct Emissions*. This variable would be used to determine the facility's impact on global warming. Future uses of this variable can begin with complementing TRI information on greenhouse gases with other datasets, such as the *Greenhouse Gas Emissions* data from the California Environmental Protection Agency's Air Resources Board (ARB). With the passage of California Assembly Bill 32, facilities, suppliers, and electric power entities in California are now mandated to report greenhouse gas emissions to ARB. 2011 and 2012 greenhouse gas emission data was available from ARB at the time of our analysis, but because ARB uses an "ARB ID" to identify facilities and TRI uses "TRIF ID", we refrained from complementing data. Future research should complement this data and ensure data validity between TRI and ARB facilities (California Air Resources Board).

We also experimented with DEA methodology Appendix C in determining facility environmental performance, but were met with data limitations. By using different variables in future DEA models, DEA could prove to be a more robust methodology in determining facility efficiency and providing environmental performance ratings.

6.3 Expansion beyond Los Angeles County

Cal EcoMaps is just the beginning for the development of multiple interactive mapping websites to communicate local toxic release and waste management trends. Since California averages for certain variables have already been determined, expanding *Cal EcoMaps* beyond Los Angeles County to include facilities all throughout California would be the next step for expansion. Local geographies and air emission models would have to be considered to calculate the *Regional Contribution to Lifetime Cancer Risk due to Air Emissions* variable for facilities in different geographic locations in California, but all other variables discussed in our analysis can be applied similarly.

6.4 Expansion beyond 2010-2012 TRI Data

The TRI provides annual information on toxic release and waste management activities since its creation in 1987. Our analysis focused on the three most recent years of TRI data, but historical information is available to track facility trends over a longer timeframe. Examining facility historical data over the past five or ten years can reveal more information about toxic releases and waste management trends.

6.5 Facility Best Management Practices Survey

We had hoped to solicit input on each facility's best management practices for reducing toxic releases into the environment and provide these responses on *Cal EcoMaps* for comparisons between facilities and industries. We created a Best Management Practices Survey to be sent out to the environmental managers or other responsible party at each facility. Currently, our survey is still awaiting Institutional Review Board (IRB) approval. Future research should focus on distributing this survey and compiling responses to be displayed on *Cal EcoMaps*.

6.6 Mobile Application

Currently, *Cal EcoMaps* is available online at http://www.environment.ucla.edu/ccep/calecomaps. *Cal EcoMaps* can be accessed on computer web browsers and viewed on mobile phones with web browsing capabilities, but future research should focus on developing a downloadable mobile-friendly application. This application would be similar to *Cal EcoMaps* in providing all relevant facility information and toxic release trends, but would more user-friendly and interactive on mobile phones to explore data. A geo-locater option on the mobile application similar to that on *Cal EcoMaps* can show facilities in the immediate surrounding areas of where the user is without use of a computer or laptop.

7. CONCLUSION

The UCLA team for the 2013 US EPA TRI University Challenge achieved the stated project objectives by determining toxic release and waste management data and trends for the top-emitting facilities and industries in Los Angeles County, providing *Environmental Impact Scores* based on five *Environmental Impact Indicators* for 172 out of 194 facilities in the Top 4 Industries in Los Angeles, and mapping these 194 facilities with other facility-specific information by developing an interactive website, *Cal EcoMaps*, to share with the public.

This project made significant contributions to the understanding and advancement of TRI knowledge by developing the *Toxic Releases per $1000 of Revenue* and *Regional Contribution to Lifetime Cancer Risk from Air Emissions* variables. In both cases, TRI data was complemented with external information from multiple datasets to calculate these variables. For the *Toxic Releases per $1000 of* Revenue variable, this is the first known project to measure a facility's environmental impact relative to its performance by comparing the facility's pounds of toxic releases with its annual revenue. The *Toxicity of Total Releases* variable provided by the TRI was improved by providing a more concrete measure of health-related impacts, specifically cancer, in the *Regional Contribution to Lifetime Cancer Risk from Air Emissions* variable.

We hope that by creating *Cal EcoMaps* that the public, facilities, government, and other stakeholders are not only able to better access information on local toxic release trends, but also able to encourage facilities across Los Angeles County to reduce their toxic releases into the environment. The development of *Cal EcoMaps* and methodologies used to determine facility environmental impact scores provide a starting point for future endeavors to continue research toward more effective communication of toxic release and waste management information and trends to ultimately achieve the TRI's main goal of protecting the public health and environment of local communities.

Appendix A –Environmental Impact Indicators and Calculations

#	Variable Name	Definition	**Database** Variable Name From Database	Calculation	Units	Choices and Assumptions for Analysis	Purpose in Analysis
1	Total Toxic Releases	This is the total quantity of the toxic chemical that was released to the environment or disposed of at the facility (discharged to air, land, water and injected underground on-site) or sent off-site for disposal or other release. This quantity is the sum of the amounts reported in Sections 8 of Form R (onsite disposal or other releases plus off-site transfers to disposal or other releases and transfers to "Publicly-Owned Treatment Works" of chemicals such as metals and metal compounds that are not destroyed at the POTW) except any amount(s) associated with one-time events. Only releases related to production-related processes are considered.	**TRI.NET** 8.1 Quantity Released On- and Off-Site	Provided by TRI.NET	Pounds (lbs)	None	Used to determine the key emitting industries in the Los Angeles County. Used to account for the amount of toxic chemicals released because specific toxic releases can have significant environmental and public health effects, especially if they are released in extremely large quantities.

#	Variable Name	Definition	**Database** Variable Name From Database	Calculation	Units	Choices and Assumptions for Analysis	Purpose in Analysis
2	Toxic Releases per $1000 of Revenue	The facility's pounds of total toxic releases standardized to $1000 of facility annual revenue	**TRI.NET** 8.1 Quantity Released On- and Off-Site **ReferenceUSA** Location Sales Volume **Hoovers** Revenue **Orbis** Revenue **InsideView** Revenue	$\frac{\text{Total Toxic Releases (lbs)}}{\text{(Annual Revenue/\$1000)}}$	Lbs/$1000	ReferenceUSA was most recently updated in 2013 so values were assumed to be from 2012. ReferenceUSA was used as primary source. If ReferenceUSA value was not available, then Hoovers, Orbis, and InsideView were used in that order Where revenue is provided as a range, the highest range value was used. Facilities with different names, but same addresses were confirmed to be the same facility.	Used to control for facility size and production scale. Used as simple measure of facility efficiency. First known project to develop this variable by complementing TRI and revenue data.
3	Toxicity of Total Releases	Unitless measure of toxicity to compare health-related risks. Determined by multiplying the pounds released by the chemical-specific toxicity weight determined by EPA's RSEI for inhalation (air) exposure routes	**TRI.NET** Total On-Site Releases (Toxicity x Pounds)	Provided by TRI.NET	Lbs * Toxicity (unitless)	If reported releases were grouped under a chemical category rather than a specific chemical, the most toxic chemical was used For chemicals without toxicity data, experts extrapolated their toxicity relative to other chemicals.	Because it is a unitless measure, used as relative measure of health-related impacts to compare between different facilities. Considers many additional facets to a facility's toxicity, including noncarcinogenic risk and toxicity of water and land releases.

#	Variable Name	Definition	**Database** Variable Name From Database	Calculation	Units	Choices and Assumptions for Analysis	Purpose in Analysis
4	Regional Contribution to Lifetime Cancer Risk from Air Emissions	The cancer risk contribution of a facility's air emissions to residents of the Los Angeles County over 70 years of exposure.	**TRI.NET** Total On-Site Air Releases **Office of Environmental Health Hazards Assessment (OEHHA)** Toxic Equivalency Potential **EPA Handbook** Inhalation Rates by Sex and Age **American Geophysical Union** Los Angeles Basin dimensions **US Census** LA County Population Count by Sex and Age	$$\frac{\text{Total On-Site Air Releases (lbs benzene)}}{\frac{\text{348 lbs benzene}}{10^{-6}\text{ cancer risk}}}$$ *Note: Detailed calculations can be found below in Regional Contribution to Lifetime Cancer Risk from Air Emissions Methodology (pages 31-34)*	Conversion of facility's air emissions to cancers in a million exposed in LA County over 70 years	Lifetime cancer was chosen as a health-related impact because it is a disease of environmental exposure and is higher in populations exposed to a certain chemical. The cancer risk does not consider exposure to carcinogens in water or land releases. Assumes LA Basin is a well-mixed rectangular volume, meaning dispersal of the pollutant is immediate upon release and remains equal over 70 years of air releases across the LA Basin. Assumes 2012 TRI emissions are constant over the 70-year period and the 2010 demographics are relevant for the next 70 years in LA County	Used as a concrete, but conservative measure of health-related impacts to compare between different facilities. Can be used to evaluate the facility's contribution to regional cancer risk in the LA Basin, but does not infer any individual risk on a local-level. This estimate does not constitute a risk assessment and should not be used to draw conclusions about individual risk.

#	Variable Name	Definition	**Database** Variable Name From Database	Calculation	Units	Choices and Assumptions for Analysis	Purpose in Analysis
5	Waste Managed Through Recycling, Energy Recovery, and Treatment	The amount of toxic releases that are managed using preferred waste management activities such as energy recovery, recycling, and treatment (sum of quantities in Form R Section 8.2 - 8.7)	**TRI.NET** 8.2 Energy Recovery On-Site 8.3 Energy Recovery Off-Site 8.4 Recycling On-Site 8.5 Recycling Off-Site 8.6 Treatment On-Site 8.7 Treatment Off-Site	Provided by TRI.NET	lbs	Under the EPA's Waste Management Hierarchy, preferred waste management activities are preferentially ranked based on the most environmentally sound ways to reduce pollution and toxic releases. From most to least preferred by the EPA: recycling, energy recovery, and treatment	Used to account for the facility's mitigation strategies at managing toxic waste

Appendix B –Other Considered Variables

1) *Production Ratio*

We also looked at the *Production* Ratio variable, which is provided by the TRI to control for facility size and production scale. Facility annual revenue is a relative measure of production, but not an exact measure of the total production, or amount of products produced, at a particular facility. The production ratio that is reported to the TRI is the production ratio of a specific chemical and "indicates the level of increase or decrease from the previous year, of the production process or other activity in which the toxic chemical is used," (*Envirofacts Column: Production Ratio*, US EPA). For example, a facility reporting a production ratio of 1.6 indicates that production associated with the use of the chemical has increased by 0.6, or 60%. Conversely, a facility reporting a production ratio of 0.6 indicates that production associated with the use of the chemical has decreased by .4, or 40%.

It is important to emphasize that the *Production Ratio* provided by the TRI is not the production ratio of the entire facility, but rather of a specific toxic chemical. In order to calculate the *Facility-level Production Ratio*, we could not simply aggregate the production ratios of all toxic chemicals. Instead, we assigned weights for each chemical based on the facility's total production-related waste (Section 8.1-8.7) to calculate the *Weighted Chemical Production Ratio*. The summation of *Weighted Chemical Production Ratio* for all chemicals is the facility-level production ratio. This *Facility-level Production Ratio* represents the total changes in activities or production processes for a particular facility during one year.

In order to communicate the facility-level production ratio over multiple years, we calculated a *Production Index* for the facility. *Production Index* measures the production in a given year relative to production of the base year, and thereby allows us to compare the facility-level production ratio between different years. We chose a base year for which the production ratios of all other years were compared to and set this base year value to 100. The values for subsequent years are adjusted by production ratio of the facility relative to the base year. Thus, for any given year the value of the production index is equal to the value of the prior year multiplied by the production ratio of the current year. In the case of our project, we set 2010 as our base year so that *Facility-level Production Ratio* values for 2011 and 2012 are relative to 2010.

Although production ratio provides context for reported year-to-year changes in toxic chemical and waste management quantities, we determined that revenue is a more intuitive measure of facility production that can be more readily communicated than production ratio. For that reason, we chose to use *Toxic Releases per $1000 of Revenue* as an environmental impact indicator over production ratio.

Database Variable Name From Database	**Calculation**	**Units**
TRI.NET Production Ratio 8.1-8.7 Total Production-Related Waste Managed	**Chemical Production Ratio:** Provided by TRI.NET	**Unitless**
	Weighted Chemical Production Ratio: $\mathbf{Chemical\ Production\ Ratio} \times \left(\frac{\mathbf{Total\ Production - related\ waste\ of\ chemical}}{\mathbf{Total\ Production - related\ waste\ of\ facility}}\right)$ = $\mathbf{Chemical\ Production\ Ratio} \times \left(\frac{\mathbf{8.1 - 8.7\ of\ chemical}}{\sum \mathbf{8.1 - 8.7\ of\ all\ chemicals}}\right)$	
	Facility-level Production Ratio: $\sum \mathbf{Weighted\ Chemical\ Production\ Ratio\ of\ all\ chemicals}$	
	Production Index: • Base Year = 100 • Subsequent Years = 100 * (Facility-level Production Ratio of that year)	

Table 11 – Variable database and calculations for *Production Ratio*

2b. *Toxic Releases per Employee*

We also examined the number of employees at the facility to control for size and production scale. While *Toxic Releases per Employee* can serve as a measure of a facility's total toxic releases for every job it creates, we recognized that this value is not an accurate representation because different facilities have varying production processes that may be automated or more labor intensive. However, it is still important to examine this variable as it can be compared for facilities within the same industry and across different industries.

ReferenceUSA was our primary source of employee data. Although ReferenceUSA provides two employee values, "Location Employee Size Actual," and "Corporate Employee Size," only "Location Employee Size Actual" was used to ensure that our analysis of TRI facilities is done strictly at the facility level. At the time of data compilation, ReferenceUSA was most recently updated in 2013 so we assumed that reported values reflect 2012 employee counts. Where employee count is provided as a range, we selected the highest range value as a best-case scenario measure of employee count.

If employee count data was not available through ReferenceUSA, then Hoovers and Orbis were used in that order to determine employee count. The methods Hoovers and Orbis use to collect employee count data are similar to their methods in collecting annual revenue data (see *Toxic Releases per $1000 of Revenue*).

Database Variable Name From Database	**Calculation**	**Units**
TRI.NET 8.1 Total On- and Off- Site Releases **ReferenceUSA, Hoovers, Orbis** Employee Count	$$\frac{\textit{Total Toxic Releases}}{\textit{Employee Count}}$$	**lbs / Employee**

Table 12 – Variable database and calculations for *Toxic Releases per Employee*

Appendix C.1 – Top 10 Facilities in Each Environmental Impact Indicator of the Primary Metals Industry

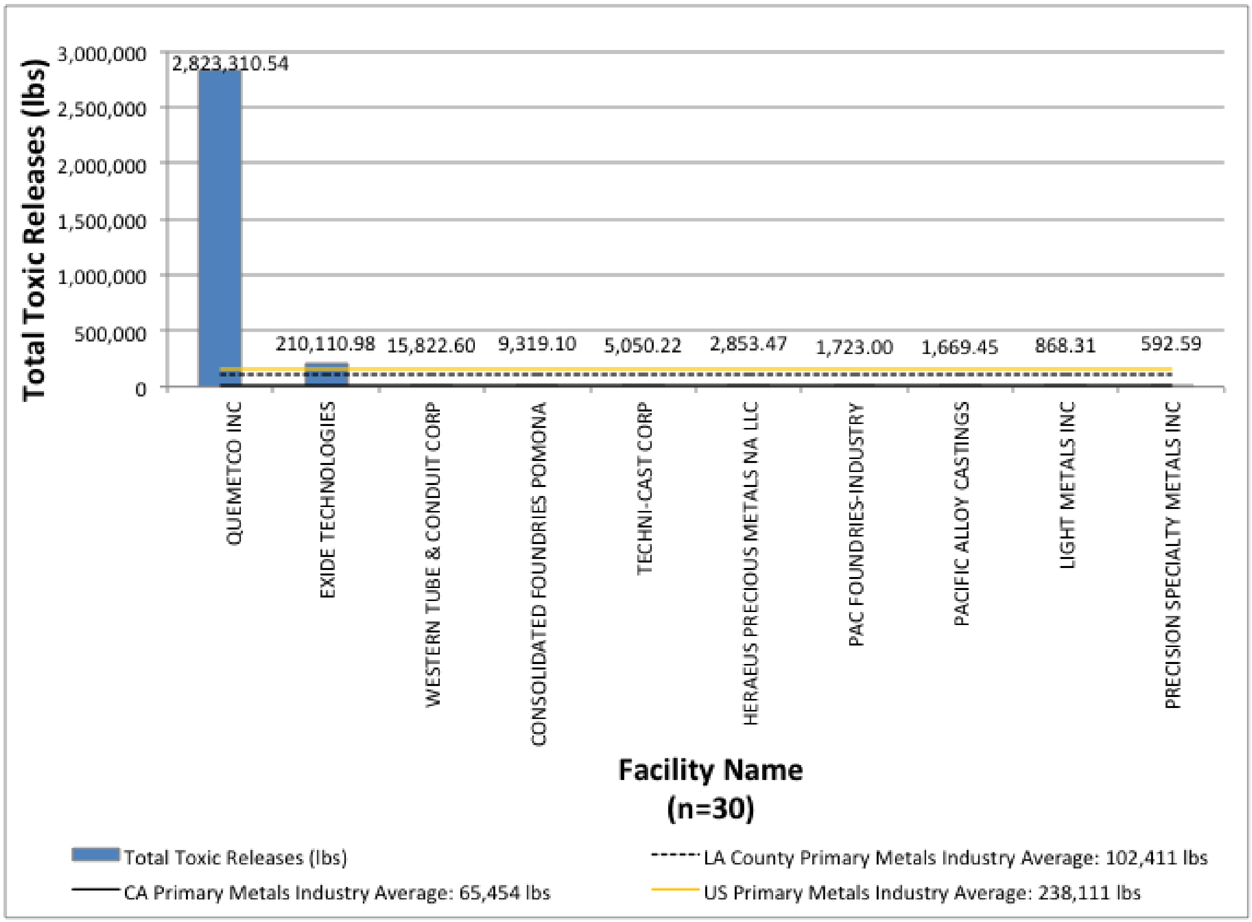


Figure 13 – The 10 facilities in the Primary Metals Industry with the highest *Total Toxic Releases* in Los Angeles County in 2012.

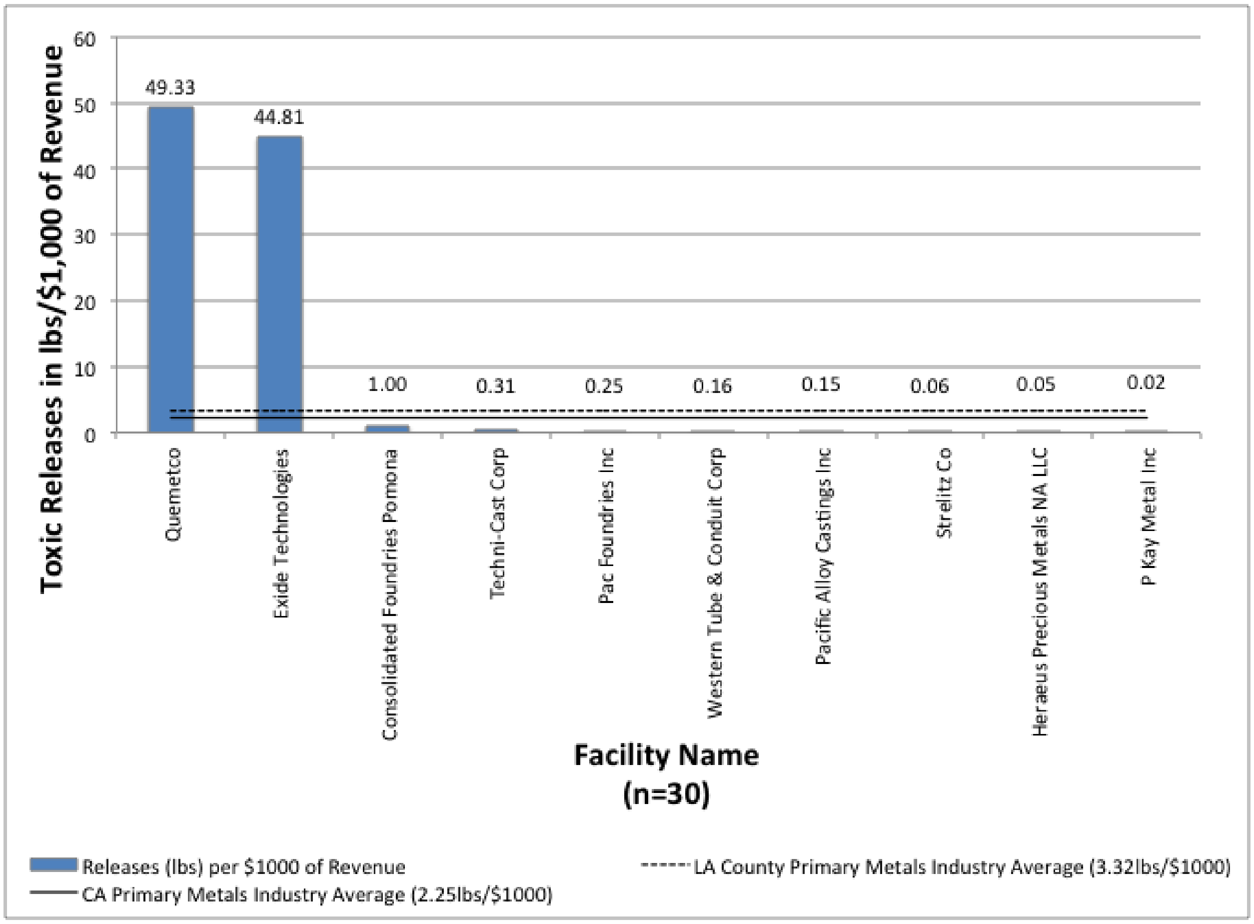


Figure 14 – The 10 facilities in the Primary Metals Industry with the highest *Toxic Releases per $1000 of Revenue* in Los Angeles County in 2012.

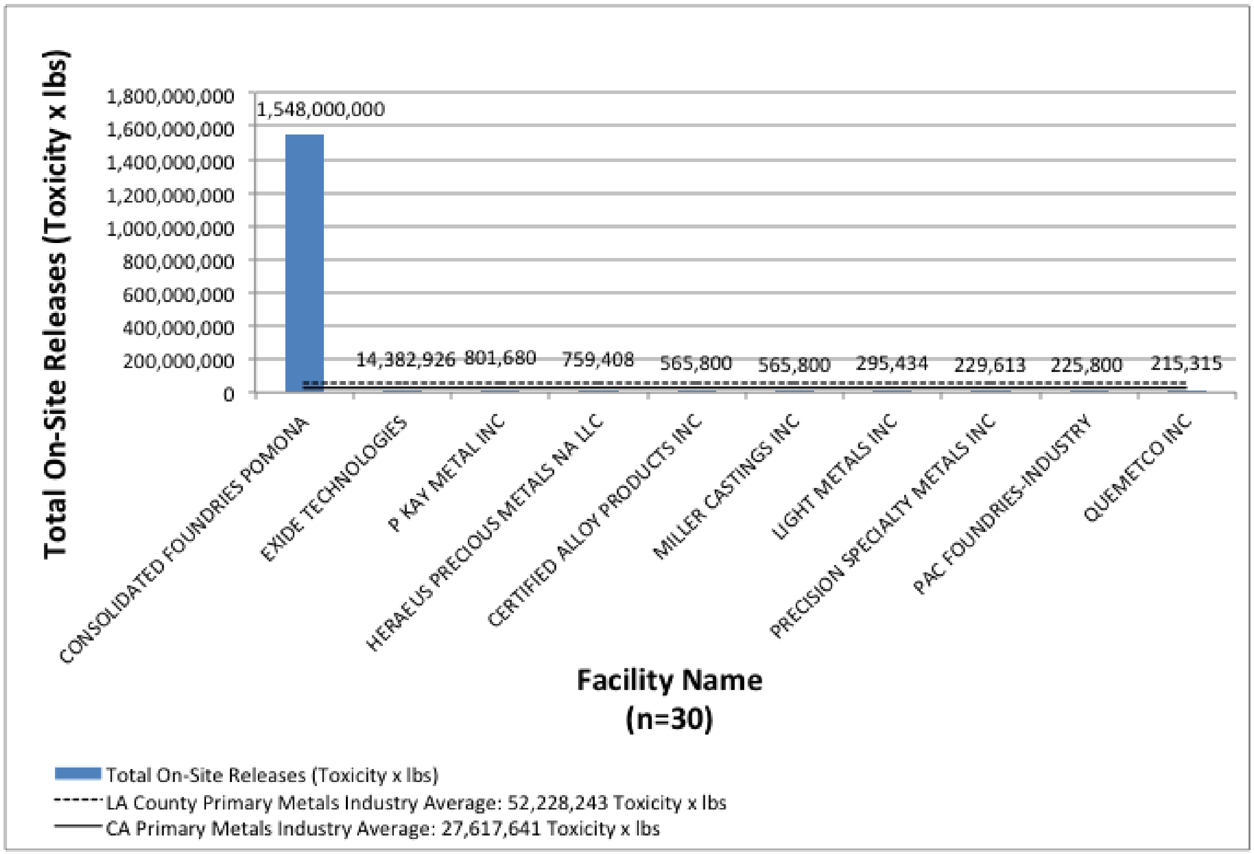


Figure 15 – The 10 facilities in the Primary Metals Industry with the highest *Toxicity of Total Releases* in Los Angeles County in 2012.

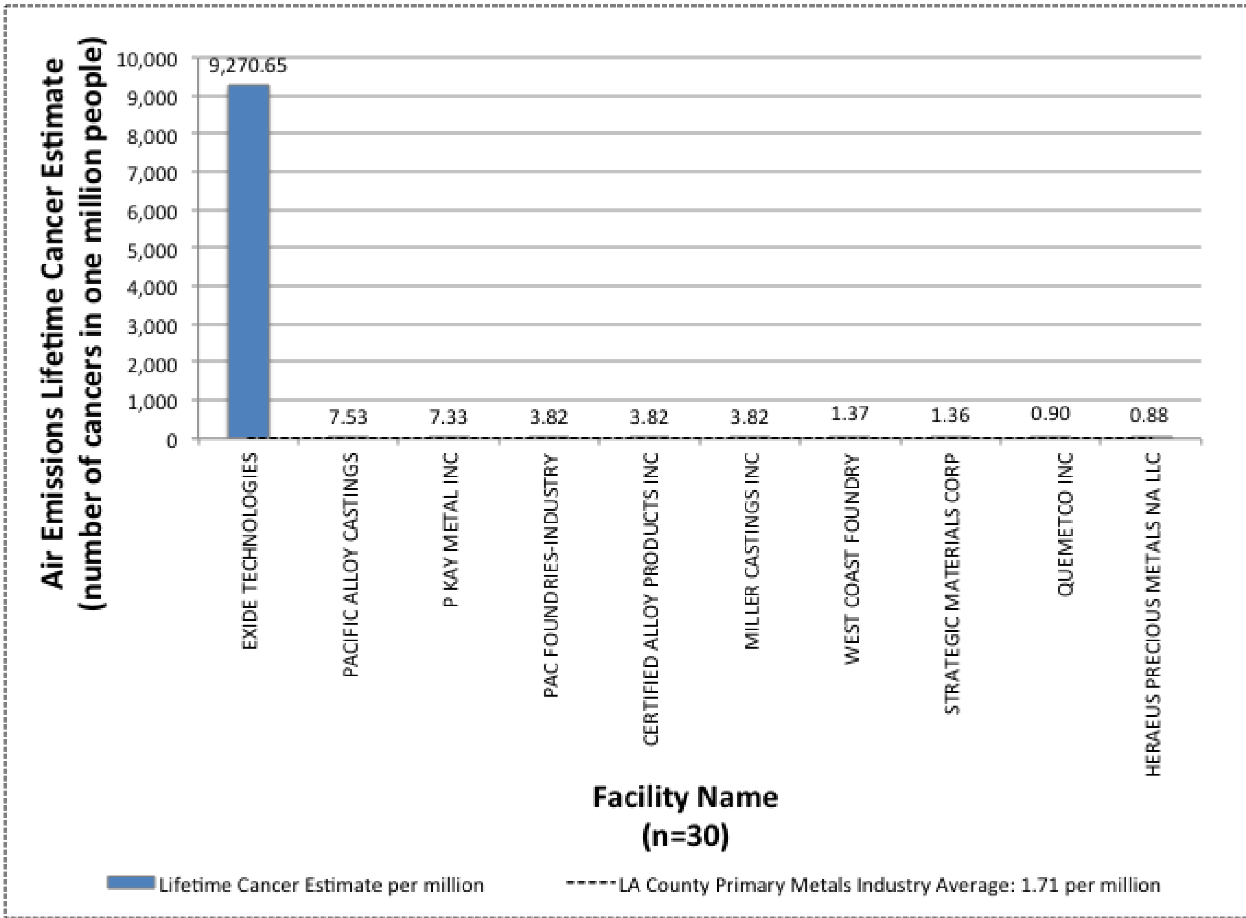


Figure 16 – The 10 facilities in the Primary Metals Industry with the highest *Regional Contribution to Lifetime Cancer Risk from Air Emissions* in Los Angeles County in 2012.

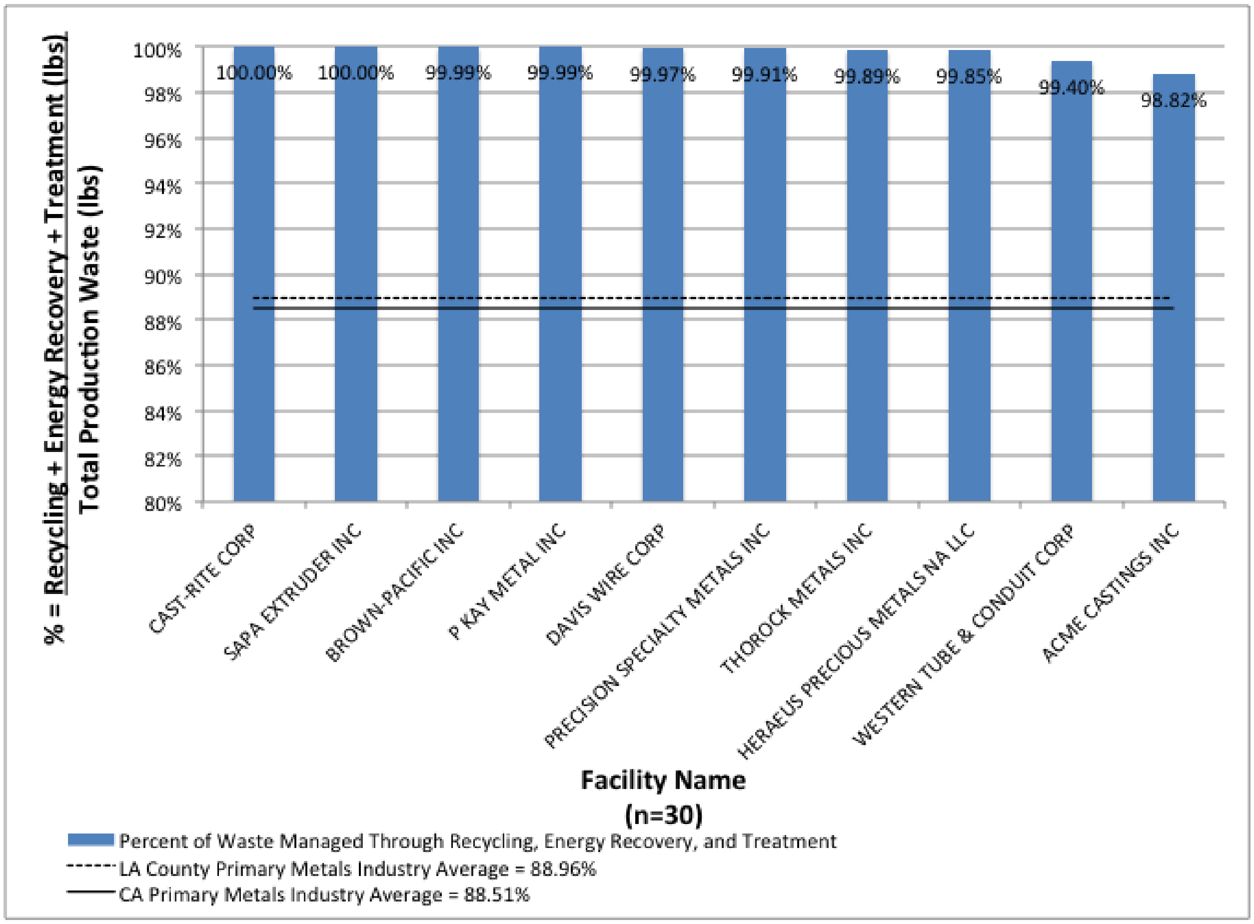


Figure 17 – The 10 facilities in the Primary Metals Industry with the highest *Percent of Waste Managed Through Recycling, Energy Recovery, and Treatment* in Los Angeles County in 2012.

Appendix C.2 – Top 10 Facilities in Each Environmental Impact Indicator of the Petroleum Industry

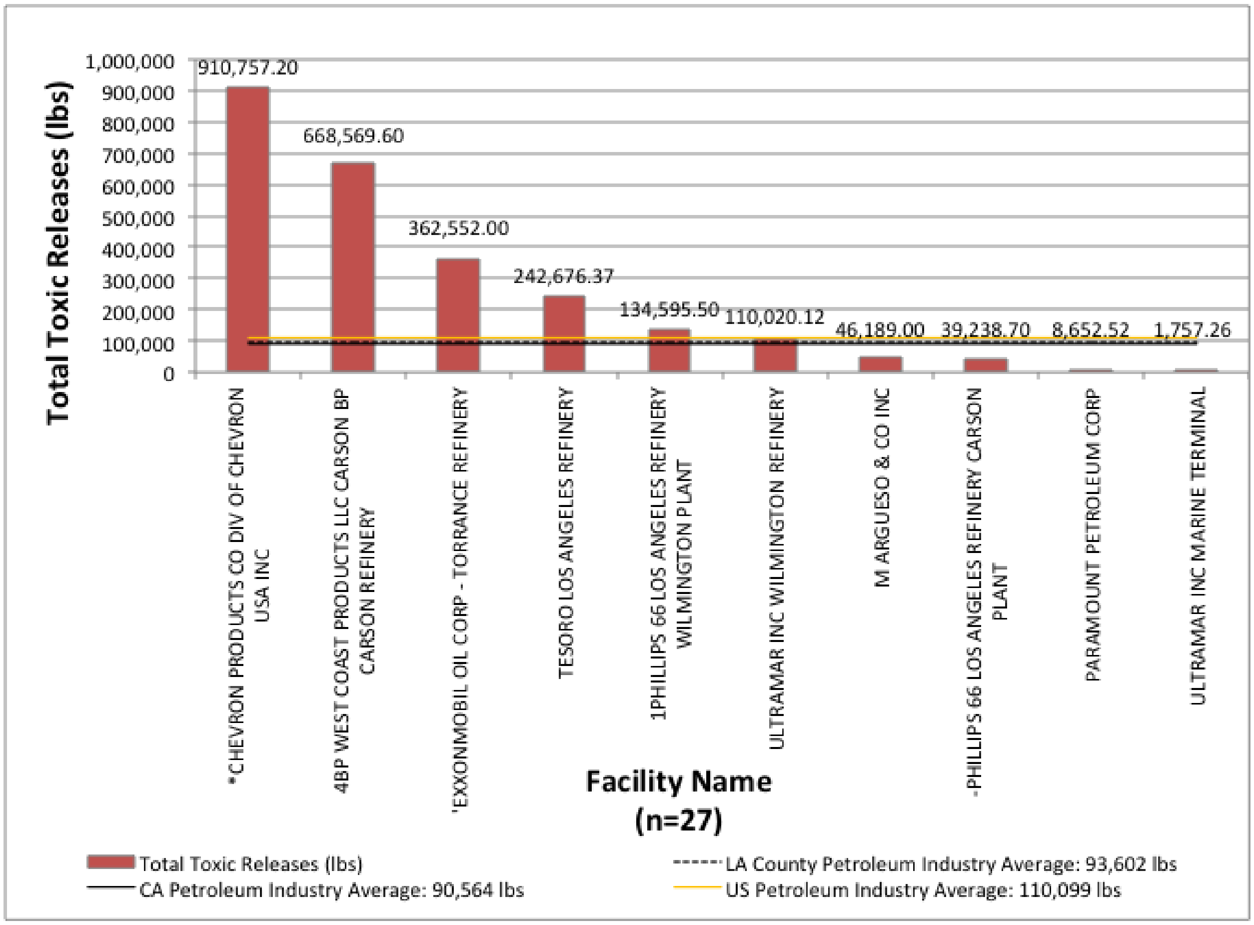


Figure 18 – The 10 facilities in the Petroleum Industry with the highest *Total Toxic Releases* in Los Angeles County in 2012.

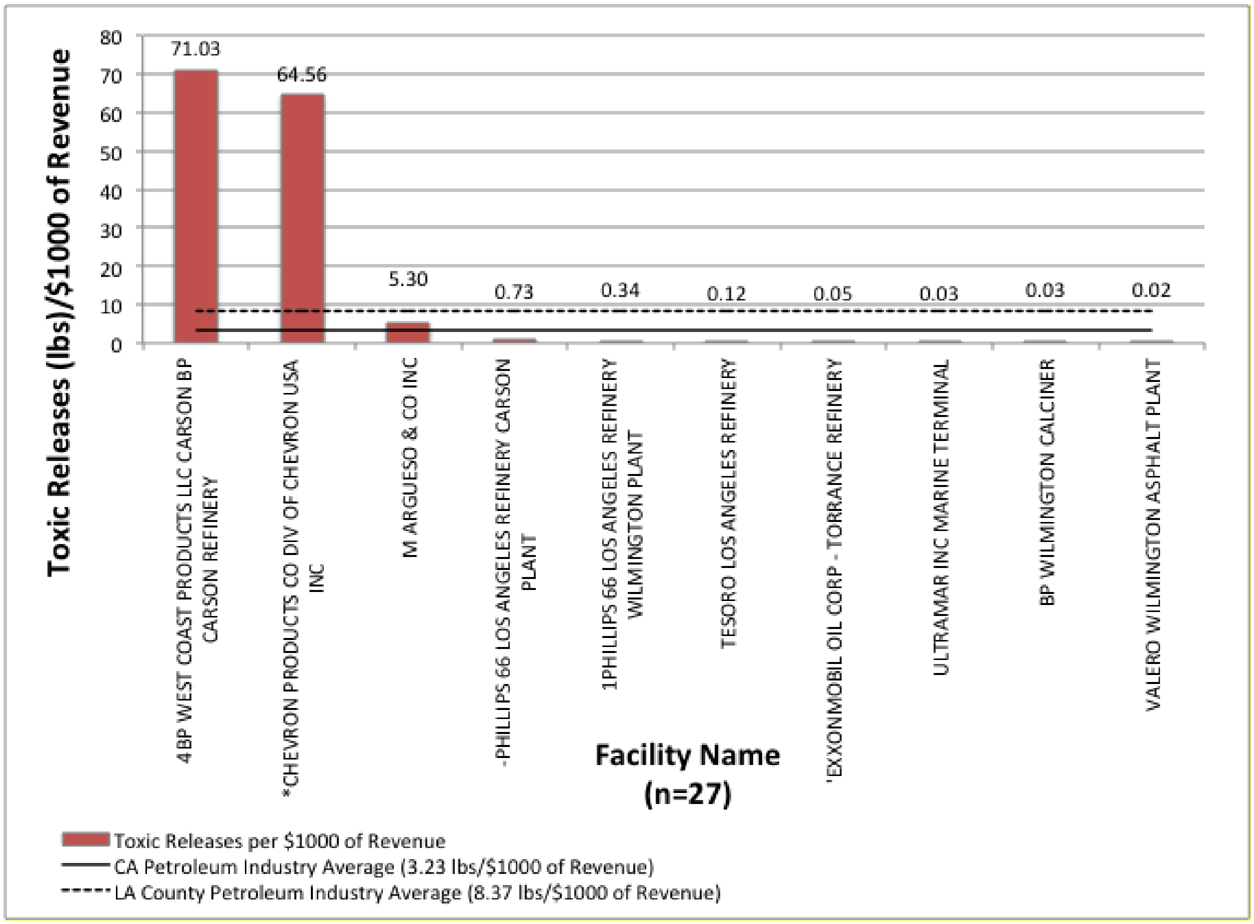


Figure 19 – The 10 facilities in the Petroleum Industry with the highest *Toxic Releases per $1000 of Revenue* in Los Angeles County in 2012.

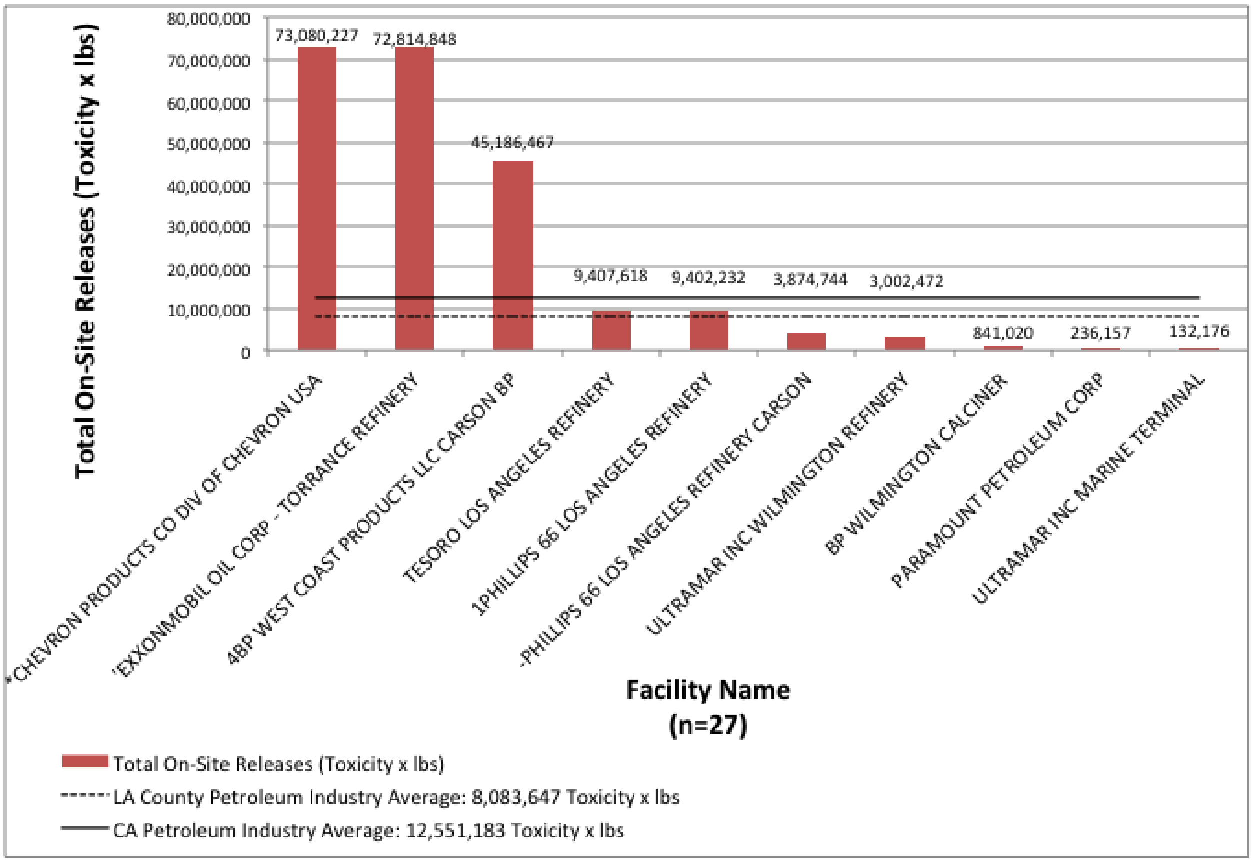


Figure 20 – The 10 facilities in the Petroleum Industry with the highest *Toxicity of Total Releases* in Los Angeles County in 2012.

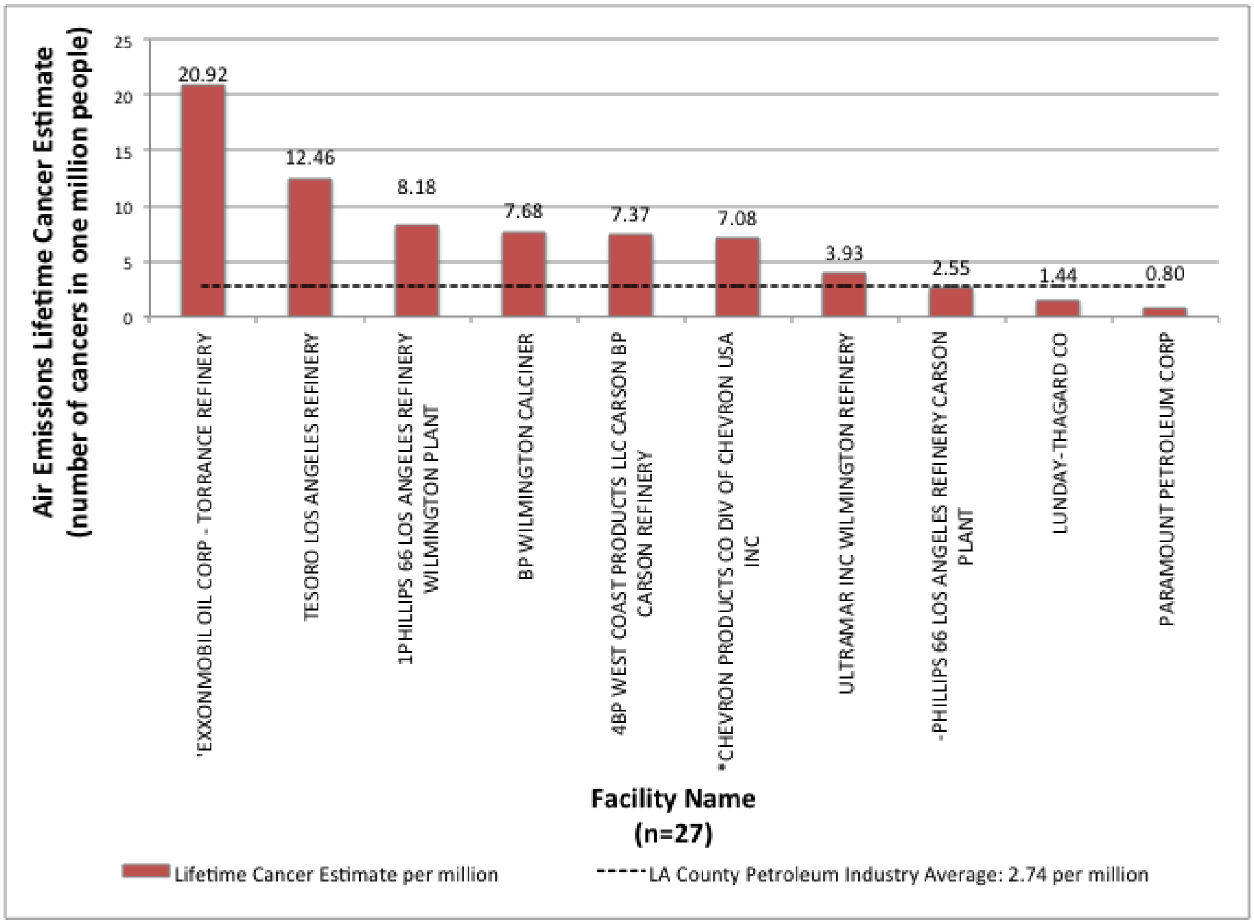


Figure 21 – The 10 facilities in the Petroleum Industry with the highest *Regional Contribution to Lifetime Cancer Risk from Air Emissions* in Los Angeles County in 2012.

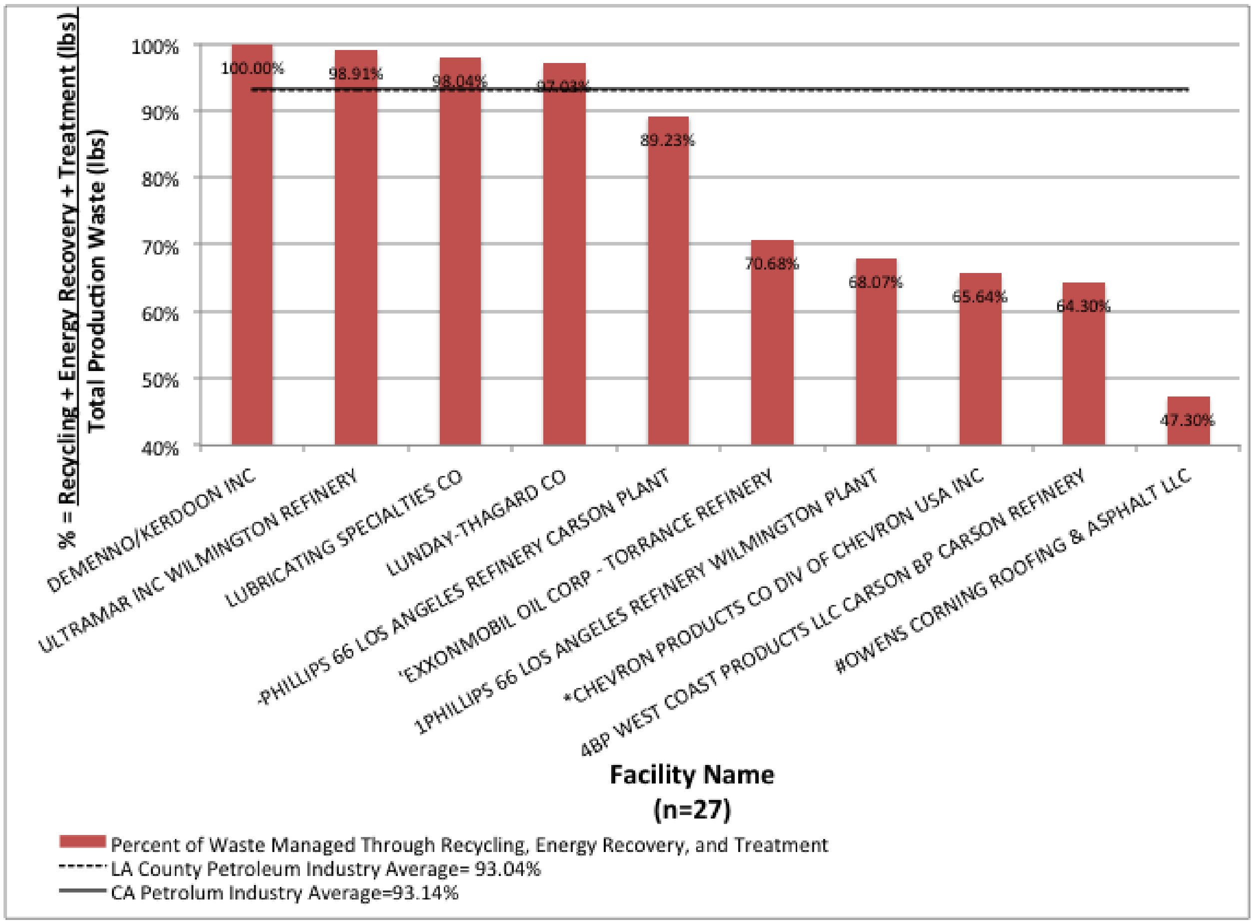


Figure 22 – The 10 facilities in the Petroleum Industry with the highest *Percent Waste Managed Through Recycling, Energy Recovery, and Treatment* in Los Angeles County in 2012.

Appendix C.3 – Top 10 Facilities in Each Environmental Impact Indicator of the Fabricated Metals Industry

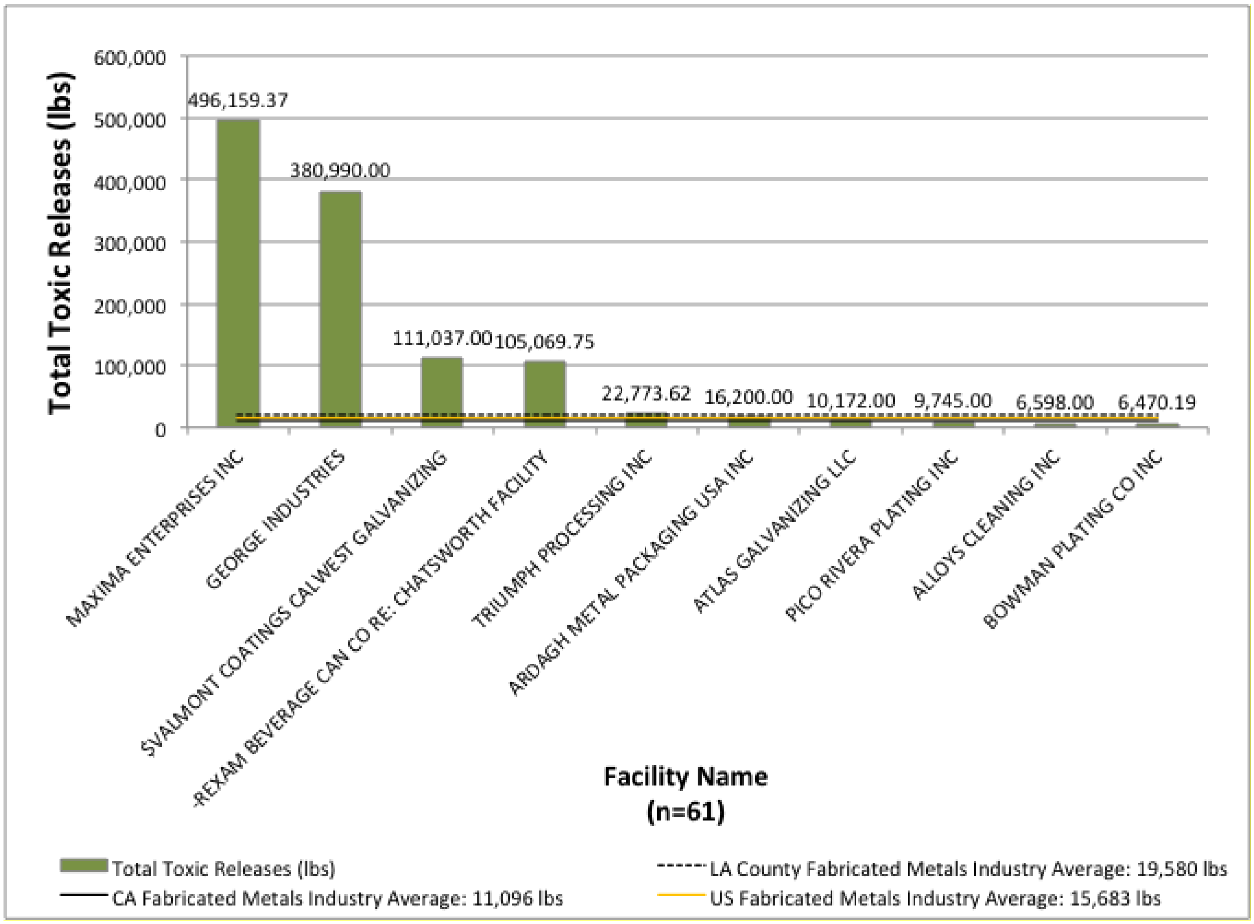


Figure 23 – The 10 facilities in the Fabricated Metals Industry with the highest *Total Toxic Releases* in Los Angeles County in 2012.

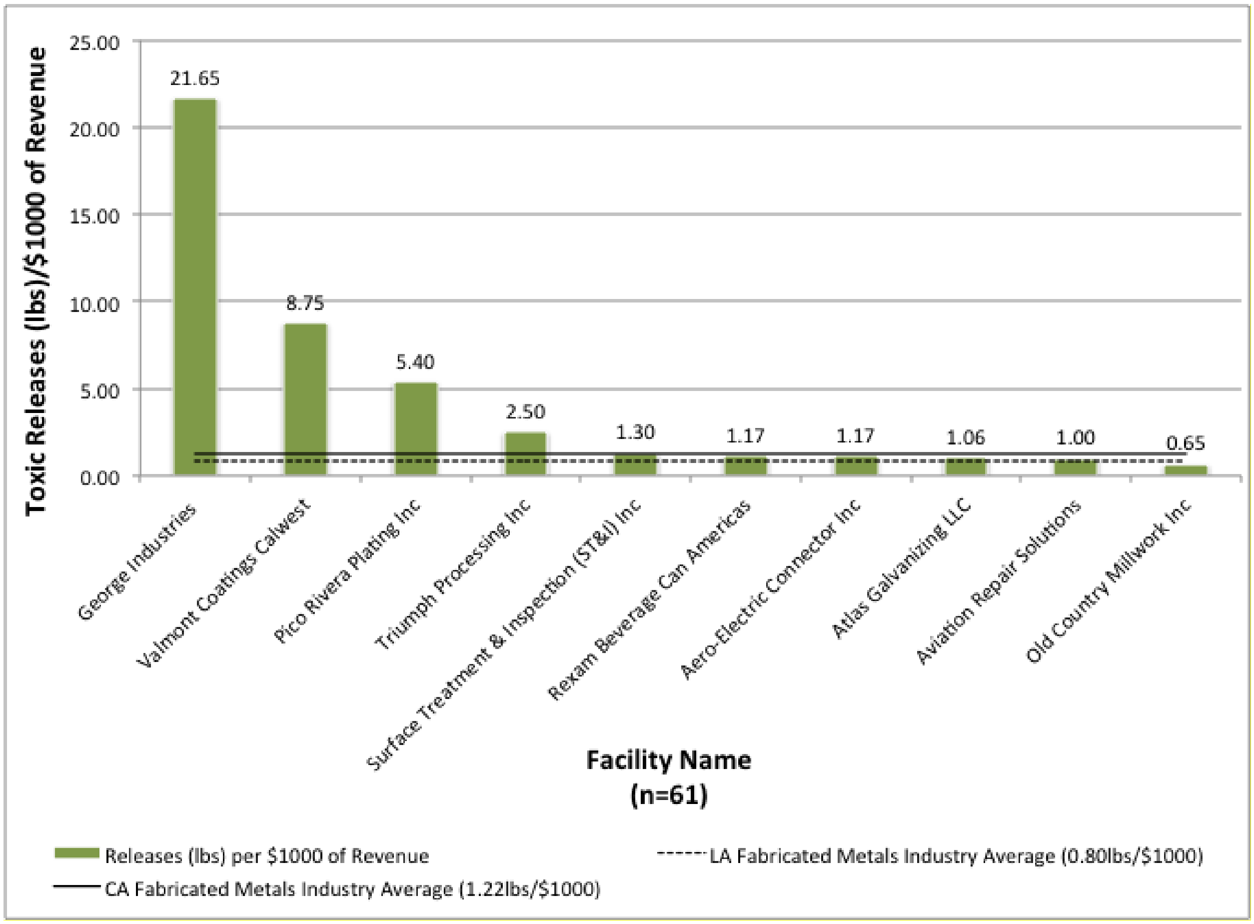


Figure 24 – The 10 facilities in the Fabricated Metals Industry with the highest *Toxic Releases per $1000 of Revenue* in Los Angeles County in 2012.

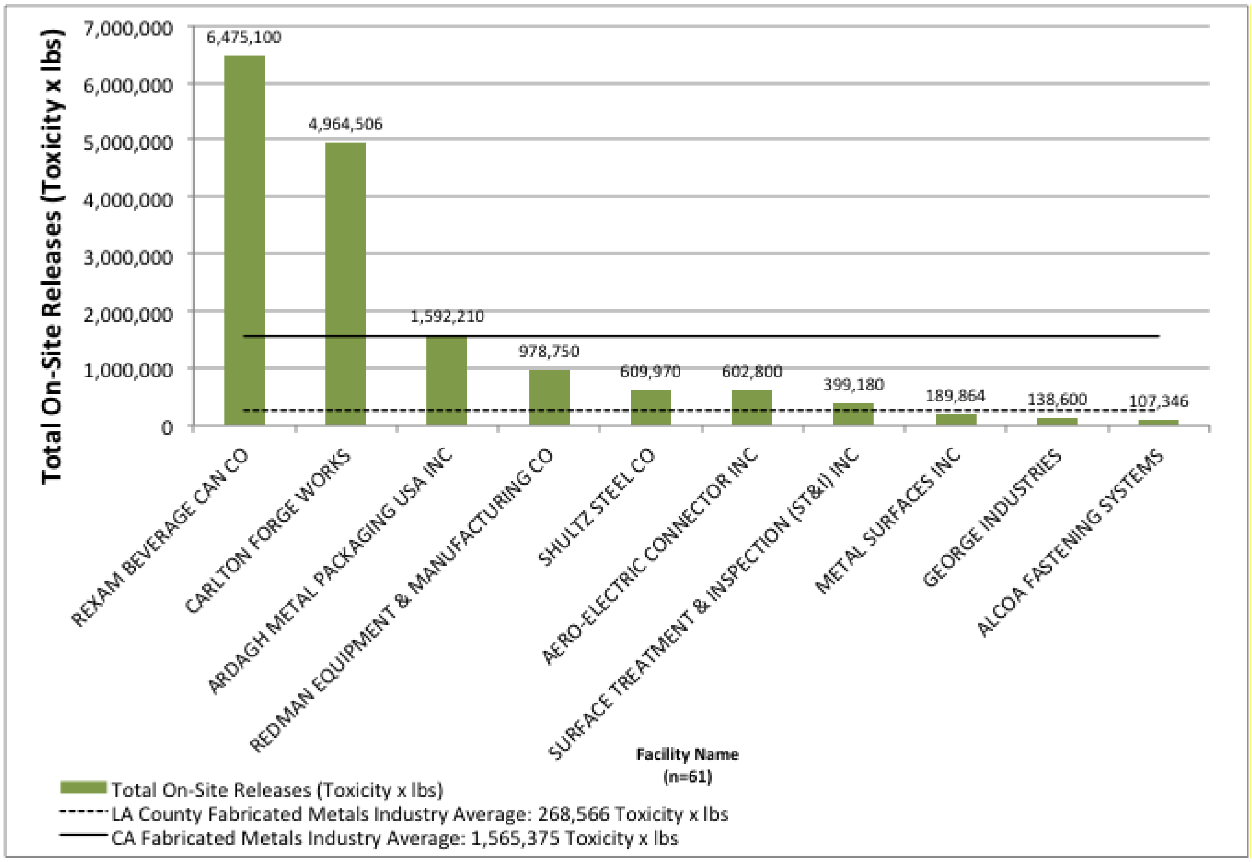


Figure 25 – The 10 facilities in the Fabricated Metals Industry with the highest *Toxicity of Total Releases* in Los Angeles County in 2012.

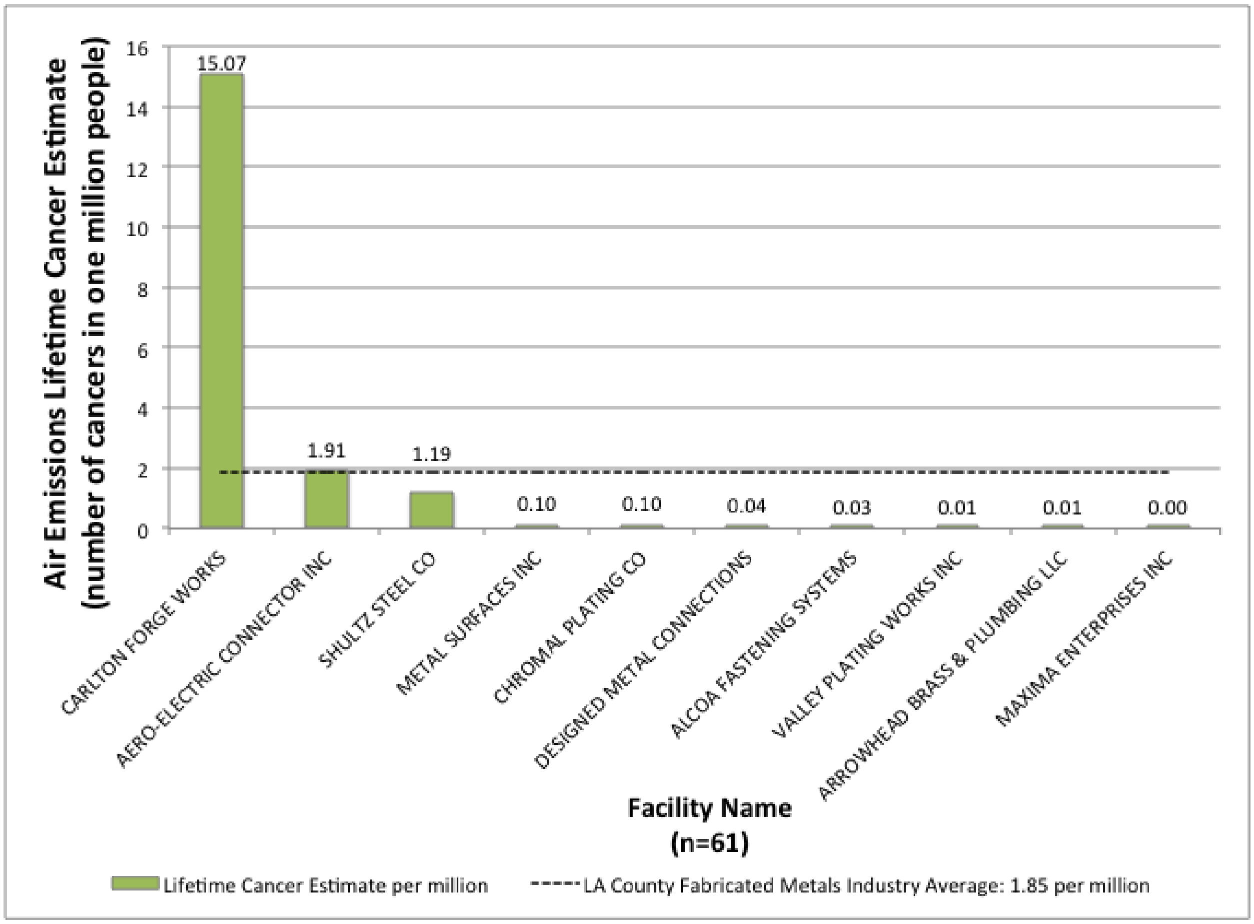


Figure 26 – The 10 facilities in the Fabricated Metals Industry with the highest *Regional Contribution to Lifetime Cancer Risk from Air Emissions* in Los Angeles County in 2012.

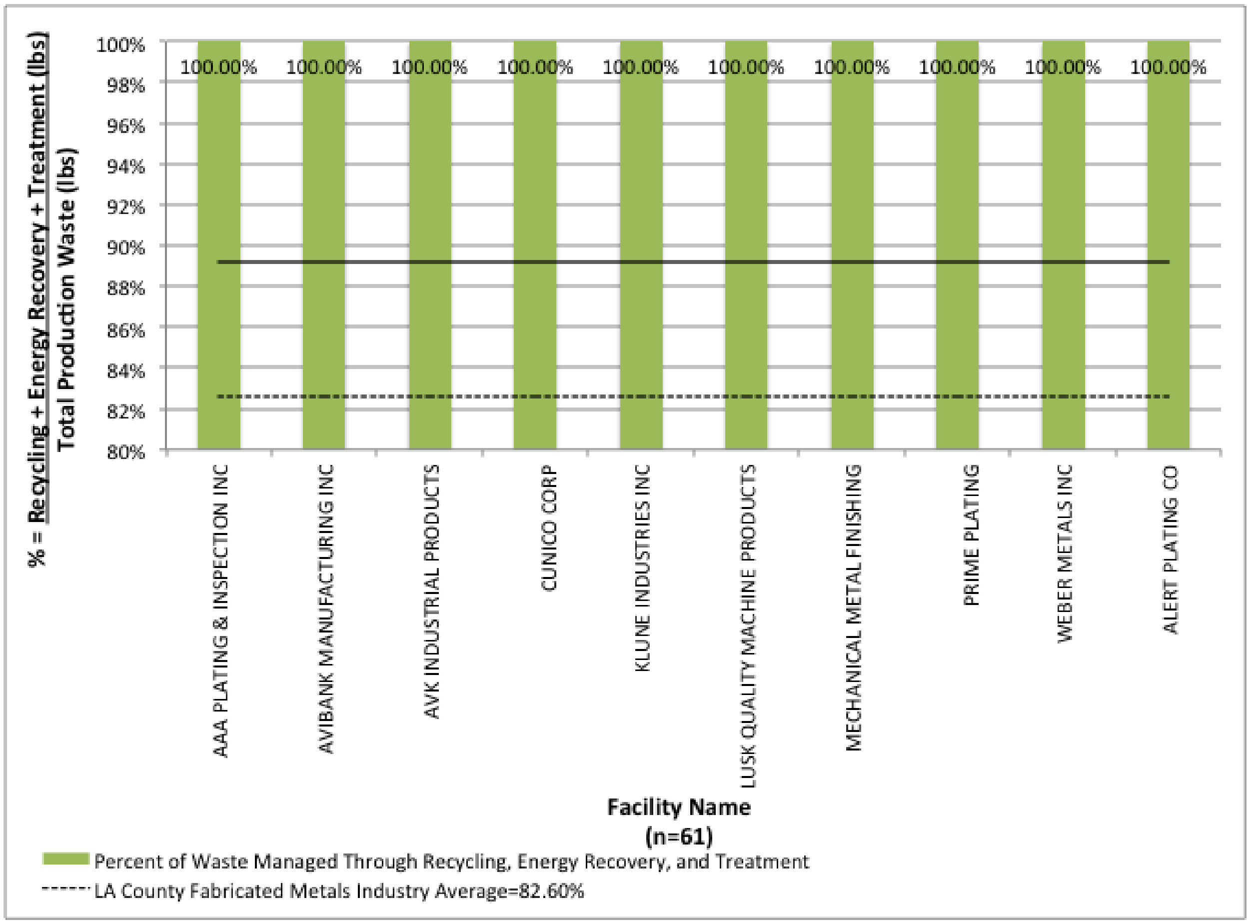


Figure 27 – The 10 facilities in the Fabricated Metals Industry with the highest *Percent Waste Managed Through Recycling, Energy Recovery, and Treatment* in Los Angeles County in 2012.

Appendix C.4 – Top 10 Facilities in Each Environmental Impact Indicator of the Chemicals Industry

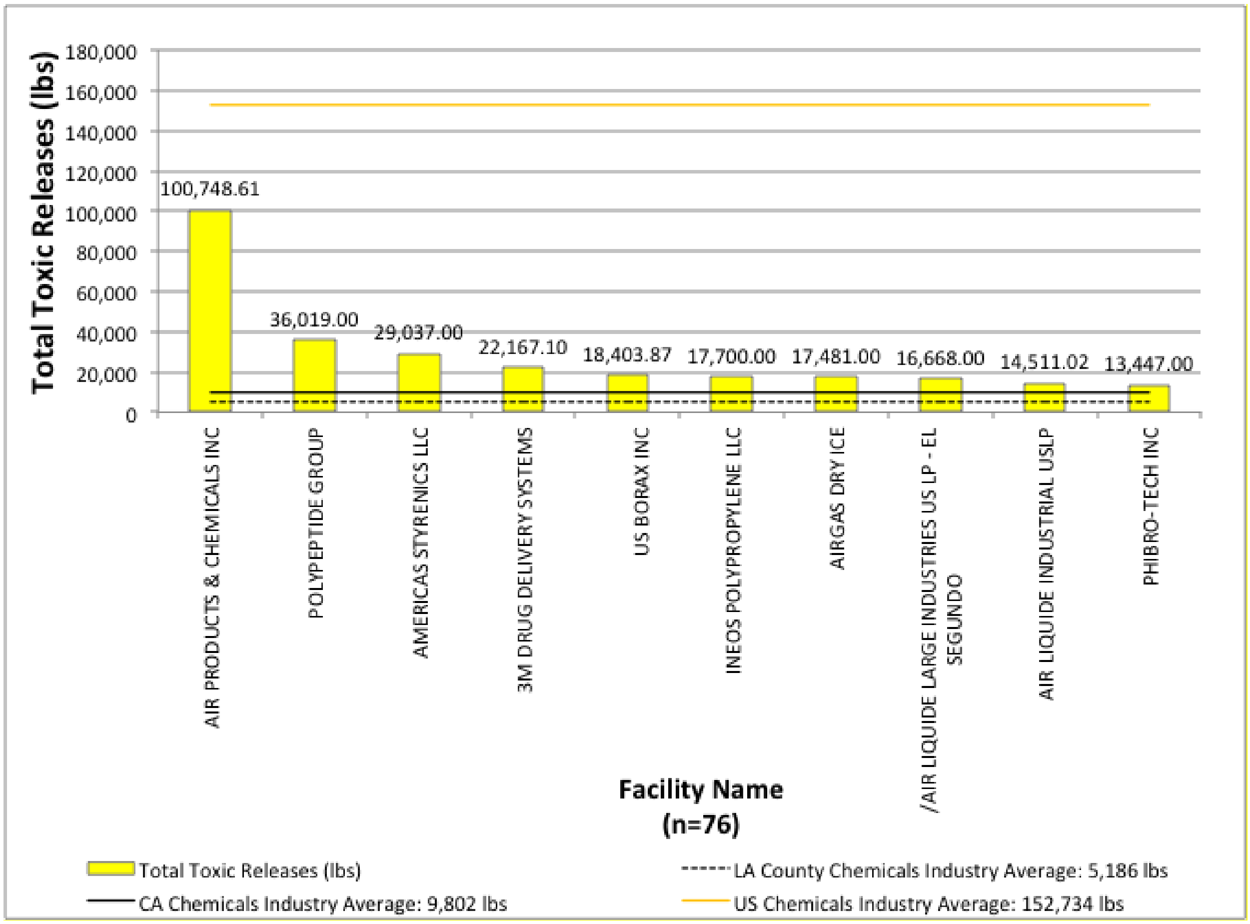


Figure 28 – The 10 facilities in the Chemicals Industry with the highest *Total Toxic Releases* in Los Angeles County in 2012.

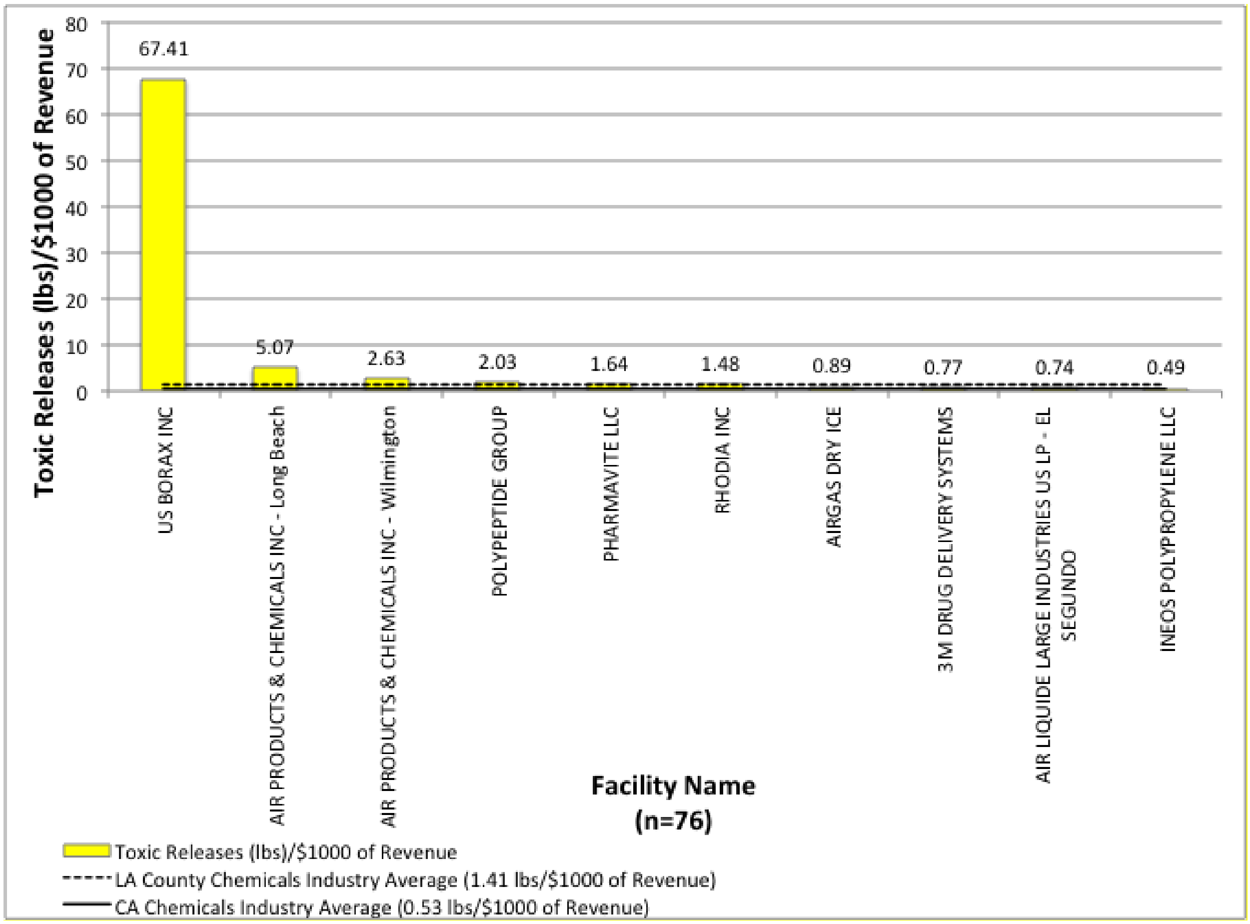


Figure 29 – The 10 facilities in the Chemicals Industry with the highest *Toxic Releases per $1000 of Revenue* in Los Angeles County in 2012.

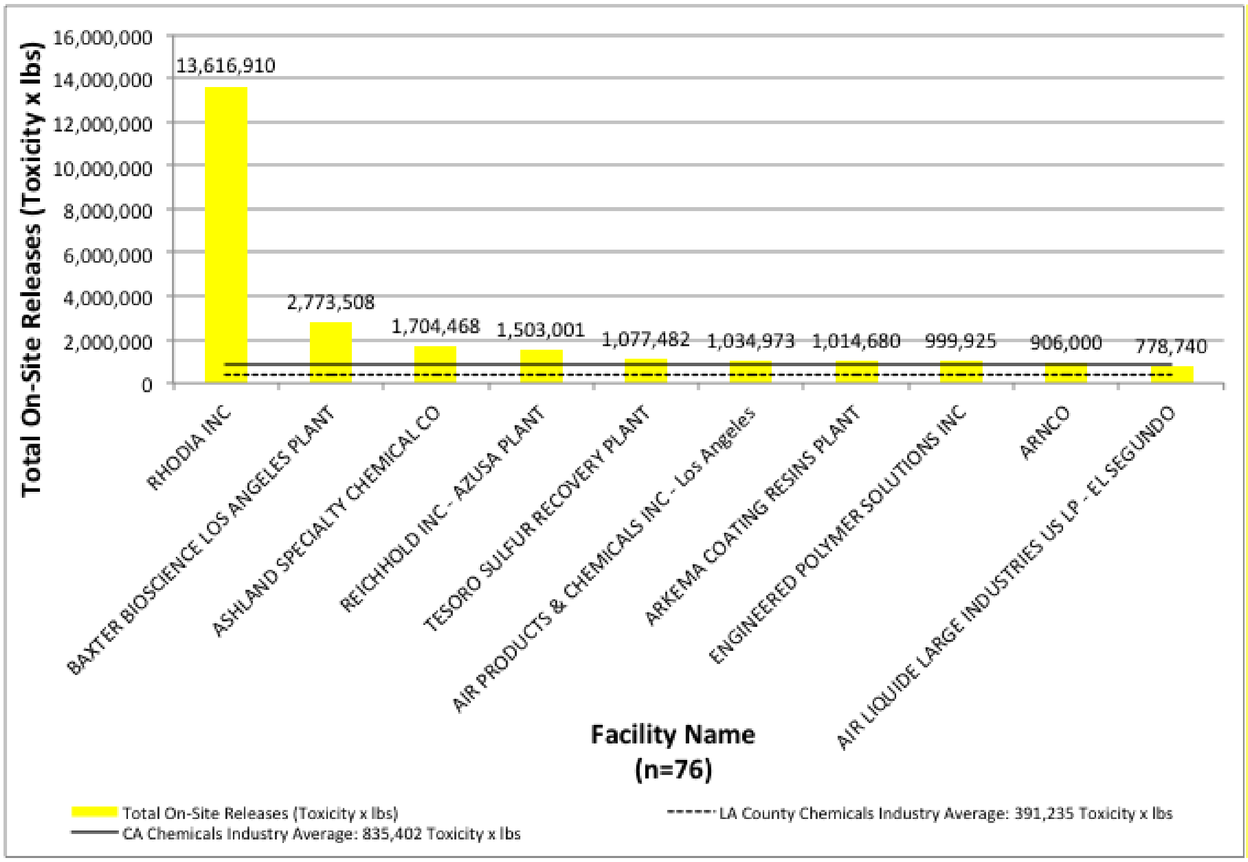


Figure 30 – The 10 facilities in the Chemicals Industry with the highest *Toxicity of Total Releases* in Los Angeles County in 2012.

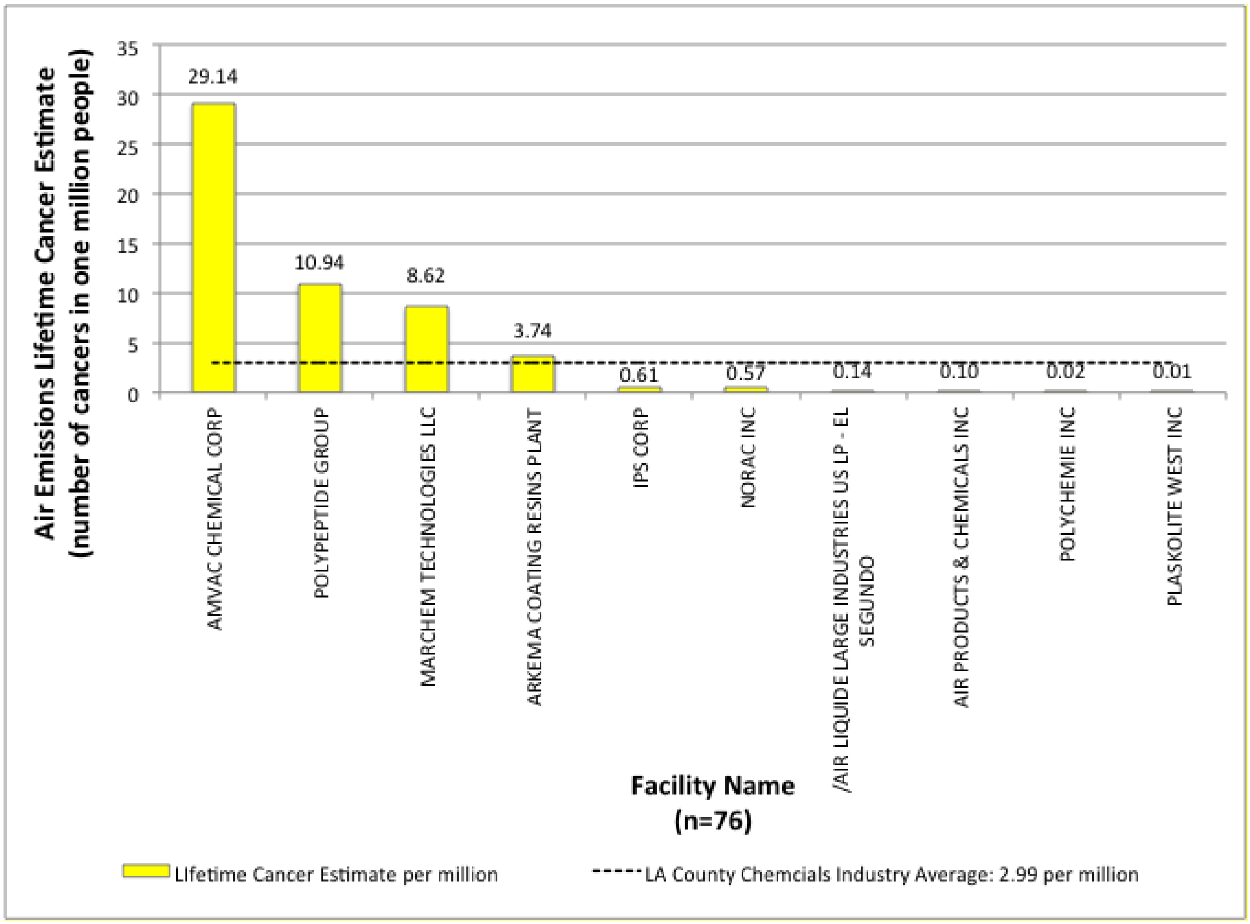


Figure 31 – The 10 facilities in the Chemicals Industry with the highest *Regional Contribution to Lifetime Cancer Risk from Air Emissions* in Los Angeles County in 2012.

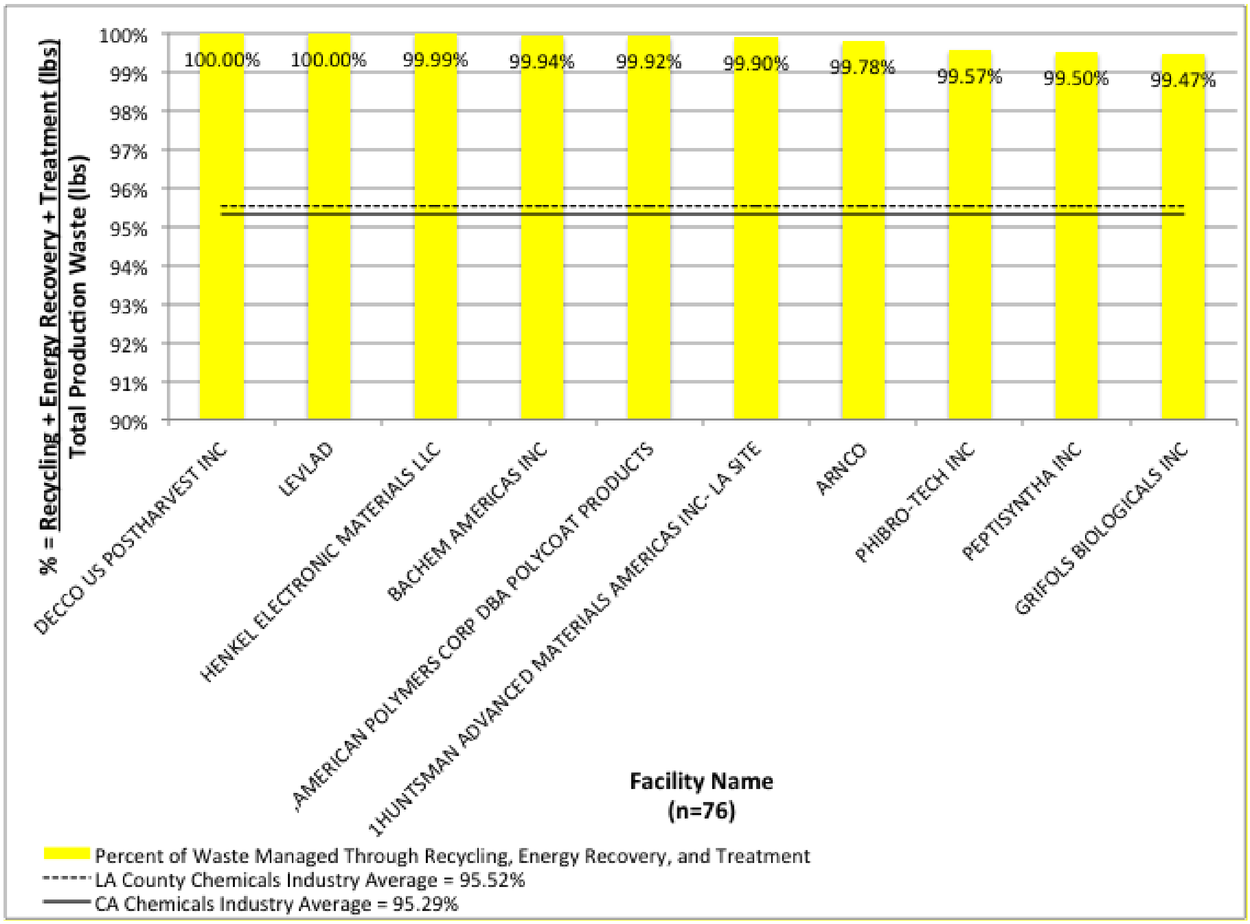


Figure 32 – The 10 facilities in the Chemicals Industry with the highest *Percent Waste Managed Through Recycling, Energy Recovery, and Treatment* in Los Angeles County in 2012.

Appendix D – Data Envelopment Analysis (DEA)

Although we did not use DEA to provide facility environmental performance ratings, we describe the DEA methodology and our DEA analysis on facilities in the Top 4 Industries of Los Angeles County in the following section for future research purposes.

Our objective in identifying the facilities in the Top 4 Industries is not only to showcase the most- or less-polluting facilities, but also encourage these facilities to reduce their overall amount of toxic releases into the environment without detriment to their annual revenue. We utilize Data Envelopment Analysis (DEA) to measure each facility's efficiency within their respective industries at achieving this outcome. Previous researchers, including our advisor Dr. Magali Delmas, have utilized DEA's robust methodology to measure facility efficiency with multiple inputs and outputs. This is the first known project to utilize DEA to measure facility efficiency with multiple inputs and outputs that were determined by complementing TRI data with other datasets.

D.1 DEA Methodology

In general, a facility is efficient if it best minimizes its inputs, while maximizing its outputs (*Measuring Eco-Inefficiency:A New Frontier Approach*, Chen and Delmas). This concept of efficiency is intuitive if we examine one input (i.e. total toxic releases into the environment) and one output (i.e. annual revenue). We describe this as the ratio of pounds of toxic releases per $1000 of revenue (see pages 21-22). The most efficient facilities can be easily identified as those that generate fewer pounds of toxic releases per $1000 of revenue.

DEA uses this concept of minimizing inputs while maximizing outputs to determine a facility efficiency score. However, DEA's strength lies in its ability to simultaneously use several inputs and outputs, or variables, to measure facility efficiency without assigning fixed weights. This would otherwise be difficult to achieve with the use of ratios as previously mentioned. Through an optimization procedure, DEA automatically generates the best weights for each variable that ultimately maximizes the facility's efficiency relative to other facilities within their respective industries (*Measuring Corporate Social Performance: An Efficiency Perspective*, Chen and Delmas). Facility efficiency scores reflect the best-case scenario
because each facility receives their most favorable weights and subjective weights.

As a weight-free evaluation approach, DEA serves the purposes of this project by providing a facility efficiency score that reflects the simultaneous potential decrease of inputs (i.e. toxic releases) and potential increase of outputs (i.e. annual revenue) (Ozcan, 71). This is very critical in determining facility efficiency scores because we recognize the possibility of a facility to reduce its toxic releases without detriment to its annual revenue, and conversely this facility can increase its annual revenue without increasing toxic releases.

The DEA methodology assigns efficiency scores between zero (0) and one (1), with 0 representing the least efficient facilities and 1 representing the most efficient facilities (*Measuring Corporate Social Performance: An Efficiency Perspective*, Chen and Delmas). Facilities with scores of 1 form the efficiency frontier and are used as benchmarks by which other facilities are compared to. Facility efficiency scores between 0 and 1 represent the facility's relative efficiency to the efficiency frontier, or the distance from reaching the efficiency frontier. Figures 33 & 34 illustrate the fundamental concepts of DEA methodology in determining the efficiency frontier and facility efficiency scores with one input and output.

D.1.2 Determining the Efficiency Frontier: Returns to Scale

Each point in Figure 10 represents a facility. The efficiency frontier is represented by the curve or line that envelops all facilities within the sample so that efficiency scores can be determined. We can construct the efficiency frontier as a line or curve based on the desired returns to scale, or relationships between inputs and outputs. If we suspect that there is a linear relationship between inputs and outputs and we wish to maximize facility efficiency in this manner, then the DEA model will be have a Constant Returns to Scale (CRS) structure (Ozcan, 43). However, if we suspect that there is not a proportional increase or decrease in inputs and outputs, meaning there is not a linear relationship, then the DEA model will have a Variable Returns to Scale (VRS) structure (Ozcan, 43). Figure 33[11] illustrates both CRS and VRS structure in determining the efficiency frontier.

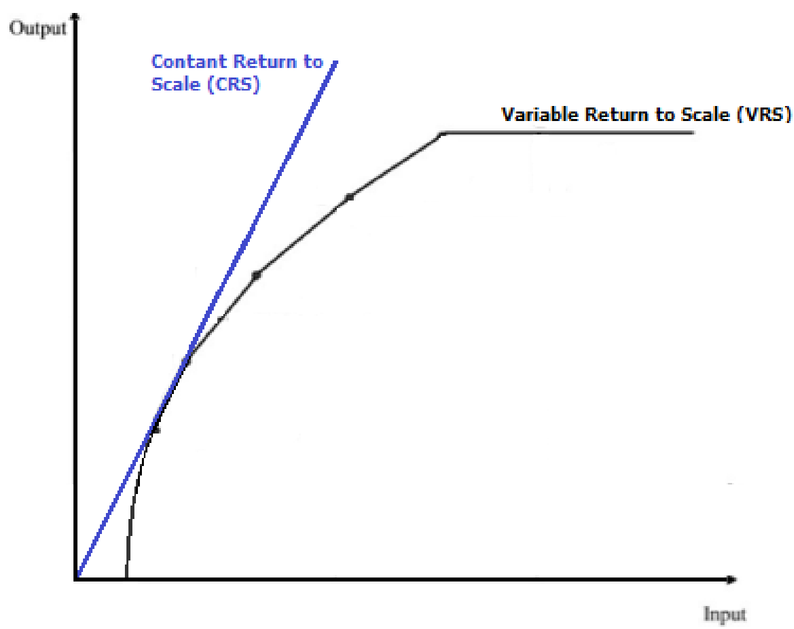


Figure 33 – Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) structure in determining the efficiency frontier

[11] Figure adopted from *Influential observations in frontier models, a robust non-oriented approach to the water sector*

Facilities connected by the solid lines constitute the efficiency frontier and are the most efficient facilities (i.e. DEA score of 1) within their industry. In CRS structure where a linear relationship exists between inputs and outputs, the efficiency frontier is a line. This is compared to the VRS structure where a linear relationship does not exist, and is instead represented by the curve (Figure 33). From the figure, CRS structure has a more restrictive efficiency frontier than VRS structure where and more facilities are considered efficient.

D.1.3 Approaching the Efficiency Frontier: Orientation

Once we determine where the efficiency frontier lies, we can model DEA to measure the distance a certain facility is from its efficiency target. This is the facility's efficiency score. In Figure 34[12] Facility A is an inefficient facility and the DEA program calculates the efficiency score of the facility by its distance to the efficiency frontier. Facility A has three approaches to reach the efficiency frontier represented by points B, F, and D:

1. Using an input oriented efficiency analysis, which minimizes inputs for a given output, Point B is the efficiency target for Facility A. Its relative efficiency is calculated by the distances CB/CA, or AB
2. Using an output-oriented efficiency analysis, which maximizes outputs for a given input, Point D is the efficiency target for Facility A. Its relative efficiency A is calculated by the distances ED/EA, or AD
3. Using a non-oriented efficiency analysis, which simultaneously maximizes inputs and outputs to reach the efficiency frontier, Point F is the efficiency target for Facility A. Its relative efficiency is the distance AF.

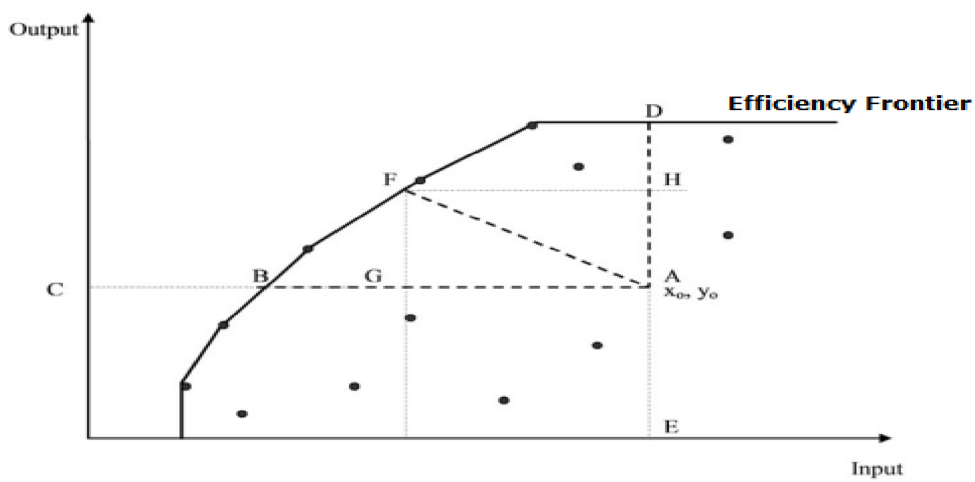


Figure 34 – Facility A is an inefficient facility. Point B represents Facility A's efficiency target for an input-oriented analysis. Point D represents the efficiency target for an output-oriented analysis. Point F represents the efficiency target for a non-oriented analysis.

[12] Figure adopted from *Influential observations in frontier models, a robust non-oriented approach to the water sector*

It is important to note again that the figures above only illustrate the DEA methodology with single- inputs and outputs. Using the same concepts described for single- inputs and outputs, DEA's robust methodology allows for the use of multiple inputs and outputs, each with different units, to assign optimal weights to maximize individual facility efficiency. This is critical to our analysis because we are able to select from the extensive list of variables that is provided by the TRI and complement them with other datasets that are not provided by the TRI such as annual revenue. We used the following inputs and outputs to evaluate individual facility efficiency within their respective industries for 173 facilities in the Top 4 Industries in Los Angeles County during 2012:

Inputs (variables to be minimized):

1. Total Toxic Releases, measured in pounds
2. Toxicity of Air Releases, measured in pounds * toxicity

Outputs (variables to be maximized):

3. Waste Managed through Energy Recovery, Recycling, Treatment, measured in pounds
4. Annual Revenue, measured in dollars

For our analysis we minimize the facility's inputs, namely toxic releases and the toxicity of those chemicals, because they represent harm to the environment and human health. Both variables are provided by the TRI. We also wish to maximize the facility's outputs, namely waste managed through energy recovery, recycling, and treatment and annual revenue, because we want to maximize the amount of toxic chemicals that are properly managed at the facility and prevented from being released into the environment as well as the facility's income. We are provided annual revenue data by datasets other than the TRI including ReferenceUSA, Hoovers, Orbis, and InsideView.

Of the 194 facilities in the Top 4 Industries, only 172 facilities (Primary Metals: 29/30 total facilities; Petroleum: 21/27 total facilities Fabricated Metals: 55/61 total facilities; Chemicals: 67/76) had all four variables to be included in the DEA analysis. Facility efficiency score based on these four variables can be quantified through rigorous mathematical formulas and equations, or more automatically using DEA software to construct models based on our preferences.

D.2 MaxDEA Software: Parameters Used for Analysis on Top 4 Industries in Los Angeles County

DEA software allows us to construct different efficiency models based on our variables. This project researched and experimented with several DEA computer programs and software including DEAFrontier and EMS before choosing MaxDEA as the principle software to calculate facility efficiency scores. Because of its free content and various parameter options, MaxDEA is best suited for the purposes of our project. We analyze facilities within their respective industries and use MaxDEA to calculate their facility efficiency scores under the following parameters:

D.2.1 Distance: Radial

The "Distance" parameter measures the facility's distance to the efficiency frontier. Using a radial approach, we measure the necessary proportional improvements of a facility's inputs and outputs to reach the efficiency frontier without detriment to its output. In Figure 3, Facility A's distance to the efficiency frontier is determined at points B, F and D, which all have the same or greater output values than Facility A. This is essential to our analysis because we do not want facilities to reduce their desirable outputs to reach the efficiency frontier.

D.2.2 Returns to Scale: Variable (VRS)

The "Returns to Scale" parameter allows us to construct the efficiency frontier. We select a VRS structure for our analysis because we suspect that there is not a linear relationship between our selected inputs and outputs. By constructing the DEA model to a VRS structure, we expect more facilities to be efficient in our analysis. This results in a conservative measure of facility efficiency.

D.2.3 Orientation: Non-oriented Efficiency Analysis

The "Orientation" parameter allows us to select for the appropriate efficiency analysis for DEA to describe how a facility reaches the efficiency frontier. We select a non-oriented efficiency analysis to control both inputs and outputs for facilities to reach the efficiency frontier. Facility efficiency scores are based on the facility's optimal mix of inputs and outputs by allowing for simultaneous reductions in inputs and increases in outputs. This again is critical in our analysis because we calculate facility efficiency scores under a best-case scenario.

Given these parameters, all facility efficiency scores are conservative and MaxDEA calculates them under a best-case scenario.

Because of the DEA's sensitivity to zero values in a small dataset, we replace zeros for each variable in the dataset with 0.1 because it is the smallest positive value that best envelopes all facilities under the efficiency frontier. Values smaller than 0.1 generate negative efficiency scores due to the program's sensitivity to zero values.

D.3 DEA Results & Limitations

The power of DEA lies in its ability to generate scores for facilities that are similar to each other and are part of a large sample sizes. Even though we choose to run the DEA on each industry separately, there may still be differences within the facility that are not accounted for by limiting the DEA to an intra-industry comparison. For example, within the petroleum industry there are facilities categorized as refineries, asphalt paving and block manufacturing, asphalt shingle and coating materials manufacturing, lubricating oil and grease manufacturing, and all other petroleum and coal products manufacturing. A refinery may or may not utilize manufacturing processes comparable to those used by a facility that specializes in asphalt paving, and therefore it may differ in the quantity and types of toxic releases as well as its revenue scale and ability to recycle, recover, or treat waste. The magnitude of these differences is unknown and therefore cannot be accounted for when comparing DEA scores.

Another limitation is sensitivity to zero values. When we run the DEA analysis with some facilities reporting zero emissions, these facilities may be interpreted as “hyper-efficient” by MaxDEA, which over-shifts the inter-variable weights to favor them. This leads to other facilities receiving a negative score. We corrected this error by replacing zero values with 0.1, which is a small enough positive value to ensure that it is interpreted by MaxDEA as a minimal input or output while large enough to prevent other facilities from receiving a negative score.

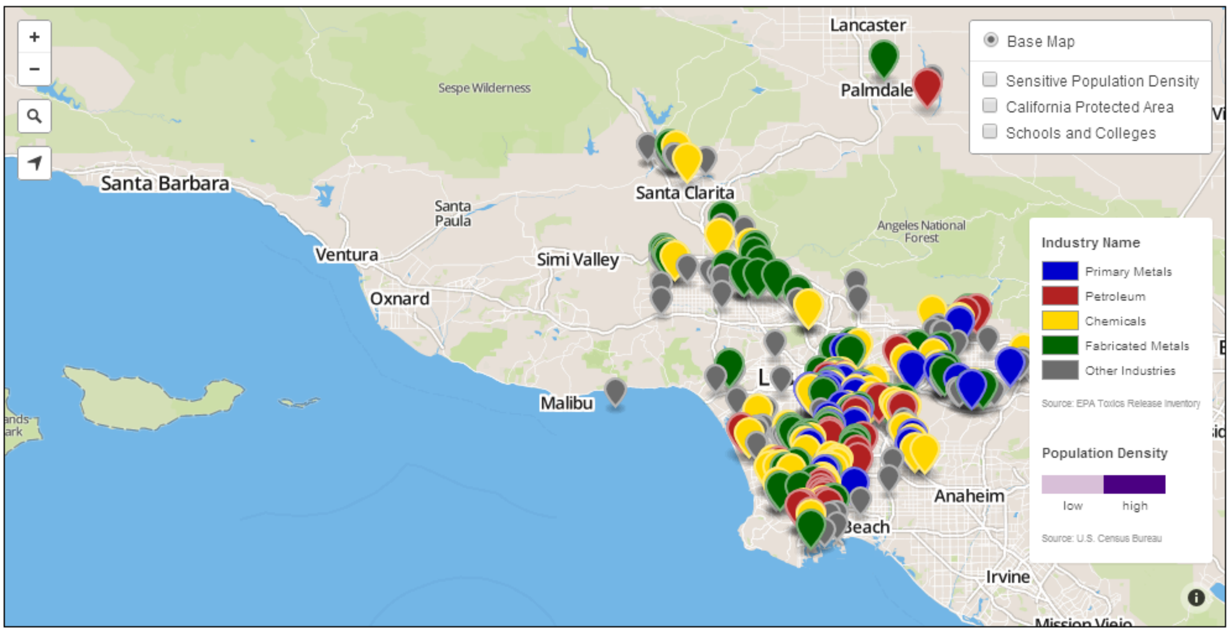
Appendix E - Quick Guide on the *Cal EcoMaps* Map Applet

CalEco Maps is an interactive mapping tool that identifies facilities reporting to the Environmental Protection Agency's Toxics Releases Inventory (TRI) in the Los Angeles County. The 194 facilities displayed on this map applet are from the top four industries (Primary Metals, Petroleum, Chemicals, and Fabricated Metals) based on 2012 reported values of total toxics released on- and off-site.

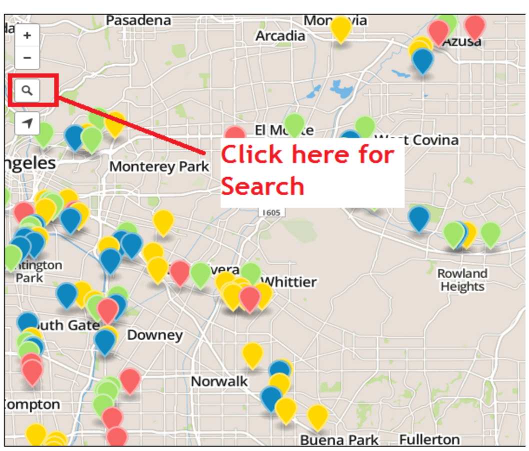
When you first enter our site, you will see this page with a map:

Welcome!

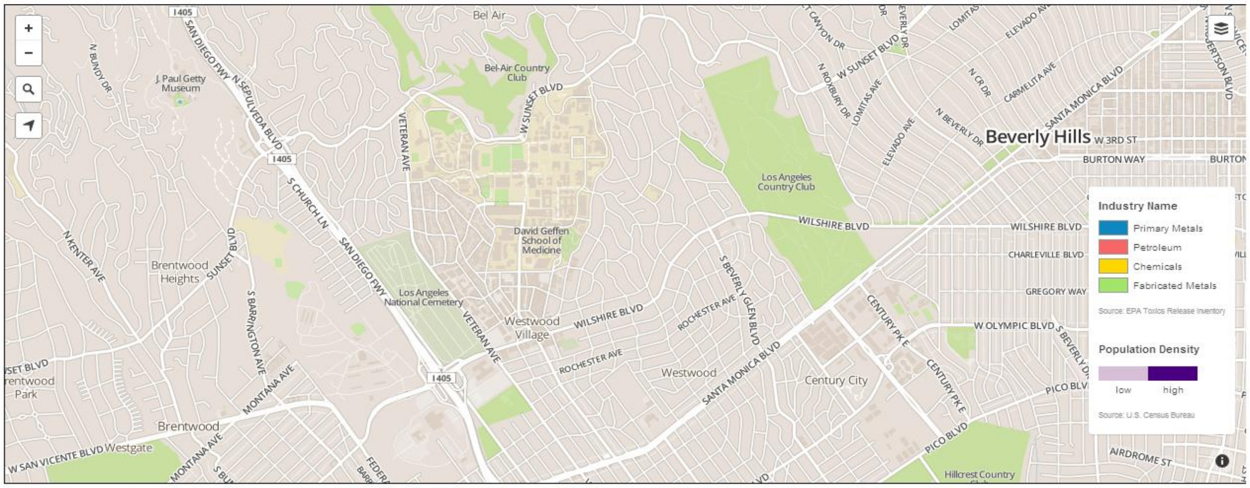
Cal EcoMaps is a tool to share the environmental performance of Toxic Release Inventory (TRI) facilities through the development of a robust methodology that currently evaluates facilities in the Greater Los Angeles Area. Use the interactive map below to learn more about your facility or your neighborhood.



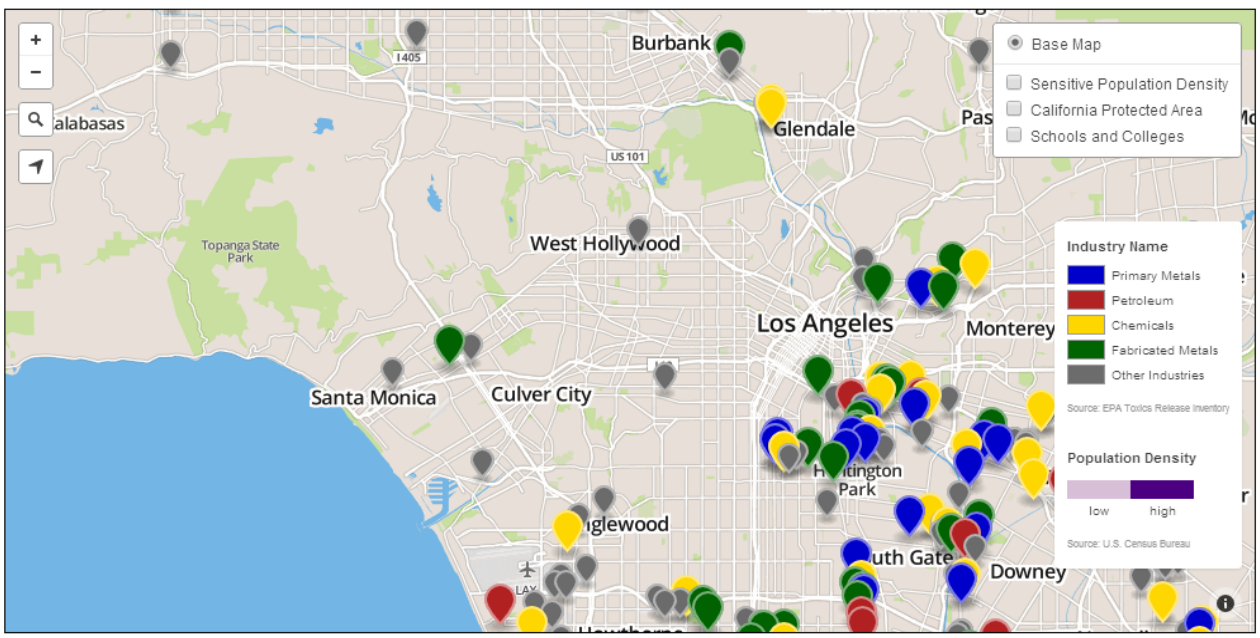
First, you will search for an address or a zip code you are interested in. Alternatively you could click the geo-locator button on the left side in order to zoom the map to your current location.



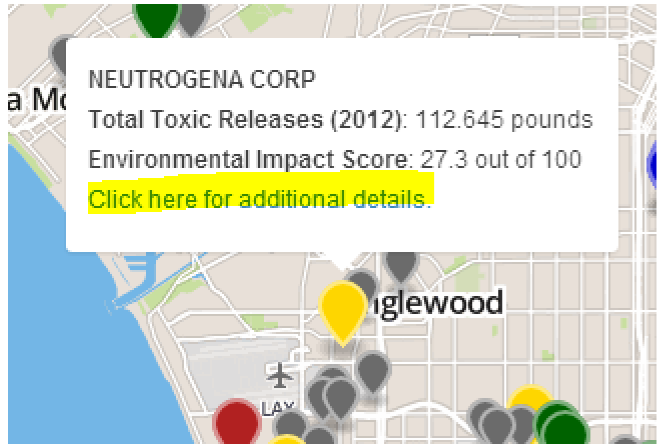
For example, here we will search for the zip code 90024, the zip code for UCLA.



As you can see, there are no TRI facility markers in view. Put your mouse at the center of the screen, and you can zoom out using your mouse scroll. You should start seeing markers indicating the nearest facilities that report TRI. Alternatively you could also use the – or + button on the top left of the map applet:

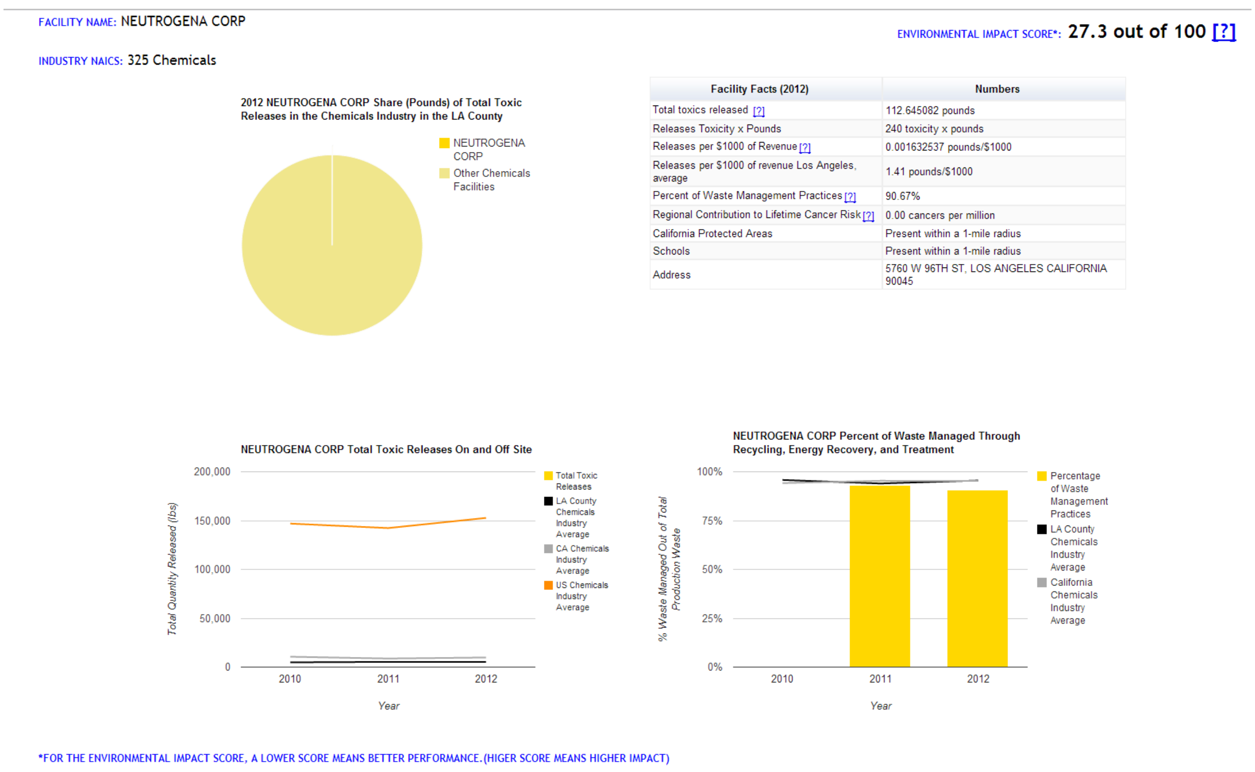


Now, you click the nearest facility to the address in question, like the example below. A popup will show with the facility name, its total toxic releases, and *Cal EcoMaps Environmental Impact Score*.



More information on a certain facility can be found by clicking on the link "Click here for additional details" under its marker. This is the main feature of the applet that display facility-specific information.

On the facility page, interactive graphs displaying the facility's share of total toxic releases in their respective industry (top right), total quantity released between 2010 and 2012 (bottom left), and percent of waste managed through recycling, energy recovery, and treatment between 2010 and 2012 (bottom right) are shown:

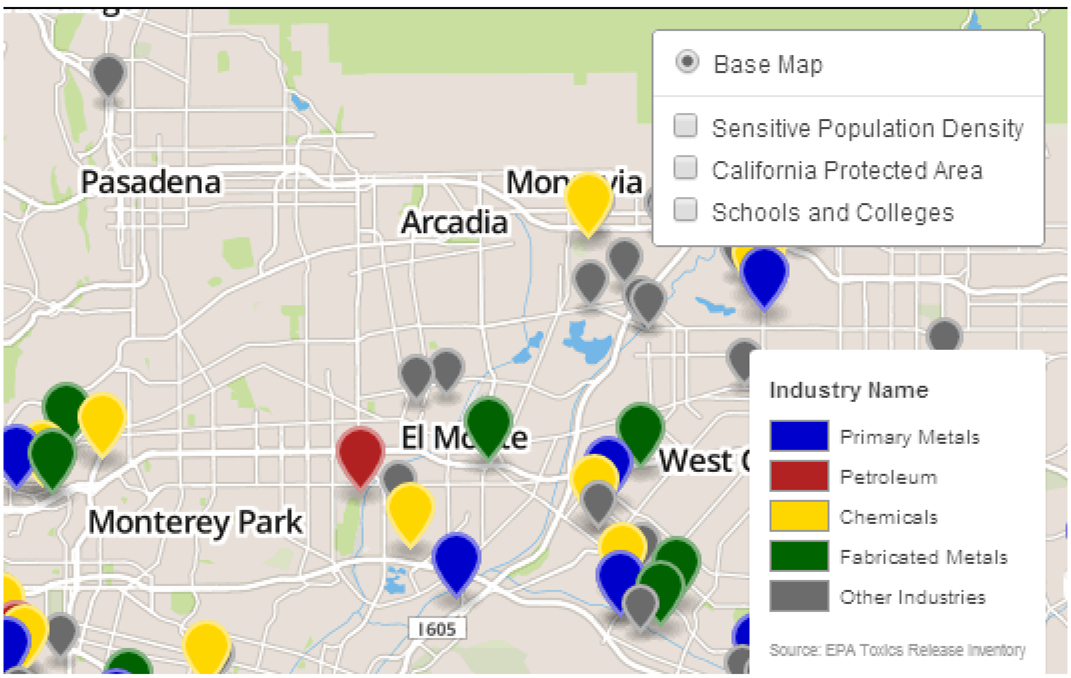


Under the "Facility Facts" table (top left), you can click on each of the hyperlinks in the first column [?] for more information about the different variables this project examined:

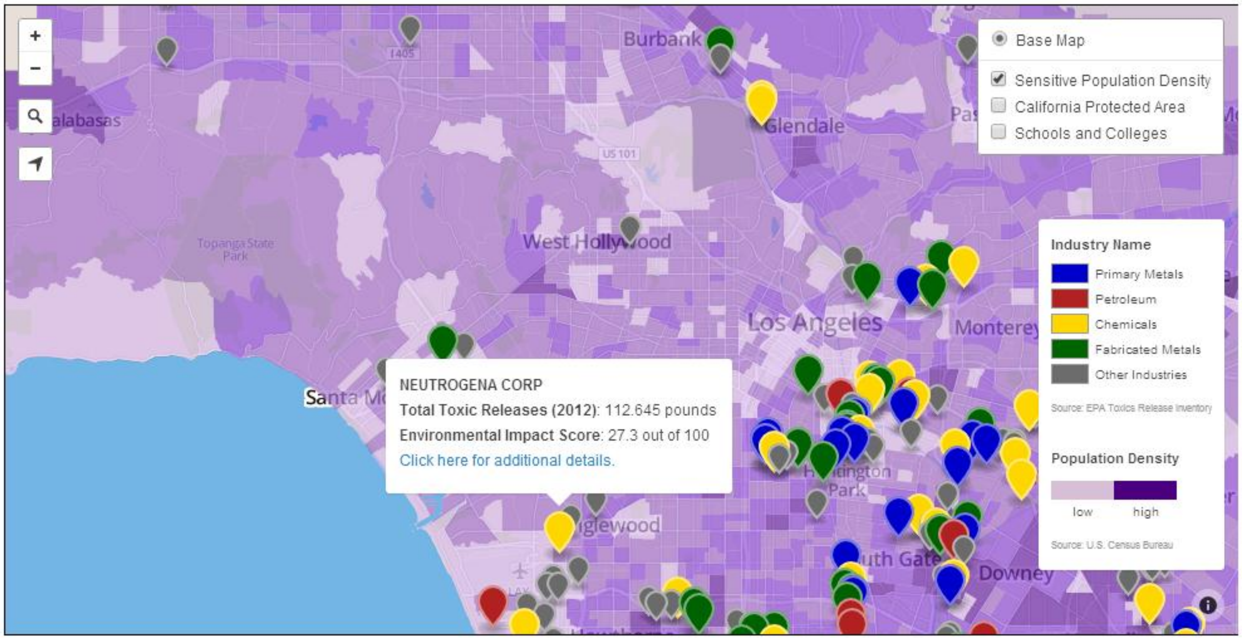
Facility Facts (2012)	Numbers
Total toxics released [?]	112.645082 pounds
Releases Toxicity x Pounds	240 toxicity x pounds
Releases per $1000 of Revenue [?]	0.001632537 pounds/$1000
Releases per $1000 of revenue Los Angeles, average	1.41 pounds/$1000
Percent of Waste Management Practices [?]	90.67%
Regional Contribution to Lifetime Cancer Risk [?]	0.00 cancers per million
California Protected Areas	Present within a 1-mile radius
Schools	Present within a 1-mile radius
Address	5760 W 96TH ST, LOS ANGELES CALIFORNIA 90045

Additional features:

If you look at the top right of the map, you will see a layer section:



Checking different layers will show more information about the locations surrounding the facility. For example, the Sensitive Population Density layer will show you the sensitive population density around a facility:



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