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Evaluating Equity in Transportation Greenhouse Gas Emission Reduction Strategies in Local Climate Action Planning in Oakland, California

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This Master's Project

**Evaluating Equity in Transportation Greenhouse Gas Emission Reduction Strategies in
Local Climate Action Planning in Oakland, California**

by

Eliza J. Kane

is submitted in partial fulfillment of the requirements

for the degree of:

Master of Science

in

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Abstract

Emissions from California’s transportation sector contribute to global climate change and impact local air quality and public health. Forty-one percent of California’s greenhouse gas emissions in 2019 were from transportation. Transportation emissions are also a source of many health-harming air pollutants such as carbon monoxide, volatile organic compounds, and particulate matter. Disadvantaged communities in California experience disproportionate impacts from transportation emissions and suffer worse health effects, including higher incidences of asthma, cardiovascular disease, and premature death. Cities have led the way in policymaking to mitigate and adapt to climate change, including creating Climate Action Plans (CAPs) to propose strategies to reduce greenhouse gas emissions. Many of these plans acknowledge that considering equity in climate action planning is essential, but no protocol exists to ensure that equity goals are being met. This work examines equity in climate action planning through a detailed case study analysis, a framework and equity analysis, and a comparative analysis to determine how an equity focus affects the transportation emission reduction strategies proposed in CAPs. The research determined that there are substantial co-benefits to transportation emission reduction, including reduction in air pollution concentrations and improved public health. This work also found that cities that prioritized equity attempted to address underlying socioeconomic vulnerabilities simultaneously with emissions reduction efforts, and prioritized extensive, community-led engagement efforts that encouraged participation through the design and implementation of the CAP. Finally, this work makes recommendations for steps that city planners can take to facilitate the creation of more equitable transportation emission reduction strategies.

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1. Introduction

Anthropogenic greenhouse gas emissions have powerful global warming potential and have set into motion a process that will radically change the planet. Transportation is the largest source of greenhouse gas emissions in the United States, accounting for approximately 27% of all carbon dioxide emissions in 2020 (US EPA, 2022). In California, transportation accounts for an even more significant portion of total greenhouse gas emissions at 41% in 2019 (California Air Resources Board, 2021). Transportation is also a source of health-harming air pollutants, which suggests that greenhouse gas emission mitigation will have co-benefits of improved air quality and public health (Thompson et al., 2014). The mitigation strategies for greenhouse gases and air pollutant emissions are shared and can bring multiple local benefits to cities that take action to reduce emissions (Shindell et al., 2018).

In addition to carbon dioxide, emissions from the transportation sector include nitrogen oxides (NO_x), carbon monoxide (CO), sulfur dioxide (SO₂), volatile organic compounds (VOCs), and particulate matter (PM). Many of these air pollutants have been linked to serious health issues such as asthma, respiratory conditions, cardiovascular disease, and cancer, specifically in at-risk populations, including children, pregnant women, and the elderly (Kelly & Fussell, 2015). The correlation between air pollution and public health impacts is known, and studies suggest that future increases in air pollutant concentrations will cause increases in both health impacts and premature mortality (Lelieveld et al., 2015). In addition, higher global temperatures caused by increased atmospheric carbon dioxide concentrations have been correlated to higher concentrations of air pollutants, including PM and surface-level ozone (Jacobson, 2008). PM is composed of microscopic particles and liquid droplets primarily formed in the atmosphere from chemical reactions of precursor emissions such as SO₂ and NO_x. Studies have shown that warmer temperatures are expected to increase PM_{2.5} concentrations (Vannucci & Cohen, 2022). Ozone is a secondary pollutant formed when NO_x reacts with VOCs in the presence of strong sunlight, and its formation rate increases at higher temperatures (Ebi & McGregor, 2008). Projections of 21st-century climate change estimate that the increases in particulate matter and ozone concentrations associated with climate change will increase global all-cause premature mortalities associated with particulate matter by about 100,000 and respiratory disease mortality associated with ozone by 6,300 deaths annually (Fang et al., 2013).

Climate change and air pollution highlight global issues of inequity due to their disproportionate impact on vulnerable and socially marginalized groups and are a challenge to socioeconomic equity, public health, and human rights (Shonkoff et al., 2011). Globally, populations that experience the most severe impacts from climate change are often the ones who contribute the least to greenhouse gas emissions (Shi et al., 2016). Communities of color, low-income communities, and other marginalized groups, also known as disadvantaged communities, face social, economic, and environmental conditions that make them especially vulnerable to climate impacts (Amorim-Maia et al., 2022). Often these groups experience multiple sensitivities that compound the effects of climate change, many of which are reinforced by the government's deliberate or unintentional maintenance of systems that drive inequity.

Vulnerability to climate change is a measure of a group's ability to anticipate, resist, adapt to and recover from the stresses and shocks associated with a changing climate (Shonkoff et al., 2011). A resilient community can respond to the challenges that climate change will present and overcome them. However, disadvantaged communities face additional barriers of racism, poverty, poor employment opportunities, housing insecurity, health impacts from pollution exposure, and political disenfranchisement that make it especially difficult for them to overcome the challenges of climate change. Addressing the needs of disadvantaged communities is necessary to help them respond to climate impacts and improves the overall urban resilience of the city (Meerow et al., 2019).

One of the factors that increase the vulnerability of disadvantaged communities to climate change is higher exposure to air pollutants. Higher air pollution concentrations impact communities of color in the United States at every income level (Lane et al., 2022). The increased exposure is due to the location of vulnerable populations near industrial areas and highways. As a result of the higher pollution burden, disadvantaged communities also experience higher incidences of public health impacts, including higher rates of respiratory and cardiovascular illness (Morello-Frosch et al., 2011). In addition, disadvantaged communities will benefit the most from the reductions in air pollution emissions that occur as a co-benefit of greenhouse gas emission reduction (Boyce & Pastor, 2013). Therefore, it is crucial to understand how air pollution is reduced as a co-benefit of reductions in transportation greenhouse gas emissions. This information is critical for environmental managers to understand

so that climate policies can be made that will alleviate the disparate impacts and not worsen them.

In response partly to inaction at the national and state level in addressing climate change, cities worldwide are at the forefront of innovation for climate action planning (Schrock et al., 2015). Cities utilize Climate Action Plans (CAPs) as comprehensive planning documents to mitigate climate change and adapt to its impacts. Early CAPs focused solely on strategies to reduce greenhouse gas emissions. However, in recent years, there has been an increasing focus on social equity based on the understanding that some groups will be disproportionately impacted by climate change (Schrock et al., 2015). Equity in climate action planning is still relatively new; the first CAPs were created in the 1990s, and it has only been recently that the focus on equity has begun to be mainstream. However, a city's proclaimed commitment to equity in its CAP does not necessarily translate into concrete actions that would achieve equitable outcomes. Because of its complexity, equity is a somewhat ambiguous planning goal, and no clear protocol exists to ensure that equity goals are being met (Angelo et al., 2022).

Despite the recent shift in focus on equity in climate planning, CAPs often do not include measures to address the underlying drivers that make disadvantaged communities vulnerable or alleviate their disproportionate pollution burdens (Schrock et al., 2015). Many CAPs do not acknowledge the cumulative burdens disadvantaged communities face and how that burden affects their ability to respond to climate impacts. Furthermore, CAPs have the potential to have harmful effects on social equity if they do not address the vulnerabilities that are present in disadvantaged communities. CAPs are long-term planning documents that establish targets for greenhouse gas reduction over multiple decades and include measures to radically alter an area's infrastructure, transportation system, and local economy. The strategies proposed in CAPs have long-term implications for city residents and can either alleviate a city's existing inequalities or worsen the divide and cement them into the future (Angelo et al., 2022). Therefore, it is worth considering whether members of disadvantaged communities are involved in developing and implementing the CAP and if their needs are being prioritized in the decision-making process.

1.1. Oakland Equitable Climate Action Plan

Most CAPs created in the past few years acknowledge the importance of equity considerations and public participation in the planning process. Still, without clear guidance, it is

not certain that their equity goals will be achieved. A few cities recognize this policy shortfall and have begun to center their planning and implementation processes on achieving equity and contain measures to address the underlying causes that create inequity in climate risk. One of the first cities to take this approach is Oakland, California, whose 2030 Equitable Climate Action Plan (ECAP) aims to chart an equitable path to reduce greenhouse gas emissions. The CAP also aims to transition away from fossil fuels and guarantee that, by 2030, every community in Oakland will be prepared to withstand the foreseeable effects of climate change (Oakland Public Works, 2020).

Oakland's Equitable Climate Action Plan is one of the first planning documents to address underlying issues that make communities more sensitive to climate change. Oakland is a city that has experienced a long history of racial and socioeconomic segregation that has led to considerable disparities in city services, pollution exposure, economic opportunities, and public health (Oakland Public Works, 2020). Air pollution exposure is a known problem in Oakland, specifically pollution associated with the transportation sector, due to the presence of disadvantaged communities near major highways and the Port of Oakland (Oakland Public Works, 2020). As a result, disadvantaged communities in Oakland experience public health impacts that are not present in more affluent areas (Oakland Public Works, 2020). The ECAP aims to address the social, political, environmental, and economic systems that drive inequity in Oakland to reduce greenhouse gas emissions from transportation, improve air quality, and protect public health. The ECAP is one of the first documents of its kind and should be evaluated to determine how the strategies presented in the document differ from other CAPs that do not focus on equity and whether an equity focus improves the ECAP's efficacy and potential for reaching its goals.

1.2. Research Questions

The main objective of this research is to evaluate Oakland's 2030 ECAP to determine how a focus on equity affects the types of mitigation strategies proposed to reduce greenhouse gas emissions from transportation and whether this focus will result in strategies that will reduce the city's inequities in air pollution burden and public health. First, this work will examine the air quality and public health co-benefits of transportation emission reduction to ascertain the outcomes that Oakland communities may experience due to climate change mitigation. A

comparative analysis will examine the ECAP and a non-equity-focused CAP to determine the key differences in the proposed emissions reduction strategies. Finally, the transportation emission reduction strategies presented in the ECAP will be evaluated to ascertain whether they address the root causes and social factors that make disadvantaged communities especially sensitive to climate change and if protections are included to ensure that the mitigation strategies will not disproportionately impact these communities. This evaluation aims to determine the essential qualities of mitigation strategies that reduce disproportionate burdens on disadvantaged communities so that informed recommendations can be made to improve future climate mitigation policy.

2. Background

2.1. Equity and Climate Risk

To effectively determine the equity implications of climate policies and planning practices, it is crucial to understand what equity is and how it affects climate risk, especially in disadvantaged communities. Equity is often confused with equality, yet the terms have different meanings. Equality is about uniformity, where everyone receives the same number of resources regardless of their needs or privileges (United Way of the National Capitol Area, 2021). The problem with equality is that it does not acknowledge the uneven playing field that exists that predominately favors some groups over others, and so its application maintains the existing disparities between populations. Equity, however, is about fairness, ensuring that all people have the same access to opportunities and are provided with the things they need to succeed to achieve an equal outcome (United Way of the National Capitol Area, 2021). Inequity is caused when people of a given racial, socioeconomic, gender, or ability status are positioned at different levels of advantage or disadvantage. Barriers between the groups make it more difficult for those most disadvantaged to achieve the same opportunities as the advantaged groups.

Climate change is expected to worsen the disparities between advantaged and disadvantaged groups because the magnitude of impacts will differ between populations. Disadvantaged groups are expected to be disproportionately impacted due to the underlying factors that make these populations especially sensitive to change. Because of these disproportionate impacts, disadvantaged groups must be given support that addresses their specific needs and allows them to overcome the barriers preventing them from accessing resources and opportunities. Without protections to address equity issues, future climate change will likely reinforce and exacerbate these disparities, leaving disadvantaged communities at even greater climate risk (Shonkoff et al., 2011).

The goal of implementing equitable solutions is to achieve justice, where the underlying social systems that perpetuate inequalities are changed so that barriers between advantaged and disadvantaged groups are removed, and all people have equal opportunities (Shi et al., 2016). Justice entails more than just the equitable distribution of resources. Recognizing cultural differences and removing procedural barriers that prevent marginalized groups from meaningfully participating in decisions that affect their well-being and risk are also essential

components of justice (Shi et al., 2016). Justice is often considered a multi-generational concept because of the time it takes to fix the systems that create inequality and lead to the need for equity to rebalance advantage (Gee & Ford, 2011). The implementation of equity and justice-oriented solutions takes longer than equality-based solutions because it is necessary to do background research to identify the underlying drivers of inequality within a community. Justice-oriented solutions are also more costly as they are individualized to the community's needs or require overhauling existing systems that perpetuate inequalities (Braveman et al., 2022). Policies must be purposefully created to address the systems that sustain both climate change and inequity to achieve climate justice.

Climate risk is a function of root causes and social factors that predispose certain groups to greater sensitivity to the impacts of climate change (Figure 1, (Yuen et al., 2017). These root causes are further exacerbated by systemic and institutional racism and classism, which perpetuate systems where risk and benefit are unequally distributed. The degree to which various communities are vulnerable to climate change depends significantly on the current development patterns (Shi et al., 2016). Many low-income residents are forced to live in unsafe and high-risk areas like informal settlements or public housing, have pre-existing medical issues, and have few resources available to help them prepare for and recover from stresses and shocks.

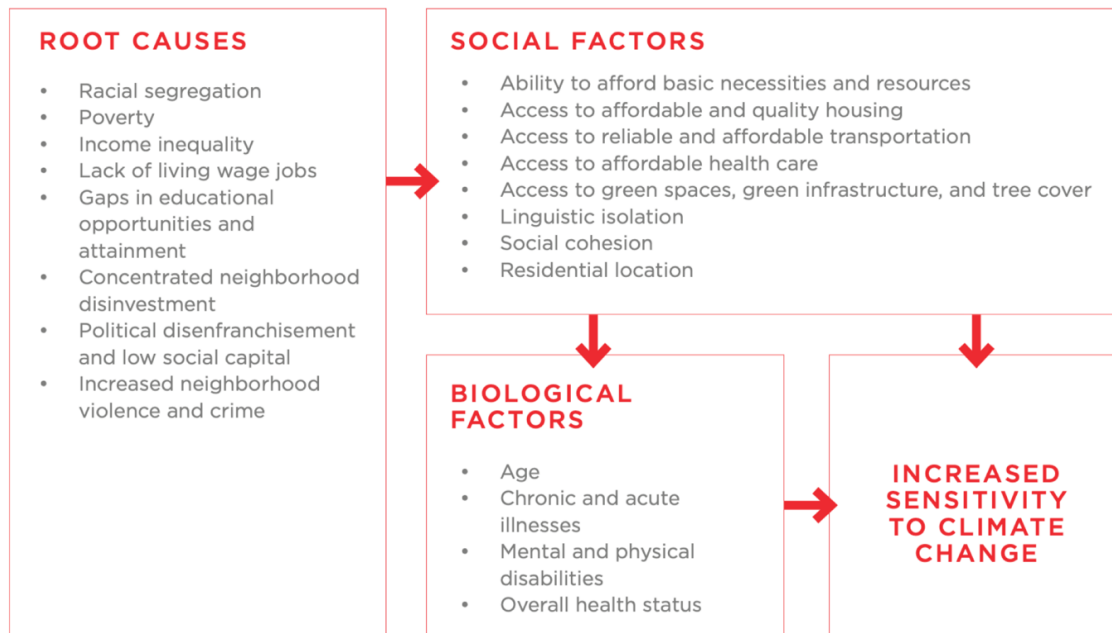


Figure 1: Climate sensitivity is a function of social and economic factors that exacerbate physical vulnerabilities, and the cumulative effect makes disadvantaged communities even more sensitive than one factor alone (Yuen et al., 2017).

Poor residents may be more vulnerable to the effects of climate change since these conditions of poverty can exacerbate individual traits, such as age, gender, and disability, as well as social marginalization, including racial segregation or cultural, religious, or linguistic isolation (Shi et al., 2016). How racial and social disparities amplify climate risk is not well understood or addressed by traditional planning techniques. This lack of understanding can result in climate plans that unintentionally perpetuate or worsen existing racial and social injustices (Yuen et al., 2017). Yet, policy can become a driver toward a more just future if it can create equitable solutions to mitigate climate risk, especially if those solutions contain sufficient protections for the most vulnerable communities.

2.2. Government's Role in Driving Inequity

Historically, governments have played a key role in maintaining the barriers perpetuating racial and social inequities that drive disproportionate climate risk (Yuen et al., 2017). In the United States, race is one of the predominant factors in determining life outcomes and is a good indicator of climate risk and adaptive capacity. Systemic and structural racism are not always conscious or immediately apparent but have an enormous influence on creating policies that drive inequity (Braveman et al., 2022). One of the first to note the connection between racial inequality and the factors that shape it was W.E.B. Du Bois, who argued that the disproportionate mortality and morbidity burden that racial minorities bear is due to social and economic conditions that minorities live in rather than racial characteristics and tendencies (Burghardt DuBois, 2003). Du Bois stated that if racial minorities had access to improved sanitation, better education, and more economic opportunities, the observed health disparities would be substantially reduced (Burghardt DuBois, 2003). Unfortunately, decisions made by governments and institutions that construct the social, economic, and environmental conditions that people live in have historically maintained and amplified the disparities between racial and socioeconomic groups (Yuen et al., 2017). Often these decisions have discriminated against communities of color and low-income communities by underserving their communities, excluding them from the decision-making process, or unequally distributing resources and hazards within the community. Discrimination against communities of color and low-income communities has resulted in poorer life outcomes and a lack of access to opportunities (Yuen et al., 2017).

Structural racism includes the social forces, institutions, ideologies, and processes that create and maintain imbalances between racial and ethnic groups (Gee & Ford, 2011). Some types of structural racism, such as redlining and social segregation, are explicitly discriminatory. Still, others result from well-intentioned government actions that end up reinforcing the existing racial and socioeconomic disparities. Structural mechanisms do not depend upon the intent of the individual making decisions. Still, unless these unseen types of discrimination are addressed, future actions may worsen the divide between communities (Gee & Ford, 2011).

One of the clearest examples of structural racism is redlining, a discriminatory historical mortgage practice that segregated communities based on racial and economic factors. Redlining is a clear example of structural racism because it is well-documented and widespread, and the federal government actively participated in its discriminatory administration (Lane et al., 2022). Redlining is also one of the contributing factors to the disproportionate air pollution impacts currently affecting disadvantaged communities. Following the Great Depression, the government-sponsored Home Owner's Loan Corporation (HOLC) created maps describing neighborhood security for government-insured mortgages for homeowners in several hundred American communities starting in the 1930s. The HOLC maps graded communities according to the following four-point scale: A (most desirable), B (still desirable), C (definitely declining), and D (hazardous). Neighborhoods earned low grades due to the presence of communities of color, specifically Black and immigrant communities, and known sources of environmental pollution (Lane et al., 2022). Homes in D-rated communities were considered unsuitable for government-backed loans or favorable mortgage terms, which isolated communities of color and prevented them from accumulating wealth through home ownership (Lane et al., 2022).

The HOLC grades also informed local governments' land use decisions regarding the location of polluting industries, such as industrial facilities, railroads, and ports, which were intentionally placed in D-rated neighborhoods (Lane et al., 2022). Emissions infrastructure is typically long-lived, and in many cities, the land use decisions made during the redlining era have created the current spatial distributions of pollution sources, subjecting generations of people to higher exposures and health impacts. The HOLC maps were drawn based on the existing racial segregation in residential neighborhoods. Still, the practice created a barrier that kept disadvantaged communities from achieving generational wealth, perpetuated segregation, and solidified the disparate environmental impacts.

2.3. Transportation Greenhouse Gases and Air Pollution Emissions

Transportation is the largest source of greenhouse gases in California. California’s total greenhouse gas emissions in 2019 were 418.2 million metric tons of carbon dioxide equivalent (CO₂e). Carbon dioxide equivalent measures the global warming potential of greenhouse gases relative to the warming potential of carbon dioxide (The Climate Center, 2022). The transportation sector accounted for 171.5 million metric tons of CO₂e, approximately 41% of the total emissions (California Air Resources Board, 2022).

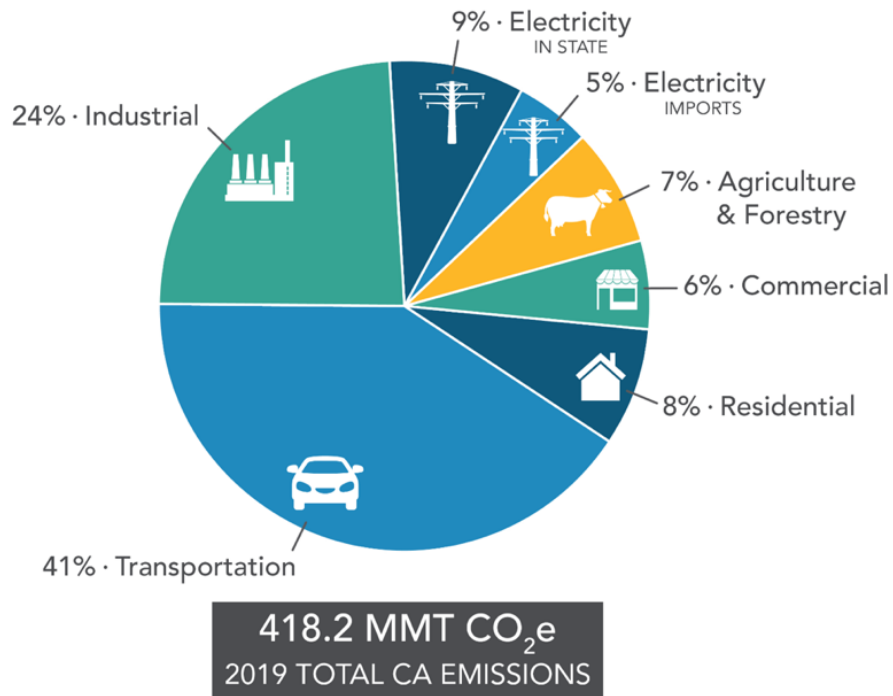


Figure 2: Transportation accounted for 41% of statewide greenhouse gas emissions in 2019 (California Air Resources Board, 2022).

The primary source of transportation-related greenhouse gas emissions is the combustion of fossil fuels, including gasoline and diesel, which fuel over 90% of all cars, trucks, trains, ships, and airplanes (US EPA, 2022). Greenhouse gases, mainly carbon dioxide emissions, accumulate in the atmosphere and are the primary drivers of climate change. Though transportation emissions have decreased over time, this sector is still responsible for more emissions than the industrial and electricity sectors combined (Figure 3, (California Air Resources Board, 2022)). Since transportation accounts for over one-third of California’s carbon dioxide emissions, meeting the state’s climate goals will not occur without significant changes to the transportation sector.

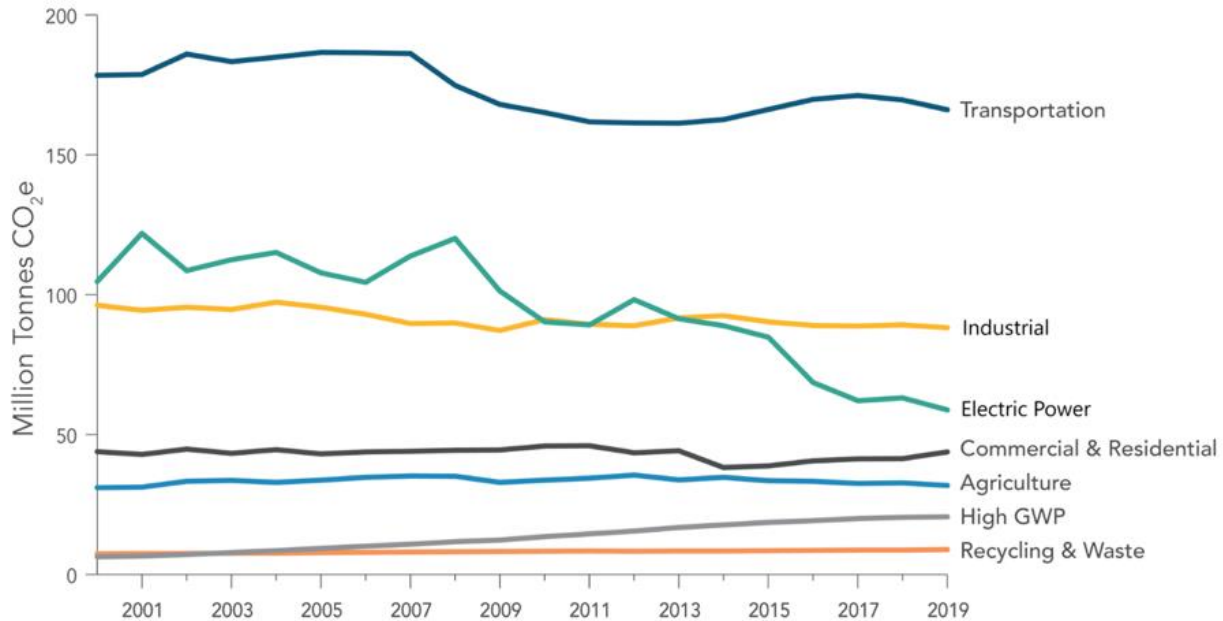


Figure 3: While transportation emissions have decreased over time, this sector is still California's largest source of greenhouse gas emissions. 2019 greenhouse gas emissions from transportation in California were higher than the industrial and electricity sectors combined (California Air Resources Board, 2022).

In addition to emitting greenhouse gases, transportation is also one of California's most significant sources of air pollution (Raju et al., 2021). Combustion of fossil fuels, including gasoline and diesel, release nitrogen oxide (NO_x), carbon monoxide (CO), volatile organic compounds (VOCs), and particulate matter (PM). National Ambient Air Quality Standards (NAAQS) are national health-based standards established by the EPA for criteria air pollutants, which are outdoor air pollutants known to be harmful to public health and the environment (Raju et al., 2021). The federal and California governments have been tightening their emissions standards for greenhouse gases and criteria air pollutants over the years. In California, NO_x emission reduction is key to achieving federal and state ambient air quality standards. Total NO_x emissions in California in 2019 were 1,245 tons per day, 70% of which were generated from mobile sources (Raju et al., 2021). Mobile source emissions also accounted for 90% of diesel particulate matter, including PM₁₀, PM_{2.5}, and ultrafine particulate matter (Raju et al., 2021).

There are three main ways to reduce greenhouse gas emissions from transportation; increasing the fuel efficiency of vehicles, reducing total vehicle miles traveled (VMT), and transitioning to using lower-carbon fuel sources, also known as the “three-legged stool” model (Lewis et al., 2018; Raju et al., 2021). Two of these solutions rest upon innovation in vehicle

and fuel technologies, while the reduction in total VMT is a function of social, political, and economic factors that shape public behavior around transportation. In general, total VMT rises as the population grows. More recently, VMT per capita has increased as cities expand and residents tend to make longer and more frequent trips, which causes overall VMT to grow more quickly than population (Lewis et al., 2018). Reducing VMT is an essential component of any strategy to reduce greenhouse gases from transportation, and many cities have recognized this and are including measures to change modes of transport and encourage compact development in proximity to public transit (Lewis et al., 2018). In contrast to the efforts to increase vehicle efficiency and fuel economy, which can be accomplished by top-down federal action, reducing VMT calls for changes to state or local laws and personal behavior (Lewis et al., 2018).

Despite the federal government adopting increasingly stringent fuel economy standards and fuel content changes, the increases in VMT are expected to outweigh the emissions reductions gained by these two factors (Lewis et al., 2018). Therefore, it is essential to reduce VMT as part of any emissions reduction strategy for transportation. Strategies to reduce VMT include instituting taxes, tolls, and congestion pricing in downtown areas, adding pricing parking schemes and reducing the number of available parking spaces, and encouraging alternate forms of transit, including public transportation, carpooling, and active transport. Cities and states are also looking to land-use changes to reduce VMT, including promoting compact development around public transit routes.

California has consistently been a global leader in the fight against climate change, enacting some of the nation's most aggressive climate policies to reduce greenhouse gas emissions and the state's carbon footprint. In addition, the California Air Resources Board (CARB) has been instrumental in advancing clean air and climate action goals for transportation through various motor vehicle control programs. California's measures to promote clean air are guided by key policy goals, including attaining criteria air pollutant NAAQS, reducing greenhouse gas emissions to slow the advancement of climate change, and relieving the disproportionate impact of air pollution on vulnerable communities, including low-income communities and communities of color (Raju et al., 2021). However, despite California's advances in reducing emissions and improving air quality, additional NO_x controls are necessary to meet the NAAQS goals (Raju et al., 2021).

California has passed legislation to set targets for greenhouse gas emission reduction both in general and specifically from transportation. Assembly Bill 32 (AB 32) was passed in 2006 and requires that the state reduce greenhouse gas emissions to 1990 levels by 2020 and establishes a target of achieving 80% below 1990 levels by 2050 (Raju et al., 2021). The state achieved 1990 levels of greenhouse gas emissions by 2016, primarily due to decreases in emissions from the energy sector. However, transportation emissions have grown in the past few years, primarily from an increase in VMT in light-duty vehicles, which threatens to undo much of the progress of AB 32 (Raju et al., 2021). AB 32 also directed the California Air Resources Board (CARB) to create an environmental justice advisory committee, comprised of members from disadvantaged communities across the state, to advise CARB on AB 32 policies and programs. Governor Jerry Brown signed Senate Bill 32 (SB 32) to follow up on AB 32, which aims to reduce greenhouse gas emissions to 40% below 1990 levels by 2030. Governor Brown also signed an executive order in 2012 ordering that greenhouse gas emissions from the transportation sector be reduced to 80% below 1990 levels by 2050 (California Air Resources Board, 2021). More recently, Governor Gavin Newsom signed an executive order that requires all new cars and passenger trucks sold in California to be zero-emission by 2035 to reduce greenhouse gas emissions (Newsom, 2020). These legislative efforts aim to reduce greenhouse gas emissions from all sources, but transportation emissions must be reduced significantly to meet these goals.

The mobile source sector contributes a large portion of air pollutant emissions that impact disadvantaged communities. Poor air quality in disadvantaged communities is a known equity issue. Studies suggest that disadvantaged communities experience higher exposure to air pollutants due to their location near major roadways, airports, railways, and ports (Boyce & Pastor, 2013; Morello-Frosch et al., 2011). PM 2.5 pollution from transportation is not equally distributed in California; communities of color experience higher pollution burdens associated with mobile source emissions than white Californians (Figure 4). Latino and African American communities experience PM 2.5 burdens of 15% and 18%, respectively, higher than the average person in California, while white communities' average PM 2.5 exposure is 17% lower than the average. Thus, African Americans in California have a 43% higher PM 2.5 pollution burden than white communities in the state (Reichmuth, 2019).

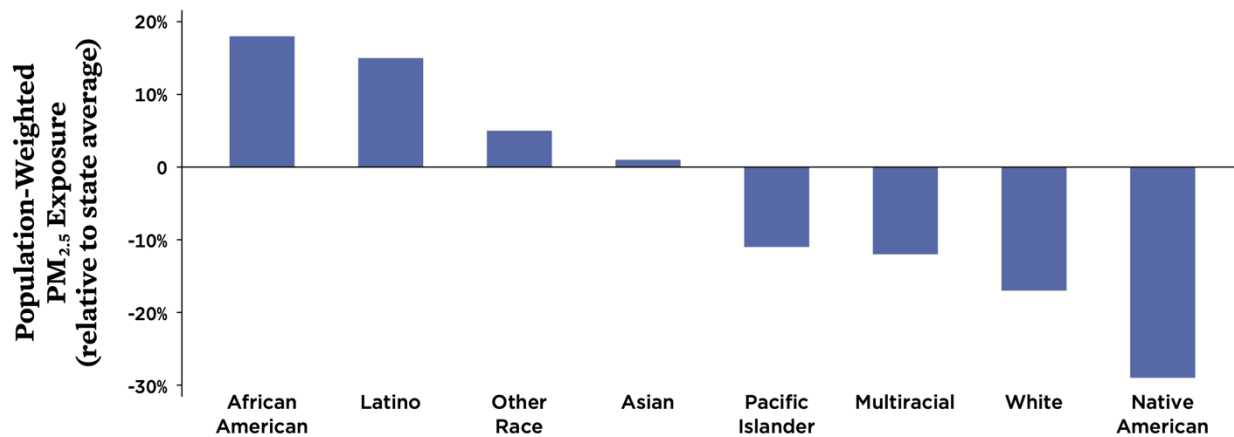


Figure 4: Latino and African American communities are exposed to 15% and 18% more PM 2.5 than the average Californian, whereas white communities are exposed to 17% less than average. Communities of color are exposed to approximately 40% more PM 2.5 than white communities in California (Reichmuth, 2019).

While California has made significant strides toward improving air quality, disadvantaged communities are still exposed to higher levels of air pollution than the more advantaged neighborhoods. Racial and ethnic disparities in exposure to air pollution endure partly because the underlying sociological, economic, and regulatory factors generally evolve over the span of several generations. In addition, studies have shown that even when air pollution concentrations decline due to mitigation efforts, patterns of disparate exposures are preserved (Clark et al., 2017). Figure 5 shows estimated NO_x exposure, an indicator of traffic-related air pollution, against demographic data of the contiguous United States in 2000 and 2010. In the figure, overall NO_x exposure decreased over time, but communities with higher nonwhite populations continued to be exposed to higher NO_x concentrations than white communities (Clark et al., 2017).

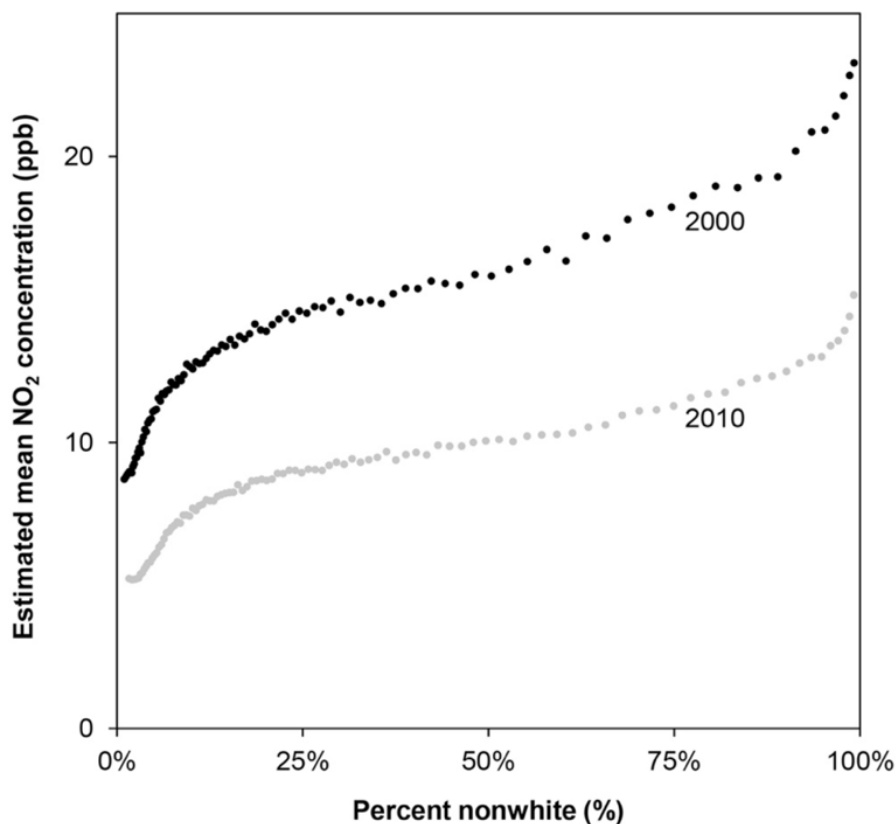


Figure 5: Communities with higher nonwhite populations experience higher exposures to NO_x, and this pattern persists despite reductions in air pollutant concentrations, suggesting that air pollution mitigation alone is insufficient to address disparities in exposure (Clark et al., 2017).

The present-day spatial distributions of pollution sources among various populations result from several past discriminatory policies, including redlining and land use decisions (Lane et al., 2022; Nardone, Chiang et al., 2020). Today, residents in 64% of former HOLC D-rated neighborhoods are people of color, and the median income is low to moderate in 74% of former D-rated neighborhoods (Lane et al., 2022). The correlation between HOLC grade and transportation pollution exposure is shown in Figure 6, where the number of people living near railroads and main thoroughfares increase with each HOLC grade from A to D (Lane et al., 2022). While most railways were constructed before the HOLC designations in the 1930s, most highways were built after the 1930s and were constructed predominantly through communities of color. The disproportionate exposure to railway and highway pollution shows that the racial disparities that existed prior to HOLC redlining regarding preferential infrastructure placement persisted after the HOLC grades were determined (Lane et al., 2022). These studies suggest that overall emission reduction efforts may not be sufficient to alleviate the disproportionate air

pollution impacts faced by disadvantaged communities. If reducing unequal exposures to air pollution is not identified as a goal of climate mitigation policy, these patterns will likely persist, and equity goals will not be met. Because disadvantaged communities are disproportionately affected by climate change, they could greatly benefit from climate change policies that consider the distribution of economic and health vulnerabilities between demographic groups.

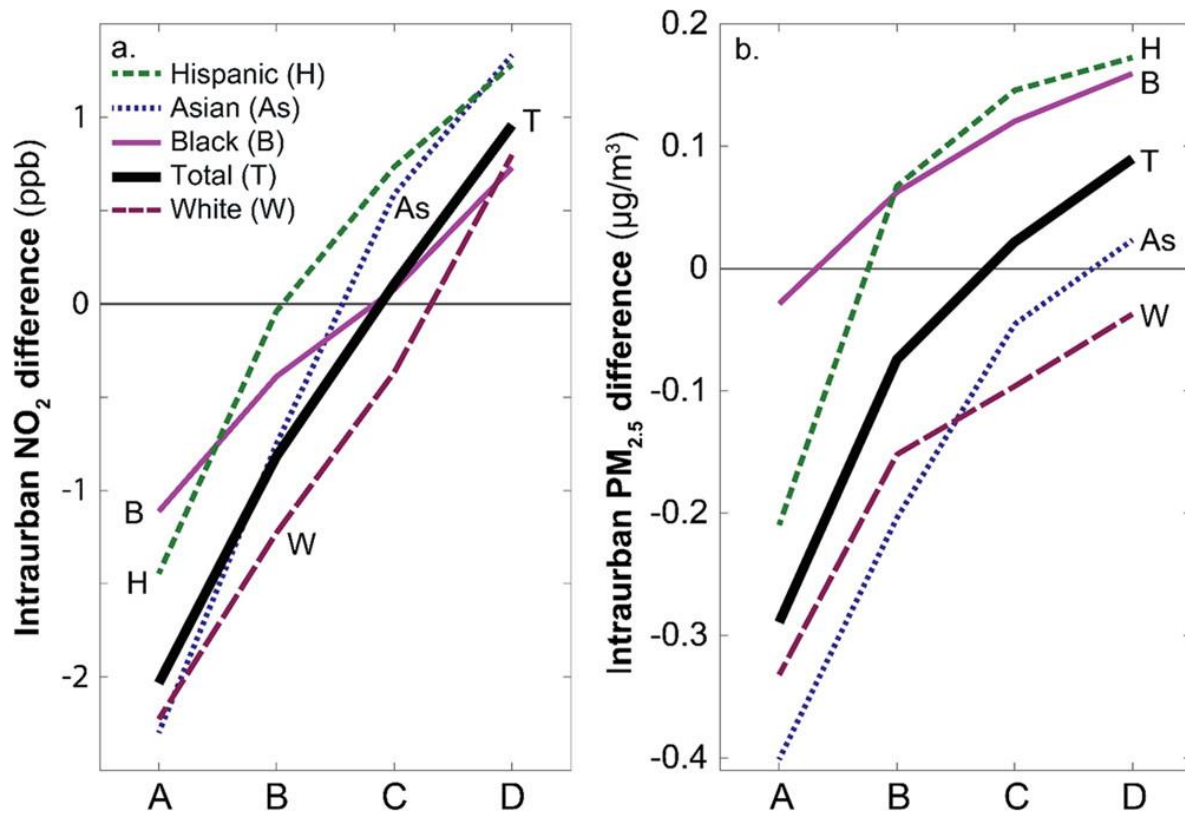


Figure 6: Residents in historically redlined areas continue to experience higher pollution exposures. Communities of color in all HOLC designations are exposed to higher NO_x and PM_{2.5} concentrations than white populations (Lane et al., 2022).

2.4. Oakland Community Demographics and Disadvantaged Communities

Oakland is in Alameda County on the east side of San Francisco Bay in California. Oakland is the largest city in Alameda County with a population of approximately 434,000 people with a median age of 37 and a median household income of \$80,143.00 (United States Census Bureau, 2021). Founded in 1852, Oakland is currently a mix of residential, commercial, and industrial activity, a composition that is a direct result of the city's history of industrialization. One of the major sources of the city's historical development was the Transcontinental Railroad, which built its terminal stop in Oakland in 1869 and opened a

shipping route to the Pacific Rim, bringing people to the city and developing its harbor for shipping activities (Bay Area Air Quality Management District & West Oakland Environmental Indicators Project, 2019). The railroad brought a diverse array of people from across the country, and after the 1906 earthquake in San Francisco, refugees fled to Oakland and its population grew substantially (Encyclopedia Britannica, 2022). Today, Oakland has consistently ranked as one of the most diverse cities in the country.

Beginning in the 1930's, Oakland's residential communities began to segregate because of redlining. Redlining in Oakland, like cities across the country, explicitly targeted communities of color and immigrants and directed federal money away from these communities that were deemed too risky to receive mortgages. The 1937 HOLC map for Oakland is shown in Figure 7, with desirable areas shown as green and blue areas, intermediate areas are yellow and undesirable and hazardous areas are depicted in red (Thomas Brothers, 1937). Residents of redlined communities were unable to secure mortgages, which made it extremely difficult to achieve homeownership and led to divestment in these areas and decreased home values (Bay Area Air Quality Management District & West Oakland Environmental Indicators Project, 2019). Furthermore, communities in redlined areas were predominantly selected for the placement of both mobile and stationary source pollution infrastructure (Fujita et al., 2013).

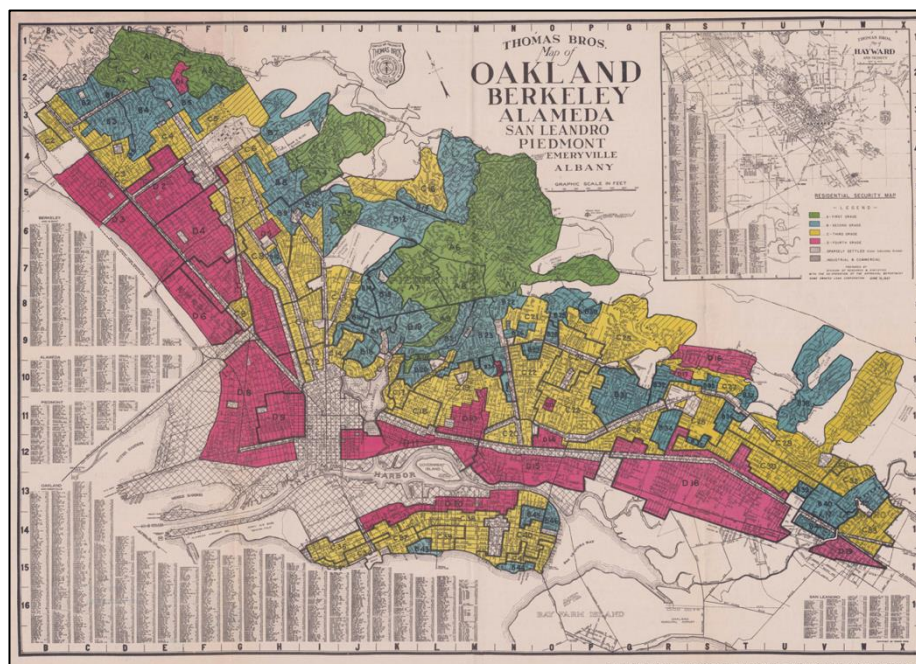


Figure 7: Redlining was a driving force behind segregation in the Bay Area. Historically redlined areas are still exposed at higher rates to air pollutants due to city's land use decisions to place polluting infrastructure through redlined communities (Thomas Brothers, 1937).

The effects of historical redlining can be seen in Oakland today. Communities that were historically redlined still contain higher populations of people of color and have lower socioeconomic status than areas that were designated as more desirable by the HOLC (Bay Area Air Quality Management District & West Oakland Environmental Indicators Project, 2019). Redlining in Oakland is visible in the present-day disparities in demographics, socioeconomic status, and health impacts between redlined communities and the surrounding areas (Nardone, Casey et al., 2020). Population demographics of West Oakland and East Oakland as compared to Alameda County and the Bay Area is shown in Figure 8. The data indicate that Oakland's disadvantaged communities have higher percentages of people of color than the county and the Bay Area overall. Both West Oakland and East Oakland also have fewer white residents than the Bay Area overall, though West Oakland has more white residents than Alameda County, a sign of the gentrification occurring in neighborhoods that have been historically communities of color. Gentrification has not occurred in East Oakland to the same extent, where white residents account for a smaller demographic percentage than in Alameda County and Bay Area overall (Cummings, 2019). Additionally, according to the Bureau of Labor Statistics, West Oakland and East Oakland had higher rates of unemployment at 8.2% and 6.7% respectively in 2020, as compared to 6.1% in Alameda County. West and East Oakland also have higher rates of poverty, with 22.3% and 17.8% percent of residents living below the poverty line versus 14.6% in Oakland overall and 8.6% in Alameda County (Figure 9).

2020 Oakland Demographic Data



Figure 8: Demographic data show that West Oakland and East Oakland are composed of more people of color than Alameda County and the Bay Area overall. West Oakland and East Oakland have been identified as disadvantaged communities per SB535 and are among the most pollution-burdened communities in the state (Data retrieved from US Census).

2020 Oakland Poverty and Unemployment Data

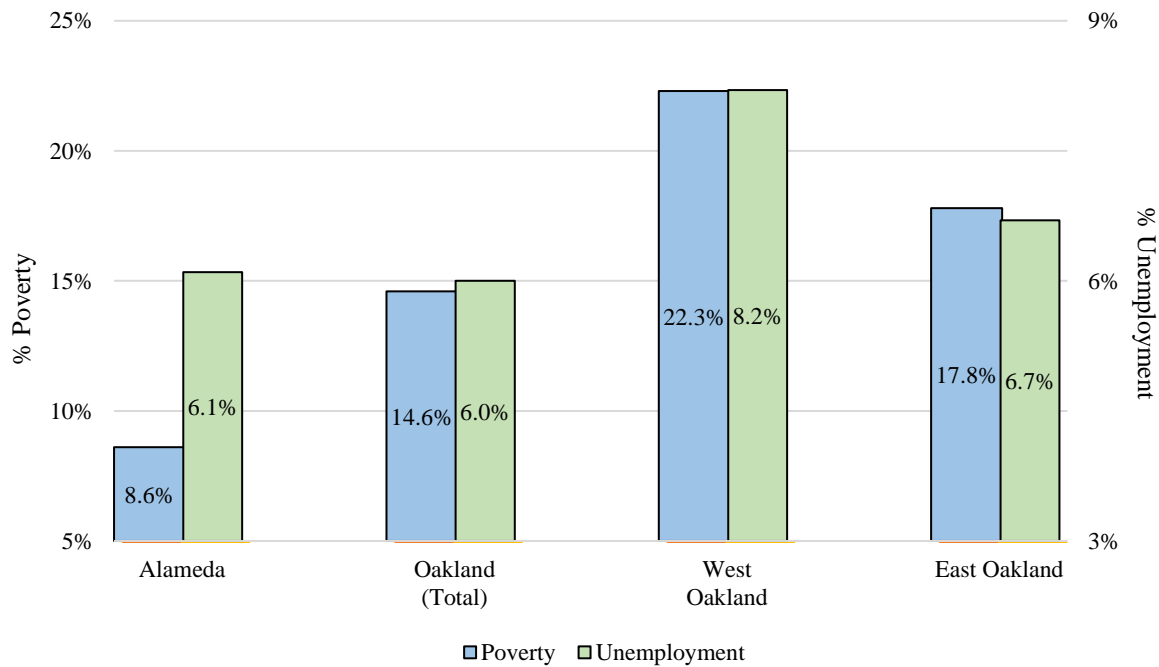


Figure 9: Poverty and unemployment both affect the disadvantaged communities of West Oakland and East Oakland to a greater extent than the city of Oakland overall and of Alameda County. While unemployment in Oakland is approximately equal to that of Alameda County, the rate of poverty is nearly twice as high as the County poverty rate (Data retrieved from US Census).

Disadvantaged communities in Oakland identified by SB 535 are shown in Figure 10 (California Office of Environmental Health Hazard Assessment, 2022). SB 535 identified both West Oakland and East Oakland as disadvantaged communities. Both communities are located in areas that were redlined in the past. Figure 10 also shows diesel particulate matter pollution, poverty rates and rates of asthma-related emergency room visits to demonstrate the correlation between air pollution and health impacts with disadvantaged communities (California Office of Environmental Health Hazard Assessment, 2022). Much of West Oakland and East Oakland are ranked in the 80th and 90th percentiles of total pollution burden, 80th and 90th percentiles of poverty, 90th percentile in diesel particulate matter burden and 90th percentile for asthma-related emergency room visits according to CalEnviroScreen (Figure 10).

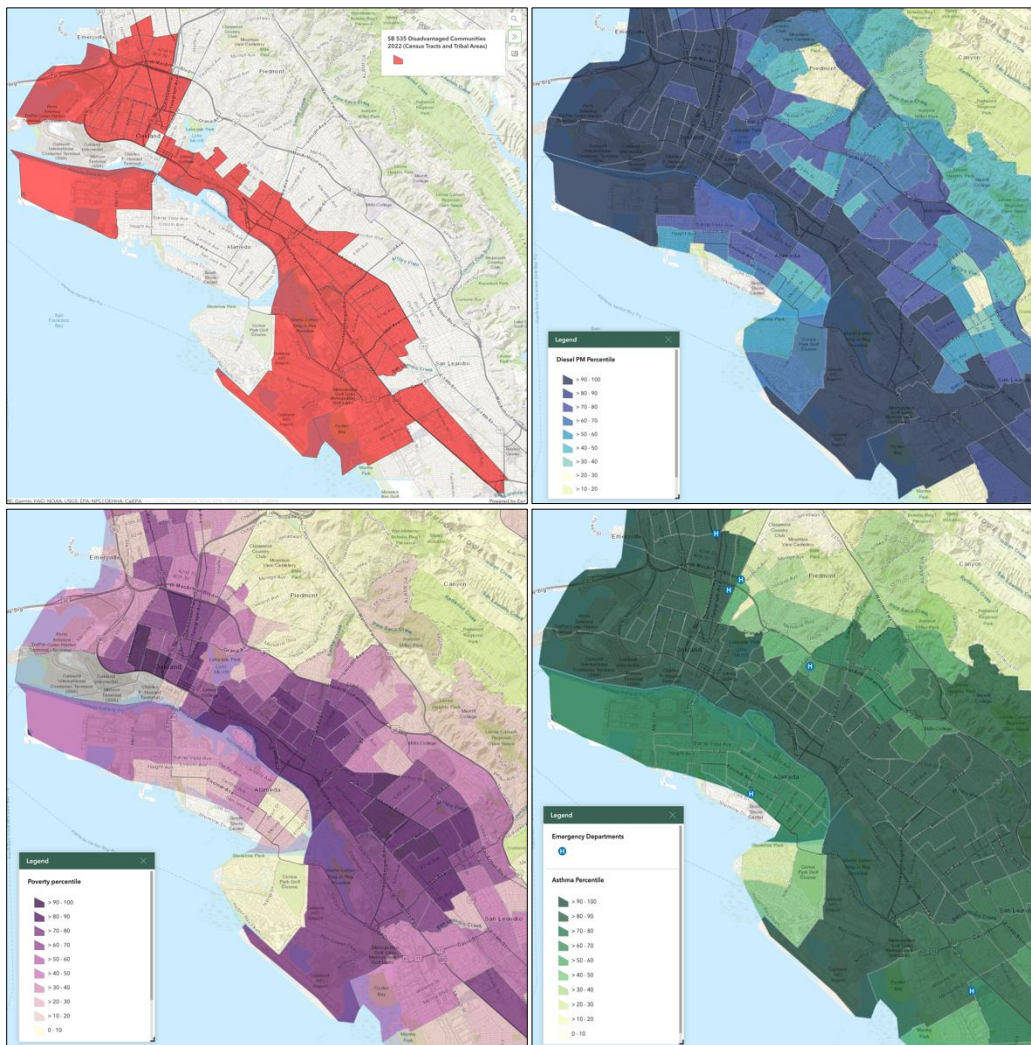


Figure 10: East and West Oakland are identified as disadvantaged communities by SB 535, and suffer worse air pollution (top right), poverty (bottom left) and public health impacts (bottom right) than the surrounding communities due to a history of prejudice that has resulted in these communities being disproportionately burdened and more vulnerable to change (California Environmental Protection Agency, 2018; California Office of Environmental Health Hazard Assessment, 2022).

West and East Oakland currently suffer worse air pollution and public health impacts than the rest of the city because of pollution from the transportation sector (Alexeeff et al., 2018; Fisher et al., 2006; Fujita et al., 2013; Nardone et al., 2020; Riddell et al., 2021). This is because these areas historically have been selected for the location of polluting infrastructure such as major highways to support freight and marine activity at the Port of Oakland and Oakland airport as well as industrial activities such as cement manufacturing and large distribution centers. In addition, the development of the technology industry in Silicon Valley changed the distribution of business centers from being concentrated in San Francisco to the South Bay and changed commute patterns to worsen traffic-related air pollution along Oakland's roadways. The changes in location of business centers also exacerbates existing transportation and economic mobility disparities (Ku et al., 2021). These issues have been compounded by the gentrification that has occurred in recent decades, which has further marginalized disadvantaged communities by raising property values and increasing housing insecurity (Cummings, 2019).

2.5. Oakland ECAP Greenhouse Gas Emission Inventory

The City of Oakland's first greenhouse gas emissions reduction goal was established in 2009 to reduce emissions to 36% below 2005 levels by the year 2020 and 83% below 2005 levels by 2050 (Oakland Public Works Department, 2018). Oakland's first Energy and Climate Action Plan was adopted in 2012 to outline a plan for the city to meet the emission reduction goals. In 2018, the City of Oakland passed a Climate Emergency and Just Transition Resolution, which called on the city to act urgently to reduce greenhouse gas emissions, reverse global warming and increase the city's resilience to the impacts of climate change. The 2020 Energy and Climate Action Plan was revised in 2018 to add an additional goal of 56% reduction in greenhouse gases by the year 2050 (Oakland Public Works Department, 2018). While these earlier CAPs both highlighted the importance of considering how social equity issues can be impacted by implementation of adaptation and mitigation actions, no specific equity goals or measures were proposed in these documents.

The City of Oakland created the ECAP in 2020 with the intention that it be used as a roadmap document to help the city equitably transition to a low-carbon economy. Not only does the ECAP contain measures to reduce greenhouse gases, but also contains actions for the city to create green jobs, reduce environmental pollution and help city residents thrive (Oakland Public

Works, 2020). The ECAP is premised on the scientific consensus that there is a limited time available to avoid the most catastrophic impacts of climate change; governments have only until the year 2030 to take decisive action to reduce greenhouse gas emissions if these effects are to be averted. With this goal in mind, the city set ambitious greenhouse gas emission reduction targets and focuses on sectors where the city has the most authority to influence decisions and require specific actions. The ECAP is not a comprehensive guide for climate change mitigation and adaptation, but rather focuses on those municipal actors and decisions that are controlled by the city.

The greenhouse gas emission inventories for Oakland are shown in Figure 11. The ECAP tracks two types of greenhouse gas emissions: local emissions and lifecycle emissions. Local emissions are those that occur within the city. Local emissions are easier to measure and are more directly impacted by city policies. Lifecycle emissions include local emissions, as well as those emissions generated by the extraction, manufacture, shipping, and other activities conducted outside of Oakland, mainly overseas, to meet the local demand for goods and services within the city limits. In most cities in the United States, lifecycle emissions are typically three times larger than local emissions. In 2017, the transportation sector accounted for 32% of lifecycle emissions in Oakland, but 67% of the local greenhouse gas emissions. The transportation sector is the largest source of local emissions in Oakland and is a primary target of many city-level policies to reduce greenhouse gas emissions.

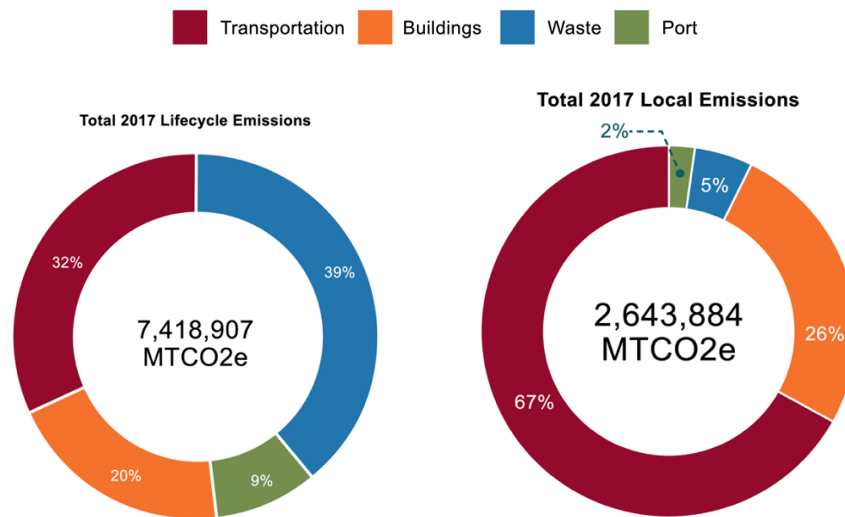


Figure 11: Transportation accounted for approximately 32% of Oakland’s lifecycle greenhouse gas emissions but approximately 67% of the city’s local emissions), making this sector the largest source of the city’s greenhouse gas emissions overall. The goals of the ECAP cannot be met without significant changes to the transportation sector (Oakland Public Works, 2020).

3. Methods

A literature review was performed to determine the air quality and public health benefits of emission reduction in the transportation sector. A case study analysis was performed to evaluate Oakland's 2030 ECAP, including an overview of the city's characteristics and demographics, the locations of disadvantaged communities, and an identification of the transportation-related impacts in each area. The case study investigated how the transportation emission mitigation strategies proposed in the ECAP addressed equity and whether the plan contained protections for disadvantaged communities to prevent adverse outcomes from the mitigation measures. The case study included an analysis of the ECAP using the Greenlining Institute's *Mobility Equity Framework*. The ECAP was also evaluated to determine the types of equity included in the plan as defined by the Natural Resources Defense Council: Procedural Equity, Distributional Equity, Structural Equity, Transgenerational Equity and Transformational Equity. Finally, a comparative analysis was performed against another California city to determine how the emission mitigation strategies for the ECAP compared to another city CAP where similar equity issues are present.

3.1. Case Study Analysis

Oakland is a city with areas that are designated as disadvantaged communities as defined by the California Environmental Protection Agency (CalEPA). CalEPA defines 'disadvantaged communities' as part of Senate Bill 535, which was signed into law in 2012 to require that 25% of the state's cap-and-trade revenue be spent on programs to help disadvantaged communities. SB 535 builds on AB 32, which created the cap-and-trade system to limit greenhouse gas emissions. Companies that exceeded their credit limits could purchase additional credits, generating revenue to be spent on programs benefitting disadvantaged communities. CalEPA is responsible for identifying disadvantaged communities. To identify disadvantaged communities, CalEPA and the state's Office of Health Hazard Assessment (OEHHA) created the California Communities Environmental Health Screening Tool, or "CalEnviroScreen" in 2013 to evaluate the pollution burden on communities and identify the defining characteristics of disadvantaged communities. CalEnviroScreen uses census tract data as well as pollution and health data to calculate the cumulative pollution burden to determine the pollution "score" at a particular area. These scores are overlaid on census tract maps to visually represent spatial patterns of disparity

that more clearly highlight cumulative impacts. Disadvantaged communities are defined as (California Environmental Protection Agency, 2022).

- Census tracts with the highest 25% pollution burden scores
- Census tracts with the highest 5% pollution burden indicator scores
- Census tracts designated as disadvantaged in 2017
- Lands under federally recognized tribes

An overview of Oakland’s population demographics will be presented, as well as a description of the city’s disadvantaged communities and the air pollution burdens from transportation faced by these communities. Demographic data will be used to identify the socioeconomic and health vulnerabilities of the disadvantaged communities. In addition to pollution data, CalEnviroScreen also contains information on population characteristics such as public health data on the incidence of asthma and cardiovascular disease and low birth weight. CalEnviroScreen also contains maps of socioeconomic factors such as housing insecurity, poverty, low educational attainment, and linguistic isolation that show the spatial correlation between the social and economic characteristics of disadvantaged communities and pollution burden as well as the resulting health impacts. The CalEnviroScreen data was used in conjunction with the demographic data to generate a comprehensive picture of the factors that contribute to increased climate risk in the disadvantaged communities in Oakland.

3.2. Framework Analysis

To determine how well the ECAP incorporates equity into its transportation emission mitigation strategies, the plan was evaluated using the Greenlining Institute’s Mobility Equity Framework. The Framework was developed in 2018 to create a decision-making policy structure for the state of California to use as a guide for transportation planning and investment allocation to meet the mobility needs of disadvantaged communities in the state. The Greenlining Institute recognized that the state lacked adequate policy and decision-making tools to deliver mobility benefits to disadvantaged communities, and transportation planning and policy have contributed to worsening inequitable land use patterns and disproportionate economic and environmental burdens as a result (Creger et al., 2018). The purpose of the Framework is to establish a policy and planning structure so that the state can prioritize the mobility needs of disadvantaged

communities and rectify the historical injustices that they have endured (Creger et al., 2018). The Framework contains 12 Mobility Equity Indicators that are used during equity analyses of transportation plans to evaluate how the proposed transportation options advance three central goals specific to disadvantaged communities.

3.3. Equity Analysis

Equity is not a one-dimensional concept, but a dynamic objective that has many components. There are many diverse aspects of equity that require unique strategies to achieve; a solution for economic inequity may not be sufficient to alleviate disproportionate pollution exposure or address political disenfranchisement in communities of color. Achieving climate justice requires many types of solutions to address the myriad ways in which disadvantaged communities are disproportionately impacted by climate change. Disadvantaged communities are impacted by inequitable systems in many ways that require different mechanisms to correct the system and alleviate disparities. An analysis of the transportation emissions mitigation strategies was conducted to determine the presence of the following equity objectives (Natural Resources Defense Council, 2019; Yuen et al., 2017):

- **Procedural Equity** – inclusive, accessible, authentic engagement and representation in process to develop or implement programs or policies.
- **Distributional Equity** – programs and policies result in fair distribution of benefits and burdens across all segments of a community, prioritizing those with highest need.
- **Structural Equity** – decision-makers institutionalize accountability; decisions are made with recognition of historical, cultural and institutional dynamics and structures that have routinely advantaged privileged groups in society and resulted in chronic, cumulative disadvantage for subordinated groups.
- **Transgenerational Equity** – decisions consider generational impacts and don't result in unfair burdens on future generations.
- **Transformational Equity** – “transformational equity” is the distinct notion that communities (internally) have the indigenous capacity to govern and sustain themselves and that communities (externally) have voice, influence and agency in regional, state and/or national affairs.

3.4. Comparative Analysis

Two California cities, Oakland and Long Beach, were chosen because they are similar in size, demographics, and both have known equity issues related to transportation emissions. Both cities have disadvantaged communities identified by SB 535 that are disproportionately impacted by air pollution and experience greater health impacts than the surrounding areas. The two cities are also heavily impacted by transportation emissions and have recently authored CAPs that contain emissions reduction strategies aimed at the transportation sector. The comparative analysis will evaluate the emission mitigation strategies in the Long Beach CAP to determine the key differences between those actions and those of the ECAP.

4. Results and Discussion

4.1. Literature Review: Air Quality and Public Health Co-Benefits of Greenhouse Gas Mitigation in Transportation

Human activities produce greenhouse gases and other types of air pollutants from common sources. Therefore, policies intended to reduce greenhouse gas emissions may also improve air quality. Climate change is expected to raise air pollution concentrations in the future but reducing pollutant emissions would mitigate the adverse effects of climate change and improve air quality (Orru et al., 2017). There are considerable co-benefits to air quality from policies aimed at reducing emissions from fossil fuel combustion, including reductions in several criteria air pollutants in addition to greenhouse gas emissions (Anderson et al., 2018). Strategies to reduce transportation greenhouse gas emissions decrease air pollutants and precursor species, including PM, NO_x, and SO₂ (Alexeeff et al., 2018; Anderson et al., 2018; Bell et al., 2008; Fujita et al., 2013). Many of these pollutant emissions have significant health effects. For example, NO_x and VOCs react with sunlight to create tropospheric ozone, a health-harming pollutant that contributes to additional climate forcing on local as well as regional and global scales (Shonkoff et al., 2011). Higher ambient temperatures increase the rate at which ozone forms, creating a positive feedback loop that worsens both air quality and climate change (Orru et al., 2017; Shonkoff et al., 2011). In addition, greenhouse gas co-pollutants such as sulfur dioxide, black carbon, and carbon monoxide are linked to population health burdens and additional climatic forcing (Shonkoff et al., 2011).

Studies have shown that over the last two decades if the emissions rate of the smog-forming precursor emissions remained constant, approximately one degree of warming in Fahrenheit was associated with a 1.2 ppb increase in ozone concentrations (Bloomer et al., 2009). As temperatures are expected to rise with climate change, reducing the precursor emissions of NO_x and VOCs is necessary to avoid increased impacts from tropospheric ozone. Mobile sources were responsible for approximately 45% of statewide NO_x emissions in 2017 and are the most significant contributors to ozone formation in the state (California Air Resources Board, 2021). Therefore, substantial changes to the state's transportation sector are critical to reducing the impacts of tropospheric ozone.

In addition to NO_x and VOC emissions that contribute to ozone formation, transportation emissions include particulate matter such as PM₁₀, PM_{2.5}, ultrafine PM, and black carbon, as well as gases such as carbon monoxide and sulfur dioxide associated with incomplete combustion of fossil fuels (Kelly & Fussell, 2015). Some of these compounds, such as sulfur dioxide, oxidize in the atmosphere to form aerosols that scatter light and cool the atmosphere, whereas others absorb sunlight and contribute to atmospheric warming (Fiore et al., 2015). Including these air quality co-benefits would have significant implications for climate policy by helping determine overall costs and distributional effects of emission reduction strategies that can inform optimal policy stringency (Nemet et al., 2010).

However, despite the well-established air quality co-benefits of climate change efforts, most policy analyses generally do not consider them. Policy analysis typically focuses on minimizing the cost associated with greenhouse gas reductions and not on costs associated with climatic harm (Nemet et al., 2010). Because air quality co-benefits to greenhouse gas emission reduction are substantial, including them in the development and assessment of climate policy will improve societal outcomes. Air quality benefits are more local, immediate, and health-related and can help incentivize the creation of stringent climate policy due to the enormous benefits that would be gained (Nemet et al., 2010). Furthermore, given that the distribution of air pollution effects is unequal, policymakers should focus on seeking the highest emissions reductions where the co-benefits are maximized (Boyce & Pastor, 2013).

Air pollution is now widely recognized as a major public health issue, responsible for an increasing number of health impacts that have been thoroughly documented by studies around the world. The International Panel on Climate Change (IPCC) has recognized that greenhouse gas emission reduction can have local health benefits from reductions in air pollution emissions (Smith et al., 2014). In California, the intensification and shifting patterns of outdoor air pollution are the primary climate change exposures that threaten public health (Shonkoff et al., 2011). Air pollution is now acknowledged as the leading environmental cause of premature death, overtaking lack of access to drinking water and poor sanitation (Kelly & Fussell, 2015). Despite decades of progress in improving air quality, many regions of California continue to have some of the nation's worst air quality, much of which is caused by the transportation sector (California Air Resources Board, 2021). Mobile source emissions are linked to various heart and lung diseases, chronic health issues, higher cancer rates, and premature death (Kelly & Fussell,

2015). Studies have estimated 1,000 extra air pollution-related deaths in the United States for every 1 degree Celsius (1°C) rise in temperature (Jacobson, 2008). Several anthropogenic air pollutants are recognized as causing health impacts, but PM_{2.5} and tropospheric ozone are considered the most significant outdoor air pollutants associated with mortality and morbidity, both of which are associated with fossil fuel combustion from transportation (Caiazzo et al., 2013; Kelly & Fussell, 2015). Recent toxicological and epidemiological research has shown that ozone and particulate matter pollution are responsible for a wider variety of health outcomes than previously thought, and both acute and chronic exposure are associated with adverse health outcomes (Kelly & Fussell, 2015).

Six of the ten most ozone-polluted cities in the United States are in California (American Lung Association, 2022). In addition, the five smoggiest communities in California also have the highest densities of people of color and low-income communities in the state (Shonkoff et al., 2011). The impacts of ozone pollution depend on the atmospheric concentrations of NO_x and VOCs, which react with sunlight to form ozone (O₃). Ozone is responsible for 209 premature deaths per year and hundreds to thousands of hospital visits annually (Caiazzo et al., 2013). Other health impacts associated with tropospheric ozone are lung tissue irritation, worsening of asthma, and chronic respiratory conditions, including obstructive pulmonary disease and reduced lung function. Studies have also linked short-term exposure to ozone with an increased risk of death (Caiazzo et al., 2013).

There is a robust scientific consensus on the impact of particulate matter exposure, including PM₁₀ and PM_{2.5}, on adverse health impacts and premature mortality (Caiazzo et al., 2013; Kelly & Fussell, 2015). Studies have shown that particulate matter pollution has contributed to approximately 6,000 premature deaths in California annually and tens of thousands of emergency room visits for cardiovascular and respiratory illnesses (Caiazzo et al., 2013). Diesel particulate matter is responsible for most of the cancer burden in disadvantaged communities, which are frequently situated close to high-traffic roads, intermodal locations such as rail yards and ports, and distribution centers (Boyce & Pastor, 2013). The size of particles is closely related to their ability to cause health problems. Small particles fewer than 10 micrometers in diameter are the most dangerous since they can penetrate deep into the lungs and even enter the bloodstream.

While PM2.5 is not the only air pollutant that has a detrimental impact on health, it is estimated that it is responsible for nearly 95% of the global public health impacts caused by air pollution (Lelieveld et al., 2015). Fine particulate matter is associated with the highest number of pollution-related fatalities and contributes to respiratory and cardiovascular impacts due to acute and chronic exposure (Kelly & Fussell, 2015). Short-term exposure to elevated PM2.5 concentrations can irritate the eyes, nose, and throat, aggravate lung and heart problems, trigger asthma attacks, and increase hospitalizations and mortality from cardiovascular diseases (Lelieveld et al., 2015). Chronic exposure to PM2.5 causes cardiovascular disease, chronic obstructive pulmonary disease (COPD), ischemic heart disease, irregular heartbeat, heart attacks, and lung cancer (Lelieveld et al., 2015). Studies have also linked particulate matter pollution exposure to respiratory illnesses, including asthma, pneumonia, and low lung function in children (Kelly & Fussell, 2015). More recent health studies have found evidence linking PM2.5 exposure to adverse birth outcomes, diabetes, neurodevelopment, and decreased cognitive function (Kelly & Fussell, 2015).

4.2. Case Study Analysis

4.2.1. Oakland ECAP Transportation Emission Mitigation Strategies

The main goals of Oakland's 2030 ECAP are to identify strategies that will reduce the city's local greenhouse gas emissions by a minimum of 56%, transition the city away from fossil fuel dependence, and ensuring that, by 2030, all of Oakland's communities are resilient to the effects of climate change (Oakland Public Works, 2020). The ECAP contains mitigation strategies for each city sector, including transportation and land use, buildings, material consumption and waste, as well as climate adaptation strategies, actions for carbon removal and city leadership, and a section specifically for emission reduction at the Port of Oakland. Regarding transportation and land use (TLU), the ECAP proposes the following actions to mitigate greenhouse gas emissions (Oakland Public Works, 2020):

- **TLU-1:** Align All Planning Policies & Regulations with ECAP Goals & Priorities
- **TLU-2:** Align Permit and Project Approvals with ECAP Priorities
- **TLU-3:** Take Action to Reduce and Prevent Displacement of Residents & Businesses
- **TLU-4:** Abundant, Affordable, and Accessible Public Transit

- **TLU-5:** Create a Zero Emission Vehicle (ZEV) Action Plan
- **TLU-6:** Establish Temporary and Permanent Car-Free Areas
- **TLU-7:** Rethink Curb Space
- **TLU-8:** Expand and Strengthen Transportation Demand Management Requirements
- **TLU-9:** Ensure Equitable and Clean New Mobility
- **TLU-10:** Expand Neighborhood Car Sharing

Transportation emission mitigation strategies are also proposed in the ECAP for the Port of Oakland. The Port contributed 2% of Oakland’s local greenhouse gas emissions in 2017 and is a known source of diesel particulate matter pollution from heavy-duty trucks, marine vessels, and other equipment necessary to support freight movement and shipping activities. The ECAP proposes the following strategy to mitigate the Port’s transportation greenhouse gas emissions (Oakland Public Works, 2020):

- **P-1:** Reduce Emissions from Port Vehicles and Equipment

Finally, the transportation sector in Oakland is also affected by municipal activities. The city owns a fleet of vehicles that contribute directly to transportation emissions, but other municipal activities contribute indirectly to increase emissions. City policies can greatly influence local greenhouse gas emissions and municipal programs partnered with community-based organizations can impact how the ECAP is implemented. The city leadership (CL) strategies that will influence transportation emissions and ECAP implementation include the following (Oakland Public Works, 2020):

- **CL-2:** Phase Out Fossil Fuel Dependency in All City Agreements and Contracts
- **CL-3:** Accelerate City Fleet Vehicle Replacement
- **CL-5:** Establish the Oakland Climate Action Network to Support Inclusive Community Engagement on ECAP Implementation

4.2.2. Disadvantaged Community Protections in ECAP Mitigation Strategies

Oakland’s history has shown how influential land use policies are in contributing to inequities in pollution exposure, public health, economic opportunity, housing security,

educational attainment, and poverty that endures over generations. Land use and transportation are inextricably linked; people are likely to drive more if housing is built far from jobs and basic amenities, which would increase greenhouse gas emissions (Oakland Public Works, 2020). If public transportation and active mobility options are inaccessible or prohibitively expensive, cars will be the only available option (Ku et al., 2021). Oakland's ECAP is designed to prioritize the needs of disadvantaged communities when creating policies to mitigate greenhouse gases from transportation. The ECAP acknowledges the disproportionate burdens faced by DACs in Oakland and aims to alleviate them so that the transition to low-carbon mobility does not contribute to any adverse effects on these communities, such as displacement. The following strategies highlight the city's attempt to reduce disproportionate burden and promote equity in the transition to low-carbon transportation:

4.2.3. Incorporation of Equity Goals in City Planning Documents and Procedures

Oakland recognizes the long-term impact that structural racism has had on communities of color, and the ECAP includes strategies to revise and update the city's General Plan, Specific Plans, Zoning Ordinance, Subdivision Regulations, Parks Master Plan to align with the greenhouse gas emission reduction, adaptation, and equity goals of the ECAP (Oakland Public Works, 2020). Furthermore, policies furthering equity goals are prioritized, such as updating the city's Transit Oriented Development Guidelines to remove barriers and incentivize the creation of affordable housing near transit routes, including housing for low, very low, and extremely low-income households. These actions, in addition to strategies to change zoning so that most residents live within 1/2 mile of the most important daily destinations and infrastructure planning that encourages the use of buses, trains and ferries as well as active transportation, allows the benefits of city planning to be accessible to all residents.

The city of Oakland aims to use its regulatory authority to reduce transportation emissions and enhance equity by aligning city permits and project approvals with ECAP priorities. By modifying the Standard Conditions of Approval (SCAs) and other permit conditions to align with the goals of the ECAP, the city plans to use its authority to add conditions to regulatory approvals to ensure greenhouse gas emission reduction and promote equity (Oakland Public Works, 2020). SCAs are a powerful regulatory tool that can be used to help ensure that climate-friendly transportation and land-use solutions are implemented as part of

development projects. Where onsite greenhouse gas mitigation is not cost-effective, the developer is required to fund projects that benefit local communities with priority given to projects in disadvantaged communities (Oakland Public Works, 2020). These strategies include infrastructure improvements such as bicycle corridors, wider sidewalks, pedestrian crossing improvements, public transit improvements, tree planting and urban greening and green stormwater infrastructure. The ECAP strategies that involve changing city policies and procedures for land development and planning to ensure that disadvantaged communities benefit the most from development projects are the beginning of a long process to undue the harms associated with structural racism and redlining in Oakland (Braveman et al., 2022; Oakland Public Works, 2020).

4.2.4. Displacement Prevention

Displacement of households and businesses occurs when costs of living in a particular area increase to a point where they are unsustainable. Displacement predominantly impacts those who are least able to cope with rising prices, particularly those who are low income and who have the highest housing burden (Cummings, 2019; Oakland Public Works, 2020). When individuals and businesses are forced to leave to areas with a lower cost of living, they increase transportation emissions due to the increased driving distances that individuals need to travel to access employment and services. Oakland is already experiencing high rates of displacement due to overall cost of living increases and gentrification where wealthy individuals, mainly white, buy properties in lower income neighborhoods and cause property values to increase to an unsustainable level to the community already living there (Cummings, 2019).

To prevent displacement, the ECAP proposes actions to expand city services, including the Housing and Community Development and Economic and Workforce Development Departments to develop anti-displacement programs that align with the city's climate goals, such as building electrification and weatherization (Oakland Public Works, 2020). The ECAP also contains measures to leverage state funding to rehabilitate existing affordable housing and acquire new market-rate housing to convert to affordable housing, preventing more low-income households from being displaced. The city plans to increase support for programs to increase community wealth building in Opportunity Zones, which are 30 census tracts in Oakland that offer tax benefits to investors as an incentive to invest in projects that will spur economic

activity. Workforce training funding for businesses that help to meet the goals of the ECAP will also be prioritized, particularly for locally owned and minority-owned businesses and those that aim to generate wealth in disadvantaged communities. Finally, a central goal of the city's Zero Emission Vehicle (ZEV) Action Plan (ECAP Action TLU-5), which is described in more detail below, is to ensure that no outcome of the draft Action Plan would exacerbate displacement or exclusion (Oakland Department of Transportation & Oakland Sustainability Program, 2022).

4.2.5. Making Clean Transportation Accessible

Public transit

Affordable, accessible public transit is a critical component of an equitable low-carbon city. Fewer than 1/10th of Oakland residents commute to work primarily via public transit, in part because the current public transportation system's frequency of service, hours of operation and access are unevenly distributed (Oakland Public Works, 2020). Disadvantaged communities are more dependent upon the public transportation system than white communities because more people lack access to a personal vehicle (Ku et al., 2021). However, despite this increased reliance, bus service to disadvantaged communities is among the lowest in the city (Ku et al., 2021). Oakland aims to influence transit authorities through advocacy, cooperative projects, and investments in capital improvements to incentivize service in disadvantaged communities. The ECAP indicates that the city will collaborate with AC Transit to expand and improve routes in both West Oakland and East Oakland, with a particular focus on those groups that benefit the most from safe, affordable, accessible public transit, including low-income individuals, seniors, people with disabilities and youth (Oakland Public Works, 2020). Additionally, AC Transit plans to take part of regional initiatives to standardize youth fares, create reduced fares for low-income individuals and provide coordinated fares and schedules for trips involving multiple agencies. These efforts aim to make public transit more affordable and accessible to those who would get the most benefit from those improvements. In this way the city can help promote the transition to low-carbon transportation solutions without increasing the cost-burden on disadvantaged communities. The ECAP strategies also intend to increase investment in public transit and active transportation in disadvantaged communities.

Additional strategies in the ECAP serve to incentivize Oaklanders to utilize the public transportation system. The ECAP contains measures to prioritize the use of curb space to

promote public transit and active transportation that is currently used for vehicle parking (Oakland Public Works, 2020). This measure intends to dismantle the inherently inequitable municipal parking policy that subsidizes single-occupancy vehicle drivers by reserving public land for parking that could otherwise be used for improved public transit and active transportation infrastructure. This strategy also includes an equitable fee structure for residential parking permits and a redistribution of parking funds toward transportation improvements in disadvantaged communities. The city also plans to evaluate an initiative to temporarily close certain streets in the city to vehicle traffic to evaluate the viability of permanent car-free zones in Oakland. Street closures increase pedestrian traffic, incentivize active transportation such as walking and bicycling, and help remove the obstacles to recreation and open space in frontline communities. Closing streets to vehicle traffic also helps to reduce VMT and greenhouse gas emissions and air pollutants associated with transportation. Strategic street closures can help reduce some of the disproportionate impacts that transportation has on disadvantaged communities, and Oakland is considering utilizing this strategy as an additional measure that would yield health benefits in disadvantaged communities (Oakland Public Works, 2020).

Single-occupancy electric vehicles

The ECAP considers the unique vulnerabilities of disadvantaged communities in West Oakland and East Oakland in their strategies to incentivize clean electric transportation. Electric vehicle (EV) adoption is a critical component of any transportation emission reduction plan; greenhouse gas emission reduction goals will not be met without widespread electric vehicle adoption. Some residents and businesses are not able to use public transit for all their transportation needs and must still have a private vehicle. Clean transportation has come a long way in the past few years and zero emission vehicles are either commercially available or in development to suit most types of transportation needs. The Bay Area is leading the nation in EV adoption, but these are mainly adopted by higher income residents, many of which live in single-family homes where they can access charging. Low-income individuals and residents of multi-family housing do not have equal access to EVs and charging infrastructure (Ku et al., 2021). Electric vehicles are generally more expensive than internal combustion vehicles, and concerns about vehicle reliability and range anxiety are additional barriers that must be overcome before widespread EV adoption can become a reality.

Incentive programs, such as the state-wide Clean Cars for All program as well as other local incentive programs, exist to help residents in areas that experience high air pollution burden purchase EVs. These programs, in addition to the increased viability of a used EV market, help make EVs more accessible to low-income Oaklanders. However, barriers still exist to widespread EV adoption in Oakland (Ku et al., 2021). The ECAP contains an action for the city to prepare a ZEV Action Plan by 2021 to help encourage EV ownership across all transportation sectors, including medium and heavy-duty vehicles, school and transit buses, and fleet operators (Oakland Public Works, 2020). The draft ZEV Action Plan is designed to incorporate ECAP equity goals and prioritize EV adoption in disadvantaged communities. The draft ZEV Action Plan utilizes a tool that was created in 2020 by the Oakland Department of Transportation called the “Geographic Equity Toolbox”, which uses demographic information, such as race and income level, to identify areas to prioritize investment of transportation funding (Oakland Department of Transportation & Oakland Sustainability Program, 2022). Information was collected at the census tract level and ranked from lowest priority to highest priority, with highest priority tracts being those that experience the highest socioeconomic burdens. These priority neighborhoods will be the focus of EV infrastructure investments, including Level 1, Level 2, and Level 3 Direct Current fast chargers, to help ensure that the transition to a low-carbon transportation system is equitable (Oakland Department of Transportation & Oakland Sustainability Program, 2022).

Among the strategies proposed in the draft ZEV Action Plan includes prioritizing older multifamily buildings for locating charging infrastructure in residential neighborhoods. Implementation of this strategy would help the city overcome a large equity barrier and make EVs more accessible to people living in multifamily buildings. Furthermore, the ECAP indicates that actions to educate the public about EVs be performed in a culturally appropriate way to show that drivers will be able to charge their vehicles safely and affordably. Low-income and residents of disadvantaged communities could benefit the most from widespread EV adoption in their neighborhoods, so prioritizing infrastructure investments in these communities would bring about the most significant reduction in pollution burden and public health impacts.

An additional way to help ensure that lower-income residents have access to EVs is by using rideshare and neighborhood car sharing services. Oakland currently has several car sharing programs, and the ECAP proposes to have all shared vehicles be electric by 2030

(Oakland Public Works, 2020). This action could be supported by collaborative partnerships with property developers and managers to reserve dedicated spaces for car sharing services in multifamily affordable housing buildings to make the services accessible to low-income households. Services like this would be especially valuable in neighborhoods where vehicle ownership is low and for trips that are not possible using public transportation.

4.2.6. ECAP Design and Implementation

Oakland's ECAP outlines actions for the city to take over the next 10 years to achieve its climate goals. The proposed ECAP strategies aim to make substantial changes to the long-term function of city programs, policies, and services. Because historical systems have caused the present-day racial and socioeconomic disparities in climate change impacts, correcting those systems through new policies and laws can help eliminate the inequities (Braveman et al., 2022). Advocacy is essential to dismantling systemic racism because the beliefs and attitudes that underpin oppressive systems are widespread and pervasive and require focused, sustained action to overcome (Braveman et al., 2022). To achieve its equity goals, Oakland aims to promote equity in both the design and implementation of the ECAP to ensure that equity remains a central focus of the measures through time. The city endeavored to center the ECAP development process on equity by committing to a series of actions that facilitated community involvement and allowed for varied perspectives to be heard. Studies have shown that strong public participation in CAP design and implementation is a best practice to help ensure equitable outcomes (Hess & McKane, 2021; Karner & Marcantonio, 2018; Shonkoff et al., 2011).

The city conducted community engagement events for over one year prior to publishing the ECAP and developed an Equity Facilitator (EF) model to help promote equity in the development process (Oakland Public Works, 2020). The city sought an EF team that had deep local knowledge of the area as well as a thorough understanding of climate equity issues and experience in creating policies and plans based in equity principles. The EF led outreach efforts for ECAP development workshops and town hall meetings, as well as facilitated online surveys and social media outreach. The EF also initiated Climate Equity Work Days, which were outreach events where city staff and EF members traveled around the city to give presentations on climate action and included hands-on projects that made the work of the ECAP more tangible for residents. The EF also conducted an equity impact analysis for the ECAP to evaluate the

plan and make recommendations to ensure that it is implemented equitably. By removing obstacles to participation, the overall process was created to specifically include frontline community members and make sure that their perspectives are meaningfully incorporated into the ECAP (Oakland Public Works, 2020). The mayor of Oakland also appointed an ad hoc Community Advisory Committee composed of 13 community members representing the city's racial and geographic diversity to advise the City Council during the development of the ECAP. The EF also selected two Oakland residents from each district of the city to participate in a Neighborhood Leadership Cohort, in which the residents received training in the basics of climate science, governmental processes, equity principles as well as an overview of the goals of the ECAP so that Cohort members could facilitate town hall meetings and ECAP workshops in their districts.

Eight ECAP workshops were presented by the EF and the City Council in 2019 with members of the Neighborhood Leadership Cohort facilitating the dialogue between residents and the city (Oakland Public Works, 2020). During the workshops, residents exchanged information about their neighborhoods, helped define the local priority community needs and values. EF and city staff would provide information on the climate crisis and the types of solutions that Oakland could use to lower the city's emissions. Participants cast votes for the most important equity-based climate solutions for their communities at the conclusion of each workshop. An online survey was made available to residents after each workshop so that attendees and others could provide the city with information on the types of emission mitigation strategies that Oaklanders wanted the city to pursue. The survey was a way for the city to gather residents' perspectives on what they felt were the most important issues for staff to address and this process helped the city understand the citizens' most pressing concerns. Every workshop was free to attend and came with a full meal with childcare and simultaneous interpretation in Chinese and Spanish upon request. In addition to the workshops, two town halls were held in November 2019, where EF and city staff presented on the draft ECAP in order to encourage engagement from all residents, with priority given to disadvantaged community involvement, so that residents could provide feedback on the draft plan and make recommendations on additional ways to improve the plan. The draft ECAP was published online several weeks before the town hall meetings were hosted so that city residents could review and make public comments on the plan before the meetings,

and conversations about climate action and equity goals were facilitated by EF members during these meetings.

City staff also interviewed stakeholders in the transportation industry, including technical experts and racial and climate equity advisors, to ensure that the strategies proposed in the ECAP were technically viable and able to achieve the emission reduction goals desired (Oakland Public Works, 2020). The city also designed the ECAP to include recommendations that were based on community engagement efforts for two plans that were developed in 2018 and 2019; the East Oakland Neighborhoods Initiative and the West Oakland Community Action Plan. These plans aimed to improve resilience in the disadvantaged communities of East and West Oakland and address the disproportionate environmental pollution burdens faced by these communities. The city of Oakland made significant efforts to gather as much community input as possible when designing the ECAP and aimed to prioritize the concerns identified by disadvantaged communities that were identified during outreach events.

The city of Oakland also endeavored to maintain equity as a central focus during the implementation of the ECAP. The city's EF team developed a "Racial Equity Impact Assessment and Implementation Guide" to establish a set of recommendations and best practices for the city to follow in order to maximize equity throughout the ECAP's 10-year implementation timeline (Oakland Public Works, 2020). The Guide is founded on Oakland's existing resources such as the California Office of Planning and Research's "Resiliency Guidebook Equity Checklist", the National Association for the Advancement of Colored People's (NAACP) "Our Communities, Our Power", as well as material developed by the city's Department of Race and Equity. The Guide accompanies the ECAP and includes key performance metrics for community involvement, local economic development, and for specific goals associated with individual emission mitigation strategies. This Guide sets specific equity goals, creates a timeline for their achievement, and establishes how city departments can address equity gaps and predicts the expected equity outcome of each gap (Hess & McKane, 2021; Oakland Public Works, 2020). The Guide is a way to ensure the long-term involvement of the community during ECAP implementation and helps hold the city accountable to follow through on their promises to local residents.

4.3. Mobility Equity Framework Analysis Results

The transportation emission mitigation strategies were compared against the equity indicators of the Greenlining Institute’s Equity Mobility Framework. Definitions of the indicators with their associated equity goals are shown in Figure 12 and Table 1 (Creger et al., 2018). The indicators measure various components of equity that are present in transportation plans to determine whether the measures in the plan further equity goals or contribute to inequitable outcomes. Not all indicators may be present in every measure, however the measures were analyzed as to whether they furthered the equity goals present in the Framework overall. The results of the framework analysis are shown in Table 2.

Goal #1 Increase Access to Mobility	Goal #2 Reduce Air Pollution	Goal #3 Enhance Economic Opportunity
<ul style="list-style-type: none"> 1. Affordability 2. Accessibility 3. Efficiency 4. Reliability 5. Safety 	<ul style="list-style-type: none"> 6. Clean Air and Positive Health Benefits 7. Reduction in Greenhouse Gases 8. Reduction in Vehicle Miles Traveled 	<ul style="list-style-type: none"> 9. Connectivity to Places of Employment, Education, Services, & Recreation 10. Fair Labor Practices 11. Transportation-Related Employment Opportunities 12. Inclusive Local Business & Economic Activity

Figure 12: Metropolitan Planning Organizations conduct equity analyses on long-range transportation plans, but many transportation justice researchers have indicated that these analyses do not produce equitable outcomes and advocate for near-term equity goals and that plans should be evaluated to determine if they include measures to address community-identified mobility needs and include actions to benefit disadvantaged communities (Creger et al., 2018).

Table 1: Equity indicators as defined by the Greenlining Institute’s Mobility Equity Framework. Indicators are divided into three groups corresponding to three overarching equity goals: Increasing access to mobility, reducing air pollution and enhancing economic opportunity (Creger et al., 2018).

Goal #1: Increase Access to Mobility	Definition
Affordability	This metric will vary by transportation mode and location, and therefore should be set by the community; a recommended default is that households should spend no more than 20% of budgets on transportation costs
Accessibility	Transportation mode is physically accessible (available in neighborhood), accessible to disabled people, accessible to people with various cultures/languages, accessible without the need for banking or a smartphone
Efficiency	Frequency of transit, travel times, time spent in traffic, optimal availability of parking, etc.
Reliability	Consistency and variability of travel times, predictability of travel times
Safety	Collision rate and severity; personal safety issues (harassment, profiling, etc.)

Goal #2: Reduce Air Pollution	Definition
Clean Air and Positive Health Benefits	Quantities of air pollutants (PM, NOx) reduction, level of physical activity, etc.
Reduction in Greenhouse Gases	Quantities of greenhouse gas reduction
Reduction in Vehicle Miles Traveled	Compact development and greater clustering of destinations, VMT per capita
Goal #3: Enhance Economic Opportunity	
Connectivity to Places of Employment, Education, Services, & Recreation	Number of households by income within walking distance to schools and services. Number of households within 30-minute transit ride or 20-minute auto ride of employment center, etc. Number of transit transfers needed, and time spent in transit.
Fair Labor Practices	Fair wages, basic employment benefits and protections throughout construction, operation, and maintenance
Transportation-Related Employment Opportunities	Direct and indirect employment throughout construction, operation, and maintenance
Inclusive Local Business & Economic Activity	Local hire agreements, increased foot traffic to local businesses, new businesses created, increased property values, benefiting the local community without displacing residents, etc.

The framework analysis indicates that 13 of the 14 transportation-related emission reduction strategy proposed in Oakland’s ECAP included indicators for equity goal #2, reducing air pollution. The proposed measures aim to reduce greenhouse gases, air pollutants and vehicle miles traveled by encouraging active transportation, investing in pedestrian and public transit infrastructure, and expanding transportation demand management requirements to reduce reliance on single-occupancy gasoline vehicles. Nine of the 14 greenhouse gas mitigation measures in the ECAP contained equity indicators to further equity goal #3, enhancing economic opportunity. These measures include establishing car-free streets to encourage pedestrian traffic and help support local businesses, employing local residents to help construct, operate and maintain transportation infrastructure, and promoting clean new mobility options in the city, which opens the door for new economic opportunities for carbon-free transportation technology companies to establish themselves in Oakland. Eight of the 14 mitigation strategies include equity indicators for goal #1, increasing access to mobility. Among these actions are measures to make public transit more accessible by increasing the frequency of bus routes and expanding into historically underserved areas, investing in EV infrastructure that would allow residents of multifamily dwelling units to purchase zero-emission vehicles, and expanding neighborhood car sharing.

Table 2: Analysis of Oakland ECAP’s transportation emission reduction strategies against the Greenlining Institute’s Mobility Equity Framework’s equity indicators (Creger et al., 2018).

Oakland	Affordability	Accessibility	Efficiency	Reliability	Safety	Clean Air and Positive Health Benefits	Reduction in Greenhouse Gases	Reduction in Vehicle Miles Traveled	Connectivity to Places of Employment, Education, Services, & Recreation	Fair Labor Practices	Transportation-Related Employment Opportunities	Inclusive Local Business & Economic Activity
TLU-1 - Align All Planning Policies & Regulations with ECAP Goals & Priorities		X			X	X	X	X	X			
TLU-2 - Align Permit and Project Approvals with ECAP Priorities						X	X					
TLU-3 - Take Action to Reduce and Prevent Displacement of Residents & Businesses						X	X	X	X			X
TLU-4 - Abundant, Affordable, and Accessible Public Transit	X	X	X	X		X	X	X	X		X	
TLU-5 - Create a Zero Emission Vehicle (ZEV) Action Plan	X	X	X			X	X	X				
TLU-6 - Establish Temporary and Permanent Car- Free Areas	X	X			X	X	X	X	X			X
TLU-7 - Rethink Curb Space	X	X	X			X	X	X			X	
TLU-8 - Expand and Strengthen Transportation Demand Management Requirements	X	X	X	X	X	X	X	X	X		X	X
TLU-9 - Ensure Equitable and Clean New Mobility		X	X	X	X	X	X	X	X		X	
TLU-10 - Expand Neighborhood Car Sharing	X	X			X	X	X		X		X	
P-1 - Reduce Emissions from Port Vehicles and Equipment						X	X					
CL-2 - Phase Out Fossil Fuel Dependency in All City Agreements and Contracts						X	X					
CL-3 - Accelerate City Fleet Vehicle Replacement						X	X				X	X
CL-5 - Establish the Oakland Climate Action Network to Support Inclusive Community Engagement on ECAP Implementation												

The equity indicators in the Mobility Equity Framework measure the effect of transportation projects on mobility, air pollution and economic opportunity in disadvantaged communities. Results of the equity analysis can help communities compare projects and prioritize the most equitable options for implementation. This type of analysis can help a city ensure that they are not weighing one equity goal more significantly than another, and can help a city diversify their efforts in order to meet the needs of disadvantaged communities that may otherwise go overlooked. The equity indicators provide communities with the opportunity to choose those goals that are of most concern to residents and their mobility needs. Disadvantaged communities have many shared burdens, including poverty, housing insecurity and lack of educational and employment opportunities, but the extent to which communities are burdened is not uniform. Each disadvantaged community has unique needs, and the ability to tailor the equity indicators to select mobility options to suit those needs would allow the community to select the most effective, equitable solutions to suit their individual needs. Communities also can add new equity indicators or modify the definitions of the indicators to make the analysis more relevant and reflective of the area. Having the ability to evaluate the equity impacts of different transportation solutions helps ensure that the mobility solutions will help achieve the intended equity goals, and cities are able to select strategies that will bring about the most positive outcomes.

4.4. Equity Analysis Results

In addition to the Equity Mobility Framework analysis, a separate equity analysis was performed to determine how the transportation emission mitigation strategies align with the following equity objectives (Natural Resources Defense Council, 2019):

- Procedural Equity
- Distributional Equity
- Structural Equity
- Transgenerational Equity
- Transformational Equity

The results of the equity analysis are shown in Table 3. The ECAP transportation strategies were found to encompass a wide variety of equity objectives. Distributional equity was the most common type of objective, which was present in 11 out of the 14 emission reduction strategies.

The distributional equity measures included efforts to prioritize disadvantaged communities for emission reductions at the Port of Oakland in order to alleviate disproportionate burdens in air pollution and public health, ensuring that affordable housing is included in development near transportation, and requiring incentives for low-income households to purchase electric vehicles. Structural equity was observed in six of the 14 emission reduction strategies, including those that proposed changes to Oakland’s municipal planning and permitting processes to help change land use planning procedures and ensuring that new mobility programs focus on meeting the needs of disadvantaged communities. Procedural equity was found in six of the 14 strategies and focused on the inclusion of disadvantaged communities in the outreach and engagement processes and efforts to include residents’ perspectives and suggestions about the best way to implement the programs. Oakland has a strong community advocacy presence, with several groups involved with soliciting input from disadvantaged communities on city policy actions. Including the perspectives of residents of disadvantaged communities helps ensure that the strategies benefit the communities and meet their needs, as well as avoid any negative consequences that the mitigation strategies might have on those communities.

Table 3: Analysis of Oakland ECAP’s transportation emission reduction strategies against equity objectives (Natural Resources Defense Council, 2019).

	Procedural	Distributional	Structural	Transgenerational	Transformational
TLU-1 - Align All Planning Policies & Regulations with ECAP Goals & Priorities		X	X		
TLU-2 - Align Permit and Project Approvals with ECAP Priorities			X		
TLU-3 - Take Action to Reduce and Prevent Displacement of Residents & Businesses		X		X	
TLU-4 - Abundant, Affordable, and Accessible Public Transit	X	X			
TLU-5 - Create a Zero Emission Vehicle (ZEV) Action Plan	X	X	X		
TLU-6 - Establish Temporary and Permanent Car- Free Areas	X	X			
TLU-7 - Rethink Curb Space		X			
TLU-8 - Expand and Strengthen Transportation Demand Management Requirements			X		
TLU-9 - Ensure Equitable and Clean New Mobility	X	X	X		
TLU-10 - Expand Neighborhood Car Sharing	X	X			

	Procedural	Distributional	Structural	Transgenerational	Transformational
P-1 - Reduce Emissions from Port Vehicles and Equipment	X	X			
CL-2 - Phase Out Fossil Fuel Dependency in All City Agreements and Contracts		X			
CL-3 - Accelerate City Fleet Vehicle Replacement					
CL-5 - Establish the Oakland Climate Action Network to Support Inclusive Community Engagement on ECAP Implementation	X	X	X	X	X

Transgenerational equity was found in two emission reduction strategies, including in actions to prevent displacement of residents and businesses from the city. When residents are unable to afford to remain in the city and move farther away, they often lose access to opportunities for their entire family that affect their ability to build generational wealth. Poorer residents have less access to opportunities to build generational wealth, such as home ownership and educational and employment opportunities.

Finally, transformational equity was present in one emission reduction strategy, the establishment of the Oakland Climate Action Network. Transformational equity indicates that communities have the innate capacity to manage and sustain themselves and have agency and influence in governmental decision-making. The goal of the Network is to ensure that the ECAP is implemented equitably by partnering with community advocacy organizations to increase grassroots organizational capacity to lead and execute emission reduction strategies. The purpose of the Network is to create a long-term community engagement procedure that ensures that disadvantaged communities are included in the development of climate action strategies. By partnering with local grassroots organizations, the Network intends to develop a system where residents lead outreach and engagement within their own communities and develop climate action strategies that are adaptable to the evolving needs of the disadvantaged communities. The Network intends to give the local communities a voice in determining how the ECAP is implemented and is a long-term strategy for self-determination. This ECAP strategy was the only measure to include all types of equity, including structural, procedural, distributional, transgenerational, and transformational. This action intends to involve local residents in the process of creating new municipal climate policies (procedural and structural) that will prioritize disadvantaged communities for benefits (distributional) and aims to create a self-regulating

system that is able to respond to the long-term needs of the community to allow it to thrive in the future (transformational and transgenerational).

4.5. Comparative Analysis Results

The Oakland ECAP was compared to another city with similar issues pertaining to equity, air pollution and public health. The city of Long Beach, California is also a port town and has several major highways that support freight traffic. The disadvantaged communities identified by SB 535 are shown in Figure 13, which are predominantly located adjacent to the highways and near the port (California Environmental Protection Agency, 2018). These areas also have higher pollution burdens and public health impacts, as shown in Figure 14 (California Office of Environmental Health Hazard Assessment, 2022).

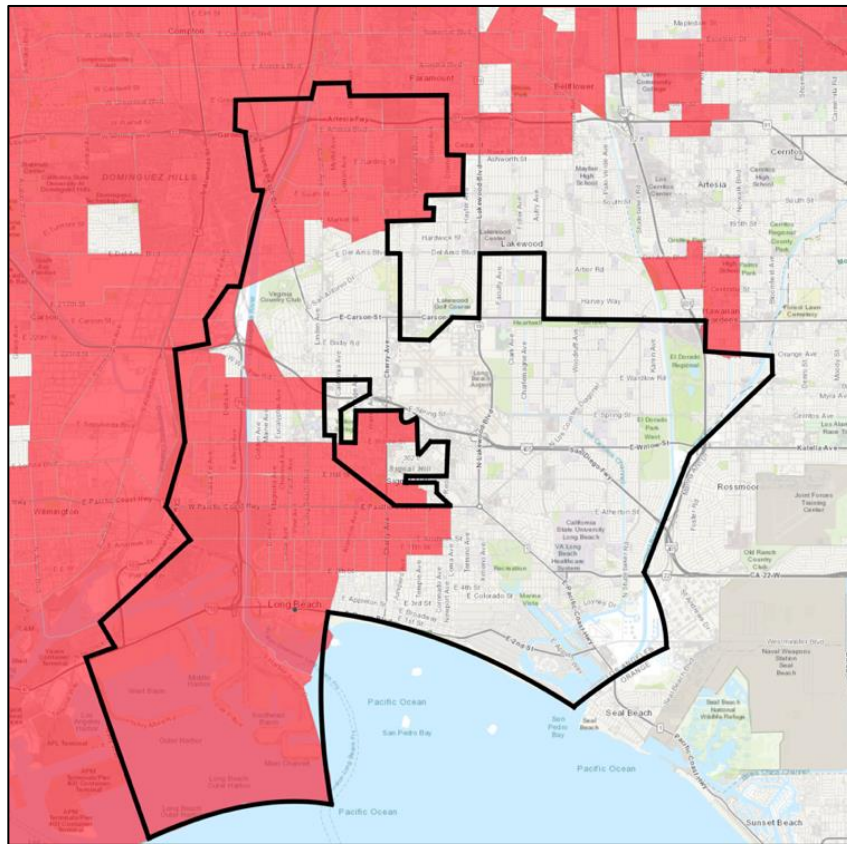


Figure 13: The Long Beach SB 535 disadvantaged communities, depicted in red, are predominantly located near the Port of Long Beach and along major highways that support freight traffic to the port (California Environmental Protection Agency, 2018).

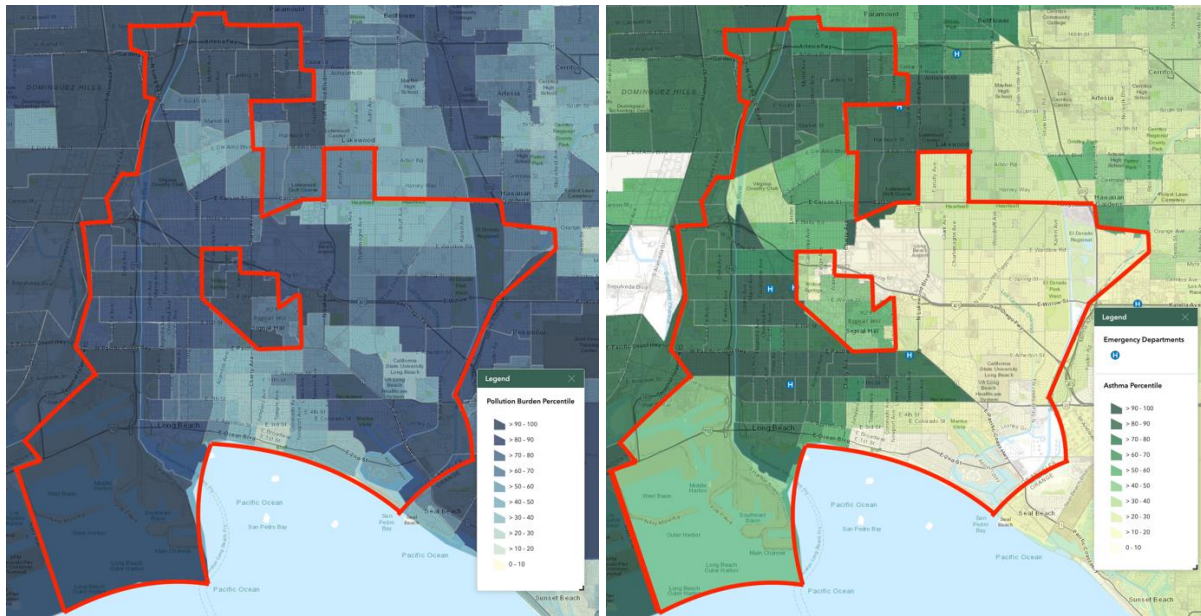


Figure 14: Disadvantaged communities in Long Beach experience greater air pollution and public health impacts than non-disadvantaged communities due to the location of polluting infrastructure associated with the Port of Long Beach and the location of major highways (California Office of Environmental Health Hazard Assessment, 2022).

The city adopted the Long Beach Climate Action and Adaptation Plan (CAAP) in August of 2022, which aims to reduce greenhouse gas emissions by 40% by 2030 (2015 baseline) and to achieve net zero emissions by 2045. Transportation accounted for 44% of the city’s 2015 greenhouse gas emissions (City of Long Beach, 2020). The Long Beach CAAP proposed the following strategies to address greenhouse gas emissions from transportation (City of Long Beach, 2020):

- **T-1:** Increase the frequency, speed, connectivity, and safety of transit options
- **T-2:** Expand and improve pedestrian infrastructure citywide
- **T-3:** Increase bikeway infrastructure citywide
- **T-4:** Implement the Port of Long Beach Clean Trucks Program
- **T-5:** Develop an Electric Vehicle Infrastructure Master Plan
- **T-6:** Increase employment and residential development along primary transit corridors
- **T-7:** Update the Transportation Demand Management Ordinance
- **T-8:** Increase the density and mixing of land uses
- **T-9:** Integrate SB 743 planning with the CAAP process

The city of Long Beach acknowledges the impact that equity has on air pollution burden and public health impacts (City of Long Beach, 2020). The transportation emission reduction actions in the CAAP include “Equity Strategies” that propose measures intended to decrease the disproportionate burdens faced by disadvantaged communities. Similar to the Oakland ECAP, the Long Beach CAAP includes actions to prioritize low-income and communities of color in CAAP implementation, to increase affordable housing near transit lines and measures intended to reduce displacement. Also, like the ECAP, the CAAP equity strategies are the result of extensive outreach and community engagement efforts undertaken by city staff beginning in 2017 (City of Long Beach, 2020). The city of Long Beach participated in over 60 public outreach events to solicit input from residents on the climate actions that were most important for their communities. These events were intended to “meet people where they are” and involved city staff giving talks and presentations on the CAAP at community events, cultural fairs, neighborhood association meetings and faith-based organization events. Efforts were made to include multilingual outreach, to provide two-way, culturally competent engagement, to provide meals and services at CAAP outreach events and to use art and other creative outlets to help reach a wider audience for both the in-person events and the online engagement activities (City of Long Beach, 2020). Finally, similar to Oakland, Long Beach city staff convened three working groups, including a scientific working group, a business working group and a community working group, to provide input in the CAP design process from pertinent stakeholders.

Results of the framework and equity analyses for the city of Long Beach CAAP are shown in Tables 4 and 5. Similar to the Oakland ECAP, the transportation emission reduction strategies proposed in the Long Beach CAAP primarily addresses equity goal #2, reducing air pollution, and includes measures intended to reduce greenhouse gases, air pollutants and to reduce total vehicle miles traveled. The second most common equity indicators that are present in the CAAP’s emission reduction strategies address equity goal #1, increasing access to mobility, and the least common equity indicators that are present in the strategies are those associated with equity goal #3, enhancing economic opportunity. The equity indicator distribution of the framework analysis for the ECAP and the CAAP are shown in Figure 15. In the figure, the equity indicators are shown as percentages to account for the difference in number

of strategies present in the two plans. The plans have similar distributions of equity indicators, with nearly every strategy addressing equity goal #2 (Figure 15).

Overall, more strategies in the Oakland ECAP address equity goal #1 than do the strategies proposed in the Long Beach CAAP. Regarding equity goal #3, the most common equity indicator in both plans is “Connectivity to Places of Employment, Education, Services, & Recreation”, and approximately 30% of both plans contain strategies that address “Inclusive Local Business & Economic Activity”. However, the Oakland ECAP contains twice as many strategies that address “Transportation-Related Employment Opportunities” (Figure 15). A comparison of the equity analysis results of the Oakland ECAP versus the Long Beach CAAP are shown in Figure 16. Distributional equity is the most common objective present in both plans at 11 strategies for the Oakland ECAP and eight for the Long Beach CAAP. The Long Beach CAAP contains an equal number of strategies with procedural and transgenerational equity as the Oakland ECAP at three and two strategies respectively. The Oakland ECAP contains more strategies with structural equity at six versus one in the Long Beach CAAP. The ECAP is the only plan that contains transformational equity, which was not observed in the Long Beach CAAP.

Table 4: Analysis of Long Beach CAAP's transportation emission reduction strategies against the Greenlining Institute's Mobility Equity Framework's equity indicators (Creger et al., 2018).

Long Beach	Affordability	Accessibility	Efficiency	Reliability	Safety	Clean Air and Positive Health Benefits	Reduction in Greenhouse Gases	Reduction in Vehicle Miles Traveled	Connectivity to Places of Employment, Education, Services, & Recreation	Fair Labor Practices	Transportation-Related Employment Opportunities	Inclusive Local Business & Economic Activity
T-1: Increase the frequency, speed, connectivity, and safety of transit options		X	X	X	X	X	X	X	X		X	
T-2: Expand and improve pedestrian infrastructure citywide	X	X			X	X	X	X	X			
T-3: Increase bikeway infrastructure citywide	X	X	X	X	X	X	X	X	X			
T-4: Implement the Port of Long Beach Clean Trucks Program						X	X					
T-5: Develop an Electric Vehicle Infrastructure Master Plan	X	X	X			X	X	X				
T-6: Increase employment and residential development along primary transit corridors	X	X	X	X		X	X	X	X			X
T-7: Update the Transportation Demand Management Ordinance	X	X	X	X	X	X	X	X	X		X	X
T-8: Increase the density and mixing of land uses	X	X	X	X		X	X	X	X			X
T-9: Integrate SB 743 planning with the CAAP process						X	X	X				
C-1: City Transportation Initiatives						X	X	X				

Table 5: Analysis of Long Beach CAAP's transportation emission reduction strategies against equity objectives (Natural Resources Defense Council, 2019).

	Procedural	Distributional	Structural	Transgenerational	Transformational
T-1 - Increase the frequency, speed, connectivity, and safety of transit options	X	X			
T-2 - Expand and improve pedestrian infrastructure citywide	X	X			
T-3 - Increase bikeway infrastructure citywide	X	X			
T-4 - Implement the Port of Long Beach Clean Trucks Program		X			
T-5 - Develop an Electric Vehicle Infrastructure Master Plan		X			
T-6 - Increase employment and residential development along primary transit corridors		X		X	
T-7 - Update the Transportation Demand Management Ordinance			X		
T-8 - Increase the density and mixing of land uses		X		X	
T-9 - Integrate SB 743 planning with the CAAP process		X			
C-1 - City Transportation Initiatives					

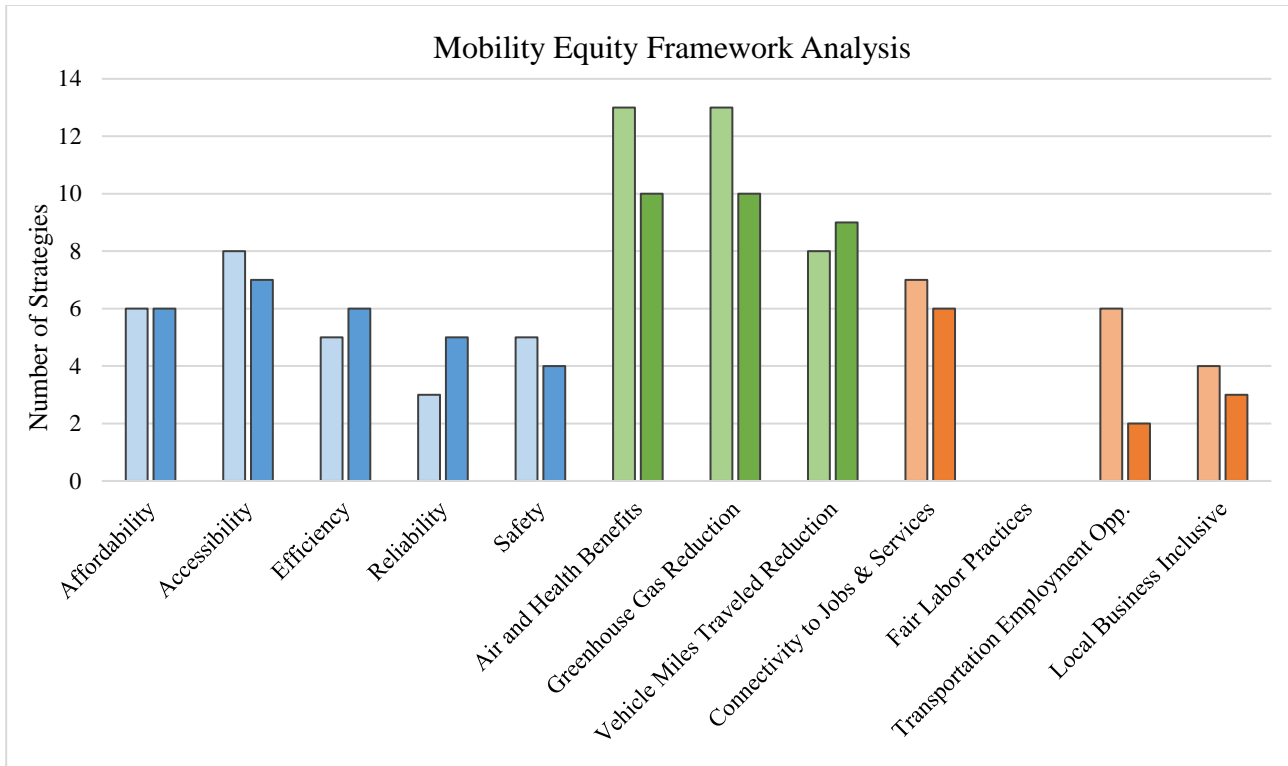


Figure 15: Results of the framework analysis indicate that both Oakland and Long Beach CAPs contained emission reduction strategies that primarily addresses equity goal #2, reducing air pollution, followed by increasing access to mobility options (goal #1) and enhancing economic opportunity (goal #3) (City of Long Beach, 2020; Creger et al., 2018; Oakland Public Works, 2020).

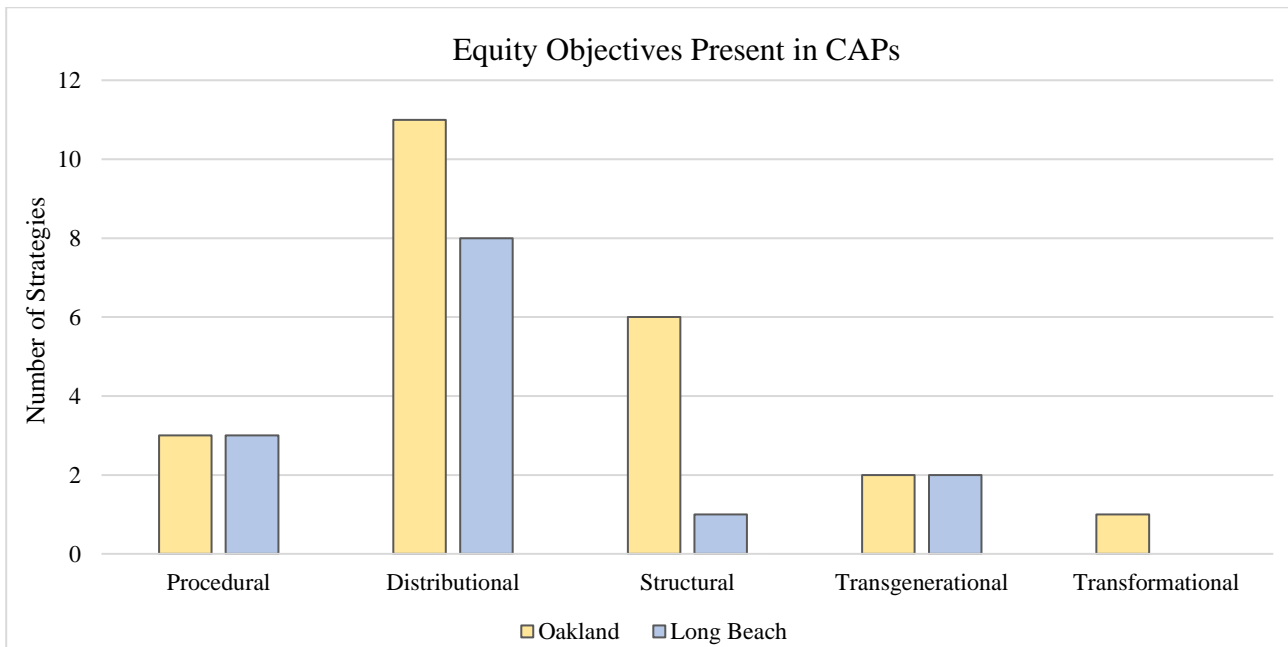


Figure 16: Both Oakland’s ECAP and Long Beach’s CAAP primarily contain strategies that include distributional equity, but Oakland’s ECAP contains more structural and transformational equity (City of Long Beach, 2020; Natural Resources Defense Council, 2019; Oakland Public Works, 2020).

The framework and equity analyses of the Oakland ECAP and the Long Beach CAAP indicate that the two plans propose different types of strategies to achieve greenhouse gas emission reductions from transportation. The Long Beach CAAP primarily contains strategies that are focused on improving the public transit system and bicycle and pedestrian infrastructure, actions where the public was able to make recommendations and directly influence the direction of strategy implementation. This resulted in the CAAP strategies having high procedural and distributional equity results in the equity analysis, and more strategies that contained equity indicators for equity goal #1 in the framework analysis. These strategies align with the types of actions that are traditionally proposed in CAPs to reduce transportation emissions by focusing solely on greenhouse gases rather than by addressing the known mobility inequities in the city. CAPs have generally recognized the emission-reduction benefits of bicycle lanes, ride- car- and bike-sharing programs, vehicle electrification, pedestrian infrastructure, locating housing near transit lines and increasing access to public transportation (Hess & McKane, 2021). This is a pattern observed by equity researchers when conducting evaluations of city CAPs, particularly those that recently began incorporating equity language into their mitigation strategies (Angelo et al., 2022). In this sense equity is simply a new label applied to the same emission reduction actions, which are developed to meet the goals of overarching state and federal policies rather than the needs of community members. In the case of Long Beach, the CAAP is being used as a mitigation action in the city's General Plan, and the transit actions proposed in the CAAP are designed to meet the greenhouse gas emission reduction goals of the General Plan rather than meet the needs identified by the community. The city of Long Beach is allowing these larger state and federal requirements to dictate the emission reduction strategies proposed in the CAAP.

Additionally, the city of Long Beach only proposes minimal changes to city land use planning policies, mainly incentivizing the creation of higher density housing near transit lines (City of Long Beach, 2020). This suggests that the structural mechanisms responsible for placing polluting infrastructure near disadvantaged communities will be maintained and may increase the disparities in air pollution and public health impacts. The "Equity Strategies" proposed in the CAAP also do not contain clear goals for increasing equity in Long Beach but appear to be proposed as an afterthought or an ancillary benefit to the transportation emission reductions rather than a main driver for the climate actions, whereas the Oakland ECAP proposes strategies that make deeper changes to city policies that aim to make long-term improvements to equity. The

CAAP also does not include specific protections to ensure that mitigation actions do not have unintended negative consequences for disadvantaged communities. Finally, despite extensive community engagement in the CAAP design stages, the city of Long Beach did not have as much community involvement in the design and implementation stages of CAAP development as Oakland. The structure of Long Beach's community engagement is top-down, with city staff leading and facilitating events, whereas Oakland appointed a team of community members to lead outreach efforts and serve as a liaison between residents and the city. This helps break down the power differential between city staff and community members and can allow for a more open dialogue to occur.

5. Conclusions and Recommendations

The main objective of this research was to identify transportation emission mitigation strategies in CAPs that would reduce the disparities in air pollution exposure and public health impacts in disadvantaged communities. To achieve this objective, I formulated a series of research questions to understand the effects that transportation emissions have on air quality and public health and how cities incorporate equity into emission reduction strategies to meet climate goals. I performed a literature review, a case study analysis, a framework and equity analysis and a comparative analysis to gain a detailed understanding of this complex issue and to answer my research questions. I used the results of my research to develop recommendations for management strategies that can be used by climate action planners to help ensure that transportation emission mitigation strategies achieve equitable outcomes.

5.1. Conclusions

My research examined the CAPs of two cities with disadvantaged communities as defined by SB 535 to see how equity was included in emission reduction strategies for transportation. Disadvantaged communities are disproportionately exposed to air pollutants associated with transportation due to their proximity to polluting infrastructure such as ports and major highways and suffer higher rates of public health impacts because of this exposure. Climate change is projected to worsen air pollution issues and exacerbate the vulnerability of disadvantaged communities. Cities have led efforts to address greenhouse gas emissions through the development of CAPs partly as a response to lack of progress on the state and national level to address climate change. However, many of these plans fail to acknowledge the disproportionate impacts faced by disadvantaged communities and do not include actions to alleviate those impacts or to protect the communities against unintended negative consequences of the mitigation measures. Therefore, there is a need to understand how to achieve equitable outcomes while also meeting climate goals.

The results of my analyses indicate that the Oakland ECAP proposes protections for disadvantaged communities in the emission reduction strategies in order to minimize the impact that the strategies would have on vulnerable groups. The ECAP also proposed clear actions for the city and stakeholders to take to ensure that the benefits from emissions reductions were focused in disadvantaged communities. The design and implementation strategies for the ECAP are centered around community participation and the ECAP Implementation Guide helps ensure the long-term

involvement of disadvantaged communities to make sure their voices continue to be heard. The ECAP was compared to the Long Beach CAAP and the two plans were evaluated using metrics to determine the equity-mindedness of the proposed emission mitigation strategies. The framework and equity analyses determined that Oakland and Long Beach had different approaches to incorporating equity in their transportation emission mitigation measures. Both plans primarily address greenhouse gas and air pollution emission reduction in their strategies with fewer measures that increase access to mobility and enhance economic opportunities, which suggests that these are growth areas for future iterations of the CAP to focus on to ensure that more mobility equity needs are being addressed. The types of strategies proposed in the Long Beach CAAP contained primarily distributional and procedural equity that, while still offering positive benefits to disadvantaged communities, do not fix the inequitable system that caused the disparities that are currently present. Oakland's ECAP contains more strategies with structural equity that attempt to undo the damage caused by historical land use planning policies that led to disadvantaged communities being disproportionately exposed to transportation emissions. Oakland's ECAP also included the Oakland Climate Action Network, which is an innovative effort to give the community unprecedented agency through partnerships with the city.

The emission mitigation strategies proposed in Oakland's ECAP go much farther to remedy the inequitable systems than those actions in the Long Beach CAAP. Given that inequitable systems are the source of the disparities, the plan that corrects the system most effectively will result in more equitable outcomes. The results of my analysis conclude that Oakland's ECAP contains actions that will address known inequities in air pollution and public health impacts while mitigating greenhouse gas emissions. The ECAP's equity focus results in efforts to make extensive, fundamental changes to existing city policies and procedures so that inequitable city systems can be corrected and the lives of all city residents can be improved.

5.2. Recommendations

The following recommendations are intended to address gaps identified by my evaluation of pertinent literature and two CAPs that address equity issues. The actions listed in this section are based upon the conclusions drawn from my analyses and include actions for city planners to take in future CAPs to help accomplish their equity goals. These recommendations can be used in the CAP

design and implementation process to help develop an equitable approach to mitigating emissions from the transportation sector.

Gap #1: Identification and inclusion of air quality and public health co-benefits in CAP

Many studies included in this research suggest that including the co-benefits to air quality and public health associated with greenhouse gas emission mitigation in the transportation sector result in more stringent climate policy. However, even though the co-benefits are well-known, climate policy currently does not account for them because policies focus on minimizing mitigation costs and does not measure the benefit of avoided climate damages (Boyce & Pastor, 2013; Nemet et al., 2010). Including co-benefits in climate policy would improve societal outcomes because of the immediate, substantial improvements to local communities.

Recommendation #1: City planners should consider air quality and public health benefits when selecting transportation emission mitigation actions, and strategies should be chosen that maximize these benefits in disadvantaged communities

Gap #2: Protections for disadvantaged communities

CAPs propose long-term strategies to drastically change a city's infrastructure, transportation system and local economy to reduce greenhouse gas emissions and meet climate goals. These plans aim to improve city services and increase residents' overall wellbeing, but most plans do not consider the impact that their mitigation actions will have on their most vulnerable citizens. Efforts to improve public transit, add green space and foster local economic development can increase property values which can make the area too expensive for low-income residents and force them out of the city. Improving electrical vehicle charging infrastructure does not reduce emissions if the vehicles themselves are too expensive for individuals to afford. Even efforts to encourage green job development will fall short if residents are not provided with education and training to fill the positions and may decrease local economic opportunities overall for disadvantaged communities. Oakland's ECAP recognized these potential negative effects and proposed protections for disadvantaged communities, including displacement protection, EV incentives, requirements for development near transit to include affordable housing for low and

very-low-income families. These protections are included in the ECAP Implementation Guide and are incorporated into mitigation strategies rather than being considered ancillary benefits. The Long Beach CAP mentioned many types of similar protections but failed to give any specific guidance on how to achieve them or ways to measure success. Formalizing community protections into CAP goals is an important step as it allows for the community, with agency through the ECAP Implementation Guide and the EF, to hold the city accountable to ensure that the measures are established and maintained.

Recommendation #2: City planners should consider how mitigation measures will affect disadvantaged communities and offer protections to shield vulnerable communities from unintended negative consequences.

Gap #3: Insufficient community engagement and outreach during CAP design and implementation

Research on equity in climate action planning suggest that one of the best ways to ensure that emission reduction efforts are equitable is to include residents' perspectives, particularly those from the disadvantaged communities that are most vulnerable to climate impacts (Braveman et al., 2022; Karner & Marcantonio, 2018; Ku et al., 2021). Community workshops, outreach presentations and online events are crucial to gathering community feedback that the city needs to understand the needs of disadvantaged communities, yet some cities are more successful than others. Cities need to understand the barriers to participation that exist for disadvantaged communities to remove them through strategic planning, including hosting meetings at night in locations that are accessible to residents with limited access to transportation, providing meals and childcare during events, providing simultaneous translation services, and allowing for virtual participation, among other methods, to access as many members of the public as possible. Many cities are beginning to include these methods into their CAP community engagement efforts, but some cities take it another step further and empower the community to lead outreach efforts and engage with the community as a liaison between city staff and residents. Oakland established the EF team to facilitate workshops and work with the city to educate communities on climate change and equity issues. Furthermore, Oakland established a plan to keep the community involved throughout the 10-year implementation process of the ECAP, with regular reporting on well-

defined equity goals to measure progress. This allows for the community to have more agency in the process and allows CAP development and implementation to be a collaborative process rather than one imposed upon them by the city.

Recommendation #3: Cities should conduct extensive community outreach when designing CAPs and maintain community involvement throughout CAP implementation. Cities should develop measurable equity goals and report back to the community regularly on progress

5.3. Recommendations for Future Research

More research is necessary to fully understand the impacts that transportation emissions have on local air quality and public health, including a quantification of the ratio between co-pollutant damages to carbon dioxide emissions to help guide policymakers to compare abatement costs to avoided climate impacts. Additionally, more research is necessary to evaluate the long-term implementation success of equity measures so that more effective guidance can be provided to cities on what really works to ensure equitable outcomes. Finally, research is necessary to measure the efficacy of community engagement and outreach efforts so that cities can implement best practices in the CAP development and implementation processes.

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