University of California, Berkeley

The Policy and Politics of Pollution:
Exploring Regulation, Environmental Justice, and Toxic Air Emissions Dispersion Trends from the Richmond Chevron Refinery

A Thesis submitted in satisfaction of requirements for the College of Natural Resources Honors Research Program and in partial satisfaction of requirements for the Bachelor of Science degree in Conservation & Resource Studies

by

Vanessa Gerber

Thesis Advisor:
Professor Dan Kammen

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ABSTRACT

This study aims to better understand the dispersion trends of toxic emissions coming from the Richmond Chevron refinery, analyzing the condition through the lens of relevant policy and local politics, ultimately assessing the scenario against the ideals of environmental justice. Employing a wedge model to make predictions on concentrations of tropospheric ozone, particulate matter ($PM_{2.5}$), and the BTEX toxic compound, the predictive performance is inconsistent and ultimately deemed unreliable, however the unreliability can be largely attributed to the lack of complete and consistent data and the inherent use of many assumptions. Considering the role of policy and politics on the enabling and perpetuation of the refinery operations, the lack of strong restrictive policy, poor availability of coherent data, and far outdated epidemiological studies on the impacts of exposure to known toxics in the air create a very challenging platform for public awareness and improvement of the condition. Looking into the future of the energy economy, hope is restored in the eventual reduction in emissions, though amendments to existing policy can aid in an earlier transition towards sustainability and improved public health.

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LIST OF ABBREVIATIONS

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12-15…………. BAAQMD Regulation 12, Rule 15 – Petroleum Refining Emissions Tracking
12-16…………. BAAQMD Regulation 12, Rule 16 – Petroleum Refining Emissions Analysis, Thresholds and Mitigation
2-5……………. BAAQMD Regulation 2, Rule 5 – New Source Review of Toxic Air Contaminants

b.o.e. …………. back-of-the-envelope calculation
bpd……………. barrels per day (crude oil)

CAAQS………. California Ambient Air Quality Standards
CAP…………… Criteria Air Pollutant

ERP…………… Emission Reduction Plan

FCCU……….... Fluid catalytic cracking unit

GIS…………... Geographic Information Systems
GRA………..… greater Richmond area: inclusive of Richmond, CA; San Pablo, CA; and North Richmond, CA

HAP………..… Hazardous Air Pollutant (often referred to also as TAP or TAC)

µg/m^3…………. microgram per meter-cubed… a unit indicating mass-per-volume
MWD………..… mean wind direction, in reference to centerline tangent of wedge

NAAQS…..…... National Ambient Air Quality Standard
NAD83……….. North American Datum, 1983
NEI…………..... National Emissions Inventory
NESHAPs…..… National Emission Standards for Hazardous Air Pollutants
NOx……...…… nitrogen oxides
NSPS…………. New Source Performance Standards

O_3……………... ozone

$PM_{2.5}$…………... particulate matter, <2.5 micrometers in diameter
ppb.……………. parts per billion
Point A………... origin of wedge model; mean geographic center of major refinery point sources
PREP………….. Petroleum Refinery Emissions Profile

RCR…………… Richmond Chevron refinery
REL…………… reference exposure level
RFG……...……. refinery fuel gas
RPS……………. Renewable Portfolio Standards

t/y……………… tons/year
TAC………..…… toxic air contaminant (see also HAP)
TRI…………..…. Toxics Release Inventory
TE……...…….… total emissions

VOC……..…….. volatile organic compound

WRD………..… wind rose degrees (0˚ N, 90˚ E, 180˚ S, 270˚ W)

List of Agencies, Organizations

AFPM……..…... American Fuel & Petrochemical Manufacturers
API…………..… American Petroleum Institute

BAAQMD…….. Bay Area Air Quality Management District (also referred to as: 'Air District')

CalEPA……..…. California Environmental Protection Agency
CARB………..… California Air Resources Board
CBE……………. Communities for a Better Environment

EIA…………..… United States Energy Information Administration

U.S. EPA……..… United States Environmental Protection Agency

WCTC………..… West County Toxics Coalition

Chapter 1

INTRODUCTION

Oil refineries not only produce petroleum products, which, in use in other industries and as fuel for automobiles, aircraft, and ships, produce emissions as a result of combustion, they also produce direct emissions and flares throughout the refining process, impacting local air, water, and population. Due to policy – allowing and, in some cases, endorsing the oil industry's operations – and politics – corporate spending and drastic political overpowering of disenfranchised fenceline communities – the impacts from oil refineries are not only of critical environmental concern, they are nearly always of critical environmental *justice* concern, as well.

By the most recent count of the United States Energy Information Administration (EIA), the United States houses 142 currently operating petroleum refineries, a steadily decreasing number since the peak in 1982 of 301 facilities.[1] California hosts 18 of the current refineries, and according to the California State Energy Almanac, roughly two million barrels – equal to 84 million U.S. gallons – of petroleum are processed every day amongst the state's refineries alone, with around half of that capacity designated for gasoline production.[2] Contra Costa County single-handedly hosts four of the state's refineries, with the one final facility of the region's five-refinery corridor just across the Carquinez Strait in Solano County, as seen in **Figure 1-1**. Having grown up seven miles from the Richmond Chevron refinery, seeing it from the end of my street every day and hearing news stories about major incidents and community resentment, I have been conscious of the refinery and its associated problems for a long time. Working for the San Francisco Bay Chapter of the Sierra Club during the summer of 2014, I learned more about the history and background of refinery operations and tensions in local Bay Area communities, was exposed to local and regional political processes regarding emissions regulation, and ultimately developed a passion to further understand the real

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Chapter 1 Notes:

[1]United States Energy Information Administration. "U.S. Number and Capacity of Petroleum Refineries." EIA Independent Statistics & Analysis - Petroleum and Other Liquids. June 25, 2014. Accessed October 13, 2014. http://www.eia.gov/dnav/pet/pet_pnp_cap1_dcu_nus_a.htm.

[2] California Energy Commission. "California's Oil Refineries." California's Oil Refineries. November 2014. Accessed October 13, 2014. http://energyalmanac.ca.gov/petroleum/refineries.html.

impact of the refineries and the political framework within which they operate. This zeal to produce a resource not only for the academic world on the social and environmental implications of heavy industry emissions, but more importantly for the fence-line communities suffering toxic exposure on a daily basis provides the impetus for my further learning and analysis. Through the case study of the largest and most infamous of the local refineries, and one of the most highly producing in the region – the Richmond Chevron refinery – I will model the emissions dispersion trends over the surrounding area and population, explore standards and regulations pertaining to the refinery from the regional to federal level, analyze the role of specific policy and local politics in the current condition, and examine the scenario through the lens of environmental justice. Given this motivation, I propose the following research question: How do emissions from the operation of the Richmond Chevron refinery impact the greater Richmond area, and how can the scenario be improved; with specific sub-questions:

- What quantity and concentration of airborne toxics does the Richmond Chevron refinery emit, and in what direction and velocity do they flow?
- What populations are impacted, and what are the major health concerns associated with the population's exposure?
- To what extent do relevant environmental policies and the local political landscape influence the observed condition?

Important factors in understanding the political landscape that influences policies passed and the experienced condition, include largely economic drivers, relationships, and potential. According to Dr. Henry Clark, Executive Director of the West County Toxics Coalition (WCTC), Chevron is the largest single employer in the City of Richmond and the largest non-government employer in all of Contra Costa County, employing a permanent workforce of 1,300, only roughly 5% of whom live in Richmond, even fewer living in the areas adjacent to the refinery.[3] As such a major economic actor in the area, Chevron

[3] Clark, Henry. "Conversation with Dr. Henry Clark." Telephone interview by author. April 14, 2015.

contributes nearly one-quarter of Richmond's tax base, which Clark shares "translates to a lot of power in City Hall."[4]

Figure 1-1. *Greater Richmond Area and Regional Refineries in Context of San Francisco Bay Area*

It is clear through the presence of air pollutants, community backlash, and aggressive corporate spending that there persists a critical environmental and public health challenge that has persisted as a result of serious inertia through the presence and strength of Chevron's political influence. This study aims to: i. extrapolate the emissions dispersion trends over the greater Richmond air basin through the use of toxics concentration data and local meteorological data in a wedge model, ii. to identify the populations impacted by the emissions dispersion over the community, by way of a geographic information system, and iii. to examine the social and environmental health implications of such an impact from the local refining industry.

[4] Clark. "Conversation with Dr. Henry Clark." 2015.

1.1 Setting the scene

The greater San Francisco Bay Area is home to five petroleum refineries, with capacity of the facilities ranging from 80,000 barrels per day (bpd) to 250,000 bpd, totaling an 831,000 bpd potential for the region as a whole.[5,6,7,8,9*] Even individually these refineries generate immense amounts of toxic air emissions that spread over the local land and community, and together they are the face of a highly scrutinized regional oil infrastructure. It is important to understand the impacts of the refineries in the context of public health, and to do so it is necessary to employ variables that account for local conditions that influence the trajectory of the toxic emissions.

Richmond Chevron, in particular, boasts the highest capacity and production of any of the region's five refineries at 250,000 bpd; even to the naïve passerby, simply comparing visual observations of the refineries, Richmond Chevron is clearly the local powerhouse, overshadowing the other refineries with 7 main stacks compared with the 2-4 stacks housed on the premises of the other four refineries.[10,11] With the large capacity and daily production of petroleum products, Richmond Chevron also produces significant emissions that have been an historic burden to the fence-line community.[12] And as if business-as-usual was not bad enough, Richmond Chevron has also been responsible for major release incidents such as significant flares and even fires that have hospitalized thousands in the community.[13] Understanding that the fence-line community surrounding the Richmond Chevron refinery has seen

[5]Phillips 66. "San Francisco Refinery Public Affairs." Phillips 66 - About. Accessed October 13, 2014. http%3A%2F%2Fwww.phillips66.com%2FEN%2Fabout%2Four-businesses%2Frefining-marketing%2Frefining%2FSFRPA%2FPages%2FSFRPA.aspx.
[6] Chevron Corporation. "What We Do - About Chevron Richmond." Chevron - Richmond. 2011. Accessed October 13, 2014. http://richmond.chevron.com/home/aboutchevronrichmond/whatwedo.aspx.
[7] Shell. "Martinez Refinery." Shell - United States. Accessed October 13, 2014. http%3A%2F%2Fwww.shell.us%2Faboutshell%2Fprojects-locations%2Fmartinez.html.
[8] Valero Marketing and Supply Company. "Refineries: Benicia." Valero. 2014. Accessed October 13, 2014. http://www.valero.com/ourbusiness/ourlocations/refineries/pages/benicia.aspx.
[9] Tesoro Corporation. "Tesoro - Golden Eagle Fact Sheet." Tesoro. May 1, 2014. Accessed October 13, 2014. https://tsocorpsite.files.wordpress.com/2014/08/gefact.pdf.
*831,000 bpd regional capacity calculated with values sourced from each of the sources 5-9.
[10] Chevron. "What We Do." 2011.
[11] Bay Area Air Quality Management District. "BAAQMD - Compliance & Enforcement Division - Refinery Flare Reports." Bay Area Air Quality Management District. 2014. Accessed October 13, 2014. http://hank.baaqmd.gov/enf/flares/.
[12] Clark. "Conversation with Dr. Henry Clark." 2015.
[13] Jonassen, Wendi. "Air Quailty District Hosts Informative Session on Refinery Fire." Richmond Confidential. September 11, 2012. Accessed October 13, 2014. http://richmondconfidential.org/2012/09/11/air-quailty-district-hosts-informative-session-on-refinery-fire/.

disproportionate environmental and public health burdens as a result of their proximity to emissions sources, it is crucial to evaluate this scenario through the lens of environmental justice.

1.1.1 How refineries pollute

According to the United States Environmental Protection Agency (U.S. EPA), oil refineries not only produce a lot of energy in the form of final petroleum products, they also consume a massive amount of energy in the refining process.[14] Petroleum refineries process crude oil through a variety of specialized systems to produce: "gasoline (motor fuel), distillate (diesel fuel, home heating oil), kerosene (jet fuel), petroleum coke, residual fuel oil (industrial and marine use), petroleum gases (liquefied petroleum gas, ethane, butane), elemental sulfur, asphalt and road oils, petrochemical plant feedstocks, and lubricating oils."[15] In order to operate and refine crude oil, refineries use fossil fuels themselves, producing emissions and contributing toxics to the air basin as a result. The main fuels with which they operate include refinery fuel gas (RFG), petroleum coke, and natural gas,[16] and as stated by an April 2014 permit evaluation of the Richmond Chevron refinery, the primary sources of emissions on the site are combustion units, the fluidized catalytic cracking unit (FCCU), storage tanks, fugitive emissions, sulfur plants, and wastewater treatment plants.[17] RFG, amounting to roughly 68% of U.S. refinery fuel use for energy in 2002, is a combination of collected gases from various refinery processes, treated to recover light hydrocarbons, like propane, and remove sulfur and nitrogen compounds.[18] Petroleum coke, considered a "free fuel of choice," is the product of the coking process in which heavy crude feedstocks and crude residue are converted to solid carbon materials.[19,20] It produces energy for refinery operations by "regenerat[ing]" the catalyst for the FCCU through continual burning; a steam boiler captures and

[14] U.S. EPA. "2008 Sector Performance Report." 2008, 84-89. Accessed October 13, 2014. http://www.epa.gov/sectors/pdf/2008/2008-sector-report-508-full.pdf.
[15] U.S. EPA. "2008 Sector Performance Report."79.
[16] U.S. EPA. "2008 Sector Performance Report."85.
[17] BAAQMD, and Greg Solomon. Permit Evaluation and Statement of Basis for Minor Revisions to the Major Facility Review Permit for Chevron Products Company Facility #A0010. Report. April 2014. Accessed October 21, 2014. 2. http://www.baaqmd.gov/~/media/.
[18] U.S. EPA. "2008 Sector Performance Report."85.
[19] Gary, James H., and Glenn E. Handwerk. "Coking and Thermal Processes." In Petroleum Refining: Technology and Economics, 67-92. Fourth ed. New York, NY: Marcel Dekker, 2001.
[20] American Fuel & Petrochemical Manufacturers. "Petroleum Coke Overview." AFPM. Accessed October 21, 2014. http://www.afpm.org/policy-position-petroleum-coke/.

stores the heat from the combustion.[21] Petroleum coke in use as a recovered fuel in the refining process contains a modifiable amount of sulfur, but more relevantly, has a mass fraction of 98 wt%.[22] According to James H. Gary, professor of Chemical Engineering and Petroleum Refining at the Colorado School of Mines, and coauthor Glenn E. Handwerk, a consulting chemical engineer, "Historically, the heavy residual fuel oils (petroleum coke) have been burned to produce electric power and to supply the energy needs of heavy industry, but more sever environmental restrictions have caused many of these users to switch to natural gas."[23] Natural gas is the last common fuel source in refinery operations, and generates energy through combustion, producing a significant amount of methane in the process due to its high mass fraction of CH4 (Flagan and Seinfeld, 1988, pg. 60).

As a result of the combustion of fuels on-site at refineries, local air and environmental quality are impacted, as is the global concentration of greenhouse gases. On the local level, the introduction of Criteria Air Pollutants – as defined by the U.S. EPA – to the air basin, along with monitored toxics are of highest concern for public health. On the global level, the contribution of greenhouse gases to the already infiltrated atmosphere is of grave concern, as well, in the face of an already threatened climate and global ecosystem.

1.1.2 How urban air circulates

According to Issues in Environmental Science and Technology series editors Ronald E. Hester, Emeritus Professor of Chemistry at the University of York, and Roy M. Harrison, distinguished British Professor of Environmental Health at the University of Birmingham, in their book on Air Quality in Urban Environments, urban air pollution stems from (im)balance of emissions, the introduction or increase of pollutant concentrations in the air, and "dispersion, advection and deposition" processes, the reduction or removal of those pollutants.[24] Air pollutants and air basins are dynamic, however, and the degree to which contaminants impact certain areas is determined by local meteorological conditions; wind

[21] U.S. EPA. "2008 Sector Performance Report."85.
[22] Gary and Handwerk. "Coking and Thermal Processes." 71-82.
[23] Gary and Handwerk. "Coking and Thermal Processes." 67.
[24] Hertel, Ole, and Michael Evan Goodsite. "Urban Air Pollution Climates throughout the World." In Air Quality in Urban Environments, edited by R E Hester and R M Harrison, 1-22. Vol. 28. Issues in Environmental Science and Technology. Cambridge, UK: Royal Society of Chemistry Publishing, 2009.

conditions and urban air circulation disperses those releases throughout the air basin.[25] In this study, the main governing meteorological condition is wind speed and direction; though physical location of a study area in the regional topography as well as atmospheric temperature and pressure conditions can also influence how the urban air circulates, for the purposes of this study, wind speed and direction fulfill the needs of dispersion-influencing data.

1.1.3 How fenceline communities are impacted

The U.S. EPA offers a definition of environmental justice as being "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies."[26] Environmental justice is at the heart of community-industry tensions in many fenceline communities, and particularly in the case of the Richmond community and chronic exposure to toxic emissions from the Richmond Chevron refinery. Dr. Robert D. Bullard, professor and acclaimed author often described as the 'father of environmental justice,' writes most famously in his book Dumping in Dixie on the disproportionate impact of industrial facility siting near low-income and minority populations. While the book focuses largely on the American South, many trends are observed throughout the nation and even around the world; Bullard raises awareness about the fact that, "Race continues to be a potent variable in explaining the spatial layout of urban areas, including housing patterns, street and highway configurations, commercial development, and industrial facility siting."[27] This proves to be true in Richmond, with 86.3% of the population living in the urban center, directly adjacent to the refinery and nearby industry identifying as minority.[28] As Bullard shares in an article published in the Yale Journal of International Law in 1993, the combination of the "distribution of wealth, housing and real estate practices, and land use planning… give rise to what can be called 'environmental racism': practices that

[25] Hertel and Goodsite. "Urban Air Pollution." 2.
[26] U.S. EPA. "Environmental Justice." EPA. 2015. Accessed January 6, 2015. http://www.epa.gov/environmentaljustice/.
[27] Bullard, Robert D. "Environmental and Social Justice." In Dumping in Dixie: Race, Class, and Environmental Quality, 1-20. Third ed. Boulder, CO: Westview Press, 2000.
[28] U.S. Census Bureau. "Richmond, CA Population Estimates, July 1, 2014." U.S. Census Bureau QuickFacts. 2014. Accessed February 12, 2015. http://www.census.gov/quickfacts/.

place African Americans, Latinos, and Native Americans at greater health and environmental risk than the rest of society."[29]

1.2 Standards and Regulations

Like every industry in the United States, the oil industry is regulated by a variety of agencies. From regional permitting and emissions standards, to state and national air quality standards, refineries like Richmond Chevron are legally required to operate and emit only within those guidelines, facing legal or financial penalties, as well as community backlash if they fail to meet the standards.

1.2.1 Permits and regional emissions standards

Regulated by the Bay Area Air Quality Management District, or BAAQMD, the Richmond Chevron refinery is legally obliged to operate only within the limits of the permitted volume of crude throughput, releasing only the permitted volume of emissions, comprised of toxic concentrations no higher than the permitted levels. The refineries in the region are currently subject to 21 region-specific regulations by the Air District; according to a 2014 press release by the agency, the mandates have resulted in a steady decrease in emissions over time.[30] Given the guidelines of the 21 regulations, refineries apply for project-specific permits through BAAQMD, authorizing, if approved, individual facility source throughput and emissions levels. BAAQMD Director of Technical Services, Eric Stevenson, stated that the Air District does not compile aggregate permit sanctions to provide a total limit for each refinery as a whole, so determining the net permitted levels of throughput and emissions for Richmond Chevron is challenging and confidence in estimations is rough and inauspicious.[31] Through piecemeal collection of approximate values, it is inferred that the Richmond Chevron refinery currently holds permits for operation of roughly 250,000 barrels of crude per day.[32]

BAAQMD Regulation 2, Rule 5 regulates the permitting process, focused on new source review of toxic air contaminants. Within this regulation, 2-5 aims to "provide for the review of new and modified

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[29] Bullard, Robert D. "Race and Environmental Justice in the United States." Yale Journal of International Law 18 (1993): 319-35. Accessed February 12, 2015. Hein Online.
[30] BAAQMD. Board of Directors. "Air District Board Passes Resolution Addressing Refinery Emissions." News release, October 15, 2014. Bay Area Air Quality Management District. Accessed December 10, 2014. http://www.baaqmd.gov/~/media/.
[31] Stevenson, Eric. "BAAQMD Permitting Procedure Question." E-mail message to author. April 19, 2015.
[32] Chevron. "What We Do." 2011.

sources of toxic air contaminant (i.e. TAC/HAP) emissions in order to evaluate potential public exposure and health risk."[33] 2-5 does offer a table inclusive of toxic air contaminant (TAC/HAP) trigger levels, meaning an emission threshold level for each HAP "below which the resulting health risks are not expected to cause, or contribute significantly to, adverse health effects;"[34] these are in essence standards for HAP ambient air concentrations, though the legislation does not specify which concentration on the complex table is to be used as the maximum limit.

Of particular importance to recent policy decisions, but also to this study are BAAQMD Regulation 12, Rules 15 and 16. Regulation 12 outlines Miscellaneous Standards of Performance with various rules pertaining to a variety of different industry facility types and processes. Regulation 12, Rule 15 (12-15) outlines petroleum refining emissions tracking policy, while Regulation 12, Rule 16 (12-16) outlines petroleum refining emissions analysis, thresholds, and mitigation.[35] In March 2013, BAAQMD staff composed a preliminary draft for 12-15, citing the intention as to "address potential increases in air emissions from Bay Area petroleum refineries that might occur over time, including emission increases associated with the use of lower quality crude slates."[36] Relatedly, 12-16 responds to the need to better "identify the cause of, and to mitigate, any significant emissions increases from petroleum refineries."[37] Both rules were recently – as of March 2015 – subject to public comment, with the Air District holding a series of public workshops in refinery towns. BAAQMD staff used the workshops as opportunities to explain the proposed legislation, as well as gather community feedback. In attendance of the March 17, 2015 public workshop at the Richmond Public Library in Richmond, California, I observed a very tense dynamic between the district staff and the public; though in place to "protect and improve public health, air quality, and the global climate," so claims the district's mission statement, the comments of various

[33] Bay Area Air Quality Management District. Regulation 2: Permits; Rule 5: New Source Review of Toxic Air Contaminants. By Stationary Source Committee. January 6, 2010. Accessed February 10, 2015. http://www.baaqmd.gov/~/media/.
[34] BAAQMD. "Regulation 2, Rule 5." 6.
[35] BAAQMD. "Refinery Emissions Tracking Mitigation and Reduction Rules." Bay Area Air Quality Management District. 2015. Accessed February 10, 2015. http://www.baaqmd.gov/Divisions/.
[36] BAAQMD. Preliminary Draft: Air District Regulation 12, Rule 15 - Petroleum Refining Emissions Tracking. Report. March 2013. Accessed February 10, 2015. http://www.baaqmd.gov/~/media/.
[37] Bay Area Air Quality Management District. Regulation 12: Miscellaneous Standards of Performance; Rule 16: Petroleum Refining Emissions Analysis, Thresholds and Mitigation. By BAAQMD. February 23, 2015. Accessed February 27, 2015. http://www.baaqmd.gov/~/media/.

community members quickly illuminated their observed discrepancy between the intentions and actions of the agency.[38]

As a result of BAAQMD standards and regulations however, the agency does provide equipment and readings of toxic air contaminant concentrations at different community monitoring stations to determine attainment status, and respond appropriately if a monitor identifies a concentration in excess of the permissible and healthy levels.

1.2.2 Ambient Air Quality Standards and Criteria Air Pollutants

Established by the U.S. EPA, National Ambient Air Quality Standards (NAAQS) are a subset of the United States Clean Air Act set to identify benchmark levels for certain pollutants in the environment proven to be harmful to both environmental and public health.[39] Within the Clean Air Act, two categories of air quality standards are set forth; primary standards address public health, particularly the protection of more vulnerable sub-populations such as youth, seniors, and asthmatics, and secondary standards serve to protect "public welfare," inclusive of visibility, building integrity, and plant, animal, and habitat health.[40] The U.S. EPA has set NAAQS to outline six "criteria" pollutants and their permitted maximum ambient levels. The six Criteria Air Pollutants, or CAPs, identified by the U.S. EPA are: carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO2), ozone (O3), particulate matter (PM), and sulfur dioxide (SO2).[41] Additionally, the California Environmental Protection Agency (CalEPA), provides its own set of Ambient Air Quality Standards (CAAQS) developed in conjunction with the California Air Resources Board (CARB) to more appropriately regulate air quality specific to California and its populations.[42] BAAQMD states on their site dedicated to ambient air quality standards and attainment statuses that California's state-specific standards are "generally more stringent" than NAAQS, which Figure X proves to be true

[38] BAAQMD. "BAAQMD - Mission Statement." BAAQMD. August 9, 2010. Accessed February 10, 2015. http://www.baaqmd.gov/The-Air-District/Mission-Statement.aspx.
[39] U.S. EPA. "National Ambient Air Quality Standards (NAAQS)." EPA. October 21, 2014. Accessed November 20, 2014. http://www.epa.gov/air/criteria.html.
[40] U.S. EPA "NAAQS." 2014.
[41] U.S. EPA "NAAQS." 2014.
[42] CalEPA - CA Air Resources Board. "California Ambient Air Quality Standards (CAAQS)." CalEPA. November 24, 2009. Accessed November 20, 2014. http://www.arb.ca.gov/research/aaqs/caaqs/caaqs.htm.

through the side-by-side comparison of the two sets of standards; CAAQS even boast a more comprehensive list of air pollutants regulated and monitored.[43,44]

This study will focus on and model the emissions of ground-level ozone and particulate matter – explicitly $PM_{2.5}$, particulate matter measuring <2.5 micrometers in diameter – as they pertain to public health (primary standards), with understanding of inherent impact on local and regional air quality (secondary standards).[45] While ozone and $PM_{2.5}$ are the only two of the six CAPs explicitly modeled in this study, it is critical to acknowledge the presence and prevalence of the remaining four CAPs in the study area that also contribute to the impact on the local environment and populations.

1.2.2.1 Ozone

Ozone (O3) is an unstable gas that, unlike other CAPs, is not directly emitted from any source, but rather is created through chemical reactions that occur between compounds that stem from industrial operations, namely nitrogen oxides (NOx) and volatile organic compounds (VOC).[46,47] Though ozone occurs both in the upper atmosphere and at ground-level, atmospheric ozone occurs naturally, while ground-level, or tropospheric, ozone occurs anthropogenically; for the purposes of this study, exclusively tropospheric ozone will be examined given its relation to industrial processes and its negative health effects.[48] Exposure to ozone elicits health problems relating to the human respiratory system, particularly among more vulnerable sub-populations explicitly targeted in the protections provided through the NAAQS and CAAQS.[49] The respiration of ozone seriously compromises the health and functioning of the lungs, causing symptoms like coughing, sore throat, shortness of breath, inflammation of the airway and lining of lungs, not to mention the exacerbation of existing asthma, and potential long-term scarring of the

[43] BAAQMD. "Air Quality Standards and Attainment Status." BAAQMD. 2015. Accessed February 10, 2015. http://www.baaqmd.gov/Divisions/.
[44] CalEPA - CA Air Resources Board. "Ambient Air Quality Standards." CalEPA. June 4, 2013. Accessed February 10, 2015. http://www.arb.ca.gov/research/aaqs/.
[45] U.S. EPA "NAAQS." 2014.
[46] CalEPA - CA Air Resources Board. "Ozone and Ambient Air Quality Standards." CalEPA. February 01, 2001. Accessed March 3, 2015. http://www.arb.ca.gov/research/aaqs/caaqs/ozone/ozone.htm.
[47] U.S. EPA. "Ground Level Ozone." EPA. March 2015. Accessed March 4, 2015. http://www.epa.gov/airquality/ozonepollution/.
[48] U.S. Environmental Protection Agency. "Ground-level Ozone." EPA. November 26, 2014. Accessed March 4, 2015. http://www.epa.gov/groundlevelozone/faq.html.
[49] CalEPA. "Ozone and AAQS." 2001.

lungs and increased susceptibility to infection.[50] Permissible levels of ozone in the ambient air by NAAQS standards are 75 ppb, and by CAAQS standards are 70 ppb, or 137 µg/m^3 over an 8-hour averaging time.

1.2.2.2 PM$_{2.5}$

As is implied in its name, PM$_{2.5}$ is not necessarily composed exclusively of any one material, but is commonly understood to be solid particles of metal, dust, smoke, etc. and liquid droplets suspended in the air, contributing to poor air quality and respiratory health issues.[51] Particulate matter with a diameter of <2.5 micrometers – also called “fine particles” and comparable to 1/30th the width of a human hair – is what we attribute to decreased visibility, particularly in areas with heavy industry.[52] PM$_{2.5}$ is also highly dangerous to heart and lung-related respiratory illnesses, as the particles easily enter the airway and penetrate the respiratory system, given their microscopic size, and can present even graver health problems upon entering the bloodstream.[53] Permissible levels of PM$_{2.5}$ in the ambient air by NAAQS standards are 35 µg/m^3 over a 24-hour averaging time, and are the same by CAAQS standards.[54,55]

1.2.3 National Emission Standards for Hazardous Air Pollutants

In addition to CAP identification and regulation, there are also 187 pollutants originating from toxic air releases that the U.S. EPA has identified as hazardous air pollutants, or HAPs.[56] These HAPs are often found in smaller concentrations than CAPs and are not covered by NAAQS, but can pose equally threatening public and environmental health hazards. As a result, the U.S. EPA established National Emission Standards for Hazardous Air Pollutants (NESHAPs) in 1989 – pursuant to the Clean Air Act – to regulate and ultimately reduce the toxic air releases of these dangerous contaminants.[57,58] The national

[50] U.S. EPA. “Ground Level Ozone.” 2015.
[51] U.S. EPA. "Particulate Matter: Basic Information." EPA. March 8, 2013. Accessed March 3, 2015. http://www.epa.gov/airquality/particlepollution/basic.html.
[52] U.S. EPA. “Particulate Matter: Basic Information.” 2013.
[53] U.S. EPA. “Particulate Matter: Basic Information.” 2013.
[54] U.S. EPA “NAAQS.” 2014.
[55] BAAQMD. "Air Quality Standards and Attainment Status." 2015.
[56] U.S. EPA. "About Air Toxics." EPA. April 9, 2015. Accessed April 13, 2015. http://www.epa.gov/ttn/atw/allabout.html.
[57] U.S. Environmental Protection Agency. Benzene NESHAP FAQ Handbook. By U.S. EPA. September 1997. Accessed March 3, 2015. http://www.epa.gov/.
[58] Bay Area Air Quality Management District. "Air Toxics Programs." BAAQMD. February 21, 2013. Accessed March 3, 2015. http://www.baaqmd.gov/Divisions/.

standards also inform local BAAQMD regulations, vaguely outlined in District Regulation 11 on Hazardous Pollutants.[59]

Upon request, Eric Stevenson of BAAQMD provided specific HAP concentration data, measured at the community monitoring sites. These measurements included average, maximum, and minimum mass-per-volume (μg/m^3) concentration values based on an average of 30 measurements sampled per year; the years provided range from 2002 to 2014 (omitting 2009), but to match the average meteorological trends, only the years 2011-2014 were more deeply analyzed. That being said, it is important to acknowledge a trend of concentration reductions of HAPs over the years examined, as seen in **Figure 1-2**.

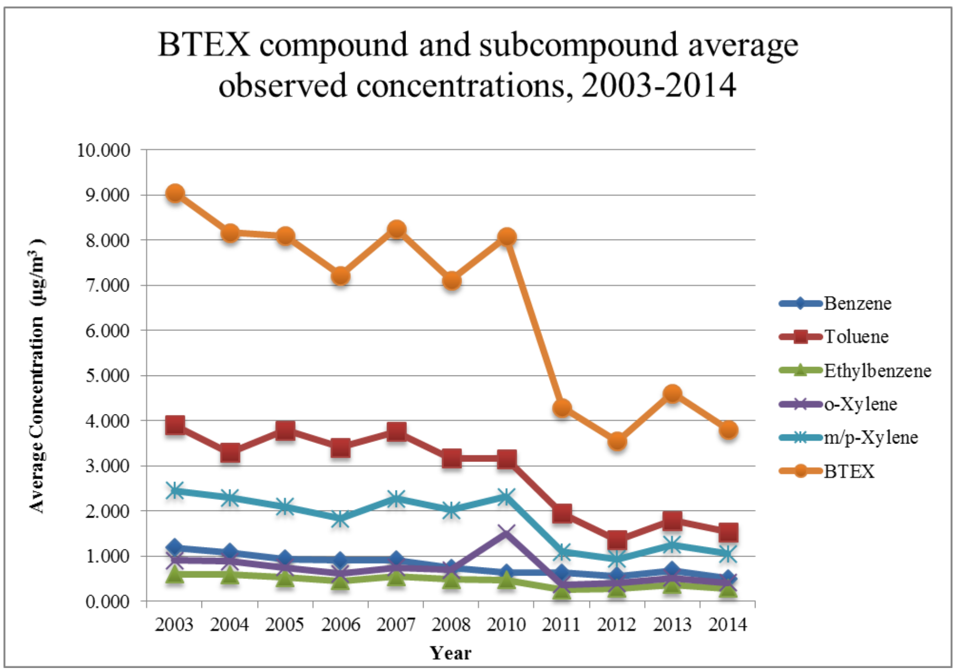

Figure 1-2. *HAP concentration reductions over time for focus toxics, 2003-2014*

In order to put these HAP concentrations in context, U.S. EPA Toxics Release Inventory (TRI) publicly provides emissions volume data by city, divulging the breakdown of emissions type/release destination (i.e. airborne, waterborne, or landfill) and facility sources within the city limits. Through the online TRI resource, I found that 366,076 lbs of airborne toxic releases came from the Richmond Chevron

[59] BAAQMD. "Air Toxics Programs." 2013.

refinery in the year 2013, helping to contextualize specific HAP concentrations in the ambient air and their volume in the original refinery emissions.

1.2.3.1 BTEX

BTEX is an acronym that stands for benzene, toluene, ethylbenzene, and o/m/p-xylenes. All four are toxic air contaminants are released to some extent at every stage in the petroleum refining process, and have been historically detected at the community monitoring stations surrounding the Richmond Chevron refinery. These compounds are highly hazardous to human health, with the U.S. EPA citing exposure as threatening to reproductive health, developmental stability, and even the central nervous system; benzene and ethylbenzene have been classified by the U.S. EPA as known human carcinogens, with "clear evidence of a causal association between exposure to benzene and acute nonlymphocytic leukemia… chronic nonlymphocytic leukemia… and chronic lymphocytic leukemia."[60] Permissible levels of BTEX in the ambient air by NESHAP standards amount to a compound total of 33.22 tons/year, deduced as the sum of sub-compound chronic trigger levels outlined in BAAQMD's 2-5.[61]

1.3 Modeling

Environmental modeling, though a broad term, offers mechanisms that help quantify the influence of different systems – both natural and anthropogenic – and represents the studied impact numerically and often visually, as well; scientific analysis of mathematical modeling is often used to inform decisions and policies. While there are a wide variety of computational and visual modeling tools in the realm of environmental modeling applicable for different phenomena and scenarios, this study employs explicitly a wedge model – a mathematical representation of the dispersion of urban air pollutants from the Richmond Chevron refinery, given local wind and site conditions – as well as mapping of the air dispersion and impacted populations through use of a geographic information system (GIS).

[60] U.S. EPA. Benzene: Toxicity and Exposure Assessments for Children's Health, Chemical Summary. Report. February 27, 2009. Accessed March 3, 2015. http://www.epa.gov/.
[61] BAAQMD. "Regulation 2, Rule 5." 9-17.

1.3.1 Wedge Model

A wedge model is one variation of an air pollution transport model that is utilized to analyze the concentration of air pollution downwind of a point source.[62] The two main components of a wedge model are that it: i. produces an area of influence originating from one stationary, or point source (i.e. an industrial plant or refinery), and ii. that it integrates local meteorological conditions which, exclusively in this study, are restricted to wind speed and direction. Another important factor in the model, determining the vertical scope of the model, is the stack height; in addition to "temporal variations in emissions and meteorology," the height at which emissions are released is influential in the dispersion of pollutants and the degree to which the pollutants remain in the immediate local air basin or contribute to regional air quality levels.[63] The model, as seen in **Figure 1-3**, generates a 3D wedge spanning out in the direction of the wind, providing a zone of influence of estimated pollutant concentration.[64]

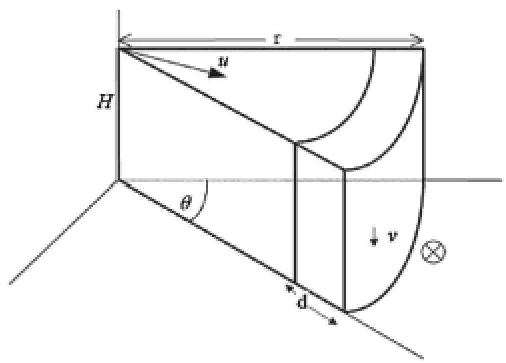

Figure 1-3. *Abstract wedge model; source: Lui. "Comparison of the Wedge." 758.*

It is important to acknowledge a similar model that was considered for this study, as well. The Lagrange model, or Gaussian plume, was also considered as it is an alternate model that produces a similar representation of air contaminant dispersion, but generates a more specified and concentrated plume from the point source out over the impacted area, unnecessarily more technical than needed in this

[62] Kantenbacher, Joseph. ER102 - Air Pollution Transport Models, Section Notes. University of California, Berkeley, 2014.
[63] Hertel and Goodsite. "Urban Air Pollution." 3.
[64] Brauer, Michael, Bruce Ainslie, Michael Buzzelli, Sarah Henderson, Tim Larson, Julian Marshall, Elizabeth Nethery, Douw Steyn, and Jason Su. "Models of Exposure for Use in Epidemiological Studies of Air Pollution Health Impacts." In Air Pollution Modeling and Its Application XIX, edited by Carlos Borrego and Ana Isabel Miranda, 589-`604. NATO Science for Peace and Security Series - C: Environmental Security. Dordrecht, The Netherlands: Springer, 2008.

study given limited variables and intention of generating simply a stripped-down model simulation of the dominant emissions dispersion trend in the study area.

1.3.2 GIS

Geographic Information Systems are data management systems that allow the visualization, manipulation, and analysis of geographically referenced data.[65,66] The key benefit of using a GIS in the modeling and analysis of the social and environmental impact of local air pollutants and the interaction with local meteorological influences – i.e. wind speed and direction – is the ability to visually display the greater study area, the impacted area, and the demographics of the population dispersed across the study area and impacted area. Contextualizing the scenario through use of maps and isolated geographic data can greatly assist in the portrayal of problems, findings, and solutions. Within the software I was able to incorporate public census data, digitize areas and the emissions wedge (i.e. draw digital points, lines, or polygons that represent different features), and manipulate the data in a way that tells a story.

I used computer access granted by the Geospatial Innovation Facility at the University of California, Berkeley to use ArcGIS software to perform my analysis.

1.4 Problem Statement

The next three subsections divulge into how the three relevant phenomena listed in Section 1.1 are problematic in regards to community exposure and public health.

1.4.1 What is problematic about how refineries pollute?

Petroleum refinery campuses are complex and consist of various different processes and system facilities. Emissions can come from a plethora of sources within an entire refinery site, including: process heaters and boilers, flares and thermal oxidizers, wastewater collection and treatment systems, cooling towers, fugitive equipment leaks, tanks, product loading operations, Catalytic Reforming Unit Catalyst Regeneration Vents, Catalytic Cracking Unit Catalyst Regeneration Vents, Sulfur Recovery Units/Sulfur

[65] Esri. "What Is GIS?" September 2, 2014. Accessed May 13, 2015. http://www.esri.com/what-is-gis.
[66] National Oceanic & Atmospheric Administration. "What Is GIS?" NOAA. Accessed September 2, 2014. http://nerrs.noaa.gov/.

Plant Vents, and miscellaneous other process vents;[67] **Figure 1-4** contextualizes these facilities in the greater refinery campus. A major challenge arises with the complexity and scope of a refinery in regards to accurately and fully monitoring and recording relevant emissions values. Particularly in estimating volumes for leaks or fugitive emissions, as well as in extrapolating the volume of toxic components in venting, as described through the various descriptions of uncertainties in estimates listed in the EPA 2002 report, it becomes challenging to both accurately estimate emissions volumes in total, and then to further accurately understand the toxic composition of such emissions, as opposed to the pure water vapor content.

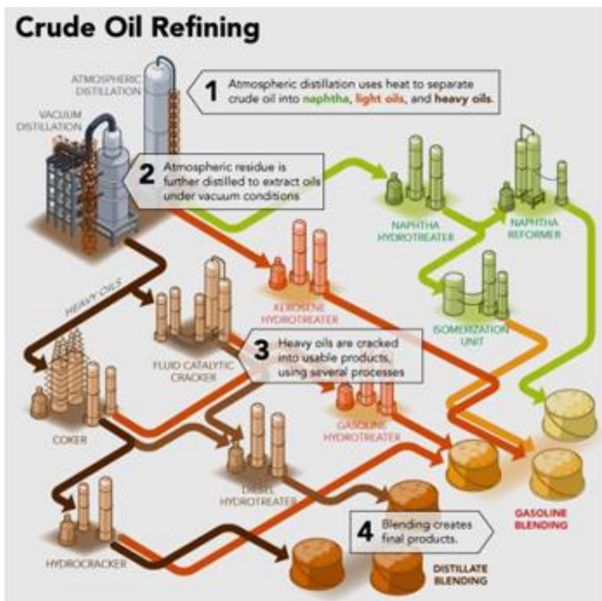

Figure 1-4. *Overview of petroleum refining process and refinery facilities; source: Spectro Analytical Labs Limited.*

Gary and Handwerk also point out a major economic reason for refinery trepidation in making operational or facility changes to meet requirements. The authors claim that many environmental requirements often result from “political stipulation with little regard to true economic and environmental impacts.”[68] As is true with many forms of technology today, innovation and development of new benchmark equipment happens very quickly. The same goes for policy; particularly in highly scrutinized industries, like oil refining, regulations have the potential to change as local or regional politics shift, or as

[67] U.S. Environmental Protection Agency. Petroleum Refinery Source Characterization and Emission Model for Residual Risk Assessment. By U.S. EPA. July 1, 2002. Accessed November 4, 2014. http://www.epa.gov/.
[68] Gary, James H., and Glenn E. Handwerk. "Preface." Preface to Petroleum Refining: Technology and Economics, Iii-V. Fourth ed. Boulder, CO: Marcel Dekker, 2001.

climate policy tightens down on emissions allowances. This creates a tough decision for refiners because, by the time the firm makes a massive investment in what they presume to be the next best equipment that can produce the best product at the most efficient rate, and/or best meet the standards and regulations of their industry, either new technology, new regulations, or both have been established.[69]

1.4.2 What is problematic about how pollution circulates?

As Salmond and McKendry claim, “Although the nature and characteristics of urban emissions can be variable in time and space, it is changes in pollutant dispersion pathways both locally and regionally that often determine the temporal and spatial patterns of atmospheric composition in urban areas.”[70] The stability of the atmosphere, along with “meteorological consequences of the built form and human activities associated with the urban environment” influence how air circulates within an urban context, with the authors sharing that, “Although urban surfaces vary considerably in form and composition around the globe, they are recognized to produce distinctive climates at a variety of temporal and spatial scales.”[71] This being said, given the dynamic influence of the built environment in urban and semi-urban areas, higher concentrations of pollutants in an urban air system poses increased health threats as the air has a greater potential to circulate within the area.[72]

1.4.3 What is problematic about impact to the greater Richmond area community?

Historically, minority and lower-income populations have been disproportionately burdened by many social ills, importantly environmental contamination like industry, highways, incinerators, and landfills.[73] Brauer et al. discuss the health impacts of chronic toxic exposure, claiming not only that public health impacts associated with long-term exposure are often greater and more significant than acute exposures, but that the study of chronic exposure is also heavily influenced by “spatial comparisons

[69] Gary and Handwerk. “Preface.” Iii.
[70] Salmond, Jennifer A., and I G McKendry. "Influences of Meteorology on Air Pollution Concentrations and Processes in Urban Areas." In Air Quality in Urban Environments, edited by R E Hester and R M Harrison, 23-41. Vol. 28. Issues in Environmental Science and Technology. Cambridge, UK: Royal Society of Chemistry Publishing, 2009.
[71] Salmond and McKendry. “Influences of Meteorology.” 26-27.
[72] Salmond and McKendry. “Influences of Meteorology.” 27-28.
[73] Bullard. “Dumping in Dixie.” 1-20.

between areas of differing air pollutant concentrations."[74] Given that the fenceline community surrounding the Richmond Chevron refinery is largely low-income and minority populations, and has been historically disenfranchised by the corporate presence in the community, this case study is the epitome of an environmental justice issue.

1.5 Research objectives

The research and analysis performed in this study is ultimately motivated by awareness of the study area and regional community, with the overarching goal to gather relevant data and policy information and paint a picture of the physical and political forces that enable the current condition in the greater Richmond area. That being said, the first objective of this study is to extrapolate and visualize the emissions dispersion patterns from the Richmond Chevron refinery over the nearby community, and to analyze the role of policy and politics in the social and environmental impact. A secondary objective of this study is to gather and synthesize cryptic, fragmented, and/or publicly unavailable emissions data, presenting the greater impacted community with a resource to better understand the volume and consequences of their toxic exposure so as to overcome a barrier of 'meaningful engagement.'

[74] Brauer et al. "Models of Exposure," 591-592.

Chapter 2

LITERATURE REVIEW

In the research process for this study, familiarity with the existing body of knowledge proved essential to modeling approach decisions and evaluation procedures, as well as analysis of impact findings. In order to confidently produce an appropriate air emissions dispersion trend model and understand the impact of exposure on public health, it was crucial to turn to existing literature and studies on dispersion modeling approaches and uses, along with impacts of toxic air contaminants resulting from industrial and refining operations elsewhere.

Air dispersion models range vastly in terms of technicality and complexity. Some studies employ advanced computer-aided modeling programs, like the U.S. EPA's integrated AERMOD or Industrial Source Complex Short Term (ISCST-3) systems, which utilize input data to produce software-generated simulations of real-world conditions with the highest accuracy of the variety of models. The 2004 U.S. EPA AERMOD guidebook and model evaluation explains the system's popularity and dependency in the modeling world as attributed to its comprehensive modeling options; while AERMOD can model general dispersion trends, it can also model source parameters and emission rates, the simultaneous consideration of multiple receptors, and complex meteorological and terrain conditions with the AERMET and AERMAP preprocessors, respectively.[1] Perhaps the most critical aspect of AERMOD is systems regulatory applicability; with a comprehensive modeling system in AERMOD and the accompanying guidelines providing the U.S. EPA with "guidance on regulatory applicability of air quality dispersion models," the resources exist to support a comprehensive and accurate package of representation of the condition in the given study area *with* the appropriate pairing of regulation to affect the condition.[2] Similarly, as employed by Krishna et al. (2005) and Sivacoumar et al. (2000), the ISCST-3 model also developed by the U.S. EPA utilizes special software so as to efficiently model ground-level

Chapter 2 notes:

[1] United States Environmental Protection Agency. Air Quality Planning Standards. User's Guide for the AMS/EPA Regulatory Model - AERMOD. By U.S. Environmental Protection Agency. September 2004. Accessed October 10, 2014. http://www.epa.gov/scram001/7thconf/aermod/aermodugb.pdf.

[2] U.S. EPA. "User's Guide for AERMOD." 14.

concentrations of pollutants, incorporating and adjusting for phenomena such as wet and dry deposition of compounds, terrain conditions, and even building downwash.[3] Using the ISCST-3 approach, Krishna et al. (2005) generate a simulation of an industrial complex near Hyderabad, India, subjecting it to an analysis of differing ambient air quality impacts at different times of year, and Sivacoumar et al. (2000) generate a similar model of steel production emissions in Jamshedpur, India, then extrapolating sector contribution levels of NO_x emissions; studies like this provide an example of the degree of accuracy and complexity possible in location- and industry-specific emissions dispersion modeling.[4,5] Aware of the best available procedures, though understanding my access limitations and this study's commitment to providing a stripped-down representation of the dominant trend, I turned to literature on simpler and more calculable methods.

Both AERMOD and ISCST-3 employ a steady-state Gaussian plume air dispersion model, which is an alternative to the wedge model, produces a similar representation of air contaminant dispersion, but on different scale and with different deposition assumptions; according to F. Liu (2013) in their comparison of different diffusion mechanisms, Gaussian plumes are more appropriate generally for the representation of larger scale spread.[6] A Gaussian plume model generates a concentrated plume from the point source out over the impacted area assuming normal distribution of the air pollutants both horizontally (y) and vertically (z) within the plume, while the wedge model assumes normal distribution only in the vertical direction (z), but uniform, or perfectly dispersed distribution in horizontal direction (y), with an assumed concentration of zero outside of the wedge.[7] Acclaimed scholars in the field highlight benefits and aptitude of the wedge model particularly in exposure assessment and epidemiological study applications.[8]

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[3] Krishna, T V B P S Rama, M K Reddy, R C Reddy, and R N Singh. "Impact of an Industrial Complex on the Ambient Air Quality: Case Study Using a Dispersion Model." Atmospheric Environment 39, no. 29 (July 21, 2005): 5395-407. Accessed November 4, 2014. doi:10.1016/j.atmosenv.2005.06.003.
[4] Krishna et al. "Impact of an Industrial Complex." 5396.
[5] Sivacoumar, R., S K Goyal, S K Gadkari, and A L Aggarwal. "Air Pollution Modeling for an Industrial Complex and Model Performance Evaluation." Environmental Pollution 111, no. 3 (October 26, 2000): 471-77. Accessed November 4, 2014. doi:10.1016/S0269-7491(00)00083-X.
[6] Lui. "Comparison of the Wedge." 758.
[7] Dupont, R Ryan. "Air Dispersion Modeling." In Air Toxics: Problems and Solutions, edited by Kumar Ganesan and Louis Theodore, 51-62. Amsterdam, The Netherlands: Gordon and Breach Publishers, 1996. Accessed February 4, 2015. https://books.google.com/.
[8] Brauer et al. "Models of Exposure." 600.

Once assured the decision to use the wedge model, it was key to then understand the procedures for evaluating the model's performance. Though Sivacoumar et al. (2000), through use of ISCST-3, utilized a Gaussian plume model approach, their accompanying literature on general statistical analysis of any predicting models' strength proved insightful. Using the index of agreement formula to compare observed and predicted values, this study offers an appropriate outline of model evaluation procedures relevant to the analysis of my study.[9]

In researching the role that modeling a condition can play in the understanding of the condition's social and environmental effects, I found parameters are important, but that no model is dynamic enough to completely simulate reality or changing conditions the way they exist in reality. Similar to the study I produce here, Baltrénas et al. (2011) explore the role of meteorological parameters on concentration predictions in modeling atmospheric BTEX concentrations near a crude oil refinery (of comparable size to Richmond Chevron) in the rural northern Lithuania, comparing the observed concentrations both to the predicted concentrations, as well as to observed concentrations in different spatial distributions.[10] They found that meteorological conditions influenced the degree of impact in areas close to the refinery, and that the refinery itself indeed had a regional impact, with BTEX concentrations drastically lower in the vicinity than in other regions. Baltrénas et al. (2011) provided me with a relevant example concentration determination in a comparable case study.

Relating modeling dispersion conditions and strength of predictability to health concerns, Brauer et al. (2008) segments together the importance of model choice and evaluation with the analysis of health effects that result from the emissions dispersion trends. Acknowledging persistent challenges surrounding model accuracy in regards to demonstrating *exposure*, Brauer et al. (2008) write that still, "epidemiological studies are increasingly the main measure upon which policies, standards, guidelines and regulations are based."[11] This is important as the disconnect between epidemiological exposure

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[9] Sivacoumar et al. "Air Pollution Modeling." 472.
[10] Baltrénas, Pranas, Edita Baltrénaité, Vaida Sereviciene, and Paulo Pereira. "Atmospheric BTEX Concentrations in the Vicinity of the Crude Oil Refinery of the Baltic Region." Environmental Monitoring and Assessment 182, no. 1-4 (January 18, 2011): 115-27. Accessed November 4, 2014. http://link.springer.com/article/10.1007/s10661-010-1862-0#page-1.
[11] Brauer et al. "Models of Exposure." 589.

findings and ambient air quality standards and guidelines that effectively address risks should be addressed through the thorough comprehension of risk sources and emissions dispersion trends, but inefficiencies in modeling can limit the effective communication between public health conditions and policy response. Finally, considering a study on the presence and effects of toxic air contaminants on human health, McCann (1994) classifies aromatic hydrocarbons, particularly BTEX, as some of the most hazardous airborne solvents, imposing risk most dramatically upon inhalation. By disclosing the epidemiological effects of exposure to each toxic, McCann (1994) contextualizes the importance of modeling and deducing concentrations of such compounds as they are emitted into the ambient air by instilling the knowledge of the detrimental effects of human exposure.[12]

[12] McCann, Michael. Health Hazards of Solvents. Report. 1994. Accessed November 4, 2014. http://www.uic.edu/sph/glakes/harts1/HARTS_library/solventhazards.txt.

Chapter 3

STUDY AREA

The study area for this project includes the cities of Richmond and San Pablo, California and the unincorporated neighborhood of North Richmond, California; for the purposes of this study, the aggregate of these three entities will be referred to as the greater Richmond area. The greater Richmond area is situated just north of center on the eastern shore of the San Francisco Bay Area, about 10 miles northeast of San Francisco. The population of the greater Richmond area was 129,431 in 2000 and had increased to 136,557 as of the 2010 decennial U.S. Census.[1,2]

3.1 Richmond Chevron refinery

The Richmond Chevron refinery site sits on the western quadrant of the study area, which is also the western edge of the City of Richmond, bound by the coastline of the San Pablo Bay, an inlet of the greater San Francisco Bay. Refinery site boundaries and the extent of the greater Richmond area are identified and distinguished in red and orange, respectively, as seen previously in **Figure 1-1**. The Richmond Chevron refinery has been in operation since 1902, steadily expanding over time.[3] By way of oil tankers that dock at the company-owned Long Wharf just on the other side of Interstate 580 from the refinery campus, Richmond Chevron receives upwards of 240,000 barrels of oil per day.[4] On the refinery site there are storage tank facilities, as well as the following three primary processing areas: distillation and reforming, cracking, hydroprocessing; all of these facilities are identified on the site map provided as **Figure 3-1**.[5]

Chapter 3 notes:

[1] Association of Bay Area Governments. "Bay Area Census -- City of Richmond." Bay Area Census -- City of Richmond. 2010. Accessed December 3, 2014. http://www.bayareacensus.ca.gov/cities/Richmond.htm.

[2] U.S. Census Bureau. "Richmond, CA Population Estimates, July 1, 2014." U.S. Census Bureau QuickFacts. 2014. Accessed February 12, 2015. http://www.census.gov/quickfacts/.

[3] BAAQMD, and Greg Solomon. Permit Evaluation and Statement of Basis for Minor Revisions to the Major Facility Review Permit for Chevron Products Company Facility #A0010. Report. April 2014. Accessed October 21, 2014. http://www.baaqmd.gov/~/media/.

[4] BAAQMD and Solomon. “Permit Evaluation and Statement.” 2014.

[5] BAAQMD and Solomon. “Permit Evaluation and Statement.” 2014.

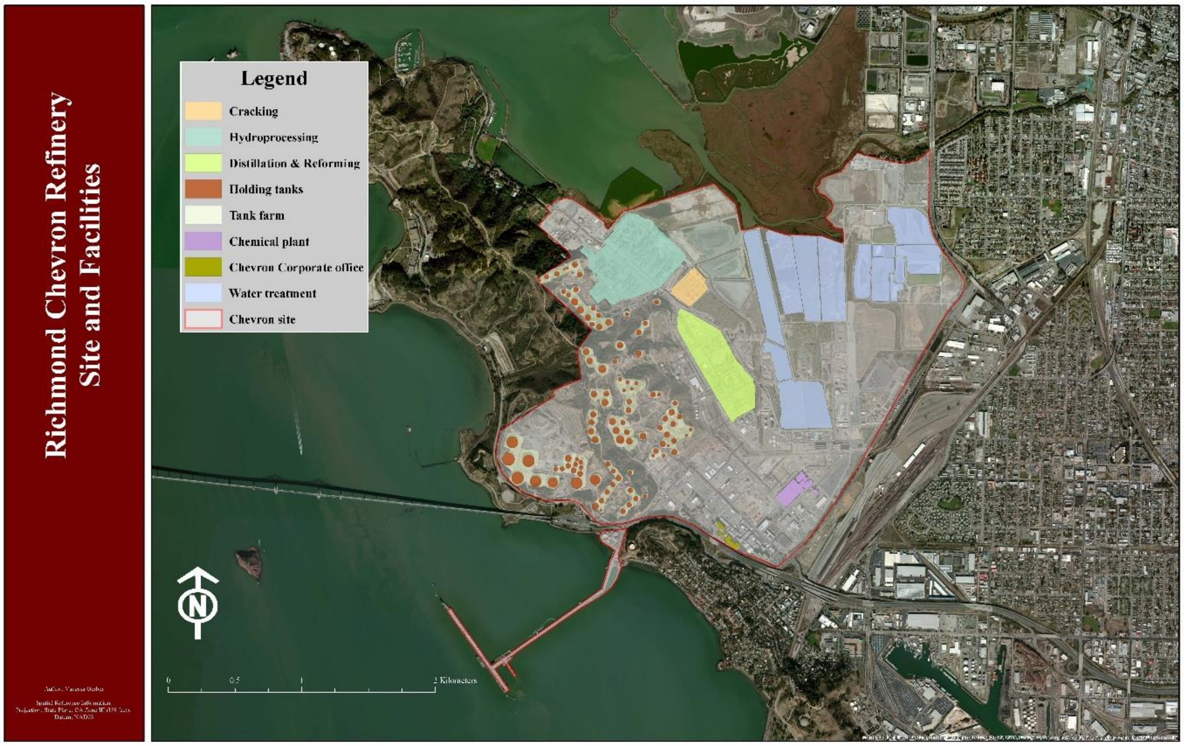

Figure 3-1. *Richmond Chevron refinery site and facilities*

3.2 Data Sources

With many types of data to collect, there is an inherently large number of sources from which to gather the appropriate information. While some data is publicly available and easily accessible online, some data is much more difficult to obtain, some is even impossible to obtain without direct authorization by Chevron. Of the data utilized in this study, sources vary from public agency web resources to personal contacts within agencies or institutions.

3.2.1 Geographic data and parameters

While the state of California used to host a site inclusive of a comprehensive state resource of orthophotograph files, due to budget cuts, the State eliminated the hosting service. Upon request, Dennis Chebotarev at the Department of Information Technology for Contra Costa County provided access to the appropriate base map files for this study, upon which relevant features were and spatial analysis was performed. The GIS data is displayed is the State Plane projected coordinate system for California Zone III, projected in U.S. feet, and based on the North American Datum 1983 (NAD83) geographic coordinate system.

3.2.2 Census data and parameters

Shapefiles for the 2000 Census Blocks of the entirety of Contra Costa County were downloaded from the public Contra Costa County Mapping Information Center, and were then clipped within ArcGIS to include exclusively Richmond, San Pablo, and North Richmond data based on the zip code field. 2010 Census data was unavailable on both the County and U.S. Census Bureau sites. The census data provides figures regarding demographic composition such as race, age, household size and configuration, status of occupants, and census block area.

3.2.3 Toxics data and parameters

Criteria pollutant concentration data was publicly available through the BAAQMD Air Monitoring Data section of the agency site, while more obscure toxic concentration data had to be obtained through a personal inquiry to BAAQMD Director of Technical Services, Eric Stevenson. The CAP measurements published on the BAAQMD agency site are provided in monthly average concentrations for each month of the year, the highest hourly average concentration for each month of the year, the annual average concentration, and the maximum hourly concentration throughout the year.[6] General hazardous air pollutant release volume was obtained on a city-wide and facility-wide basis from the 2013 U.S. EPA Toxic Release Inventory (TRI).

3.2.4 Source parameters

The Richmond Chevron refinery has many point sources on the site in the form of various stacks, combustion units, and treatment facilities, but for the purposes of this study, point A – (37°56’49’’ N 122°23’42’’ W) – has been determined as the geographic mean center of major refinery point sources, and is considered a representative origin of emissions for the wedge model.

3.2.5 Receptor parameters

BAAQMD employs 40 ambient air quality monitoring sites throughout the nine counties in the Bay Area, with 13 housed in Contra Costa County, and 4 monitors exclusively located in the greater Richmond Area. The monitors collect, measure, and record ambient air quality data, with CAP

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[6] BAAQMD. "Air Monitoring Data." Bay Area Air Quality Management District. February 18, 2015. Accessed April 11, 2015. http://www.baaqmd.gov/Divisions/.

measurements publicized on the BAAQMD Air Monitoring Data section of their agency website, and specific toxics data from the same monitors obtained through a personal contact with Stevenson of BAAQMD.[7] Monitoring sites are selected on the basis of their relevance to population exposure, or the expectation as the location of the highest pollutant concentration, and are located where they can be operated for at least one year at a time.[8]

I employed air quality data from the San Pablo-Rumrill monitor, located at 1865 D Rumrill Boulevard, San Pablo, CA 94806.[9] The Air District also takes meteorological measurements at various weather stations throughout the region, and this study utilizes wind speed and direction data recorded at the Point San Pablo district weather station, located on the small peninsula that protrudes to the northwest of the Richmond Chevron refinery campus. Wind roses displaying 2011-2014 meteorological trends recorded at the Point San Pablo weather station, as were included in a consulting report on the Air District's community air monitoring capabilities near refineries, were provided by Stevenson upon request, and are displayed below as **Figure 3-2**.

[7] BAAQMD. "Regulation 12, Rule 15." 3.
[8] BAAQMD. "District Air Monitoring Sites." BAAQMD. Accessed February/March, 2015. http://hank.baaqmd.gov/.
[9] Fujita, Eric M., and David E. Campbell. Review of Current Air Monitoring Capabilities near Refineries in the San Francisco Bay Area. Report. Compiled by Desert Research Institute. July 3, 2013. Accessed March 3, 2015. http://hank.baaqmd.gov/~/media/.

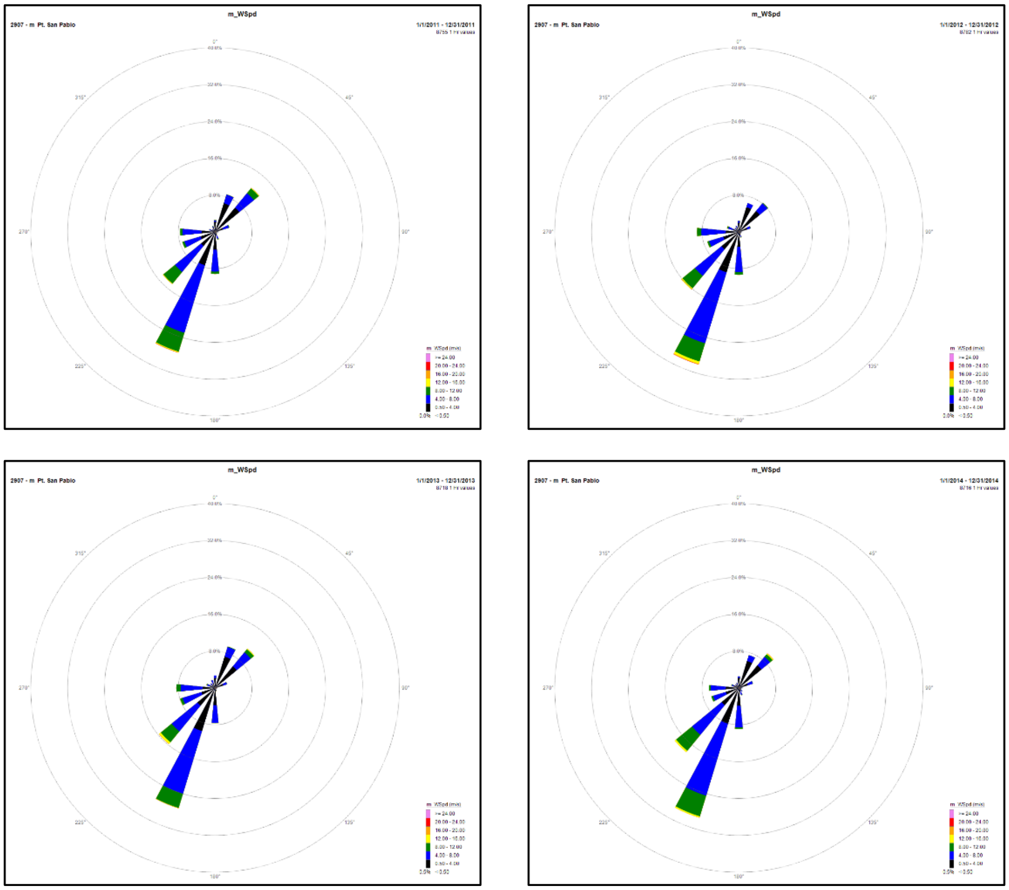

Figure 3-2. *Point San Pablo wind roses, 2011-2014*

3.2.6 Baseline air quality

In addition to the Richmond Chevron refinery, the greater Richmond area houses a number of other industries and, like many urban areas, experiences automobile and rail traffic, which all contribute to ambient air quality and toxics concentrations. While the refinery is the dominant emitting source in the greater Richmond area – contributing 94.2%, at 183.04 tons per year of on-site airborne toxic releases from industry in according to the 2013 TRI – it is crucial to acknowledge and account for baseline emissions from transportation and other industry.[10] **Figure 3-3** shows that, according to the U.S. EPA TRI dataset, total on-site emissions in Richmond have generally decreased over the past ten years, with a

[10] U.S. Environmental Protection Agency. "Toxic Release Inventory - Summary Information, Richmond." U.S. EPA. 2013. Accessed March 10, 2015. http://www2.epa.gov/toxics-release-inventory-tri-program.

relative plateau from 2009-2013; a similar trend applies to airborne toxic releases, exclusively, though following a slightly less drastic decrease.[11]

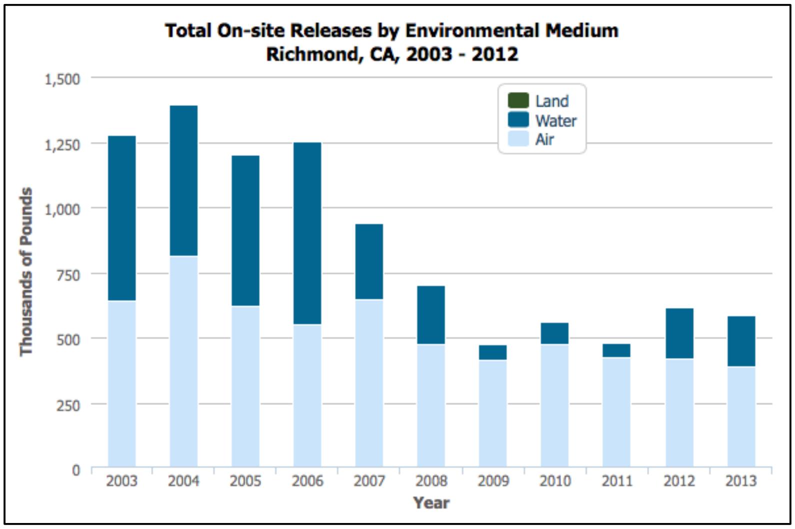

Figure 3-3. *Richmond toxic releases over time, 2003-2013(TRI graph)*

[11] U.S. EPA. "Toxic Release Inventory." 2015.

Chapter 4

METHODOLOGY

Revisiting the application of the wedge model instead of alternatives, this method accomplishes a very similar task to Gaussian plume models, but simplifies the process by better accommodating the utilization of the strictly essential environmental condition variables – in this case, wind speed and direction – and simplifies the model by assuming uniform distribution of emissions horizontally, normal distribution of emissions vertically, and a null concentration outside of the model. In order to obtain the values and the final model, I had to make many intermediate calculations and assumptions. This section outlines the steps taken to deduce the values used in the baseline toxic concentrations and wedge model and to perform the spatial analysis in ArcGIS.

4.1 Baseline concentrations

While Chevron is by far the largest industrial campus and polluter in the greater Richmond area, the area's ambient air quality also depends on toxic releases from other local industry, as well as from transportation.[1,2] The U.S. EPA TRI provides city-level toxic release data, and while neither San Pablo nor North Richmond are included in the 2013 TRI national dataset, the Richmond release data is sufficient as it is provides data on toxic emission volumes that come from emitting sources within a city, and the City of Richmond houses the primary emitters, most importantly: Chevron. In other words, the 194.28 tons of toxic air releases attributed to the City of Richmond in 2013 accounts for the total volume of releases that entered the air basin in Richmond specifically; however, the effects are not exclusively experienced in Richmond, of course, as wind conditions and urban air circulation disperses those releases throughout the air basin in ways described in Section 1.1.2. To calculate the baseline concentrations of CAPs and HAPs in the greater Richmond area – that is, the toxic presence in the air in the hypothetical absence of Richmond Chevron – first the total on-site airborne toxic releases was calculated for all

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[1] U.S. Environmental Protection Agency. "Toxic Release Inventory - Summary Information, Richmond." U.S. EPA. 2013. Accessed March 10, 2015. http://www2.epa.gov/toxics-release-inventory-tri-program.

[2] Bae, Chang-Hee Christine. "Transportation and the Environment." In The Geography of Urban Transportation, edited by Susan Hanson and Genevieve Giuliano, 356-81. Third ed. New York, NY: Guilford Press, 2004.

industrial sources other than the refinery, amounting to 11.24 tons, only 5.79% of the total 194.28 tons per year from industry.[3]

To calculate the releases from transportation, I utilized percentages set forth by Bae (2004) in her chapter of The Geography of Urban Transportation, 3rd Ed. on "Transportation and the Environment." Bae employs transportation mode-specific and sector-total values regarding contributions of CAP emissions on a national scale, citing a 7.6% transportation sector-total contribution of PM2.5, and a 53.45% and 43.5% contribution of NOx and VOCs, respectively;[4] I used the sector-total value – inclusive of highway vehicles, aircraft, railroads, vessels, and other off-highway transit – as Richmond houses stretches of a number of freight and passenger rail lines, a shipping terminal, stretches of the I-580 and I-80 highways, and many urban streets.[5]

I chose these percentages, in combination with a U.S. EPA estimate, over a back-of-the-envelope estimation of transportation related emissions because the data for each mode was largely unavailable, inconsistent, or based on too many assumptions of its own to instill confidence in the numbers. The U.S. EPA estimates that the transportation sector contributes about 30% of all emissions on a national scale, assuming this value as a result of averaging percent contributions of compounds within the total emissions volume. Assuming that the two major categories of emissions sources in the greater Richmond area are the stationary industrial sources that the 2013 TRI Report stated to contribute 192.28 tons/year, and mobile transportation sources, given the assumption that transportation contributes roughly 30% of all emissions, I deduced that the total emissions from these two categories in the greater Richmond area amount to 277.54 tons/year, with mobile sources contributing 83.26 tons/year; this is outlined in **Table 4-1** below.[6,7]

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[3] U.S. EPA. "Toxic Release Inventory." 2015.
[4] Bae. "Transportation and the Environment." 361.
[5] Bae. "Transportation and the Environment." 360.
[6] U.S. Environmental Protection Agency. "State and Local Transportation." EPA. 2015. Accessed April 14, 2015. http://www.epa.gov/statelocalclimate/state/topics/transportation.html.
[7] U.S. EPA. "Toxic Release Inventory." 2015.

Table 4-1. Breakdown of emissions sources within greater Richmond area

Emitting Source	*Total Emissions in GRA*	*Percent of Total Emissions*
Stationary and Mobile	277.54 tons/year	100%
Richmond Industry	194.28 t/y	70.0%
Richmond Chevron	*183.04 t/y*	*66.14%*
Non-refinery industry	*11.24 t/y*	*3.86%*
Transportation	83.26 t/y	30.0%

The percentage of baseline pollutant presence – that is, the total volume of non-refinery industry releases, along with transportation contributions – can be applied to the CAP and HAP concentrations recorded by the monitors to produce estimated values for those pollutant concentrations that can be attributed to the local sources other than the refinery; doing so generates values of 5.96 tons/year of $PM_{2.5}$, 35.61 t/y of ozone, and 10.4 t/y of BTEX stemming from non-Chevron sources.

4.2 Wedge air dispersion model

Following the lead of F. Liu's text outlining the mechanism and application of the wedge model, along with the guidance of Joseph Kantenbacher, a University of California, Berkeley Ph.D. candidate in the Energy and Resources Group, I determined the variables to utilize in the wedge model using the concentration formula, outlined below:

$$C(r) = \frac{(\frac{dn}{dt})}{\theta hur},$$

Where:
r = distance from the point source [meters]
C(r) = concentration at distance r [grams/m³]
(dn/dt) = emissions rate from the point source [grams/second]
θ = angle of the plume wedge [radians]
h = height of emissions entry into ambient air [meters], and
u = wind speed [meters/second]

To obtain *r* I simply measured the geodesic distance – that is, the distance 'as the crow flies' – between pt. A and the San Pablo-Rumrill monitor, reaching a value of 3,655.44m. The emissions rate *(dn/dt),* or *E,* for general emissions from Richmond Chevron was calculated by employing the U.S. EPA's most recent TRI data for the City of Richmond, attributing 183.04 tons of on-site toxic air releases per year to the Richmond Chevron refinery exclusively. I then did a b.o.e. calculation to convert this tons/year value into grams/second, ending with an emission rate value of 5.27g/s**.** This process was repeated for each of the study toxics, employing deduced weight-per-year concentrations from provided concentration values ultimately providing individualized *E* values for each toxic to be utilized in the prediction of concentrations of that specific toxic (see **Table 4-2**).

Table 4-2. *Predicted concentrations of study toxics from wedge concentration equation*

Pollutant	*Emissions Rate*	*Predicted Concentration*
Ozone*	2.36 g/s	11.26 μg/m^3
PM$_{2.5}$	2.26 g/s	10.8 μg/m^3
BTEX$_{compound}$	0.88 g/s	4.198 μg/m^3

The angle by which the wedge opens created some challenge, but was ultimately determined to be twice the angle between the pt. A-Rumrill tangent and the mean wind direction (MWD) tangent; the MWD tangent is determined to be the average direction in which the wind blows in the dominant wind experience, serving therefore as the centerline for the model. Constrained to the incorporation of the Rumrill monitor, the wedge spreads quite wide with a total θ value of 61.32˚, or 1.07 radians; in many wedge model cases there are more frequent monitor sites so it is easier to select one more closely aligning with the dominating wind direction.[8] The atmospheric entry of emissions, or simply the average stack height, *h*, was assumed to be 10 m. Based on conclusions from Seibert et al. (2000), most atmospheric entry and mixing heights are carefully determined through the use and analysis of many atmospheric chemical and temperature properties, but can also be conjectured by "application of paramaterisations or models based on operationally available data;" the latter approach was taken and the final assumed value was confirmed.[9] Wind speed and direction were determined through manipulation of meteorological data obtained directly from BAAQMD, as it was not made publicly available. As was presented in **Figure 3-2**, the dominant wind experience observed at the Pt. San Pablo weather station is a south-southwesterly

[8] Krishna et al. "Impact of an Industrial Complex." 5400.
[9] Seibert, Petra, Frank Beyrich, Sven-Erik Gryning, Sylvain Joffre, Alix Rasmussen, and Phillippe Tercier. "Review and Intercomparison of Operational Methods for the Determination of the Mixing Height." Atmospheric Environment 34, no. 7 (February 14, 2000): 1001-027. Accessed March 11, 2015. doi:10.1016/S1352-2310(99)00349-0.

wind, blowing most commonly around 4.00-8.00m/s; note that the degree orientation of a wind rose places 0˚ as North, and counts upwards in the clockwise direction. In order to present the case of the most common wind experience, instead of a comprehensive hourly average for every hour of the 4-year period, I filtered the data to look exclusively at the records from within the southwest quadrant of the wind roses; I averaged these records that showed a from-direction of anywhere between 180 wind rose degrees (WRD) and 270 WRD. Records that fell within this range occurred 62.9% of the time. Within this range of data, I took annual averages of both wind speed and direction for each of the years provided and then calculated a 4-year average from those values. This resulted in an average wind experience, in the dominant direction, coming from 215.93 WRD (234.07˚ in standard degree orientation), therefore heading through the origin and in the direction of the tangent at 35.93 WRD (54.07˚ standard), and averaging a speed, u, of 5.36 m/s. Finally, utilizing all of these derived values, I calculated the predicted concentrations $C(r)$. **Tables 5-1** and **5-2** (see chapter 5) outline the values derived as predicted concentrations of ozone, $PM_{2.5}$, and BTEX distance r from pt. A within the wedge area, as they compare to actual observed concentrations, and **Figure 4-1** graphically illustrates the comparison between predicted and observed values of the HAPs specifically considered in this study.

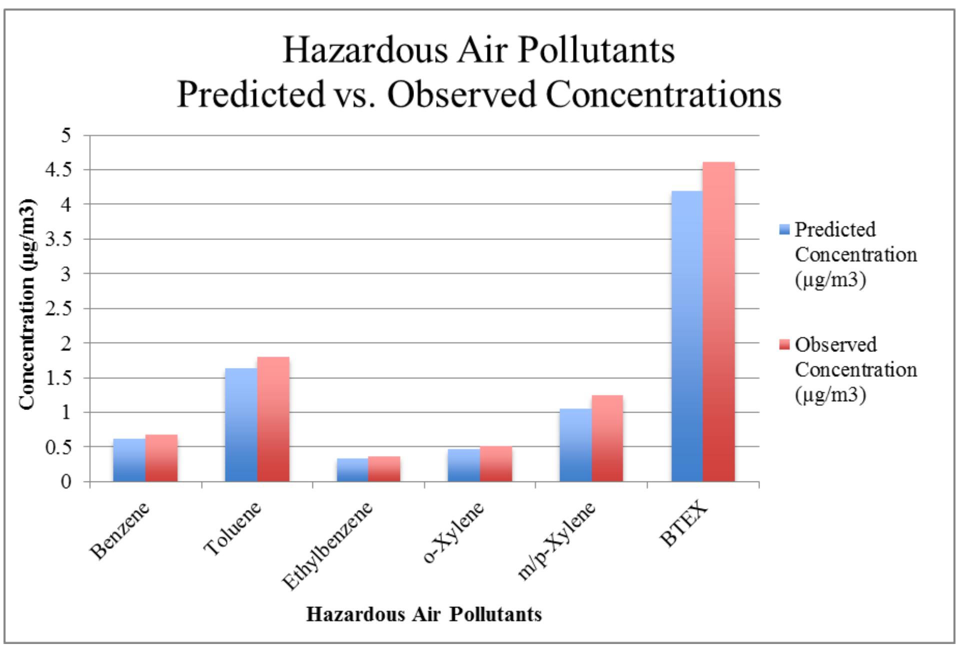

Figure 4-1. *Predicted vs. observed concentrations of BTEX compounds*

4.2.1 Model evaluation

To evaluate the accuracy and effectiveness of this model, I turn both to the literature –Brauer et al. (2008) – as well as to the *index of agreement* model performance evaluation function provided in Sivacoumar et al. (2000). Before any evaluation is done, however, it is critical to acknowledge known shortcomings that arise through either data inconsistencies or as a result of assumptions. That being said, first and foremost, I acknowledge that the significant simplification of meteorological and atmospheric condition variables to include exclusively wind speed, direction, and an assumed entry height inherently simplify the resulting model as a representation of reality; not accounting for dynamic variables that, as Bloss (2009) writes, can largely influence atmospheric chemical processing and pollutant levels.[10] The degree of accuracy of an air dispersion model depends on the number of variables employed, and the accuracy of those variables. For the purposes of this study, the wedge model was chosen over alternate models for its ability to provide a decent model without the consideration of every physical condition; many other models rely upon the input and influence of factors such as: topography, atmospheric pressure and stability, temperature, etc. but in order to give attention to the impacts and political factors involved in the enabling of the condition, a stripped-down wedge model was used.[11] Brauer et al. (2008) extends the scope of model utilization further by emphasizing the importance and role of exposure models in epidemiological studies, similar to the interests of this study.[12]

Considering all of these factors and shortcoming of the model, it is important to then statistically evaluate the performance of the specific model in order to determine its effectiveness in predicting concentrations of the given toxics. By following the *index of agreement* expression presented in Sivacoumar et al. (2000), I calculated a coefficient representative of the performance of the model by comparing predicted values to observed values, to be seen in **Tables 5-1** and **5-2**. The index of agreement expression is as follows:

[10] Bloss, William. "Atmospheric Chemical Processes of Importance in Cities." In Air Quality in Urban Environments, edited by R E Hester and R M Harrison, 42-64. Vol. 28. Issues in Environmental Science and Technology. Cambridge, UK: Royal Society of Chemistry Publishing, 2009.
[11] Bloss. "Atmospheric Chemical Processes." 45-46.
[12] Brauer et al. "Models of Exposure." 2008.

$$d = 1 - \frac{(P_i - O_i)^2}{(|P_i - O| + |O_i - O|)^2}$$

The index coefficient *d* considers observed concentrations (O_i), the observed mean (O) and predicted values (P_i), and will lie between $0 \leq d \leq 1$; values closer to 1 indicate higher accuracy of predictions of the model.[13]

Observed concentration values were selected from 2013 data out of the set provided by BAAQMD, while the observed mean was calculated by the four values from years 2011-2014. I used observed concentration values from 2013 because the emissions rate data was exclusively from 2013, as well. I used the range of 2011-2014 for the observed mean to match the range of time used for calculating other means in this study.

4.3 Spatial analysis

The wedge model on its own is helpful in creating a function through which to predict concentrations of toxics at a given distance from the point source, and overlaying the wedge on top of the area in which it occurs contextualizes the air emission dispersion trends within an air basin and over the population; utilizing ArcGIS to display the wedge within the greater Richmond area takes the abstract model and makes it more meaningful. The spatial analysis performed in this study included determining: the distribution of the population by race; the orientation and extent of the wedge in space; and the area and population most frequently and directly impacted as a result of the dominant dispersion trend identified.

After downloading Census data for all of Contra Costa County and clipping it exclusively to the greater Richmond area, I identified the boundaries and respective census blocks for North Richmond and San Pablo. Then, using the greater Richmond area census data, I created a comprehensive minority population by generating a new field in the attribute table that summed the population values of all minority races to generate a total minority population value. I acknowledge the possibility of any person included in this Census count having selected more than one race, therefore generating a deduced

[13] Sivacoumar. "Air Pollution Modeling for an Industrial Complex." 472-76.

minority population value that may include persons also included in the white population value as a result; for the purposes of this study, I assumed any person identifying with at least one minority race is to be considered part of the greater minority population. To display the spatial distribution of the population of the greater Richmond area by minority population, I selected the minority population field to display by census block, and normalized the field to the total population of the census block, creating a gradient that displayed different ranges of occupation percentage of the minority population in each census block, represented in minority persons-per-total persons. Normalization neutralizes the population values by representing percentage instead of just population per census block; it calibrates people in space, creating a unit by which census blocks of all sizes can be compared. I classified the data using Natural Breaks, employing five classifications, meaning that the density ranges were split evenly between five equal intervals and displayed in darker shades of blue as the density increased, as seen in **Figures 5-5** and **5-6**. In order to correct for imperfections, I eliminated all census blocks that recorded a value of '0' for the population field, leaving all blocks with any value >1.

Next, determining the orientation and extent of the wedge in ArcGIS involved: identifying pt. A; identifying the San Pablo-Rumrill monitor; creating a buffer circle from pt. A to the monitor; and orienting the wedge in the direction of the wind. I generated Pt.A by taking the mean center of all of the identified/digitized emissions point sources within the refinery site; 'mean center' is a spatial statistics tool for measuring geographic distributions in ArcGIS, and is calculated through the input of all of the digitized point sources, producing one point that is the geographic center for the set of point source features. Identifying the San Pablo-Rumrill monitor simply involved digitizing a point feature on the site of the monitor on Rumrill Blvd. From there, I created a buffer outward from pt. A with a radius of 3,655.44m, the geodetic distance between pt. A and the Rumrill monitor. Using this buffer circle, I then generated a line feature for the right tangent of the wedge by connecting pt. A to the Rumrill monitor point, a line feature for the left tangent of the wedge by inputting the angle at which it is oriented – 5.27 WRD (84.73˚ standard) and a radius length of 3,655.44m, and a line feature for the centerline, representing the mean direction of the wind of the dominant wind experience, at 35.93 WRD (54.07˚). Finally I digitized the representation of the wedge by connecting the two flank tangents to one another with an arc along the buffer circle that spans between the two bounding tangent lines.

Chapter 5

FINDINGS

Based on BAAQMD's monitor readings, observed concentrations of the study's focus toxics at the San Pablo-Rumrill monitoring station are outlined in **Tables 5-1** and **5-2**; observed concentrations were obtained through BAAQMD, with CAP values coming from the online Air Monitoring Data resource and HAP values coming from data directly sent by Eric Stevenson.[1] Considering how the observed values of the study's focus toxics compared with their respective concentration standards, according to this data, only three of the highest hourly concentrations of $PM_{2.5}$ in 2013 exceeded the CAAQS threshold of 35 µg/m^3, reaching 58 µg/m^3 in Jan-2013, 64 µg/m^3 in Dec-2013, and the annual peak hourly concentration of 68 µg/m^3 in July-2013.[2] Other than these three cases, along with the observed concentration of the Annual Arithmetic Mean of $PM_{2.5}$ exactly matching its limit of 12 µg/m^3 in 2013, the observed concentrations reported by BAAQMD demonstrate clear attainment of the standards that govern air quality and toxic concentrations, as seen in **Tables 5-1** and **5-2**.

Table 5-1. *Criteria Air Pollutant standards, compared with predicted and observed concentrations (2013)*

Criteria Pollutant	*Averaging Time*	*NAAQS Concentration*	*CAAQS Concentrations*	*Predicted Concentration*	*Observed Concentration[a]*	*Index of Agreement*
Ozone*	8-hr.	75 ppb (147 µg/m^3)	70 ppb (137 µg/m^3)	11.26 µg/m^3	65 ppb (127.53 µg/m^3)	0
	1-hr.	N/A	90 ppb (180 µg/m^3)	-	74 ppb (145 µg/m^3)	-
$PM_{2.5}$	Annual Arithmetic Mean	12 µg/m^3	12 µg/m^3	10.8 µg/m^3	12 µg/m^3	0
	24-hr.	N/A	35 µg/m^3	-	68 µg/m^3	-

*ozone predictions based off of RCR specific NO_x and VOC emissions volumes
a: observed concentrations as 2013 values; conversion from ppb to µg/m^3 is as follows:
µg/m^3 = [ppb]*[12.187]*[M]/(273.15 + T), where M = molecular weight (48 g/mol for ozone), and T = standard temperature at 1 atmosphere, assumed to be 25˚ C; calculation included in notes of table provided by BAAQMD.[3]

Chapter 5 notes:
[1] BAAQMD, Eric Stevenson, and Duc Nguyen. Bay Area Air Quality Management District Community Air Monitor Readings, HAPs, 2002-2014. February 25, 2015. Raw data. San Francisco, CA.
[2] BAAQMD. "Air Monitoring Data." 2015.
[3] BAAQMD, Stevenson, and Nguyen. "Air monitor reading. Raw data." 2015.

Table 5-2. Hazardous Air Pollutant standards, compared with predicted and observed concentrations (2013)

Hazardous Pollutant	*Chronic Inhalation REL[a]*	*Predicted Concentration*	*Observed Concentration[b]*	*Index of Agreement[c]*
Benzene	60 μg/m^3	0.624 μg/m^3	0.684 μg/m^3	0.723
Toluene	300 μg/m^3	1.64 μg/m^3	1.795 μg/m^3	0
Ethylbenzene	2,000 μg/m^3	0.33 μg/m^3	0.365 μg/m^3	0.875
o-Xylene	700 μg/m^3	0.47 μg/m^3	0.515 μg/m^3	0.89
m/p-Xylenes	700 μg/m^3	1.05 μg/m^3	1.253 μg/m^3	0
$BTEX_{compound}$	3,760 μg/m^3	4.198 μg/m^3	4.612 μg/m^3	0.623

a: from Table 2-5-1 of BAAQMD Regulation 2, Rule 5
b: Based on recorded concentrations as provided by Eric Stevenson, 2013 values
c: using absolute total observed concentration, not observed concentration attributable to RCR

The next step, however, is to deduce the amount of the observed concentrations attributable specifically to refinery emissions. Employing the percentages listed in **Table 5-3**, I reasoned that the total emissions (tons/year) of each focus toxic directly attributable to the emissions from the Richmond Chevron refinery were as they are set out in the "TE attributable to RCR" column of Table 5-3; I utilized total emissions volumes calculated for each toxic independently, and acknowledge that the sum of the rows of total emissions attributable to the Richmond Chevron refinery for each toxic exceeds the 183.04 t/y value deduced from the 2013 TRI Report.

Table 5-3. Concentrations and total emissions values attributable explicitly to Richmond Chevron refinery

Pollutant	*Predicted Concentration**	*Observed Concentration*	*Percent attributable to RCR*	*Observed Concentration attributable to RCR*	*Total emissions (TE) in GRA*	*TE attributable to RCR*	*Percent of total RCR emissions*
Ozone (8-hr)	11.26 μg/m^3	127.53 μg/m^3	56.5% [a]	72.05 μg/m^3	117.48 t/y[c]	81.87 t/y	44.7%
$PM_{2.5}$ (Mean)	10.8 μg/m^3	12 μg/m^3	92.4% [a]	11.1 μg/m^3	84.42 t/y	78.46 t/y [d]	42.9%
Benzene	*0.624 μg/m^3*	*0.684 μg/m^3*	66.14% [b]	*0.45 μg/m^3*	*6.09 t/y*	*4.55 t/y*	*2.5%*
Toluene	*1.64 μg/m^3*	*1.795 μg/m^3*	66.14% [b]	*1.19 μg/m^3*	*16.01 t/y*	*11.96 t/y*	*6.5%*
Ethylbenzene	*0.33 μg/m^3*	*0.365 μg/m^3*	66.14% [b]	*0.24 μg/m^3*	*3.25 t/y*	*2.43 t/y*	*1.3%*
o-Xylene	*0.47 μg/m^3*	*0.515 μg/m^3*	66.14% [b]	*0.34 μg/m^3*	*4.6 t/y*	*3.44 t/y*	*1.9%*
m/p-Xylenes	*1.05 μg/m^3*	*1.253 μg/m^3*	66.14% [b]	*0.83 μg/m^3*	*11.19 t/y*	*8.36 t/y*	*4.6%*
$BTEX_{compound}$	4.198 μg/m^3	4.612 μg/m^3	66.14% [b]	3.05 μg/m^3	41.15 t/y	30.75 t/y	16.7%
TOTAL Emissions					**277.54 t/y**	**183.04 t/y**	

*using emissions rate calculated with source-specific emissions volumes
a: non-transportation percentage from Bae (2004)
b: used generic U.S. EPA estimate compounded with Chevron's prevalence in stationary source emissions totals; Chevron contributes 66.14% of Richmond's concentrations according to assumptions and calculations in this study
c: using VOC and NO_x total emissions from U.S. EPA National Emissions Inventory 2011 from record specifically on RCR; understand low value as result of ozone not directly emitted; TE attributable to RCR calculated as 56.5% of TE.
d: from U.S. EPA National Emissions Inventory 2011, area and industry specific report, providing total CAP emissions for 2011 for specific facilities; this value was taken from record specifically on the Richmond Chevron refinery. TE for $PM_{2.5}$ calculated as 107.6% of this value.

Looking to the model, the accuracy of predictions of toxic-specific concentrations was inconsistent. Having deduced the proportion of total ambient air toxics over the greater Richmond area attributed specifically to the Richmond Chevron refinery, I was able to calculate the wedge model for this study, predict values, and compare them to the observed concentrations. Employing the variables set out in Section 4.2, I generated toxic-specific concentration predictions, outlined in comparison to observed concentrations and relevant standards in Tables 5-1 and 5-2. Table 5-1 shows a predicted concentration of ozone drastically below the observed concentration. This is largely due to the embedded error in predictions of ozone attributed to a source; as ozone is not directly emitted, rather created from chemical reactions between NO_x, VOCs, and sunlight, I assumed full contribution of NO_x and VOC emissions to the generation of ozone, and determined this prediction based exclusively on the sum of refinery emissions of NO_x and VOCs, arriving at a predicted value <10% of the observed value. The predicted concentration of $PM_{2.5}$ was 1.2 μg/m^3 below the observed concentration of 12 μg/m^3. Both CAPs, however, yielded a *d* value of 0, meaning the predictability for ozone and $PM_{2.5}$ for this model is very poor; the relationship between observed, predicted, and standard concentration values for CAPs is also illustrated graphically in **Figure 5-1**. Table 5-2 shows predicted and observed concentrations of benzene, toluene, ethylbenzene, o/m/p-xylenes, and $BTEX_{compound}$, with both predicted and observed concentrations falling anywhere from two to five orders of operation below the Chronic Inhalation Reference Exposure Level standard, as set out in BAAQMD's Regulation 2, Rule 5.[4] The accuracy of the model in predicting concentrations of benzene, ethylbenzne, o-xylene, and $BTEX_{compound}$ is rather strong, with 72.3%, 87.5%, 89%, and 62.3% accuracy, respectively. The accuracy of the model in predicting concentrations of toluene and m/p-xylenes, however, is very weak, each yielding a *d* value of 0. The relationship between observed, predicted, and standard concentration values for these HAPs is also illustrated graphically in **Figure 5-2**.

[4] BAAQMD. "Regulation 2, Rule 5." 2015.

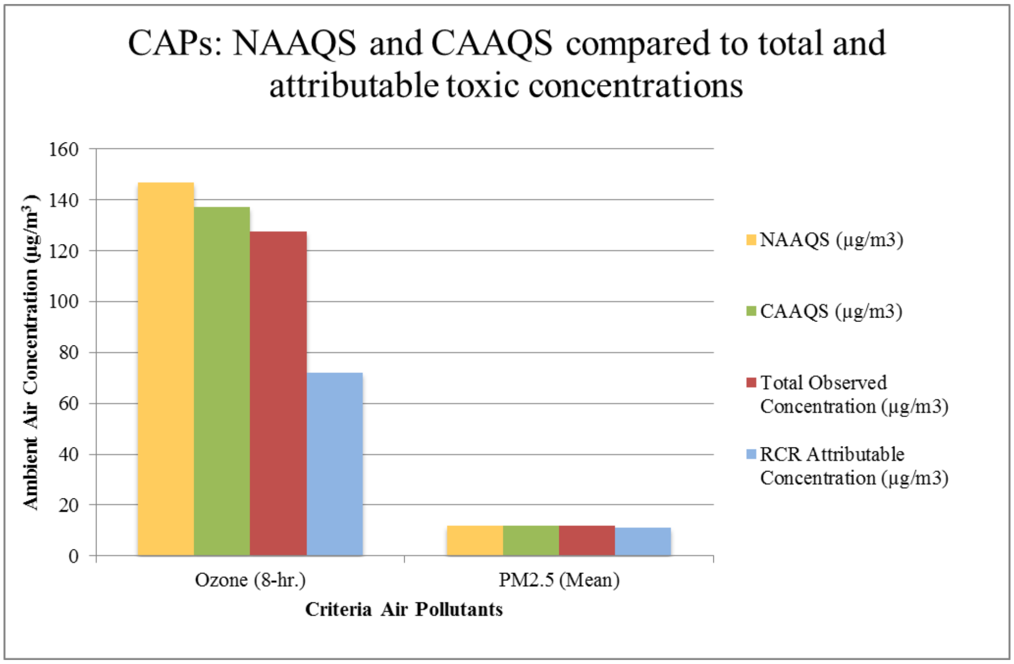

Figure 5-1. *Comparison of CAP standards, observed, and predicted concentrations*

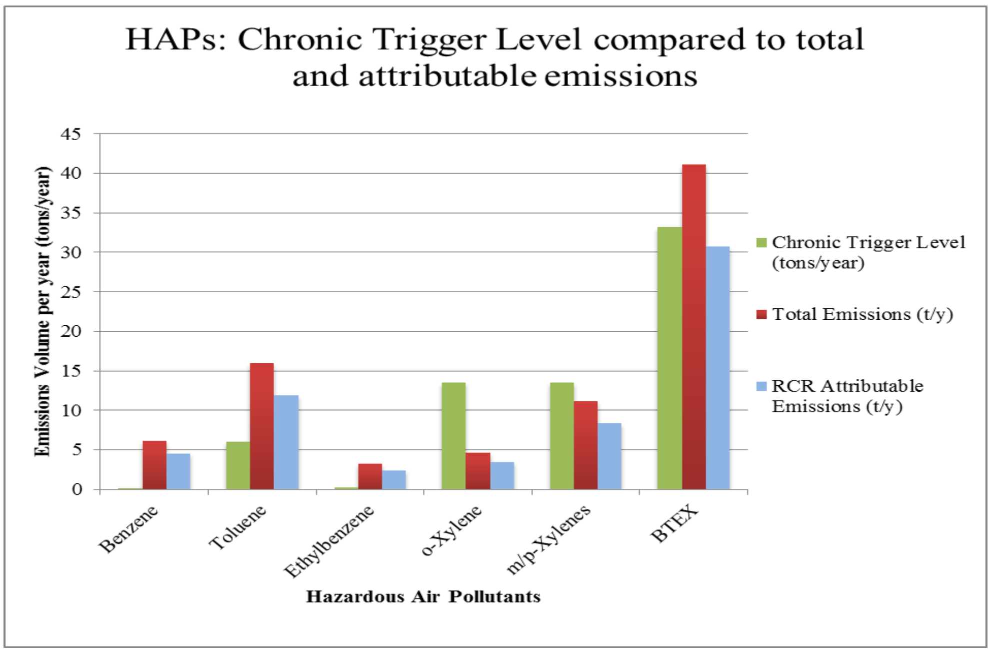

Figure 5-2. *Comparison of HAP standards, observed, and predicted concentrations*

Understanding the toxic concentrations in the greater Richmond area's ambient air, the concentrations directly attributable to Richmond Chevron operations, and the strength of the model, I then examined and analyzed the model in space; though a dominant trend is identified, it is important to note the model's generation of a dominant trend with averaged values lends itself to what Brauer et al. (2008)

describe as “imperfect characterization of temporal variability in air pollution concentrations.”[5] Looking at the orientation and cover of wedge, as seen in **Figure 5-3**, it becomes clear that, in the case of the dominant wind experience which occurs with 62.9% frequency, the area of North Richmond is the most directly and frequently impacted by the refinery emissions, with the winds also blowing the strongest in that direction, sending the emissions trajectory the farthest in that direction.

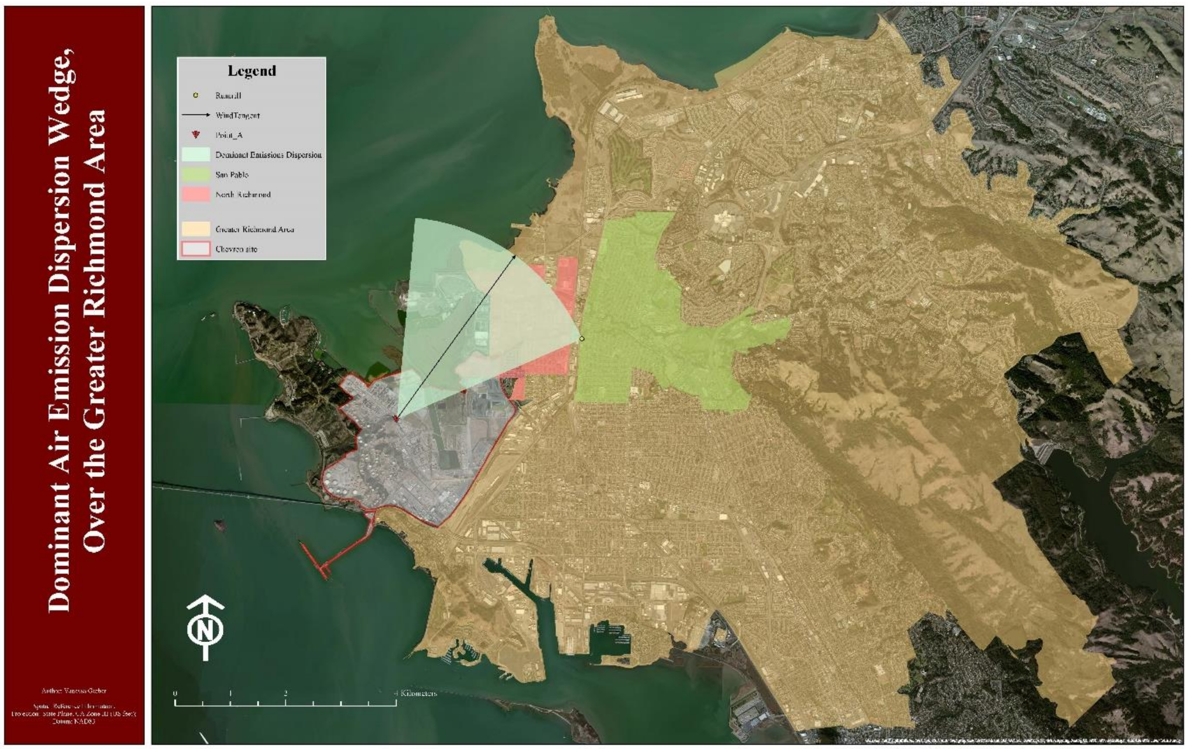

Figure 5-3. *Dominant air emission dispersion wedge over greater Richmond area*

Considering the remainder of the local meteorological data, it is critical to acknowledge the frequency of the other wind experiences, as well, so as to partially correct for the ‘imperfect temporal variability characterization’ (see **Table 5-4**). Northeasterly winds – coming in the counter-direction to the dominant southwesterly wind classified in this study – occur with an average of 23.4% frequency and flow at a lower speed of 3.61 m/s; the northeasterly winds direct the emissions trajectory towards the San Francisco Bay, with some of the outer spread reaching Point Richmond. Northwesterly winds occur 8.7% of the time and head directly towards the affluent neighborhood of Point Richmond, in the average direction of

[5] Brauer et al. “Models of Exposure.” 600.

123.92 WRD (or 326.08˚) at a speed of 3.97 m/s; this is an important finding as many Point Richmond residents believe they are unaffected by the refinery, but this shows that, even though at a lower frequency and slightly slower wind speeds, winds do occur almost one-in-ten hours/year that send the Richmond Chevron emissions over Point Richmond. Lastly, southeasterly winds occur 5.1% of the time, at a speed of 3.85 m/s. While the wind experiences out of the other three quadrants occur with notable frequency, for the purposes of this study, I will be further analyzing the impacts of the emissions dispersion in the dominant wind experience, as the southwesterly wind occurs almost three times as often as the next most frequent wind.

Table 5-4. *Local wind conditions and frequency of occurrence*

Wind	***Average Direction of Wind Origin***	***Average Direction of Wind Destination***	***Area of Impact***	***Average Speed***	***Frequency***
Southwesterly	215.93 WRD (234.07˚)	35.93 WRD (54.07˚)	North Richmond	5.36 m/s	62.9%
Northwesterly	303.92 WRD (146.08˚)	123.92 WRD (326.08˚)	Pt. Richmond	3.97 m/s	8.7%
Northeasterly	37.93 WRD (52.07˚)	217.93 WRD (232.07˚)	SF Bay, Point Richmond	3.61 m/s	23.4%
Southeasterly	158.31 WRD (291.69˚)	338.31 WRD (111.69˚)	Pt. San Pablo, SF Bay	3.85 m/s	5.1%

The next step is to understand demographics and population distributions within the greater Richmond area, and as the contrast between **Figures 5-4** and **5-5** illustrates, there are telling trends of gentrification. The minority population in the study area is clustered largely in the central, industrial areas and is disproportionately represented in the direct fenceline community, while the white population more heavily occupies the peripheral areas much farther from the refinery. Further examining the impact area of the dominant dispersion trend, the demographics lend themselves to a story that has been heard before; within North Richmond not only is there a higher relative minority population (97%) compared with the greater Richmond area as a whole (83%), but around 16% of residents are also living at or below the federal poverty line; in fact, the 2010 median income in North Richmond was $36,875 compared with $54,012 in the greater Richmond area, and $78,385 in all of Contra Costa County.[6,7] Additionally there is only one hospital in the community, with railroads separating the North Richmond population from other medical facilities. This finding raises a concern regarding environmental justice, as there is a clear trend of disproportionate minority populations not only within North Richmond – the direct area of impact of the dominant wind – but also in a vast majority of the fenceline census blocks. The minority and low-income occupancy of the census blocks nearest the Richmond Chevron refinery follows a trend seen in many fence line communities surrounding industrial or hazardous sites around the country, and around the world.[8]

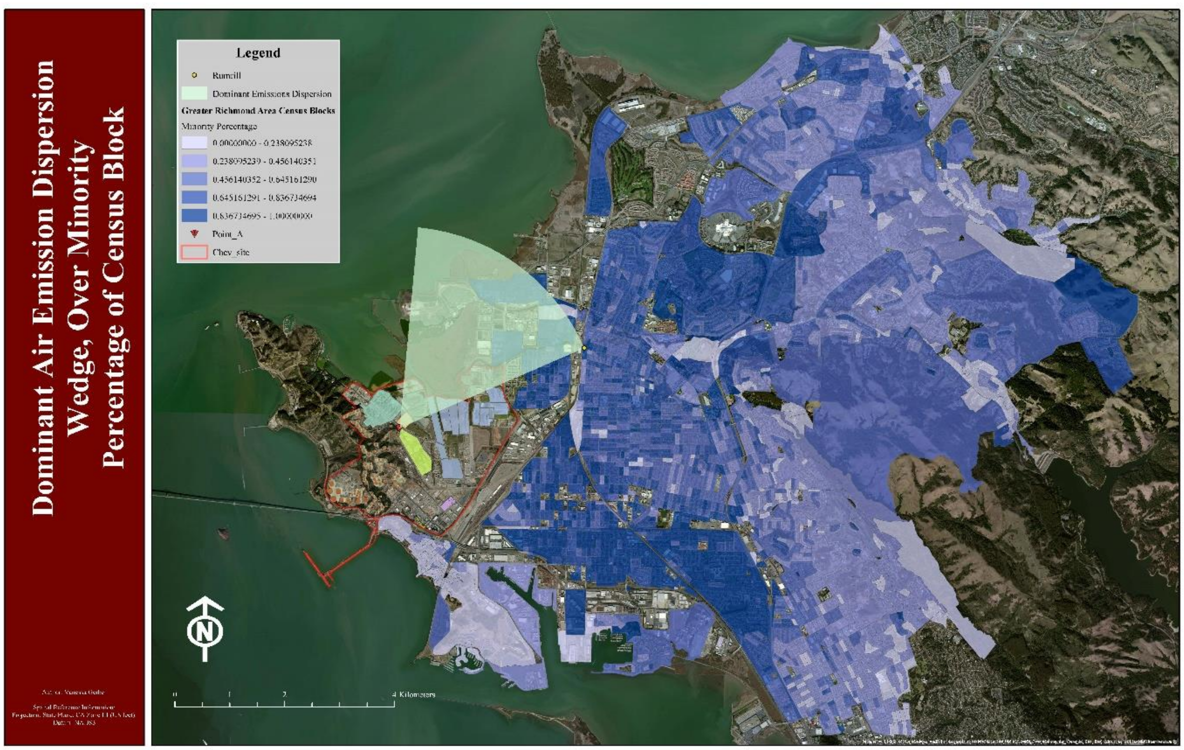

__Figure 5-4.__ Dominant dispersion wedge over minority percentage census blocks

[6] Kay, Jane, and Cheryl Katz. "Pollution, Poverty, People of Color." June 4, 2012. Accessed February 10, 2015. Environmental Health News.
[7] Association of Bay Area Governments. "Bay Area Census -- City of Richmond." Bay Area Census -- City of Richmond. 2010. Accessed December 3, 2014. http://www.bayareacensus.ca.gov/cities/Richmond.htm.
[8] Bullard. "Environmental and Social Justice." 2000.

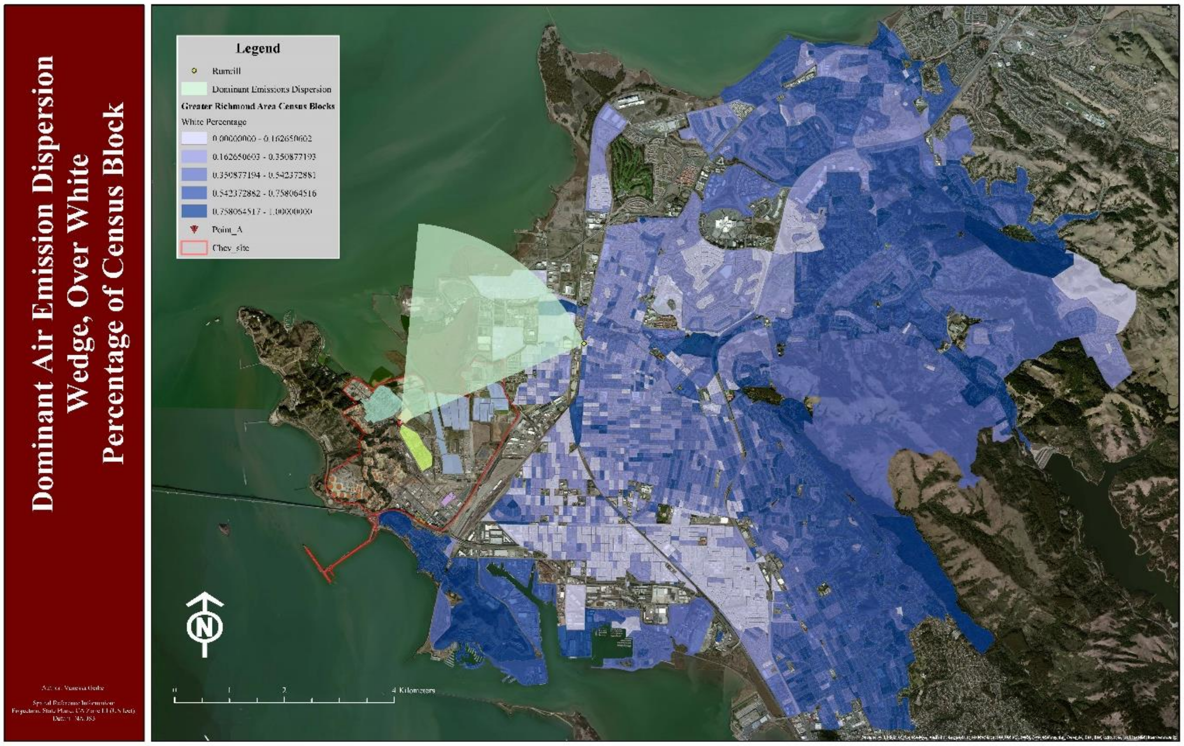

Figure 5-5. *Dominant dispersion wedge over white percentage census blocks*

Given the total concentrations observed in the wedge model employed in this study, even though almost all observed values fall below the standards outlined by the relevant regulations, the greater Richmond area – and North Richmond in particular – have some of the worst asthma and cancer rates in the state, and even the entire country.[9] According to data from the California Department of Public Health, in 2012 North Richmond saw an age-adjusted rate of asthma emergency visits of 261 for children ages 0-17, and 201.6 for adults, representing the rate at which children and adults per 10,000 persons of their age group need emergency attention for an asthma condition; in Contra Costa County, the 2012 rates were less than half of those in North Richmond, with the rate for children at 104.1 and 66.3 for adults, in California, the 2012 rate for children was 79.4 and 39.6 for adults, and, nationally in 2009 the rate was 69.7 emergency visits per 10,000 population.[10,11]. Cancer rates in Richmond, according to a 1984 health study on the association between cancer incidence and estimated residential exposure to air emissions

[9] CA Department of Public Health. Asthma Emergency Department Visit Rates by ZIP Code in 2012. 2012. Raw data.
[10] CA Dept. of Public Health.Asthma. 2012.
[11] U.S. Department of Health and Human Services. National Surveillance of Asthma: 2001-2010. Report. Accessed April 10, 2015. http://www.cdc.gov/nchs/data/series/sr_03/sr03_035.pdf.

from petroleum plants specifically in the cities of Richmond and Rodeo in Contra Costa County, show a "strong positive association between the degree of residential exposure and death rates from cardiovascular disease and cancer."[12]

[12] Kaldor, J., J A Harris, E. Glazer, S. Glaser, R. Neutra, R. Mayberry, V. Nelson, L. Robinson, and D. Reed. "Statistical Association between Cancer Incidence and Major-cause Mortality, and Estimated Residential Exposure to Air Emissions from Petroleum and Chemical Plants." Environmental Health Perspectives, March 1984, 319-32. Accessed March 10, 2015. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1568163/.

Chapter 6

POLICY and POLITICS

The observed conditions and public health repercussions outlined in the previous section result from a combination of policies and political balances. Though this study examines in depth only two of the six CAPs and four of the 187 HAPs, the overarching goal regarding public health and environmental justice is general emissions reduction; general emissions reductions should also indicate proportional emissions reductions of the focus toxics, assuming refinery emissions are a factor in general emissions, also assuming equivalent proportional toxic composition within refinery emissions. Considering limitations in existing regulations, challenges with existing energy and climate policy, and the role of Chevron's corporate spending, this section aims to examine and present the economic and political forces at play influencing the decisions that are made pertaining to the refinery's operations, and make clear who exactly is involved in making those decisions.

6.1 Refinery regulation loopholes and exemptions

Revisiting the refinery regulations outlined in Section 1.2 and acknowledging the overwhelming variety of similar guidelines and policies throughout vested agency legislation, it is critical to acknowledge the language and content of the policies, and to analyze the impacts of exemptions laid out in the legislation. The U.S. EPA and BAAQMD, as the primary agencies responsible for the relevant regulations examined in this study, produce legislation pertaining largely to key aspects of the refining process (i.e. permitting; maintenance; and emissions tracking, monitoring, and analysis). While the regulations provide a vast amount of information on the aspects aforementioned, only the NAAQS, CAAQS, and BAAQMD's 2-5 include explicit concentration regulation values, with pertinent values included in **Tables 5-1 and 5-2**.

6.1.1 Federal regulation exemptions

In addition to standards and regulations on HAPs and CAPs, the U.S. EPA also provides federal regulation regarding stationary source operations and emissions. New Source Performance Standards

(NSPS) restrict the amount of air pollution coming from new or modified existing sources.[1] The final NSPS for petroleum refineries – issued in Dec-2013 – primarily aim "to help areas attain and maintain air quality by ensuring the best demonstrated emission control technologies are installed when it is most cost effective."[2] In the U.S. EPA's third version of the Emissions Estimation Protocol for Petroleum Refineries, the April 2015 report provides the most recent and updated "guidance and instructions to petroleum refinery owners and operators and to federal, state, and local agencies for the purpose of improving emission inventories for the petroleum refining industry," highlighting the preferred estimation methods to use for each emission source type, but failing to provide explicit standard volume or concentration value limits within which the emissions should be.[3] The Emissions Estimation Protocol for Petroleum Refineries report is a very comprehensive resource outlining estimation methodologies, expected airborne pollutants and their expected facility sources within the refinery, but provides no comparable protocol for limits.[4] These two documents provide guidance, but no concentration regulations that consider toxicity reference values to be upheld in the interest of public health.

6.1.2 Regional regulation exemptions

The Stationary Source Committee of BAAQMD provides regulations outlining specific procedures, standards, and exemptions by which regional petroleum refineries, as stationary sources of emissions, must operate. While the regional regulations, like the federal regulations, appear to be comprehensive of aspects of the refining process and potential emission sources, there proves to be both explicit exemptions, as well as absence of complete emissions standards both for volume and toxic content.

Chapter 6 notes:

[1] U.S. EPA. DIRECT FINAL AMENDMENTS TO THE STANDARDS OF PERFORMANCE FOR PETROLEUM REFINERIES. 2013. Accessed April 18, 2015. http://www.epa.gov/ttnatw01/nsps/petrefnsps/20131205fs.pdf.

[2] U.S. EPA. "Direct Final Amendments." 2013.

[3] United States Environmental Protection Agency. Office of Air Quality and Planning Standards. Emissions Estimation Protocol for Petroleum Refineries. By RTI International. April 2015. Accessed April 18, 2015. http://www.epa.gov/ttn/chief/efpac/protocol/Protocol%20Report%202015.pdf. 1-1.

[4] U.S. Environmental Protection Agency. "Demonstrating Compliance with New Source Performance Standards and State Implementation Plans." Compliance. January 15, 2015. Accessed May 14, 2015. http://www2.epa.gov/compliance/demonstrating-compliance-new-source-performance-standards-and-state-implementation-plans.

Two of the BAAQMD rules include exemptions allowing emissions increases through a variety of loopholes. Regulation 2, Rule 5 (2-5), Section110 states that emissions are technically allowed to increase so long as the they maintain HAP concentrations below the trigger levels set out later in the rule, and 2-5-111 authorizes the exemption of emissions accounting for emissions resulting from "emergency use of emergency standby engines;" while 2-5 is one of few regional regulations that actually provides numerical values, or benchmarks, for toxic concentrations, these loopholes sanction emissions increases, furthering the degree to which the fence line community is exposed.[5] 12-16-103 sanctions emissions increases of both CAPs and greenhouse gases, so long as the increase only results from increased crude throughput and the proportion of emissions rate to crude processing rate remains the same; by endorsing higher production, this accomplishes the opposite of the intended "emissions mitigation."[6] It says that, if a refinery begins to process more crude than they had previously been processing, so long as it is within the limits of their permit, the increased emissions are not subject to this rule. 12-16-104 exempts greenhouse gas emissions levels in excess of the relevant trigger levels from any requirements set forth in the remainder of 12-16.[7] Lastly, and similarly to 2-5-111, 12-16-105 provides an exemption for emissions associated with flaring events.

Ultimately, these regulations primarily aim to review and evaluate processes, with few regional regulations explicitly calculating and limiting emissions. They do not address emissions reductions, with the only mention of mitigation found in 12-16, though exclusively referring to reductions necessary in the case of observed toxic concentrations in excess of the relevant trigger level. The best the regional regulations offer is to "identify the cause of… [and] mitigate, any significant emissions *increases* from petroleum refineries."[8]

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[5] Bay Area Air Quality Management District. Regulation 2: Permits; Rule 5: New Source Review of Toxic Air Contaminants. By Stationary Source Committee. January 6, 2010. Accessed February 10, 2015. http://www.baaqmd.gov/~/media/.

[6] Bay Area Air Quality Management District. Regulation 12: Miscellaneous Standards of Performance; Rule 16: Petroleum Refining Emissions Analysis, Thresholds and Mitigation. By BAAQMD. February 23, 2015. Accessed February 27, 2015. http://www.baaqmd.gov/~/media/.

[7] BAAQMD. "Regulation 12, Rule 16." 3.

[8] BAAQMD. "Regulation 12, Rule 16." 1.

Additionally, other pertinent policy also provides exemptions and loopholes that directly challenge the commitment to air quality protection claimed by the vested agencies. BAAQMD's 2-1-302 exemption evades checks and balances in the permitting process, by authorizing that, "installation and operation of a new or modified source or abatement device which qualifies for the Accelerated Permitting Program… may commence immediately following the submittal of a complete permit application;" this accelerates the process by which new projects may come onto line, and eliminates the permit evaluation stage. As another agency overseeing air quality in the state, the California Air Resources Board (CARB) states in Division 15, Chapter 4.5 of the Public Resources Code in the 2012 California Air Pollution Control Laws on "requests for confidentiality or disclosure" pertaining to petroleum supply and pricing, states that information submitted to the CARB "shall be held in confidence… to assure confidentiality if public disclosure of the specific information or data would result in unfair competitive disadvantage to the person supplying the information;" this allowance taps into the politics of the situation, by blatantly protecting the petroleum industry via classification of product information and characteristics.[9]

6.2 Existing energy and climate policy

In addition to legislation from the local to national levels regulating emissions from the petroleum refining industry, there is also policy acknowledging climate and energy issues, and providing a vision for climate change mitigation. Looking particularly at California statewide policy – appropriate as the state is considered a political pioneer in climate and energy policy, "applauded," even, for its "global leadership on climate change" – it is clear that there is a degree of concern for greater environmental issues.[10] However, given the exemptions and ambiguity of strict concentration thresholds for many toxic air pollutants, to some extent these policies enable the perpetuation of oil refining operations in the state, therefore endorsing the continued polluting of fenceline communities and regional air. Considering two of

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[9] California Air Resources Board. "Division 15 Energy Conservation and Development Chapter 4.5 Petroleum Supply and Pricing § 25364. Requests for Confidentiality or Disclosure." CARB - Public Resources Code. Accessed April 18, 2015. http://www.arb.ca.gov/bluebook/bb12/pur/pur-25364_NEW_2142.htm.

[10] Nagourney, Adam. "California Governor Orders New Target for Emissions Cuts." The New York Times. April 29, 2015. Accessed April 18, 2015. http://www.nytimes.com/2015/04/30/us/california-governor-orders-new-target-for-emissions-cuts.html?_r=0.

the most known and important state policies addressing environmental quality and climate change mitigation, I understand the inability to address, or simply the exclusion of refinery restriction.

6.2.1 AB 32

California State Assembly Bill 32 – AB 32, or the Global Warming Solutions Act – was assigned by Governor Schwarzenegger in September 2006 and establishes a comprehensive and trailblazing policy program dedicated to “real, quantifiable, cost-effective reductions of greenhouse gases” through the implementation of regulatory and market mechanisms (CA EPA/ CARB: AB32_factsheet). By establishing a statewide emissions cap, determining reporting rules for significant emission sources, mandating an outline of steps for emissions reductions, and even congregating an Environmental Justice Advisory Committee, AB 32 targets oil refineries through the reductions directive outlined for virtually every sector of the economy known as the Scoping Plan, as well as through fuel mix standards relevant to the reductions mandates for the transportation sector.[11] While CARB is responsible for designing the Scoping Plan for statewide reduction efforts by sector, there are mechanisms available through AB 32 that provide alternatives to directly decreasing a firm’s emissions; the Cap-and-Trade program is one of those mechanisms capitalized upon by major emitters, like the oil industry.[12]

6.2.2 California’s Cap-and-Trade

In compliance with the goals of AB 32, CARB administers and enforces the California Greenhouse Gas Cap-and-Trade Program, a market-based regulation scheme through which firms are given emissions caps and allowed participation in the auction of credits; caps may be exceeded upon the purchasing of credits from firms polluting less than their allotted volume.[13] The legislation, as of 2015, sets out standard procedures for the credit auction, definitions of refineries as covered entities under the program, and refining sector compliance allocation formulae, omitting sector-specific reduction rates, as qualifying firms can choose to utilize the auction to continue to emit at stable levels, or may choose to

[11] California Air Resources Board. Facts About Assembly Bill 32. 2009. Accessed April 12, 2015. http://www.arb.ca.gov/cc/factsheets/ab32factsheet.pdf.
[12] California Air Resources Board. "Assembly Bill 32 Overview." Assembly Bill 32. August 5, 2014. Accessed April 14, 2015. http://www.arb.ca.gov/cc/ab32/ab32.htm.
[13] California Air Resources Board. "Cap-and-Trade Program - Background." CalEPA - California Air Resources Board. 2015. Accessed April 14, 2015. http://www.arb.ca.gov/cc/capandtrade/capandtrade.htm.

invest in emissions reducing operations practices or technologies.[14] By putting a price on carbon, the state not only regulates emissions by introducing a new operating cost for firms, but also generates revenue to be used in the undertaking of additional measures towards statewide reduction goals. Though Cap-and-Trade has been largely successful in reducing California's overall emissions, major polluters, like oil refineries, often find it less expensive to buy credits and continue to pollute at comparable levels than it is to innovate and pollute less; from 2010 to 2011, for example, the Richmond Chevron refinery reduced its emissions only by 2%.[15] Understanding how refineries capitalize upon this auction system, it becomes clear that the Cap-and-Trade program has proven success overall, with just over a 6% emissions reduction statewide between the annual emissions sum in the inaugural year to the annual emissions sum in 2012, but does not provide appropriate restrictions to limit refinery-specific emissions.[16]

6.2.3 Policy evaluation

Given the relative resilience of the oil industry, and particularly the Richmond Chevron refinery to the regulatory and restrictive intentions of the general Cap-and-Trade program as part of the greater statewide initiative to reduce emissions, this policy is ultimately ineffective in driving a decrease in emissions at Richmond Chevron. As Bae (2004) claims, market incentives/disincentives create an arguably more efficient approach than a strictly regulatory approach, but those incentives/disincentives must be scalable for all sectors if the state wishes to see all sectors reduce emissions at comparable rates to one another, rather than at individual levels as part of a statewide effort.[17]

6.3 Corporate spending and local politics

Corporate spending plays a major role in the local, regional, and national political landscapes. It is no secret that Chevron, in Richmond as in other towns in which they operate, is influential in local

[14] California Environmental Protection Agency. California Air Resources Board. ARTICLE 5: CALIFORNIA CAP ON GREENHOUSE GAS EMISSIONS AND MARKET-BASED COMPLIANCE MECHANISMS TO ALLOW FOR THE USE OF COMPLIANCE INSTRUMENTS ISSUES BY LINKED JURISDICTIONS. By California Air Resources Board. January 2015. Accessed April 2, 2015. http://www.arb.ca.gov/cc/capandtrade/capandtrade/unofficial_c&t_012015.pdf.
[15] Environmental Defense Fund. "Major California Refineries Logging Big Pollution Reductions Under AB 32." California Dream 2.0. February 12, 2013. Accessed April 18, 2015. http://blogs.edf.org/californiadream/2013/02/12/major-california-refineries-logging-big-pollution-reductions-under-ab32/.
[16] "California GHG Inventory for 2000 to 2012 — by Scoping Plan Category." CalEPA - California Air Resources Board. May 12, 2014. Accessed April 18, 2015. http://www.arb.ca.gov/cc/inventory/data/graph/bar/bar_2000-12_by_scopingplan.htm.
[17] Bae. "Transportation and the Environment." 361.

politics as a result of the money they spend towards candidates and organizations, as well as in the community. Chevron writes proudly that it, as a corporation, "exercises its fundamental right and responsibility to participate in the political process" regarding public policy decisions.[18] This section outlines the role of U.S. Supreme Court ruling on Citizens United as it pertains to corporate spending and local politics, as well as citizen engagement and activism and the impact, or lack thereof, on local politics.

6.3.1 Citizens United

The 2010 U.S. Supreme Court decision of Citizens United enabled corporations and unions to make unrestricted independent political contributions, ruling that the entities are considered individuals and are therefore protected under the First Amendment.[19] Given this freedom, Chevron makes political donations to "support political candidates and political organizations or ballot measures that are committed to economic development, free enterprise, and good government," gifting to nearly 50 different State Assembly members and 24 State Senators.[20,21] Specifically for Congress members, Chevron contributes funds to the Chevron Employees Political Action Committee (CEPAC) which in turn "supports the election of pro-growth, pro-opportunity candidates to Congress and in states where corporate contributions are prohibited" with campaign funds, having contributed to 20 separate California state Congress people, including $1,000 to CA-District 11 Representative Mark DeSaulnier and $2,000 to CA-District 11 Representative George Miller.[22] In 2014 Chevron made direct corporate political contributions to a number of statewide and Richmond-specific organizations as well as a few California ballot measures, as is seen in **Table 6-1**. As is clear in the company's statements, Chevron's motivations and intentions as a corporation revolve primarily around 'economic development' and 'growth,' and electing the candidates who are most firmly aligned with their corporate intentions; as a result, there are

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[18] Chevron Corporation. "Political Contributions & Lobbying." Chevron. February 2014. Accessed April 18, 2015. http://www.chevron.com/investors/corporategovernance/businessconductethics/politicalcontributions/.
[19] "The ACLU and Citizens United." American Civil Liberties Union. Accessed April 14, 2015. https://www.aclu.org/aclu-and-citizens-united.
[20] Chevron Corp. "Political Contributions & Lobbying."2014.
[21] Chevron Corporation. 2014 Chevron Corporate Political Contributions. Report. January 2015. Accessed April 20, 2015. http://www.chevron.com/documents/pdf/Political-Contributions-2014.pdf.
[22] Chevron Corporation. Chevron Employees Political Action Committee Contributions. Report. January 2015. Accessed April 20, 2015. http://www.chevron.com/documents/pdf/CEPAC-2013-2014.pdf.

clear challenges that arise from this scenario in regards to the political agendas of local elected officials, as well as in the consideration of Richmond's compliance with the ideals of environmental justice, as set out by the U.S. EPA.

Table 6-1. *2014 Contributions by Chevron Corporation and CEPAC*

Contributing Entity	***Contribution Recipient***	***Amount (USD$)***
CEPAC	Mark DeSaulnier *CA District 11, House Representative*	$1,000
CEPAC	George Miller *CA District 11, House Representative*	$2,000
Chevron Corp.	African American Voter Registration, Education and Participation Project	$15,000
Chevron Corp.	Black Men & Women of Richmond	$1,300
Chevron Corp.	CA Business PAC *Sponsored by CA Chamber of Commerce*	$200,000
Chevron Corp.	CA Democratic Party	$135,000
Chevron Corp.	California Independent Petroleum Assoc. PAC	$782,970
Chevron Corp.	CA Republican Party	$300,000
Chevron Corp.	Californians for Energy Independence *Ballot measure encouraging CA oil/nat. gas production*	$2,564,094

Additionally, in 2013, as response to years under increased critique and "locked in lawsuits" over taxes, Chevron aimed to improve their reputation in the community through local investment strategies; the company's approach was marketed as the extension of a helping hand, following suit of the corporation-wide 'We Agree' campaign, ultimately covering its true intention as a response to changing local politics.[23] According to a lengthy New York Times article on the corporate-community relations surrounding the Richmond Chevron refinery, Chevron has a five-year $15.5 million economic development and educational initiative plan to further complement the company's social investments that amounted to nearly $5 million in 2012 alone.[24] The Community Revitalization Initiative, as set out by Chevron, functions to "create jobs, grow small businesses, expand job training opportunities, and improve schools over the next five years," with $10 million directed towards economic development, and the remainder invested in local education programs.[25] While the financial support to a largely impoverished city can be beneficial in the intentions dictated by Chevron – revitalization and educational resources –

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[23] Onishi, Norimitsu. "Together a Century, City and Oil Giant Hit a Rough Patch." The New York Times. January 02, 2013. Accessed April 14, 2015. http://www.nytimes.com/2013/01/03/us/chevron-hits-rough-patch-in-richmond-calif.html.
[24] Onishi. "Together a Century." 2013.
[25] Chevron Corporation - Richmond. " Community Revitalization Initiative." Chevron. 2015. Accessed April 14, 2015. http://richmond.chevron.com/home/community/community-revitalization-initiative.aspx.

community spending can also be problematic in the same way that corporate contributions are: they aim to "buy support."[26]

6.3.2 Citizen engagement

Activist and advocacy organizations like the West County Toxics Coalition (WCTC), Communities for a Better Environment (CBE), the Asian Pacific Environmental Network, and the Sierra Club, to name a few, work to educate, organize, and engage the community in speaking up about concerns over health and environmental impacts, as well as with policy structure and mandates, though struggle to raise a strong enough presence to effectively counter Chevron's corporate sway in Richmond and California. In a personal interview with Dr. Henry Clark, Executive Director of WCTC, Clark discussed the role of said organizations in response to the local condition, acknowledging the challenges, but also celebrating successes in the shifting local political landscape. He cited the formation of the Richmond Progressive Alliance in 2004 as one of those successes, noting the increasing presence of Alliance members in elected office has resulted in Chevron "[beginning] to lose their grip at City Hall."[27] Clark also applauded Richmond voters for electing Tom Butt as the 2014 mayoral victor over Chevron-endorsed Nat Bates.[28] Considering the role of citizen engagement in the 2014 review of Chevron's proposed Modernization Project, Clark credits the "historic victory" of the incorporated demand that the project yield "zero net increase in toxic emissions, greenhouse gases, or health effects" to WCTC "and others;" the list of mitigations appropriated by this political advocacy is called the Good Neighbors Agreement.[29] While the Richmond Planning Commission graciously adopted the stance set out in the Good Neighbors Agreement, and even demanded more stringent reductions, the Commission ultimately could only make recommendations, so, as Clark said, "they had no teeth" in the final City Council decision that saw a 5-2 vote denying the conditions set out by the Planning Commission.[30,31]

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[26] Onishi. "Together a Century," 2013.
[27] Clark, Henry. "Conversation with Dr. Henry Clark." Telephone interview by author. April 14, 2015.
[28] Clark. "Conversation with Dr. Henry Clark." 2015.
[29] Clark. "Conversation with Dr. Henry Clark." 2015.
[30] Clark. "Conversation with Dr. Henry Clark." 2015.
[31] Byers, Patsy. "Chevron's Refinery Project." Richmond Progressive Alliance. 2014. Accessed April 14, 2015. http://richmondprogressivealliance.net/Chevron-EIR.html.

Next, considering community engagement in policy decisions on the regional level, there is a history of inertia by BAAQMD. The agency holds required public comment periods and hears public comment at agency meetings, but fails to genuinely incorporate or enact demands of the people. Experiencing first-hand the demands of community members to the Air District for emissions reductions and caps, best available control technology, a reduction timeline, any explicit emissions requirement, and a sense of urgency, and comparing it with the policy in place, there is an apparent chasm between the stated de jure inclusion of public feedback by the Air District and the de facto omission.[32]

Finally, considering the people involved in this public engagement, while overall the public presence at many agency meetings is often limited to the same small cast of characters – most working for the environmental organizations mentioned, with concerned community members adding a final five or six to the comment line – even at the July 2014 City Council meeting regarding the final decision on the Modernization Project that yielded around one-thousand community members and Chevron employees, there was disproportionate representation of Richmond residents from all neighborhoods; of the community members who spoke, few spoke as concerned citizens hailing from Point Richmond. As Pam Stello, a member of the Point Molate Community Advisory Committee and an unofficial research mentor, observed, there is little political involvement by the residents of Point Richmond, because the dominant wind and emissions dispersion trend, as shown by this study, is what the people of Point Richmond believe to be the exclusive case; they assume immunity to the toxic exposure from the refinery, calling any claims of direct impact to their neighborhood simply "hearsay."[33] Interestingly, as Clark pointed out, and as is no secret to the greater Richmond area, Point Richmond is a more affluent neighborhood, while North Richmond is the most impoverished neighborhood in the greater Richmond area; as a result, the political voice of the poor, minority population of North Richmond is vastly overshadowed by Chevron's corporate sway over elected officials, while the awareness of Point Richmond residents to the reality of

[32] Gerber, Vanessa. BAAQMD Richmond Community Workshop Notes. March 17, 2015. Personal notes from meeting occurrences, Richmond Public Library, Richmond, CA.
[33] Stello, Pam. "Conversation with Pam Stello." Interview by author. May 7, 2015.

their own impact and the ensuing involvement of a more influential populace holds the potential for a stronger reaction from decision-makers.

6.3.3 Implications for refinery operations

Ultimately, many of Richmond's local politicians and even some state officials are endorsed by Chevron, and in turn operate to please the oil company, enabling Richmond Chevron to operate at their desired levels, even attempting to increase throughput and process an even dirtier crude slate.[34] And when it comes to rule violation, Mike Parke, who ran as 2014 mayoral candidate under the Richmond Progressive Alliance, shared at BAAQMD's March 17, 2015 public workshop that, the legislation only calls refiners to reduce emissions in the case of threshold exceedance, and only mandates reductions back to threshold limits; additionally the Air District grants the violating firm two years to meet the threshold standard again, ultimately granting two "freebie" years during which they can continue to pollute at increased hazardous levels. This all happens at the expense of the political voice and physical wellbeing of the surrounding communities, with the constant fight of environmental public health organizations, along with minority and lower-income residents falling inferior to the corporate power demonstrated by Chevron in the community.

6.4 Proposal of improvement

Understanding the economic and political forces aforementioned, the current emissions and community exposure condition in the greater Richmond area is explained as the result of ambiguous regulations with notable exemptions, the 'trade' mechanism of California's Cap-and-Trade program, and massively influential corporate spending by Chevron on supportive candidates and enabling ballot measures, as well as on social investments made to appease the community. Considering the condition-defining role of policy and politics for the *existing* condition, I reason that a holistic shift in policy and politics can result in a drastically different physical condition in the study area. Given the fact that petroleum is a finite resource, and as a result, our current fossil-fuel economy will face an inherent market

[34] KQED. "Richmond Approves Contentious Chevron Project." KQED - Science. July 30, 2014. Accessed April 14, 2015. http://blogs.kqed.org/science/2014/07/30/richmond-approves-contentious-chevron-project/.

shift to new fuels and energy sources, I identify a conducive policy framework that supports public and environmental health through increased emissions reductions in the process of greater market transition.

6.4.1 Hubbert's Peak Oil and inherent market shift

In 1949, Dr. M. King Hubbert predicted a geological limitation of the remaining petroleum stores worldwide, challenging the notion of an everlasting fossil fuel era popular at the time.[35] While some claim that we have passed the peak and others believe we still have time, the underlying knowledge that at some point industrialized society will no longer have the capacity to continue its dependence on petroleum products, gives way to an inherent market shift away from fossil fuels and toward alternative and renewable fuels. This being said, for the case in with Richmond Chevron, here lies hope for improvement. The current condition may continue for years to come, but at some point the refinery will eventually stop processing crude oil, therefore eventually stopping its toxic pollution; the worst case scenario – that is, assuming continued operation until petroleum resources run out – still means eventual termination of oil refining in Richmond.

6.4.2 Conducive policy framework

A reenvisioned policy framework, however, can hopefully bring about the termination of refinery operations much sooner than the worst-case scenario. Considering the effectiveness and efficiency of the California Cap-and-Trade Program in reducing emissions statewide, I propose the long-term deployment of the Cap-and-Trade policy instrument, with the following amendments.[36] My first proposed policy amendment is to add a baseline percentage reduction in emissions for all sectors before qualifying for the credit auction. Creating a combination regulatory *and* market-based mitigation strategy, this hypothetical cap-and-trade scheme would further what 2014 University of California, Berkeley postdoctoral scholar in the Energy Biosciences Institute, Hanna Breetz, cited as an incentive for over-abatement, while more

[35] Deffeyes, Kenneth S. "Overview." In Hubbert's Peak: The Impending World Oil Shortage, 1-14. Princeton, NJ: Princeton University Press, 2009. Accessed May 1, 2015. https://books.google.com/.
[36] "California GHG Inventory for 2000 to 2012 — by Scoping Plan Category." CalEPA - California Air Resources Board. May 12, 2014. Accessed April 18, 2015. http://www.arb.ca.gov/cc/inventory/data/graph/bar/bar_2000-12_by_scopingplan.htm.

importantly demanding reduction efforts by *all* firms, resulting in more drastic reductions overall;[37] refineries would no longer be able to buy their way out of reduction compliance to the same extent as they are currently. Second, I propose the establishment of a lower price limit on allowances, so as to correct for what Breetz describes as the current possibility for prices to drop to zero if caps are easily met.[38] This would maintain a constant incentive to innovate (i.e. emit less), as well as capture higher revenue through the system.[39] To complement the cutting-edge version of cap-and-trade, I propose a revision of the California Renewable Portfolio Standard (RPS) so as to promote the further deployment of renewable energy generation technology in the state in the process of the energy economy transition. Two important factors in the inclusion of this policy are, first, it mandates increased generation of clean electricity, which is a potential petroleum fuel replacement in the next energy market, and second, it begins the ramping up of renewable energy infrastructure and procurement before the oil industry completely decelerates as a result of peak oil.[40]

Lastly, reform to Citizens United that would limit, if not abolish, the authorization of corporate contributions would be a final piece of the greater policy framework that would promote equal consideration of community stakeholders and corporate stakeholders. Without political corruption in the form of corporate campaign contributions and bolstering of critical agencies and decision-making bodies, communities like Richmond, and the nation as a whole could see vast improvement in community representation in local government, leading to more just treatment of the community

[37] Breetz, Hanna. "Cap-and-Trade." Lecture, Public Policy 190 - Alternative Energy: Policy and Politics, Goldman School of Public Policy at University of California, Berkeley, Berkeley, CA, February 6, 2014.
[38] Breetz. “Cap-and-Trade.” 2014.
[39] Breetz. “Cap-and-Trade.” 2014.
[40] Breetz, Hanna. "Renewable Portfolio Standards." Lecture, Public Policy 190 - Alternative Energy: Policy and Politics, Goldman School of Public Policy at University of California, Berkeley, Berkeley, CA, February 18, 2014.

Chapter 7

DISCUSSION

This study aims to better understand the dispersion trends of toxic emissions coming from the Richmond Chevron refinery, analyzing the condition through the lens of relevant policy and local politics, ultimately assessing the scenario against the ideals of environmental justice. The ability of this study to determine an appropriate wedge of the most frequently occurring dispersion trend, evaluating it by its span and orientation, is quite good; using perhaps the only indisputable raw data figures, the span was determined by distance and the orientation by measured wind patterns. The findings of this study with regards to prediction accuracy of toxic concentrations inside the wedge, however, show mixed results; for some compounds the model proved to generate very strong estimates, while for others there was no predictive strength. One thing that was relatively consistent and very interesting, was that both the predicted and observed concentrations of the study toxics were well below the principal standards that exist with the intention of regulating air quality and protecting public health and welfare. To be fair, many assumptions were made in the calculations of the figures in this study, but even the *observed* concentrations managed to meet their standards on average, but it becomes curious, still, why the population in the greater Richmond area, and in North Richmond in particular, experience significantly elevated asthma and cancer rates. If the air quality is at standard attainment or better more often than not, though the community still experiences these drastic health effects, this raises a question about the teeth of the standards and the integrity of the decision-makers and invested agencies.

Now the findings of this study with regards to the policy framework and political landscape, show very moderate regulation void of much stringent restriction, along with a heavy sway by way of Chevron’s corporate spending, which together make a case for the sanction of the latter influencing the existence and perpetuation of the former. In turn, it becomes hard not to question if perhaps these air quality standards sit at a level that is set primarily as a manageably attainable level for massive refineries like Richmond Chevron so as to create the appearance and reputation that the Air District is accomplishing their mission to "protect and improve public health, air quality, and the global climate."[1] At the public workshop BAAQMD held in Richmond in March-2015, Greg Karas, a Senior Scientist at CBE highlighted a major concern with the fact that the "epidemiological studies that exist are not very good, they're not current, they're not well done in many cases, they're not persuasive."[2] With the relevant literature utilized in this study on epidemiology written largely in the 1980s and '90s, Karas has a point that the decision-making bodies have shown no action, sense of responsibility, nor urgency to produce thorough studies to understand and publicize the community's condition.

Relatedly, challenges with obtaining data, inconsistent and fragmented data, data specificity and disentanglement continued this challenge in understanding the scenario. All in all, the findings and interpretations concluded in this study make one thing very clear: as a citizen, let alone an academic, it is very challenging to tell the story of the greater Richmond area and confidently understand the impact, but when you *do* try and gather the pieces together, the people seem to be blatantly unprotected. Using the language of BAAQMD's Community Engagement Manager, David Ralston, from the March-2015 workshop about the agency's intentions to "balance public health, economic health, and community health," it seems as though the 'balance' is rigged; through the lens of environmental justice, matched with the slow to no change on behalf of the refinery or the vested agencies, Richmond Chevron has managed to maintain a political landscape enabling them to continue to operate at business-as-usual, but as an angered community member declared in response to the condition in the community: "business as usual is killing us!"[3]

Chapter 7 notes:

[1] "BAAQMD - Mission Statement." BAAQMD - Mission Statement. August 9, 2010. Accessed October 14, 2014. http://www.baaqmd.gov/The-Air-District/Mission-Statement.aspx.

[2] Gerber, Vanessa. BAAQMD Richmond Community Workshop Notes. March 17, 2015. Personal notes from meeting occurrences, Richmond Public Library, Richmond, CA.

[3] Gerber. BAAQMD Richmond Community Workshop. 2015.

Chapter 8

CONCLUSION

For years I have heard the cries of the people of Richmond about the persistent poisoning of the community and the consistent corporate efforts to make nice and evade responsibility. Perhaps the most eloquent and apt enveloping of the community's frustration, Richmond resident Rebecca Auerbach passionately critiqued Chevron's hypocrisy at a July-2014 city council meeting, as she demanded: "Don't give our kids backpacks and ice cream, and then give them asthma and cancer."[1] This community sentiment is well-known, and ultimately is justified based on the findings of this study, *even if* only the findings pertaining to flaws in the policy mechanisms and political landscape.

The case of the disenfranchised, poor, minority community's struggle against the corporate presence of a multi-national, multi-billion dollar oil conglomerate is unfortunately not an uncommon one. It is a David-and-Goliath-like tale in which the underdog victory has yet to come to fruition. There lies hope for that eventual victory, however, in the combination of: industry and agency transparency to the benefit of public access to critical information pertaining to the health of their bodies and environment; political engagement by all, from those with high potential to influence the political landscape though have restrained from activism thus far on the false presumption of immunity to the toxic exposure – largely the folks of Point Richmond – to a stronger dedication to de facto "fair treatment and meaningful engagement" in the form of validated community involvement in decision-making processes; and lastly to a reenvisioning or revitalization of the existing policy framework to include legitimate emissions reduction demands by all, along with the simultaneous market preparation and procurement efforts of alternative fuels infrastructure necessary for a smooth transition to the inherently changing energy economy of the coming years. Instead of looking at peak oil as a global crisis and the impending market shift toward alternative and renewable fuels as a terrible burden, I see the scenario as budding with hope

Chapter 8 notes:

[1] KQED. "Richmond Approves Contentious Chevron Project." KQED - Science. July 30, 2014. Accessed April 14, 2015. http://blogs.kqed.org/science/2014/07/30/richmond-approves-contentious-chevron-project/.

and potential. Especially when applied to specific community cases like Richmond, understanding that this shift not only means a more sustainable global climate condition as a result of cleaner fuels, but also healthier people and more just community dynamics, the future promises improvement, so long as the true condition is made clear and is acted upon in a cooperative effort by the community *and* the powers that be.

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