South Coast AQMD

2022 AIR QUALITY MANAGEMENT PLAN

Final Socioeconomic Report

December 2022

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Executive Summary

While air quality has improved over the years, large portions of Southern California region still have some of the most polluted air in the nation. The region exceeds federal and state public health standards for both ozone and fine particulate matter (PM2.5).[1] The 2022 Air Quality Management Plan (AQMP) is designed to meet the 2015 8-hour ozone federal standard.[2] It outlines control measures to address the nonattainment of ozone throughout the South Coast Air Basin (Basin) and Coachella Valley, primarily targeting oxides of Nitrogen (NOx) and volatile organic compounds (VOC) emissions from all emission sources.[3] The full implementation of the NOx and VOC control measures by 2037 is expected to result in health benefits from the lowered ozone concentrations, as well co-benefits from the lowered PM2.5 levels, greenhouse gases and toxic air contaminants that are also expected.

The estimated costs and benefits of the proposed control measures in the 2022 AQMP are expected to alter, to various degrees, the economic decisions made by households, businesses, and other economic factors. Some businesses would see production costs go up while other businesses would benefit from a greater demand for their services and technologies. For consumers who consider purchasing or replacing household appliances, for example, the proposed control strategies would also in some cases change or widen the range of product, that differ in fuel types, energy efficiencies, effective unit prices, and thus potential payback periods.

In order to inform decision-makers and stakeholders about the potential costs and benefits of the 2022 AQMP and how the associated socioeconomic impacts would affect the region, the Final Socioeconomic Report for the 2022 AQMP (hereinafter "Final Socioeconomic Report") has been prepared. Recommendations made by Abt Associates in 2014 to enhance the agency's socioeconomic analysis were incorporated in this Final Socioeconomic Report.[4]

The Final Socioeconomic Report uses two major modeling tools: the Regional Economic Models, Inc. (REMI)'s Policy Insight Plus, a policy simulation program for regional macroeconomic impacts, and the U.S. Environmental Protection Agency's environmental Benefits Mapping and Analysis program (BenMAP). Total incremental costs, inclusive of the cost of incentives, were compiled for proposed control measures with quantified emission reductions. Modeled air quality data for the Basin, together with mathematical functions and parameters based on the most updated epidemiological and economic studies, were used in BenMAP to quantify public health benefits due to reduced exposure to air pollution. Public health benefits were combined with incremental costs to estimate a range of regional jobs and other macroeconomic impacts from implementing the 2022 AQMP. Projected changes in health risk and monetized public health benefits were also used to analyze how implementation of the 2022 AQMP may

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[1] The South Coast Air Basin is required to meet the following National Ambient Air Quality Standards (NAAQS): 1979 1-hour Ozone standard of 120 ppb by 2022, 1997 8-hour Ozone standard of 80 ppb by 2024, 2008 8-hour ozone standard of 75 parts per billion (ppb) in 2032, and 2015 8-hour Ozone standard of 70 ppb by 2038. More discussion on nonattainment levels in Chapter 1 of the 2022 AQMP.

[2] The 2022 AQMP was adopted on December 2, 2022 and can be found here: http://www.aqmd.gov/home/air-quality/clean-air-plans/air-quality-mgt-plan.

[3] The Basin is an over 10,000 square mile area comprised of Orange County and the urban portions of Los Angeles, Riverside, and San Bernardino Counties. The Coachella Valley is a sub-region of Riverside County in the Salton Sea Air Basin that is bounded by the San Jacinto Mountains to the west and the eastern boundary of the Coachella Valley to the east.

[4] Abt Associates 2014 (available at: https://www.aqmd.gov/docs/default-source/Agendas/aqmp/scaqmd-report---review-socioeconomic-assessments.pdf). See Chapter 1 of this Socioeconomic Report for a summary of these enhancements.

affect environmental justice (EJ) communities in the Basin.

Key Findings in the Final Socioeconomic Report

- ***Nearly 57 percent of the 2022 AQMP's $2.85 billion annual average cost is attributed to mobile source emission reductions of NOx, accounting for 80 percent of overall NOx reductions needed to attain clean air standards by 2037. The relative higher cost to control emissions from stationary and area sources is largely due to the currently high cost of zero-emission technologies to further reduce emissions from some of these sources that are already tightly controlled.***

Living in a region with over 20,000 miles of highways and major surface streets, 450 miles of passenger rail, six commercial airports, and the two largest marine ports in the nation, residents in our region are exposed to emissions from a multitude of mobile sources each day. NOx is the key pollutant that must be controlled to achieve federal and state ozone standards. To reduce NOx emissions, the majority of control measures in the 2022 AQMP target combustion sources. Since over 80% of the NOx emissions in the Basin are from mobile sources, the plan prominently features mobile source control measures. Limited and strategic control of VOC emissions, which are another ozone precursor, are also pursued to optimize the region's attainment pathway.

Between 2023 and 2037, the implementation of the 2022 AQMP is projected to result in an annual average cost of $2.85 billion, incremental to the business-as-usual case. Nearly 57 percent or about $1.61 billion of the annual incremental cost is related to mobile source control strategies, and these strategies are expected to lead to about 80 percent of the emission reductions needed to attain the 8-hour ozone standard by 2037.[5] The remaining 43 percent of the annual amortized average cost, or $1.24 billion, is associated with reducing stationary and area source emissions in the Basin which account for about 20 percent of the necessary emission reductions for regional air quality attainment. The relatively high cost to reduce stationary and area source emissions is largely due to the need to deploy zero-emission technologies for source categories that are already subject to stringent NOx emission standards, but it is also associated with the sheer volume of devices that contribute to area source emissions, such as household appliances and heaters. As of today, zero-emission alternatives in almost all applications are still more costly, especially for large industrial combustion process.[6] In addition to improving air quality, zero emission technology contributes to achieving other federal and state goals for greenhouse gas reductions, and is often pursued first to achieve those goals. Costs shown here for the 2022 AQMP therefore also overlap with some costs for achieving greenhouse gas goals.

[5] Since NOx emissions also lead to the formation of PM2.5, the NOx reductions needed to meet the ozone standards will likewise lead to improvement of PM2.5 levels and attainment of PM2.5 standards.

[6] Chapter 4 of the 2022 AQMP states that "[m]obile source controls typically have higher costs per ton of emissions than stationary controls, especially if the control measure requires turnover before the end of the useful life of the mobile source equipment." This is because stationary controls have so far relied on retrofit controls rather than completely replacing boilers, turbines, etc. To further reduce emissions from a combustion source that is already tightly controlled, it will become necessary to replace the combustion-based technology with a zero-emission alternative. In these cases, stationary source controls will become more expensive than measures implemented in the past.

TABLE ES-1: COST SUMMARY OF THE 2022 AQMP MEASURES ANNUAL AVERAGE (2023-2037)[7]

Measures	Annual Amortized Average (Billions of 2021 dollars)					Percent of Total Annualized Cost
	Remaining Incremental Cost		Incentives		Total Incremental Cost	
Stationary and Area Sources	$1.12	+	$0.12	=	$1.24	43.5%
Mobile Sources	$1.44	+	$0.17	=	$1.61	56.5%
All Sources	**$2.56**	**+**	**$0.29**	**=**	**$2.85**	**100%**

(Note: Numbers may not sum up due to rounding.)

About 10 percent or $0.29 billion of the total annual incremental cost is attributed to incentive programs that eligible industries and consumers can use to offset the cost of purchasing cleaner technologies. In this report, incentives are assumed to be funded by either state or local governments. However, South Coast AQMD will continue to advocate for clean air funding from diverse sources including the federal government. More incentive funding and subsidies may become available but are not included in this analysis. For example, the Inflation Reduction Act (IRA) recently signed into law will help households offset the cost of purchasing more energy efficient heaters, furnaces, and electric home appliances in the form of tax credits and direct rebates,[8] thereby bringing down the costs currently estimated to be entirely incurred by households alone for several control measures designed to lower emissions from residential combustion sources. In the meantime, parallel state programs to combat climate change are also expected to provide additional funding including for zero-emission infrastructure. Existing state programs such as low carbon fuel standard credits will also continue to lower the costs of transitioning to clean transportation technologies. All of these incentive programs are very useful to reduce the cost to customers and businesses, however the total cost of controls would ultimately not be changed.

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[7] Costs are characterized as incremental costs, not as the total cost of a particular control equipment or program. Specifically, they represent the cost difference between a "business as usual" path and an alternative path as proposed by the 2022 AQMP. See Tables 2-1(a) and 2-1(b) in Chapter 2 for more cost details for each measure.

[8] See https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/19/fact-sheet-how-the-inflation-reduction-act-helps-asian-american-native-hawaiian-and-pacific-islander-communities/.

- ***By implementing the 2022 AQMP, the number of premature deaths and numerous other health outcomes associated with air pollution would be reduced. As a result, the four-county region is expected to gain a total public health benefit of $19.4 billion on average per year from 2025 to 2037.***

Air pollution continues to be linked to increases in death rates (mortality) as well as increases in illness and other health effects (morbidity). Implementing the 2022 AQMP would significantly reduce the numerous harmful health effects associated with exposure to air pollution. In total, it was estimated that about 1,600 annual premature deaths will be avoided by 2032, and about 3,000 annual premature deaths avoided by 2037. On average between 2025-2037 about 1,500 premature deaths would be avoided per year due to improved air quality as a result of implementing the 2022 AQMP control measures. Other health benefits included annually 8,700 fewer hospitalizations, 1,450 fewer emergency room visits related to asthma, other respiratory and cardiovascular illnesses, and nearly 163,000 fewer days of absences from work and school. These public health benefits have an estimated value of $134.3 billion, cumulatively from 2025 to 2037, or $19.4 billion annually by 2037.[9]

TABLE ES-2: MONETIZED PUBLIC HEALTH BENEFITS OF THE 2022 AQMP

	Average Annual 2025-2037[1] (Billions of 2021 dollars)
Mortality-related benefits	$18.7
Long-Term Ozone Exposure	*$4.2*
Long-Term PM2.5 Exposure	*$14.4*
Morbidity-related benefits	$0.7
Grand Total	**$19.4**

[1] Several proposed clean air strategies in the 2022 AQMP will be implemented beginning in 2023. However, to be conservative and in consideration of the transition from VOC-limited to NOx-limited ozone formation regime for several areas in the South Coast Air Basin, it is assumed that there would be minimum clean air benefits during the first two years of 2022 AQMP implementation, and health benefits of implementing the 2022 AQMP would begin accruing only in 2025.
(Note: Numbers may not sum up due to rounding.)

About 74 percent of the estimated public health benefits are associated with a lower risk of premature deaths due to reduced long-term exposure to PM2.5, and the rest are associated with ozone mortality and avoided incidence of various respiratory and cardiovascular symptoms and of work and school absences. Although not quantified in the Final Socioeconomic Report, additional public welfare benefits exist relating to how clean air promotes visibility and prevents damage to agriculture, local ecology, buildings, and other materials.

[9] It should be emphasized that, as with any scientific studies and evaluations, there are various sources of uncertainty surrounding the estimated public health benefits, including the uncertainty embedded in data inputs, uncertainty of the magnitude of various health effects of exposure to air pollutants, and uncertainty of valuation. Given the significant contribution of mortality-related benefits, several sensitivity analyses were conducted. See Chapter 3 and the associated appendices for more details.

- ***Implementing the 2022 AQMP is expected to result in jobs foregone but the region will remain on a positive job growth trajectory.***

The four-county regional economy currently generates more than a trillion dollars in GDP and supplies more than 10 million jobs.[10] Without implementing the 2022 AQMP, baseline jobs in the region are expected to grow at an annualized rate of 0.44 percent from 2023 to 2037.[11] Whether health benefits are included or excluded in the job impact analysis, the trajectory of regional job growth would remain positive throughout.

TABLE ES-3: JOB SCENARIOS OF 2022 AQMP IMPLEMENTATION

	Incremental Costs & Health Benefits Included	Incremental Costs & No Health Benefits Included
2022 AQMP	• **0.41%** annualized job growth between 2023 and 2037, compared to the baseline job growth rate of 0.44% • **17,000 jobs foregone** on average in an economy with over 10 million jobs	• **0.39%** annualized job growth between 2023 and 2037 compared to the baseline job growth rate of 0.44% • **29,000 jobs foregone** on average in an economy with over 10 million jobs

Jobs Foregone = Loss of Existing Jobs + Forecasted Jobs Not Created

As seen in Table ES-3, when the impact of public health benefits are combined with the impact of incremental costs of the proposed control measures, the resulting job impacts would be on average 17,000 jobs foregone when compared to the annual baseline jobs between 2023 and 2037, and an annualized growth rate of 0.41 percent.[12] This is equivalent to a 0.03 percentage point slowdown in job growth relative to the projected employment baseline during the same period. If excluding health benefits, about 29,000 jobs on average are forecasted to be foregone, resulting in a decline to 0.39 percent annualized growth between 2023 and 2037, which is equivalent to a 0.05 percentage point

[10] U.S. Bureau of Economic Analysis, 2020 GDP and 2020 total job estimates (including payroll jobs and self-employment) for Los Angeles-Long Beach-Anaheim and Riverside-San Bernardino-Ontario metropolitan statistical areas.

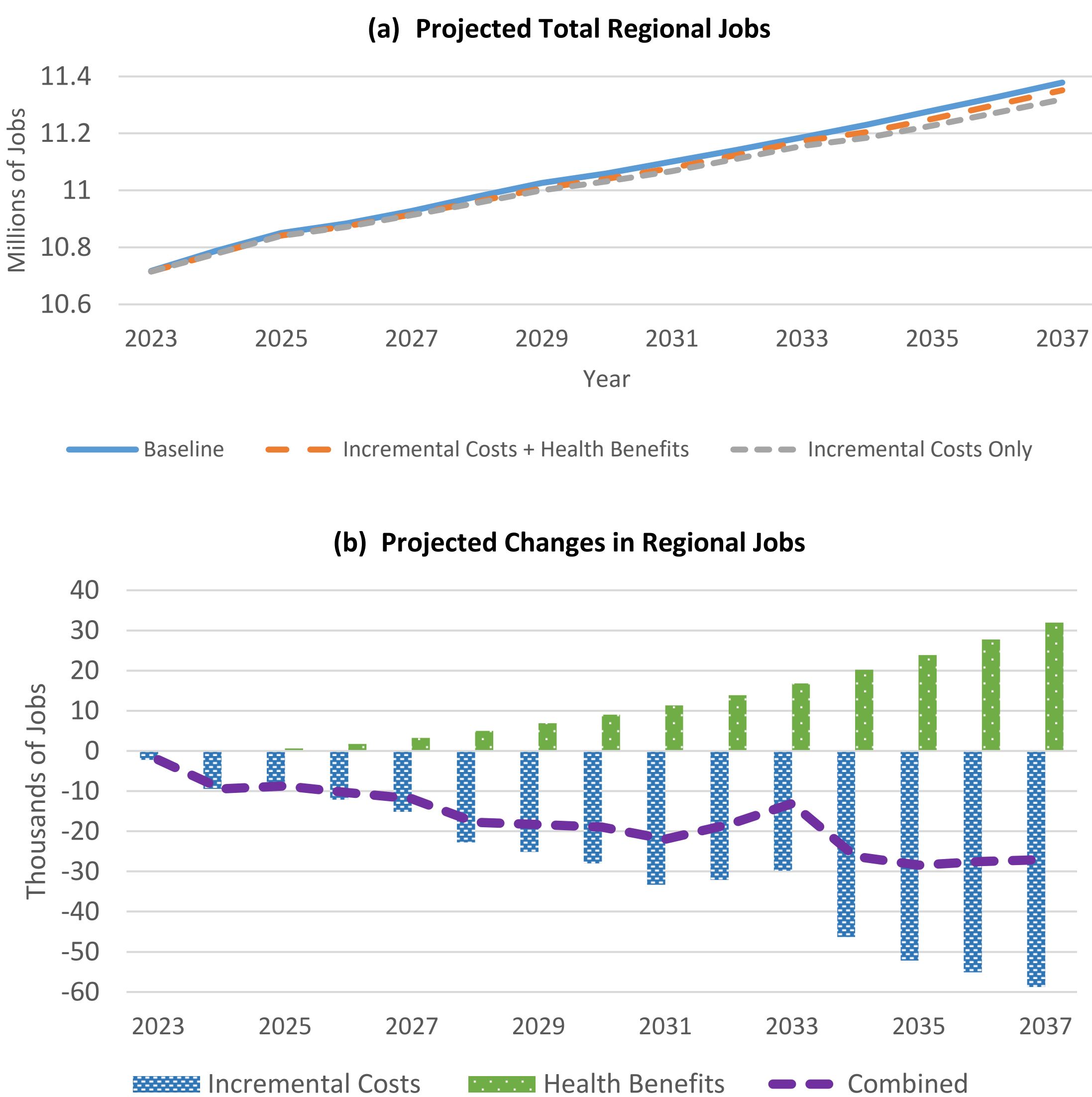
[11] The baseline scenario analyzed in this report is derived from the 2020 Growth Forecast, which is a long-term demographic and job forecast developed by the Southern California Association of Governments (SCAG 2020). SCAG's growth forecast was used to guide the development of its 2020 Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS), and it was also used by South Coast AQMD to develop the baseline emissions inventory for the 2022 AQMP and thus for air quality model projections. This growth forecast assumes that the four-county region would continue receiving federal highway funding to make the necessary infrastructure investments for implementing the 2020 RTP/SCS. The technical report can be accessed at https://scag.ca.gov/sites/main/files/file-attachments/0903fconnectsocal_demographics-and-growth-forecast.pdf?1606001579.

[12] Jobs foregone shown here are annual averages and apply only on a yearly basis. Foregone jobs should not be added across years. See 'Job Impacts Explained' callout box in Chapter 4 for further discussion.

slowdown in job growth relative to the projected employment baseline.[13] See Figure ES-1(a) for estimated total jobs in the region between 2023 and 2037.

Whether or not monetized health benefits are included, an increasing number of jobs foregone are anticipated over the next 15 years due to the fact that the proposed control measures would be phased in over time. For example, most of South Coast AQMD control measures are forecasted to begin implementation in 2033 or later. While the impact of the incremental costs would result in net negative job impacts, they are partially offset by the anticipated health benefits of implementing the proposed control measures, which are concurrently increasing over time as seen in Figure ES-1(b).

FIGURE ES-1: NET JOB IMPACTS OF THE 2022 AQMP IMPLEMENTATION



[13] Annualized job growth rates were calculated incorrectly in the Draft Socioeconomic Report and have been corrected.

Overall, inequality of adverse health outcomes is expected to decrease in the region, with greater per-capita public health benefits accrued in Environmental Justice (EJ) communities versus non-EJ communities

Many residents who live, work, and play in areas with poorer air quality throughout the region are often more economically disadvantaged. Since the adoption of State Assembly Bill 617 (AB617) in July 2017, South Coast AQMD has enhanced its EJ programs by identifying specific communities disproportionately impacted by poor air quality and higher mortality and morbidity risks of the residents therein. The EJ analysis assesses the impacts of implementing the 2022 AQMP by answering these two important questions:

1. How does implementing the 2022 AQMP impact the inequality of health risk that already exists in the region?
2. Do more health benefits accrue in EJ versus non-EJ communities as a result of implementation of the 2022 AQMP?

The analysis found that region-wide improvements in air quality and public health would be accompanied by reduced inequity in health risk between EJ and non-EJ communities, including the risk of dying prematurely or suffering from asthma as a result of exposure to ozone and PM2.5. Improved health outcomes will result in greater monetized health benefits across the region, but more in EJ communities than in non-EJ communities. Monetized benefits range between $3,400 and $3,700 per capita in EJ communities, approximately $300 to $700 higher than for non-EJ communities (about 15%). These results are consistent across all alternative EJ definitions tested.[14]

Conclusion

Overall, the implementation of the 2022 AQMP is expected to result in $2.85 billion of average annual incremental cost, while generating public health benefits of $19.4 billion annually, which is well above the estimated incremental cost. Cumulatively up to 2037, public health benefits are projected to amount to $134.3 billion in present value.[15] In an economy with more than a trillion dollars in regional GDP and more than 10 million jobs across the four counties, these costs and benefits were projected to result in relatively minor job impacts and would not alter the region's long-term job growth. Additionally, overall health risk inequality is expected to decrease throughout the region. While all residents would benefit from reductions in air pollution-related health risk, a higher per capita benefit is anticipated to accrue in EJ communities, as a result of implementing the 2022 AQMP.

[14] See Chapter 6 for more information of the EJ Analysis.

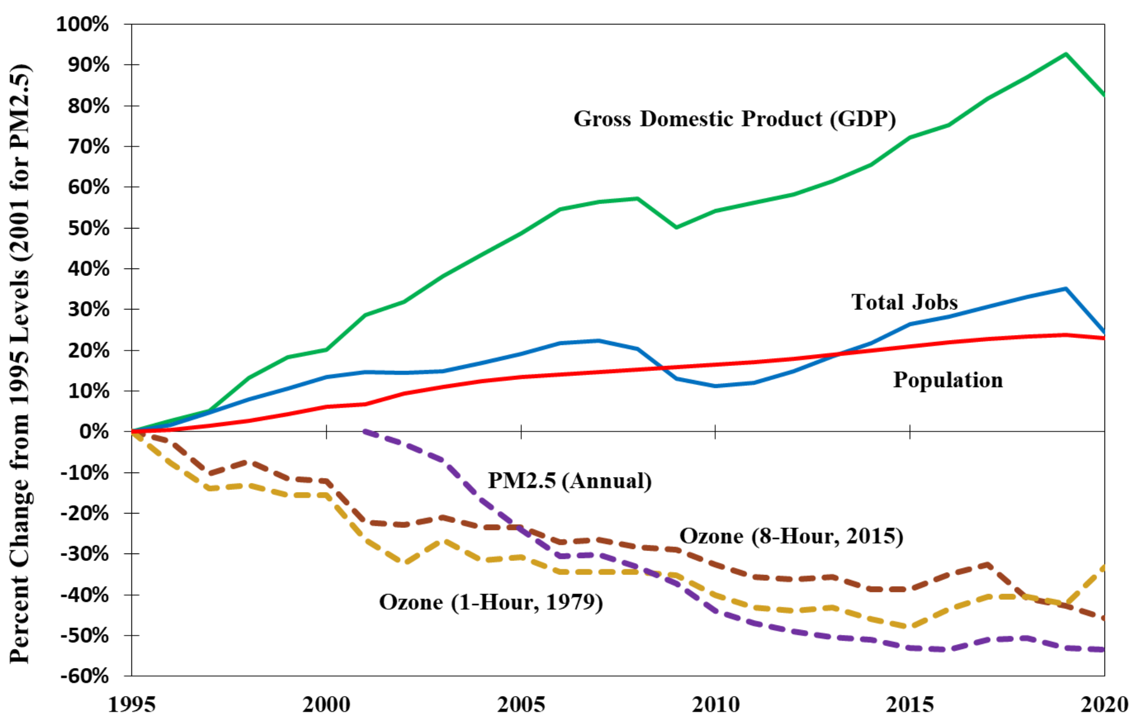
[15] Average annual monetized benefits between 2025 and 2037 is $19.4 billion annually, while projected annual monetized health benefits are $40.5 billion by 2037.

Chapter 1
Introduction

Air quality in the South Coast Air Basin (Basin) has improved substantially over the past decades, and air quality control programs at the local, state, and federal levels contribute to these improvements. These improvements are demonstrated in Figure 1-1, which shows historical air quality trends (dashed lines), including percent changes in 8-hour ozone and 1-hour ozone concentrations since 1995, and annual average fine particulate matter (PM2.5) concentrations since measurements began in 1999.[1]

Concurrent economic trends, including percent changes in regional gross domestic product, total jobs, and population, are also depicted in Figure 1-1. Over the past 15 years, both the subprime mortgage crisis induced 2008 recession and the coronavirus disease 2019 (COVID-19) induced 2020 recession reduced regional economic output and employment. Despite these ongoing challenges in the four-county region—Los Angeles, Orange, Riverside and San Bernardino counties, the macroeconomic forecast is expecting increases in jobs and population throughout the regional economy through the 2037 horizon in this report.

FIGURE 1-1: AIR QUALITY HAS IMPROVED AMID POPULATION INCREASES AND RISE IN ECONOMIC ACTIVITY (SOUTH COAST AQMD FOUR-COUNTY REGION, 1995-2020)



Note: Baseline year for regulatory PM2.5 measurement began in 2001.
Data Sources: SCAQMD, California Department of Finance, California Employment Development Department, U.S. Bureau of Economic Analysis, and REMI.

[1] Although PM2.5 measurements began in the South Coast AQMD air monitoring network in 1999, the first regulatory year of NAAQS PM2.5 data occurred in 2001.

Economic growth and other human activity generally result in increased air pollutant emissions due primarily to combustion of fossil fuels. Nonetheless, the increased utilization of low-emitting and more energy efficient technologies have resulted in decreased ozone and PM levels. Advances in technology demonstrate it is possible to maintain a healthy economy while improving public health through air quality improvements.

Recently, workplace adjustments in response to the COVID-19 pandemic induced widespread behavioral changes such as working from home (WFH). The emission inventories based on vehicle miles traveled (VMT) for light-duty vehicles relied on CARB's EMFAC 2017 model which predated the prevalence of work-from-home (WFH) observed during the pandemic. Subsequent iterations of EMFAC are expected to at least indirectly account for the emission impacts due to altered commute patterns associated with potentially sustained WFH. In the meantime, the continued expansion of electric car market also signals the beginning of a paradigm shift to more widespread penetration of zero-emission technologies, which has begun with light-duty applications (and accounted for in the projected baseline emissions inventory for the 2022 AQMP AQMP) and is anticipated to eventually expand into heavy-duty applications, facilitated by multiple regulatory and incentive measures.

Challenges to Attaining Air Quality Standards

While substantial progress and improvements in air quality have been made, the region still does not meet all federal and state air quality standards set to protect public health. The 2022 AQMP Air Quality Management Plan (AQMP) is designed to provide a path to clean air goals and address federal Clean Air Act (CAA) requirements for the most recent ozone standard – the 2015 8-hour ozone standard. The deadline for meeting that standard is 2037.

Areas that do not attain national ambient air quality standards (NAAQS) must develop and implement an emission reduction strategy that will bring the area into attainment in a timely manner. For ozone and PM2.5, the area is classified by the degree of nonattainment. This classification dictates specific planning requirements under the CAA, including the amount of time provided to attain the standard. The CAA requires attainment of the standard to be achieved as "expeditiously as practicable," but no later than the years listed in Table 1-1 below.

TABLE 1-1: U.S. EPA NATIONAL AMBIENT AIR QUALITY STANDARDS AND LATEST ATTAINMENT YEAR

Pollutant	Year Standard Approved	Measurement Timeframe	Concentration	Classification	Latest Attainment Year
Ozone	**1979**	**1-Hour**	120 ppb	Extreme	2022
	1997	**8-Hour**	80 ppb	Extreme	2023
	2008	**8-Hour**	75 ppb	Extreme	2031
	2015	**8-Hour**	70 ppb	Extreme	2037
PM 2.5	**2006**	**24-Hour**	35 µg/m^3	Serious	2019
	2012	**Annual**	12.0 µg/m^3	Moderate	2021
				Serious	2025

Note: "ppb" stands for parts per billion and "µg/m^3" stands for microgram per cubic meter.

Nitrogen oxide (NOx) emissions are the key pollutant that must be reduced to lower ozone concentrations.[2] Although existing air regulations and programs will continue to lower NOx emissions in the region, an additional 67% reduction beyond the 2037 baseline are necessary to attain the 8-hour ozone standards, which is equivalent to an 83% reduction from 2018 emissions.[3] Since NOx emissions also lead to the formation of PM2.5, the NOx reductions needed to meet the ozone standards will likewise lead to significant reduction in PM2.5 levels and attainment of PM2.5 standards.

Latest Scientific Evidence Relating Ozone and PM2.5 Exposure to Public Health

Ambient air pollution is a major public health concern. The U.S. EPA establishes NAAQS at levels that are protective of human health. Both ozone and PM2.5 are associated with significant health impacts and they continue to be linked to increases in illness (morbidity) and increases in death rates (mortality).[4]

As part of the process to review NAAQS, the U.S. EPA develops Integrated Science Assessments (ISAs). An ISA is a document that summarizes the best available science related to the health and welfare effects associated with a given criteria air pollutant. The 2020 U.S. EPA document, 2020 Ozone Integrated Science Assessment (ISA),[5] is the most recent ISA for ozone and describes the current state of the scientific knowledge and research. A summary of health effects information and additional references can also be

[2] NOx emissions are a precursor to the formation of both ozone and secondary PM2.5.

[3] Estimates are based on the inventory and modeling results and are relative to the baseline emission levels for each attainment year (see 2022 AQMP AQMP for detailed discussion).

[4] See Appendix I of the 2022 AQMP AQMP for a discussion of these studies.

[5] U.S. EPA. (2020). Ozone Integrated Science Assessment (Final Report); and U.S. EPA (2019). Particulate Matter Integrated Science Assessment. U.S. EPA is continuing to evaluate the effects of ozone: https://www.govinfo.gov/content/pkg/FR-2022-07-12/pdf/2022-14812.pdf.

found in the 2022 AQMP AQMP Appendix I: Health Effects. That document concluded that short-term exposures (lasting for a few hours) to ozone at levels typically observed in Southern California can result in breathing pattern changes, reduction of breathing capacity, increased susceptibility to infections, inflammation of the lung tissue, and some immunological changes. Elevated ozone levels are associated with asthma exacerbation, chronic obstructive pulmonary disease (COPD) exacerbation, respiratory infection, increased school absences and hospital admissions and emergency department (ED) visits for combined respiratory diseases, as well as increased mortality. An increased risk for asthma has been found in children who participate in multiple sports and live in high-ozone communities.

The most recent ISA for particulate matter was released in 2019, and updated with a supplement in 2022.[6] The 2019 ISA and the supplement concluded that both mortality and cardiovascular effects had a causal relationship with both short- and long-term PM2.5 exposures. Several studies have found correlations between elevated ambient particulate matter levels and an increase in mortality rates, respiratory infections, number and severity of asthma attacks, COPD exacerbation, combined respiratory-diseases and the number of hospital admissions in different parts of the United States and in various areas around the world.

Higher levels of PM2.5 have also been related to increased mortality due to cardiovascular or respiratory diseases, hospital admissions for acute respiratory conditions, school absences, lost work days, a decrease in respiratory function in children, and increased medication use in children and adults with asthma.

Long-term exposure to PM has been found to be associated with reduced lung function growth in children, changes in lung development, development of asthma in children, and increased risk of cardiovascular diseases in adults. In recent years, studies have reported an association between long-term exposure to PM2.5 and increased total mortality (reduction in life-span and increased mortality) from lung cancer.

The U.S. EPA, in its most recent review, has concluded that both short-term and long-term exposure to PM2.5 are causally related to cardiovascular effects and increased mortality risk. In addition, new evidence is suggestive of metabolic, nervous system, and reproductive and developmental effects for short-term and long-term exposure to PM2.5. More detailed summaries of the health effects associated with ozone and particulate matter are available in Appendix I to the 2022 AQMP AQMP.

Legal Requirements for Socioeconomic Analysis

Both the South Coast AQMD Governing Board and the California Health & Safety Code require preparation of a socioeconomic analysis whenever the South Coast AQMD adopts or amends emission reduction rules or regulations. Although these requirements do not apply to preparation of the AQMP, the South Coast AQMD nonetheless elects to perform a separate socioeconomic analysis of the AQMP in order to further inform public discussions and the decision-making process associated with adoption of the Plan.

In so doing, staff is guided by a Governing Board Resolution adopted in 1989. That resolution directed staff to prepare an economic analysis of all emissions reduction rules proposed for adoption or amendment. The analysis includes the following elements: identification of affected industries, cost

[6] U.S. EPA. (2019). Integrated Science Assessment for Particulate Matter (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-19/188.

effectiveness of control, and public health benefits in any such analysis.

Staff is additionally guided by the California Health & Safety Code requirements for socioeconomic analyses prepared during the rulemaking process. In particular, Health and Safety Code Section 40440.8 lists relevant impacts to be considered in a socioeconomic analysis. These impacts include:

1. The type of industries affected by the rule or regulation.
2. The impact of the rule or regulation on employment and the economy in the Basin.
3. The range of probable costs, including costs to industry, of the rule or regulation.
4. The availability and cost-effectiveness of alternatives to the rule or regulation.
5. The emission reduction potential of the rule or regulation.
6. The necessity of adopting, amending, or repealing the rule or regulation in order to attain state and federal ambient air standards.

Health and Safety Code Section 40728.5 identifies similar impacts to be discussed in a socioeconomic analysis and additionally states that efforts shall be made to minimize any adverse impacts.

Finally, Health and Safety Code Sections 39616 and 40920.6 also address the preparation of socioeconomic analyses. Section 39616 requires the South Coast AQMD to ensure that any market-based incentive strategy it adopts results in equivalent or greater emission reductions at equivalent or less cost and overall job impacts – i.e., no greater job losses or significant shifts from high-paying to low-paying jobs – when compared to command-and-control regulations. Section 40920.6, requires that incremental cost effectiveness – i.e., the difference in costs divided by difference in emission reductions – be performed whenever more than one control option is feasible to meet control requirements.

Economic Outlook for Industries Potentially Affected by the 2022 AQMP AQMP

Nearly 18 million people currently reside in the counties of Los Angeles, Orange, Riverside and San Bernardino. The four-county regional economy generates over one trillion dollars of gross domestic product and employs more than 8 million workers, with a four to six percent unemployment rate among the four counties.[7,8,9] The region currently supplies more than 10 million jobs including nearly 8 million payroll jobs.[10] Between February 2018 and February 2020, total payroll jobs in the region increased at an

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[7] State of California, Department of Finance, E-1 Population Estimates for Cities, Counties and the State with Annual Percent Change — January 1, 2020 and 2021. Sacramento, California, May 2021 https://dof.ca.gov/wp-content/uploads/Forecasting/Demographics/Documents/E-1_2021PressRelease.pdf.

[8] U.S. Dept. of Commerce, Bureau of Economic Analysis, GDP by County, Metro, and Other Areas https://www.bea.gov/data/gdp/gdp-county-metro-and-other-areas.

[9] California Economic Development Department (EDD), August 2022, civilian employment only. A five-percent unemployment rate is generally considered as "full employment" by the Federal Reserve. LA, Orange, and Riv-SB counties data. https://www.labormarketinfo.edd.ca.gov/file/lfmonth/la$pds.pdf.

[10] Total employment is based on the Bureau of Economic Analysis 2020 estimates. Payroll employment is based on the EDD Current Employment Survey (CES) total nonfarm employment estimates as of July 2022 for Anaheim-Santa

annualized rate of almost 2 percent in Los Angeles and Orange Counties, while job growth in Riverside and San Bernardino Counties grew over 3 percent annually, before economic impacts of COVID-19 shutdowns.[11]

It is estimated that the economic impacts of COVID-19 beginning in March 2020 accounted for a regional job loss of 700,000 jobs. By September 2021, more than half of the lost jobs were recovered, and it is projected that the region will return to its pre-pandemic job levels by the end of 2022.[12] Between February 2018 and February 2022, payroll jobs decreased slightly in Los Angeles and Orange Counties due to lingering impacts of the COVID-19 pandemic that began in March 2020 in California (-0.6 percent and -1.24 percent, annually, respectively), while Riverside and San Bernardino counties still saw annualized growth in payroll jobs over 2.3 percent, or 9.4 percent over a 4-year period. Based on projections by the Southern California Association of Governments (SCAG), total jobs in the region are forecasted to grow at an annualized rate of 0.6 percent between 2024 and 2050.[13]

The 2022 AQMP AQMP includes control strategies for emission reductions from both stationary and mobile sources to attain upcoming NAAQS. In that plan the South Coast AQMD has proposed both stationary source control measures as well as limited mobile source measures. The California Air Resources Board (CARB) has proposed broader mobile source control measures. This division is consistent with South Coast AQMD's primary regulatory authority over stationary sources and limited regulatory authority over mobile sources, and CARB's primary regulatory authority over mobile sources. The control strategies in the plan could potentially affect both public and private sectors, but are expected to mainly impact the nine private sector industries as listed below:

- Oil & Gas Extraction
- Utilities
- Construction
- Manufacturing
- Retail Trade
- Wholesale Trade
- Transportation & Warehousing
- Real Estate & Rentals
- Administrative & Waste Management Services
- Restaurants & Accommodation

Ana-Irvine, Los Angeles-Long Beach-Glendale metro divisions, and Riverside-San Bernardino-Ontario MSA. The EDD estimate does not include self-employed, family workers, and private household employees. https://data.edd.ca.gov/Industry-Information-/Current-Employment-Statistics-CES-/r4zm-kdcg.

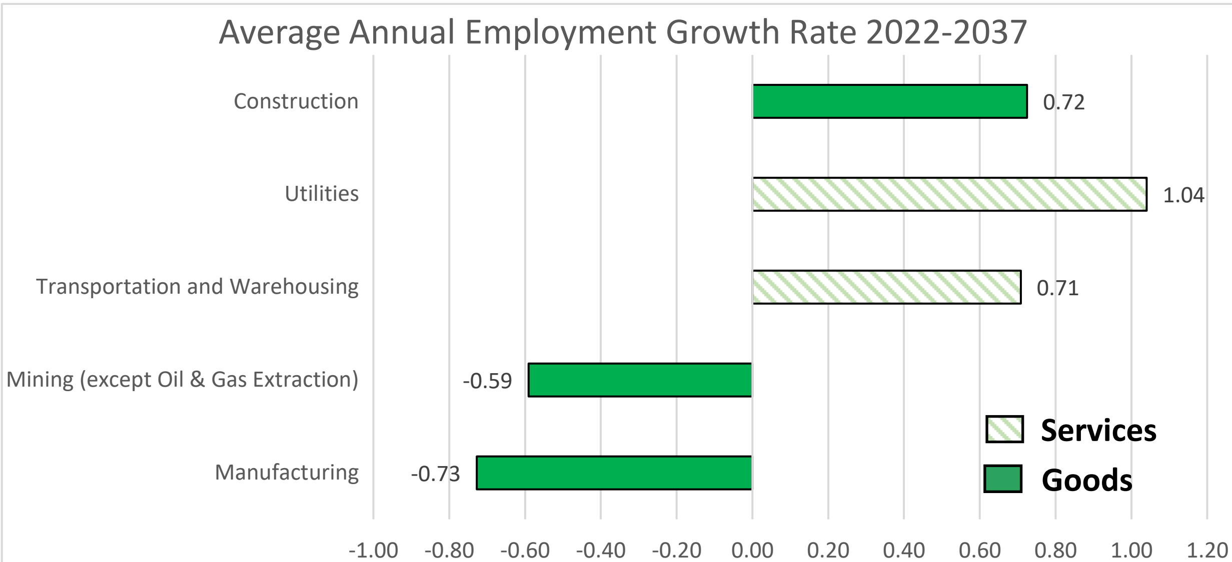
11 EDD, current employment statistics (CES), February 2018, 2020, and 2022. https://data.edd.ca.gov/Industry-Information-/Current-Employment-Statistics-CES-/r4zm-kdcg.

12 Southern California Association of Governments (SCAG), Connect SoCal 2024 Preliminary Regional and County Growth Projections, February 3, 2022 JPC Agenda #4, RC Agenda #16, https://scag.ca.gov/sites/main/files/file-attachments/cehd110421agn04.pdf?1645555889.

13 Ibid.

Figure 1-2 shows the regional job outlook between 2022 and 2037 for the potentially affected industries, based on SCAG projections.

FIGURE 1-2: JOB GROWTH RATES FOR KEY ECONOMIC SECTORS POTENTIALLY IMPACTED BY 2022 AQMP



Notes: Job growth projections are not available for the affected industries of nurseries and wholesale garden, equipment leasing and rental, and waste management, and restaurants.
Source: Staff analysis of SCAG's growth forecast in the 2024 Preliminary RTP/SCS Plan.

The goods movement sector plays a pivotal part in the regional economy. It provides the critical service of delivering goods between the region's seaports and airports and businesses across the nation. It also serves the fast-growing consumer demand for retail products purchased online.[14] The upsurge in e-commence and decreased delivery times for consumers has created a growing demand for distribution centers in the Inland Empire.

In the last four years the Ports of Los Angeles and Long Beach saw record growth in container volume despite a short disruption in the second quarter of 2020 during the peak economic effects of the global pandemic from COVID-19. The volume of TEUs (twenty-foot container equivalent units) saw significant growth between April 2020 and the peak in May 2021, when a slight downturn in container volume at the ports was due to a labor and logistics disruption that caused a backlog at the ports that recorded the worst levels in the fourth quarter of 2021.

Several mobile sources measures in the 2022 AQMP AQMP would affect the transportation and warehousing sector. This sector currently provides 422,134 payroll jobs or 5 percent of all payroll jobs in

[14] According to the 2022 market research by eMarketer, US e-commerce sales are projected to continue to grow by double digits, up 17.9% in 2021 to $933.30 billion. E-commerce penetration will continue to increase, more than doubling from 2019 to 23.6% in 2025.

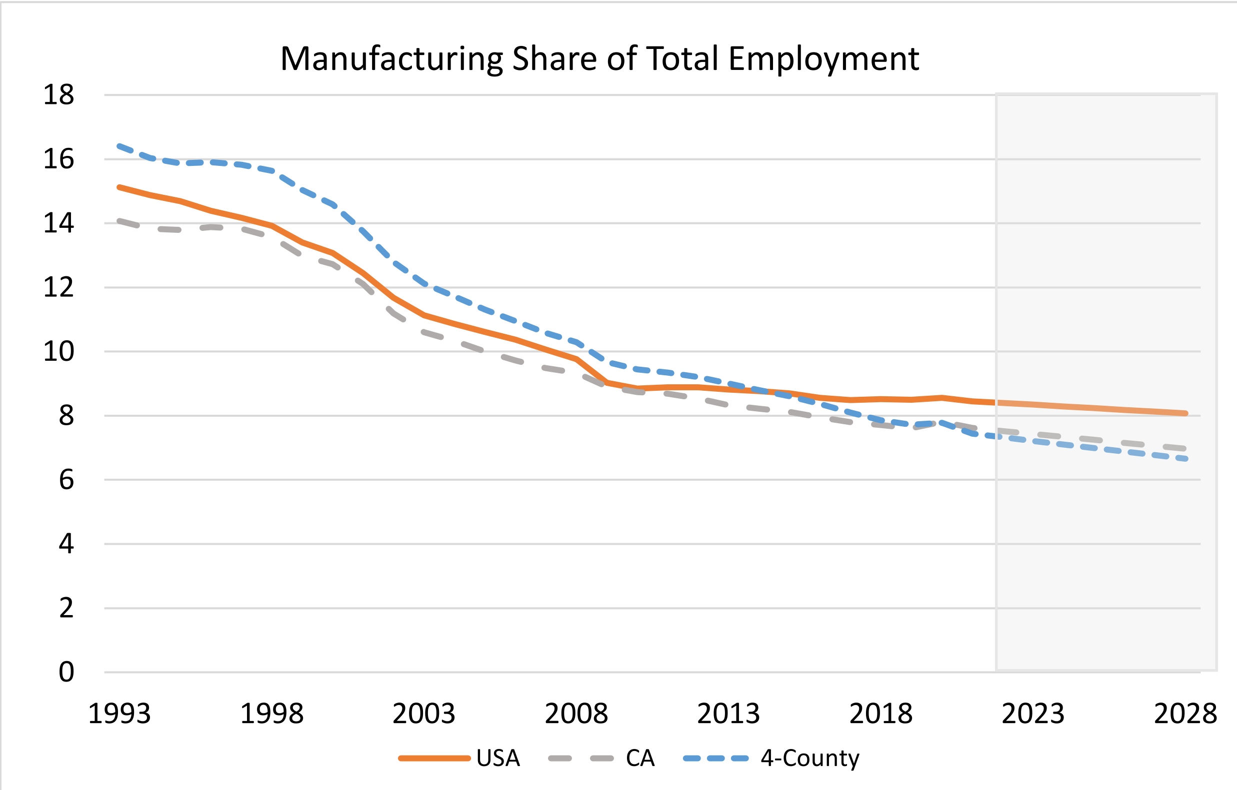
the region.[15] Over the next 15 years, the sector as a whole is expected to grow at an annualized rate of 0.71 percent. Much of this job growth will be concentrated in the Inland Empire. Currently, average pay in this sector ranges from $49,000 in Riverside County to $68,000 in Los Angeles County, which are respectively seven percent below the average wage in Riverside County and about the average wage in Los Angeles County.[16]

The manufacturing sector would be affected by stationary source measures targeting NOx and Volatile Organic Compound (VOC) emissions, which include both command-and-control regulations and incentive programs to accelerate facility modernization. In the meantime, transportation equipment manufacturers in the region and nationwide would benefit from the incentive programs proposed to accelerate the deployment of zero and low NOx emission technologies, as part of the mobile source control strategies. The manufacturing sector in the region currently provides 589,200 payroll jobs or about 7 percent of all payroll jobs in the region; however, the sector's total job count is expected to mirror the nationwide trend and continue its long-term decline (see Figure 1-3). Manufacturing jobs are projected to decrease by an annualized rate of 0.73 percent over the next 15 years. Three quarters of the projected manufacturing job losses would occur in Los Angeles County where the industry is concentrated.

[15] Based on EDD's CES for May 2022. All current job numbers listed below are from this source unless otherwise noted and unlike the BEA total jobs estimate that includes self-employment, CES estimates represent "payroll" jobs only.

[16] Historical wage data from California Employment Development Department's Quarter Census of Employment and Wage (QCEW) database for 2021 Q3 wages. All the wage data in this section is from this source unless otherwise noted and is reported for the county with the lowest average annual wage in a specific industry and the county with the highest. The average wage represents the average of all industries covered by QCEW in both private and public sectors. According to EDD, the average annual pay is affected by the ratio of full-time to part-time workers; the number of workers who worked for the full year; and the number of individuals in high-paying and low-paying occupations. When comparing average pay levels between geographic areas and industries, these factors should be taken into consideration. For example, industries characterized by high proportions of part-time workers will show average wage levels appreciably less than the pay levels of regular full-time employees in these industries. The opposite effect characterizes industries with low proportions of part-time workers, or industries that typically schedule heavy weekend and overtime work. Average wage data also may be influenced by work stoppages, labor turnover, retroactive payments, seasonal factors, bonus payments, and so on.

FIGURE 1-3: MANUFACTURING JOBS TREND



Despite the industry's shrinking workforce, its output per worker has increased over time, rising from \$95,300 to \$246,900 (in 2021 dollars) over the 2001 to 2020 time period.[17] Currently, the average pay in the sector ranges from \$58,500 in Riverside County to \$86,250 in Orange County, paying about a quarter more than the average wages in these counties. Both chemical manufacturers and refineries are expected to be impacted by stationary source measures. Chemical manufacturing has an average pay ranging from \$55,500 in Riverside County to \$78,900 in Los Angeles County. Petroleum refineries pays substantially higher, with an average pay of \$133,900 in Los Angeles County.

Transportation equipment manufacturing and related industries will be key partners in the joint effort to reduce mobile source emissions, as it plays a pivotal role in the research, development and deployment (RD&D) of advanced clean transportation technologies. Funding programs can help lower the upfront financial barriers for deploying cleaner technologies and realize long-term benefits such as fuel-savings. Long-term cost-savings can potentially become greater over time as the sector shifts towards producing not only the hardware but the software that will be needed to help increase fuel efficiency. Past funding programs have incentivized several truck engine manufacturers to develop and demonstrate that ultra-low NOx technologies (0.02 g/bhp-hr) are technologically feasible. CARB's current mobile source incentive programs are moving towards funding zero emission technology in the mobile fleet. Currently, the transportation equipment manufacturing industry in coastal counties provides 61,100 payroll jobs or nearly one percent of payroll jobs in the region and is projected to decline by 0.3 percent annually from 2022 to 2037. The average wage in this sector ranges from \$55,000 Riverside County to \$115,000 in Los Angeles County, which is about the overall average wage in Riverside County and nearly 60 percent higher

[17] Output from the U.S Bureau of Economic Analysis and employment data from the U.S. Bureau of Labor Statistics.

than the average wage in Los Angeles County.

Restaurants would be affected by a NOx measure that proposes the installation of cleaner cooking equipment. Restaurants are one of the region's major small business employers with nearly all establishments employing fewer than 100 people.[18] It currently provides over 625,000 payroll jobs and accounts for about nine percent of payroll jobs in the region. However, restaurants typically offer lower paying jobs—the recent annual compensation is on average about $25,000 in Riverside County to $29,000 in Los Angeles County, almost 60 percent below the average wages in these counties.

Energy producers, who are broadly considered to include the oil and gas extraction industry and the utilities sector, would also be affected by the proposed control measures. Oil and gas extraction is a highly capital intensive industry. While the industry's total output was as high as $2.4 billion in 2020,[19] it provides only a few thousand payroll jobs[20] in the region and pays on average six-figure wages that are similar to or higher than in the petroleum manufacturing industry. The industry sector of utilities currently provides nearly 20,000 payroll jobs in the region. It offers high paying jobs in all counties with average pay ranging from $101,000 in Riverside/San Bernardino Counties to $113,000 in Los Angeles/Orange Counties, which is 105 and 64 percent higher than the average wage in the respective counties. Job growth for energy producers is projected to grow just over one percent annually between 2022 and 2037.

Baseline Definition for Socioeconomic Assessment

A fundamental component in the practice of socioeconomic analysis is the definition of the baseline for analysis. The "baseline" is often referred to as the expected path (of pollution concentrations, the regional economy, etc.) without the implementation of a plan i.e. "policy". The difference between the baseline and policy scenario is the policy impact (an example of this is illustrated in Figure 1-4). For the purpose of this socioeconomic analysis, the impacts of the 2022 AQMP AQMP, which is implemented in the policy scenario,[21] are evaluated with respect to the baseline scenario, which is a projection of the regional economy *without* the implementation of the control measures described in the 2022 AQMP AQMP.[22] The baseline scenario is inclusive of any effects that have not yet occurred but are projected to occur as a result of all existing plans, regulations, and policies, including those adopted and implemented pursuant to previous AQMPs. Specifically, all South Coast AQMD rules adopted as of October 2020 as well as Rule 1109.1 – Emissions of Oxides of Nitrogen from Petroleum Refineries and Related Operations and all CARB rules adopted by December 2021, are incorporated into the baseline, while rules after these dates are not (for more information see 2022 AQMP AQMP Appendix III-B).

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[18] Based on the establishment-by-size data for the four counties from the U.S. Census Bureau's 2019 Statistics of U.S. Businesses Database, https://www.census.gov/data/tables/2019/econ/susb/2019-susb-annual.html.

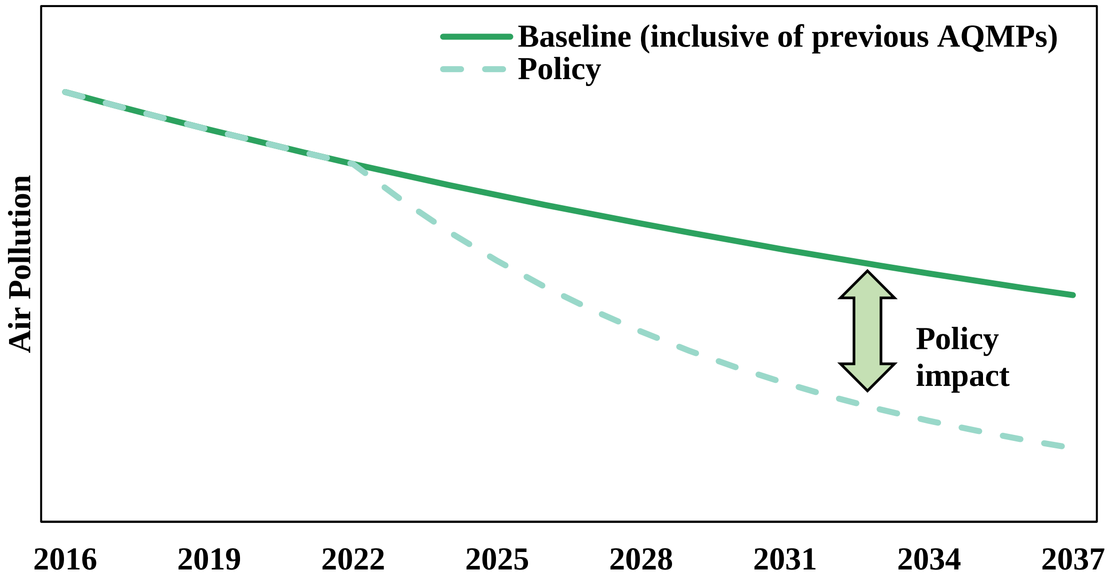
[19] Bureau of Economic Analysis. Real GDP figures expressed in 2021 adjusted dollars from chained 2012 dollars.

[20] CES data for Metro Los Angeles-Long Beach-Glendale for Petroleum Products Manufacturing estimates the current number of jobs at about 5,500. Moreover, the QCEW data indicated that, in Los Angeles County alone, the oil and gas extraction industry supplied approximately 1,600 jobs in 2021. https://www.labormarketinfo.edd.ca.gov/geography/md/los-angeles-long-beach-glendale.html.

[21] "Policy scenario" is used interchangeably with "control scenario" throughout the report, particularly in the discussion of regional air quality modeling as an input to the quantification of public health benefits.

[22] These "without" (baseline) and "with" (policy) scenarios compare different outcomes for the entire analysis horizon. "Base year" comparisons differ by looking only at a single base (or benchmark) year.

FIGURE 1-4: ILLUSTRATIVE EXAMPLE OF BASELINE AND POLICY SCENARIOS



The baseline scenario analyzed in this report is derived from the Connect SoCal 2020 Final Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS), which is a long-term demographic and job forecast developed by SCAG (SCAG 2020). SCAG's growth forecast in the 2020 RTP/SCS was also used to develop the baseline emissions inventory for the 2022 AQMP AQMP and thus for air quality model projections. This growth forecast assumes that the four-county region would continue receiving federal highway funding to make the necessary infrastructure investments for implementing the 2020 RTP/SCS. For this reason, the baseline scenario for both emission inventory and socioeconomic analysis purposes includes implementation of the 2020 RTP/SCS.

This socioeconomic analysis attempts to address any deviations from the baseline as the 2022 AQMP AQMP is fully implemented in terms of benefits of cleaner air, incremental costs of control strategies, and spillover impacts of direct benefits and costs. These deviations represent the socioeconomic impact of the 2022 AQMP AQMP, and they do not overlap with any cost, benefit, and macroeconomic impacts analyzed for the 2020 RTP/SCS. The impacts of the 2020 RTP/SCS are separately summarized and discussed in Appendix IV-C of the 2022 AQMP AQMP. Similarly, the air quality improvements projected in the 2022 AQMP AQMP do not overlap with any emission reductions attributable to the 2020 RTP/SCS or any of its components such as the Transportation Control Measures (TCMs). TCMs are included in the plan for air quality conformity purposes (for more information see Chapter 4 and Appendix IV-C of the 2022 AQMP AQMP.

This baseline definition is employed consistently throughout the socioeconomic analysis both for quantifying costs and benefits, and for determining regional macroeconomic impacts from implementation of the 2022 AQMP AQMP control strategies. The costs evaluated in this socioeconomic analysis are the total incremental cost expected to be incurred due to 2022 AQMP AQMP control strategies. Any costs and benefits associated with TCMs and TCM-type projects included in SCAG's 2020 RTP/SCS are excluded from this analysis. Public health benefits reflect air quality improvements attributable to the 2022 AQMP AQMP control measures. The regional macroeconomic impact model, REMI PI+ v3.0.0, baseline forecast is updated with the job and population forecasts from SCAG (2020), ensuring that the baseline used for costs and benefits analyses is consistent with that used for macroeconomic modeling.[23] (For more information see Appendix 4 of this report.)

The socioeconomic analysis horizon is from 2023 to 2037, where 2023 is expected to be the first year of implementing the 2022 AQMP AQMP control measures and 2037 is the last year of the planning horizon, at which time the federal 8-hour ozone standard would be attained. SCAG forecasts jobs and population in the four-county region to grow by 8.5 percent and 8.6 percent, respectively, from 2022 to 2037. The County of Riverside is projected to grow at the fastest pace: jobs are projected to increase by nearly 20 percent and population by nearly 19 percent over the period of 2019 to 2037.

Current Socioeconomic Analysis Program

South Coast AQMD staff continually improves its analysis of socioeconomic impacts by expanding the scope of analysis, as well as the methods and tools utilized. In preparation for development of the socioeconomic assessment of the 2022 AQMP AQMP, South Coast AQMD staff has consulted with the South Coast AQMD Advisory Council, the AQMP Advisory Group, the Scientific, Technical and Modeling Peer Review (STMPR) Advisory Group, SCAG, CARB, California Department of Finance, and U.S. EPA staff, as well as independent consultants to discuss possible and future refinements to data collection, modeling, and other aspects of socioeconomic of analyses.

Over the past 3 decades, South Coast AQMD socioeconomic analyses have evolved in many ways, as shown in Figure 1-5. South Coast AQMD's socioeconomic analytical evolution has been informed by two major reviews of the socioeconomic assessment procedures and guided by the STMPR Advisory Group members, who are economists from academia, other government agencies (SCAG, CARB, and U.S. EPA), and economic research and modeling firms (e.g., REMI). South Coast AQMD made refinements as a result of these two major reviews and has continued to make additional enhancements.

1992 Review Found South Coast AQMD Surpassed Most Agencies in Analytical Methods and Recommended Further Enhancements

The first comprehensive review of South Coast AQMD's socioeconomic assessment procedures was conducted by the Massachusetts Institute of Technology (MIT) in 1992 (Polenske et al., 1992). This review found South Coast AQMD surpassed most other agencies in analytical methods and recommended further enhancements, which included using alternative approaches in certain areas and working with the regulated community and socioeconomic experts to refine its socioeconomic assessment.

[23] The South Coast region has maintained strong job growth despite recent economic challenges, as the region outperformed SCAG employment projections between the years 2016 and 2020.

2014 Review Found South Coast AQMD's Socioeconomic Assessments Were More Comprehensive than the Majority of Other Agencies Considered and Made Recommendations for Improvements

In 2014, Abt Associates, Inc. (Abt) conducted a second comprehensive review of South Coast AQMD's socioeconomic assessments (Abt Associates, 2014). This review found South Coast AQMD's socioeconomic assessments are more comprehensive in both breadth and depth relative to those conducted by the majority of other agencies considered in Abt's evaluation. Abt found South Coast AQMD staff uses sound methodologies to analyze costs, health benefits, and economic impacts. For further enhancements, Abt provided a list of major and minor recommendations. These recommendations were followed in the analysis and socioeconomic report of the Final 2016 AQMP, and this report will continue this recommended approach.

The major recommendations concerned multiple areas. First, Abt recommended South Coast AQMD clearly define the baseline and policy scenarios, specifically, whether SCAG's TCMs and their associated benefits and costs are considered as part of the AQMP policy scenario. This is being addressed above, and baseline adjustments made to conform with the 2020 SCAG Growth Forecast can be found in Appendix 4-A of this report.

Second, while Abt supported the continued use of REMI for economic impact analysis, it recommended South Coast AQMD staff: 1) use other modeling tools and analysis for small industry sectors and small businesses; 2) improve the REMI amenity inputs; and 3) keep abreast of the U.S. EPA's development of methods for applying benefits in economy-wide models. This was addressed in several additional reviews conducted during and after the development of the Final 2016 AQMP Socioeconomic Report. Specific recommendations from these reviews have been and continue to be incorporated in South Coast AQMD's socioeconomic impacts assessments including in this report.

Third, Abt advised South Coast AQMD to improve the uncertainty analyses, expand the environmental justice (EJ) analysis, and institute a systematic process to review and update analytical methods based on recent literature in specific areas. This is being addressed throughout this report. EJ analysis is conducted in Chapter 6 of this report, as well as in the 2022 AQMP AQMP Chapter 8: Environmental Justice Communities.

Finally, in the interest of transparency, Abt recommended South Coast AQMD do the following: 1) continue to involve technical advisory groups; 2) increase public outreach; 3) make the peer review process clearer; and 4) enhance documentation and clarity to consider different types of audiences. The public process for developing the 2022 AQMP AQMP and its supporting documents including this report is discussed in the 2022 AQMP AQMP Chapter 9: Public Process and Participation.

In implementing some of these recommendations, staff held multiple study sessions with SCAG staff and consultants and came to consensus on the most suitable approach to define the baseline for the socioeconomic analyses. Three Requests for Proposals were issued relative to analysis of health benefits, environmental justice, and small scale economic impacts. A contract was issued for a third-party evaluation of macroeconomic modeling of public health and other non-market benefits. Based on a stakeholder request that was documented in the Abt report, but not recommended in the Abt report, South Coast AQMD entered into a separate contract for analysis of the health impacts of unemployment in the South Coast AQMD region. The findings of the latter two contracts were published and made available to the public (Lahr 2016; Tekin 2015).[24]

South Coast AQMD Made Enhancements in Addition to Those Recommended by the Reviews

Between the two comprehensive reviews of South Coast AQMD's socioeconomic assessments performed in 1992 and 2014, there have been other key enhancements to the South Coast AQMD's socioeconomic assessments. In 2000, towards the goal of expanding its analysis tools, South Coast AQMD staff commissioned BBC Research and Consulting to examine approaches to assess impacts of proposed regulations on a spectrum of facilities and to evaluate impacts of rules after their adoption. The study results indicated the need to employ a variety of external data sources, construct internal time series data, and explore data sharing opportunities with other governmental agencies.

Beginning in 2000, published economic statistics at the industry level moved away from the Standard Industrial Classification (SIC) system to the North American Industrial Classification System (NAICS) to include new and emerging industries such as information technologies, among others. In 2006, all potentially affected point source facilities in the 2002 emission inventory were re-designated with appropriate NAICS codes.

The American Community Survey (ACS) continuously samples population to provide up-to-date demographic statistics to supplement information not provided by decennial censuses. There are ACS one-year, three-year, and five-year estimates for various purposes. The 2006 to 2008 estimate was used to expand the four-county geography to 21 sub-regions from the previous 19 regions.

Since 2007, South Coast AQMD staff has used the U.S. EPA's Environmental Benefits Mapping and Analysis Program (BenMAP) to assess health benefits associated with reductions in exposure to criteria pollutants. BenMAP was developed and is used by the U.S. EPA to assess health benefits of federal rules.[25] BenMAP is a geographic information system (GIS) application which integrates epidemiological studies, air quality and demographic data, and economic valuation methodologies to quantify health effects and economic values associated with changes in pollutant concentrations.

In 2015, an Ad Hoc Governing Board Committee on Large Compliance Investments and Regulatory Uncertainty was formed to evaluate concerns raised by the business community regarding investing in pollution control technologies only to have them become stranded assets as a result of later rule amendments. In 2016, the 2016 AQMP--Socioeconomic Assessment EJ Working Group was formed to further engage stakeholders to help staff enhance the impact analyses on EJ communities.

Since 2016, South Coast AQMD has implemented additional enhancements to the costs, benefits, macroeconomic impact, and EJ analyses. They include improving the uncertainty analyses, increasing the

[24] The Evaluation of Macroeconomic Impacts of Non-Market Benefits can be found here: http://www.aqmd.gov/docs/default-source/clean-air-plans/socioeconomic-analysis/lahr_evalmacroeconimpacts_041716.pdf.
The Final Report on Unemployment and Health can be found here: http://www.aqmd.gov/docs/default-source/clean-air-plans/socioeconomic-analysis/unemploymentandhealth_dec2015_012616.pdf.

[25] Since 2015 the U.S. EPA released an open-source software platform of called the Environmental Benefits Mapping and Analysis Program – Community Edition (BenMAP-CE) (Sacks et al., 2020). Beginning with the 2016 AQMP, South Coast AQMD socioeconomic staff has used BenMAP-CE to assess health benefits associated with reductions in exposure to criteria pollutants. Prior AQMP's used earlier versions of BenMAP.

transparency of the analyses, increasing public outreach, making the peer review process more transparent, and enhancing documentation and clarity to consider different types of audiences. Socioeconomic analyses prepared by the South Coast AQMD have integrated the use of additional modeling tools like EMSI (Economic Modeling, Inc., current version 2022.3) for higher resolution industry and demographic detail in the impact analysis. In the meantime, health benefit estimates developed in the Final 2016 AQMP Socioeconomic Report were further applied using the benefits-per-ton method to estimate potential health benefits associated with major rules adopted in recent years, including Rules 2305 – Facility Based Mobile Source Measures and 1109.1– Emissions of Oxides of Nitrogen from Petroleum Refineries and Related Operations.

FIGURE 1-5: EVOLUTION OF SOCIOECONOMIC ANALYSIS

Pre 1989

1. Cost Effectiveness
2. Affected Sources

1989

3. Affected Industries
4. Range of Control cost
5. Public Health Benefit

1990-1992

6. Job & Other Socioeconomic Impacts of CEQA Alternatives
7. High- vs Low- Paying Job Impacts
8 Consumer Price Impacts by Income Group
9. Relative & Absolute Impacts

1993-2003

10. Individual Industry Studies, Facility-Based, and Post-Rule Assessment
11. Impacts on Sub-industries
12. Quantification of More Health Effects
13. Refined Visibility Benefit
14. Cost & Benefit Impacts for Sub-counties
15. Job & Other Economic Impacts for Sub-counties

2004-2007

16. Sensitivity analysis of Public Health Benefits
17. Switch to NAICS from SIC
18. Multi-function Health Effect Assessment
19. 2000 Census PUMS Data

2008-2014

20. American Community Survey Multi-Year Summary Files
21. Refined Sub-county Geography

2015-2020

22. Levelized Cash Flow & Discounted Cash Flow Cost-Effectiveness
23. Improve Uncertainty Analysis
24. Increase the Transparency of the Analyses
25. Enhance Documentation and Clarity
26. Evaluation of Macroeconomic Modeling of Public Health and other Non-Market Benefits
27. Enhance Health Benefits and Environmental Justice Analysis
28. Further Update Health Benefits and Valuation Literature
29. Update Literature Review for Visibility, Material, and Agricultural Benefits
30. Evaluate the Use of other Modeling Tools (EMSI) to Supplement the REMI Model for Small Scale Impacts
31. Monitored U.S. EPA Economy-Wide Modeling Panel Discussions and Recommendations

Future Improvements

Post 2020

32. Update Best Practices for Estimating Small Business Impacts using EDD database
33. Expand Job Impacts by Race and Ethnicity, etc. using REMI's SEI Module

Chapter 2
Incremental Costs

The 2022 AQMP control strategies seek emission reductions from stationary and mobile sources through command-and-control regulations and incentives to accelerate deployment of cleaner equipment. The cost analysis herein quantifies the incremental cost associated with the additional actions needed to achieve sufficient emission reductions for attaining the 2015 federal ozone standard by 2037.

What is Quantified in the Estimated Costs of 2022 AQMP Measures?

Estimated costs associated with the 2022 AQMP are characterized as incremental costs, not as the total cost of a particular control equipment or program. Specifically, the estimated costs represent the cost difference between the baseline scenario and the policy scenario where proposed control measures in the 2022 AQMP are implemented to reach the 2037 ozone attainment target. The cost estimates presented here are based on the best information available at this time, however cost estimates are expected to be refined as new information and analysis becomes available during subsequent rulemaking and control measure implementation.

Total incremental costs are calculated as the sum of incremental capital costs (e.g., equipment purchases and installation costs) and future incremental recurring costs over the equipment's expected lifetime associated with operation and maintenance (e.g., filter replacement and fuel costs/savings).[1] The present value, or interchangeably present worth value (PWV), of incremental capital costs is calculated by multiplying the unit cost of equipment by the number of affected units and discounting them from the year of capital spending back to the present year 2022.[2] The present value of incremental recurring costs is calculated by multiplying recurring costs or savings over the lifetime of the equipment by the number of affected units and discounting back to 2022. The present value of incentives is also discounted back from the year of capital spending to 2022. All present values are expressed in 2021 dollars. More details about the assumptions of cost estimates for each control measure can be found in Appendix 2A.

Similar to previous AQMPs, the 2022 AQMP contains control strategies with quantified emission reductions, as well as control measures with to-be-determined (TBD) emission reductions. The 2015 federal ozone standard is expected to be attained by 2037 with the quantified emission reductions alone.[3] For the cost analysis in this report, incremental costs are estimated only for control strategies with quantified emission reductions.

[1] CTS-01 (Coatings, Solvents, Adhesives, and Lubricants) has a reformulation cost and is calculated by multiplying the price difference between compliant/non-compliant products and the annual sales of the product (in tons).

[2] A discount rate of four percent is used in the Final Socioeconomic Report for the 2022 AQMP. See Appendix 2-A for more discussion on the discount rate.

[3] Control measures *without* quantified costs or emission reduction estimates were not analyzed nor included in the estimates towards the attainment of the 2015 ozone standard to meet attainment by 2037. Future rule development will quantify specific costs and emission reductions as details on emission control technologies are evaluated and deployed. Many of the control measures with quantified costs and emission reductions may still require flexibility as provided under the Clean Air Act section 182 (e)(5). The additional control measures in the 2022 AQMP with TBD emission reductions and costs are needed to assist in achieving the emission reduction commitments covered by section 182 (e)(5) measures. Specific emissions reductions and costs will be determined as these measures are developed.

Cost Summary of 2022 AQMP Measures

As seen in Table 2-1A, the total amortized annual average of incremental costs from defined South Coast AQMD control measures in the 2022 AQMP is estimated to be about $1.16 billion per year between 2023 and 2037, or about 0.08 percent of the $1.2 trillion of annual gross domestic output in the region.[4] Alternatively, we can also measure the total incremental costs associated with all costs tied to the equipment purchased and installed as a result of South Coast AQMD control measures in the 2022 AQMP, whether the costs are incurred before or after 2037. The present value of all such incremental costs is estimated to be $34.3 billion when all costs are discounted to the current year of 2022.The present value costs are expected to be about $10.8 billion during the period from 2023-2037. Post-2037 costs are incurred due to equipment that is installed before 2037, but whose operation and maintenance costs, along with amortized capital costs, may extend beyond 2037 and over the entire lifetime of the equipment.

The discount rate used in this analysis for discounting and amortization corresponds to a real interest rate of four percent. As a sensitivity test, a real interest rate of one percent—which until recently had been closer to the prevailing real interest rate—was used. Assuming a real interest rate of one percent, the amortized annual average cost of the South Coast AQMD's 2022 AQMP was estimated at $1.07 billion per year between 2023 and 2037. Amortization was performed for the upfront costs, mainly for expenditures related to capital outlay, over the equipment lifetime. However, many categories of equipment have an expected lifetime that will extend well beyond 2037. Therefore, the amortized annual average between 2022 and 2037 does not reflect the entire present worth value of the total incremental costs. The amortized annual average can be considered as the expected spending per year between 2023 and 2037, if the affected entities would be able to finance their upfront costs and pay off the loan over the equipment lifetime with an equal number of annual installments.

[4] Gross domestic product (GDP) data downloaded from the Bureau of Economic Analysis (https://www.bea.gov/data/gdp/gdp-county-metro-and-other-areas). 2020 GDP totaled $1.2 trillion in 2020 dollars for the four-county region of Los Angeles, Orange, Riverside, and San Bernardino counties. GDP values were converted from 2012 to 2020 dollars using the national GDP deflator (https://fred.stlouisfed.org/series/GDPDEF).

Table 2-1A: Estimated Incremental Costs of 2022 AQMP - South Coast AQMD Measures (Millions of 2021 dollars)*

Control Measure	Beginning Year of Measure Implementation for Cost Analysis	Present Value of Incremental Cost**	Annual Average of Amortized Cost, 2023-2037
South Coast AQMD Stationary and Area Sources Measures with Quantified Emission Reductions***			
C-CMB-03: Commercial Cooking	2031	$1,950.1	$71.8
C-CMB-05: Miscellaneous Small Commercial Combustion Equipment (Non-permitted)	2033	$3,489.1	$110.2
L-CMB-01: NOx RECLAIM	2033	$25.7	$0.7
L-CMB-02: Large Boilers and Process Heaters	2033	$2,578.9	$73.4
L-CMB-03: Large Internal Combustion Prime Engines	2033	$665.2	$14.9
L-CMB-04: Large Internal Combustion Emergency Standby Engines	2033	$7,469.7	$153.3
L-CMB-05: Large Turbines	2037	$281.5	$2.1
L-CMB-06: Electric Generating Facilities	2033	$8,457.1	$267.1
L-CMB-07: Petroleum Refining	2033	$239.2	$7.6
L-CMB-08: Landfills and POTWs	2037	$136.7	$1.0
L-CMB-09: Incineration	2033	$5.1	$0.2
L-CMB-10: Miscellaneous Combustion	2033	$251.0	$6.3
R-CMB-03: Residential Cooking	2029	$371.6	$19.4
R-CMB-04: Residential Other Combustion	2029	$2,588.9	$125.4
FUG-01: Improved Leak Detection and Repair	2032	$115.3	$4.4
CTS-01: Further Emission Reduction from Coatings, Solvents, Adhesives, and Sealants	2024	$51.0	$4.7
Subtotal of Incremental Costs:		**$28,676.2**	**$862.3**
South Coast AQMD Area Source Incentive Measure with Quantified Emission Reductions			
C-CMB-04: Small Internal Combustion Engines (Non-permitted)	2033	$3,720.3	$122.5
South Coast AQMD Mobile Source Incentive Measures with Quantified Emission Reductions			
MOB-05: Accelerated retirement of older light-duty and medium-duty vehicles	2023	$169.0	$14.9
MOB-11: Emission reductions from incentive programs	2023	$1,764.4	$155.3
Subtotal of Incentive Costs:		**$5,653.7**	**$292.7**
Total for South Coast AQMD Control Measures:		**$34,329.9********	**$1,155.1**

* A 4% real interest rate was used for both present value and amortized cost calculations. All numbers are rounded to the first decimal place and may not sum up to the total.

** Including incremental capital and operating & maintenance (O&M) costs estimated over the entire lifetime of equipment, which may occur well beyond 2037. Discounted to 2022.

*** R-CMB-01, R-CMB-02, C-CMB-01, and C-CMB-02 are excluded from this table to avoid potential double counting. These four measures would work in conjunction with CARB's Zero-Emission Standard for Space and Water Heaters measure and affect largely the same sources.

**** The present value of incremental costs from 2023-2037 for South Coast AQMD measures, discounted to 2022 (in millions of 2021 dollars) is $10,773.

Two South Coast AQMD mobile source measures for which additional quantifiable NOx emission reductions were identified, MOB-05 and MOB-11, are both incentive measures. The total amount of incentive grants anticipated is estimated to be $1.9 billion (present value), with an amortized annual average of $170.3 million between 2023 and 2037. One of these measures focuses on turning over older light- and medium-duty vehicles (MOB-05) and the other measure (MOB-11) accounts for reasonably expected emission reductions from future projects enabled by current incentive programs administered by the South Coast AQMD.[5]

South Coast AQMD control measures have the largest cost impact in the industrial sector with nearly 59 percent of the total incremental cost at $20.1 billion in present value, or $526 million in amortized annual average cost. Incentive measures total $5.7 billion (16 percent) in present value costs, or $293 million in amortized annual average. The commercial sector is affected by $5.4 billion in present value cost (16 percent), or $182 million in amortized annual average. Control measures affecting residential sources total $3.0 billion in present value costs (8.6 percent), or $145 million in amortized average annual. Lastly, control measures affecting VOC emissions total $166.3 million in present value costs (0.4 percent), or $9.1 million in amortized annual average.

As shown in Table 2-1B, the total amortized annual average of incremental costs from defined CARB control measures in the 2022 AQMP is estimated to be about $1.7 billion per year between 2023 and 2037. This amount represents the net amortized annual average costs estimated for CARB's control measures with available cost data and includes cost-savings coming from CARB's Clean Miles Standard regulation. CARB control measures predominantly target mobile source emissions. Approximately 85 percent of the CARB measures' annual amortized cost can be attributed to mobile source measures, which come from turning over on-road medium and heavy-duty vehicles like trucks and buses as well as requiring the deployment of cleaner off-road technologies used in locomotives, ocean-going vessels, aircraft, and construction equipment. The remaining 15 percent of CARB control measure costs is attributed to two area source measures, totaling 254 million in amortized annual costs between 2023 and 2037.

CARB's mobile source control strategies, while contributing to about 51 percent of combined South Coast AQMD and CARB measures' annual average cost from 2023 through 2037, would lead to about 75 percent of the NOx emission reductions needed to attain the 8-hour ozone standard by 2037. This large share reflects the large amount of NOx emissions generated from mobile sources, which contributed more than 80 percent of the region's total NOx emissions.[6]

[5] Some of the main incentive programs administered by the South Coast AQMD that are included within MOB-11 are the Carl Moyer Memorial Air Quality Standards Program, the Goods Movement Emission Reduction Program (Proposition 1B), the Lower-Emission School Bus Program, the Volkswagen Environmental Mitigation Trust for California, and the Community Air Protection Program. See Appendix IV-A of the 2022 AQMP for further discussion.

[6] Detail for mobile source emission inventory is explained in the 2022 AQMP Chapter 3 and Appendix III.

TABLE 2-1B: ESTIMATED INCREMENTAL COSTS OF 2022 AQMP - CARB MEASURES (MILLIONS OF 2021 DOLLARS)*

Control Measure	Beginning Year of Measure Implementation for Cost Analysis	Present Value of Incremental Cost From 2023-2037**	Annual Average of Amortized Cost, 2023-2037 ***
CARB Mobile Source Measures with Quantified Emission Reductions in South Coast AQMD Sources Regulated by California with Federal Waiver/Authorization			
On-Road Heavy-Duty			
Advanced Clean Fleets Regulation	2024	$2,324.0	$231.1
Zero-Emissions Trucks Measure	2030	$983.3	$104.8
On-Road Light-Duty			
On-Road Motorcycle New Emissions Standards	2025	$70.1	$7.0
Clean Miles Standard	2023	($178.3)	($18.8)
Off-Road Equipment			
Tier 5 Off-Road Vehicles and Equipment	2029	$103.7	$10.7
Amendments to the In-Use Off-Road Diesel-Fueled Fleets Regulation	2023	$568.7	$38.6
Transport Refrigeration Unit Regulation Part 2	2026	$612.1	$63.5
Commercial Harbor Craft Amendments	2023	$407.5	$39.0
Cargo Handling Equipment Amendments	2026	$1,156.6	$117.5
Spark-Ignition Marine Engine Standards	2029	$4.2	$0.5
Subtotal of Incremental Costs:		**$6,051.7**	**$593.9**
CARB Area Source Measures with Quantified Emission Reductions in South Coast AQMD			
Consumer Products Standards	2029	$36.1	$3.6
Zero-Emission Standard for Space and Water Heaters	2026	$2,430.4	$250.8
Subtotal of Incremental Costs:		**$2,466.5**	**$254.4**
CARB Mobile Source Measures with Quantified Emission Reductions in South Coast AQMD Primarily Federally and Internationally Regulated Sources			
In-Use Locomotive Regulation	2023	$821.4	$84.0
Subtotal of Incremental Costs:		**$821.4**	**$84.0**

TABLE 2-1B (CONTINUED): ESTIMATED INCREMENTAL COSTS OF 2022 AQMP - CARB MEASURES (MILLIONS OF 2021 DOLLARS)*

Control Measure	Beginning Year of Measure Implementation for Cost Analysis	Present Value of Incremental Cost From 2023-2037**	Annual Average of Amortized Cost, 2023-2037 ***
CARB Mobile Source Measures with Quantified Emission Reductions in South Coast AQMD Federally Action Needed (Clean Air Act Section 182(e)(5))* **			
On-Road Heavy-Duty Vehicle Low-NOx Engine Standards	2027	$29.6	$3.2
Off-Road Equipment Tier 5 Standard for Preempted Engines	2028	$72.9	$7.5
Off-Road Equipment Zero-Emission Standards Where Feasible	2028	$207.7	$22.1
Cleaner Fuel and Visit Requirements for Aviation	2028	$1,909.8	$192.4
Airport Aviation Emissions Cap	2028	$1,731.6	$174.3
More Stringent NOx and PM Standards for Ocean-Going Vessels	2030	$36.6	$4.1
Cleaner Fuel and Vessel Requirements for Ocean-Going Vessels	2028	$3,382.6	$359.4
Subtotal of Incremental Costs:		**$7,370.8**	**$763.0**
Total for CARB Measures Control Measures:		**$16,710.4**	**$1,695.4**

* A 4% real interest rate was used for present value calculations. Interest rate and amortization period assumptions varied in each control measure for amortized cost calculations. See CARB's Appendix A to the 2022 State SIP Strategy for more information. All numbers are rounded to the first decimal place and may not sum up to the total.
** Due to insufficient information, present values were only calculated from the annual amortized incremental capital costs and operating & maintenance (O&M) costs estimated over the period of 2023-2037. The amortization period may include years beyond 2037, which would result in a portion of the costs not accounted for in the estimates. Discounted to 2022.
*** Costs shown from all CARB statewide measure are based on the proportion of statewide emission reductions allocated to South Coast AQMD that occur within South Coast AQMD's jurisdiction, except for consumer products standards which were allocated based on population.

While production costs may rise initially for industries deploying cleaner technologies, future incentive programs targeting equipment purchase and/or utility costs may help by offsetting a portion of the initial capital spending to shorten the payback period or reduce the operating costs of the equipment.[7] This would further accelerate market penetration and promote wider adoption of low NOx and zero-emission technologies across industries. This is critical to lowering costs in the long run as demand ramps up and local supply chains are developed. Accelerating the deployment of cleaner technologies may also increase benefits over time, achieving greater emission reductions on a wider scale and ahead of schedule. For instance, if incentive programs observe a faster turnover to zero-emission and low-NOx technology, the emission reduction potential within the 2037 attainment goal would capture a larger emission reduction than the projected levels within the timeline of the analysis in this report. This analysis assumes limited

[7] Incentive programs offsets could be considered in the total capital costs but are not quantified in the stationary source control measures as the magnitude of those offsets is yet to be determined.

incentive funding available to help offset the incremental costs (incentives assumed only for C-CMB-04, MOB-05 and MOB-11); however, more incentive funding may become available in the future at the time of control measure implementation.

Distribution of 2022 AQMP Costs Across Economic Sectors

The total incremental cost of the 2022 AQMP is expected to affect various parts of the regional economy. Many private industries and the public sector are expected to incur costs, although the amount borne by each party would vary. Table 2-2 shows the sectoral distribution of the 2022 AQMP's total incremental cost of implementing South Coast AQMD control measures.

TABLE 2-2: INCREMENTAL COSTS FROM SOUTH COAST AQMD CONTROL MEASURES WITH QUANTIFIED COSTS IN THE 2022 AQMP BY SECTOR (MILLIONS OF 2021 DOLLARS)*

Sector	Present Value of Incremental Cost	Amortized Annual Average, 2023-2037
Oil and Gas Extraction	$248.6	$6.9
Utilities	$9,565.0	$286.7
Construction	$99.4	$6.1
Manufacturing	$4,127.4	$126.9
Wholesale trade	$110.4	$3.5
Retail trade	$57.3	$1.7
Transportation & Warehousing	$96.6	$2.5
Real Estate & Rentals	$153.2	$4.4
Administrative and Waste Management Services	$459.8	$14.4
Health Care and Social Assistance	$564.4	$15.9
Restaurants & Accommodation	$2,069.3	$75.2
All Industries with Specific Costs	$18,122.3	$560.9
Subtotal of Private Industries with Across-the-Board costs**	$7,469.7	$153.3
Consumers	$2,960.5	$144.8
Government Spending ***	$5,777.4	$296.1
Total	**$34,329.9*******	**$1,155.1*******

Note: * Cost totals shown are net costs by industry sector, including any offsetting benefits borne to an industry during 2023 to 2037.
** Private Industries with across the board costs category is included for measures with impacts applying to all industries (e.g., C-CMB-04).
*** Government spending captures mainly incentive funds, but it also includes expected control costs incurred by public agencies.
****Numbers are expressed in 2021 dollars and may not add up due to rounding.

The total incremental cost of South Coast AQMD control measures with industry-specific costs[8] are estimated at $18.1 billion, or $561 million annually between 2023 and 2037. For South Coast AQMD control measures affecting private industries with across-the-board costs,[9] total incremental costs are expected to incur $7.5 billion from 2023 to 2037, or $153 million annually.

The utilities sector is expected to incur a total incremental cost estimated at about $9.6 billion. L-CMB-06 affects electric generation facilities (EGFs) with NOx emission reducing measures specifically affecting turbines, burners, boilers, and diesel ICEs. The majority of the capital costs affect turbine replacement, while recurring costs of hydrogen fuel are estimated over 1 million dollars annually for over 2,000 units in the sector. Also included more broadly in the energy production sector are oil refineries affected by L-CMB-07, which target NOx emissions from process heaters and boilers. In addition, this sector would incur additional costs from FUG-01 which seeks installation of advanced leak detection devices. Energy producers,[10] are expected to incur more than half of the cost estimated of all private industries. The cost-related job impact is expected to be proportionally small because, this sector is more capital intensive.

South Coast AQMD and CARB's mobile source strategies will primarily affect passenger transportation and the "goods movement" sector, the core of which constitutes freight transportation and warehousing. As shown in Table 2-2, transportation and warehousing, among all private industries, is expected to incur an estimated incremental cost of $97 million. The incremental cost impact to the goods movement sector is relatively modest because Table 2-2 does not include costs from CARB's control measures that focus on mobile sources.

The manufacturing sector is expected to benefit from two measures affecting the transition of equipment to cleaner technologies, and the estimated purchase of manufactured clean technologies is estimated at $4.1 billion between 2031 and 2037. Some measures will impact this sector more broadly as in the case of C-CMB-04 and C-CMB-05 that affect commercial equipment with measures to transition to cleaner technologies. Other measures like C-CMB-03 affecting commercial cooking equipment, may potentially affect only a small number of commercial industries, while also benefitting the manufacturing industry producing the clean technology specified in the control measure. FUG-01 (leak detection and repair) and L-CMB-07 (Refineries) are expected to affect petroleum refineries in addition to energy producers.

The restaurant industry is expected to incur up to $2.1 billion in estimated incremental costs. Restaurants will be mainly impacted by a NOx measure (C-CMB-03) which would require the installation of zero emission and low-NOx burners in retail and quick service establishments utilizing commercial cooking ranges, ovens, and fryers.

The administrative and waste management sector is expected to experience a total cost of about $460 million between 2033 and 2037. This sector is expected to incur gross incremental costs mainly due to NOx reduction measures and that affect landfills and POTWs (L-CMB-08), as well as incineration (L-CMB-09). Both measures target the NOx emissions from burner equipment used at these facilities.

[8] Industry-specific costs pertain to control measures with facility-level or industry-level specificity.

[9] Across the board costs pertain to controls affecting equipment generally so ubiquitous that it is assumed to affect most commercial and/or industrial operations (e.g. compressors, generators, and other non-permitted small equipment powered by internal combustion engines)

[10] The energy producers sector includes oil and gas extraction and utilities, including green energy producers such as solar, wind, and hydrogen energy production.

Despite lacking detailed cost by industry information, summary information presented for CARB's mobile measures shows that they largely affect the goods movement sector. Figure 2-1 shown below was published in the 2022 SIP Strategy in Table A-9, and illustrates the top three sectors affected by CARB's mobile source measures are air transportation, transportation and public utilities, and truck transportation. South Coast AQMD and CARB will work closely with industry stakeholders during the implementation stage to further fine-tune the mobile source strategies and identify affordable and cost-effective pathways to reducing mobile source emissions.

FIGURE 2-1: TABLE A-9 FROM PROPOSED 2022 SIP STRATEGY (CARB)[11]

Table A-9 Industries and Sectors with Greatest Costs or Cost-Savings

Industry or Sector[213]	Cumulative Change in Production Costs ($2020M)[214]
Air transportation (Industry)	$14,756
Transportation and Public Utilities (Sector)	$13,876
Truck transportation (Industry)	$9,119
Construction (Sector)	$4,458
Retail and Wholesale (Sector)	$4,251
Services (Sector)	$3,893
Increased prices for commodities in motor vehicles and parts, furnishings and durable household equipment, recreational goods and vehicles and other durable goods, clothing and footwear, and other nondurable goods[215]	$3,618
Aggregation of Forestry, Mining, Utilities, Construction, and Manufacturing (Industry)	$3,450
Transit and ground passenger transportation (Industry)	$2,953
Scenic and sightseeing transportation and support activities for transportation (Industry)	$2,802
Personal and laundry services[216] (Industry)	$2,158

The changes in costs and spending across the economy would correspond with changes in demand for industries supplying goods and services. For example, transitioning to cleaner tier

Note: The costs shown in the table are for statewide costs, and AQMD costs would be proportional to the emission reductions expected from these measures in South Coast AQMD.

[11] CARB September 2, 2022. https://ww2.arb.ca.gov/sites/default/files/2022-09/2022_State_SIP_Strategy_App_A.pdf.

Small Business Analysis

The South Coast AQMD defines a "small business" in Rule 102 for purposes of fees as one which employs 10 or fewer persons and which earns less than $500,000 in gross annual receipts. The South Coast AQMD also defines "small business" for the purpose of qualifying access to services from South Coast AQMD's Small Business Assistance Office (SBAO) as a business with annual receipts of $5 million or less or with 100 or fewer employees.

In addition to South Coast AQMD's definition of a small business, the federal Small Business Administration (SBA) and the Federal Clean Air Act (CAA) also provide definitions of a small business. The CAA classifies a business as a "small business stationary source" if it: (1) employs 100 or fewer employees, (2) does not emit more than 10 tons per year of either VOC or NOx, and (3) is a small business as defined by the SBA. The SBA definitions of small businesses vary by six-digit NAICS codes. In general terms, a small business must have no more than 500 employees for most manufacturing and mining industries, and no more than $7 million in average annual receipts for most non-manufacturing industries.

Table 2-3 provides information on the share of small businesses in each industry potentially impacted by the 2022 AQMP.[12] Small business impacts will be assessed in further detail during the rulemaking process, when more facility-specific data will be available. The U.S. Census Bureau County Business Patterns (CBP)[13] database found that in 2018 the majority (54.5 percent) of business establishments were under 5 employees. However, nearly half (47.5 percent) of the workforce is employed in business establishments larger than 100 employees.

TABLE 2-3: SMALL BUSINESS SHARE OF AFFECTED INDUSTRIES, 2020

Industry Sector	Number of Establishments	Size of Employment		
		Less than 10 Employees	Less than 100 Employees	Less than 500 Employees
Oil and Gas Extraction	165	61%	98%	98%
Utilities	503	56%	89%	97%
Construction	32,558	80%	98%	100%
Manufacturing	32,523	58%	94%	98%
Transportation & Warehousing	16,481	76%	96%	98%
Waste Management	484	58%	94%	100%
Restaurants & Accommodation	40,185	46%	98%	100%
All Private Industries	**473,327**	**76%**	**98%**	**99.8%**

[12] Employment by establishment-size data from the U.S. Census Bureau's County Business Patterns for the Los Angeles-Long Beach-Anaheim and Riverside-San Bernardino metros.

[13] U.S. Census Bureau 2021. https://www.census.gov/library/stories/2021/01/what-is-a-small-business.html.

Cost-Effectiveness Analysis

Based on the estimated total incremental costs for each measure and the projected emission reductions throughout the associated project life, cost-effectiveness[14] (measured in cost per ton of emissions reduced) was calculated for each control measure proposed in the 2022 AQMP.[15] The preliminary cost-effectiveness of each measure has previously been reported in Chapter 6 of the 2022 AQMP. The values presented here in this section are updated with more refined estimates. Chapter 6 in the 2022 AQMP has been also updated to reflect the more refined estimates presented here in the Socioeconomic Report.

Following the recommendations from a 2014 analysis by Abt,[16] cost-effectiveness based on both discounted cash flow (DCF) and levelized cash flow (LCF) methods were reported in Table 2-4 to facilitate comparisons with cost-effectiveness reported by other agencies and organizations.[17] Each cost-effectiveness value listed in Table 2-4 was calculated based on emission reductions of the primary target pollutant for attaining the 2015 federal ozone standard (e.g. NOx or VOC). However, many control measures also achieve reductions of other air pollutants, which is demonstrated in the 'Modified LCF based on Carl Moyer Formula' column of Table 2-4 below.[18] For example, many of the mobile source NOx control measures would additionally result in co-pollutant reductions of VOC and PM2.5 emission reductions. The most consistent comparison between CARB's proposed control measures in the State SIP Strategy and South Coast AQMD measures in the 2022 AQMP is the Modified LCF method in Table 2-4 (2nd column from the right). This approach uses the LCF method, but modifies it to only include costs incurred between 2023-2037.

As mentioned in the 2014 Abt Report, the main difference between the DCF and LCF methods lies in how the costs are expressed. DCF utilizes the present value, or a stream of all present and future costs discounted to and summed up in the same initial year. In comparison, LCF amortizes all costs, incurred at present or in the future, into a yearly expenditure of equal amount over the project life.

As the same amount of money is usually considered to be more valuable now than in the future (i.e., the financial concept "time value of money"), the same amount of cost is therefore lower when discounted to its present value than when amortized to the present and each future period of the project life. This is why a cost-effectiveness value as calculated using DCF is always lower than that calculated using LCF. In other words, the methodological choice is to some degree analogous to the choice of measurement units: the same length can be expressed as one inch or 2.54 centimeters, and the smaller (or greater) number should not be taken to indicate a shorter (or longer) length. Similarly, a cost-effectiveness value calculated

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[14] Cost-effectiveness (C-E) is the ratio between the incremental cost of a control measure and the unit of pollution reduced in a period of time. The value of the cost-effectiveness expression can be used interchangeably with cost-per-ton such that a higher cost-per-ton is considered *less cost-effective*, and lower cost-per-ton is considered *more cost-effective.*

[15] For South Coast AQMD measures, emission reductions were estimated mainly based on equipment turnover assumptions and over the entire equipment life. For CARB measures, CARB provided the annual emission reductions between 2023 and 2037.

[16] Abt Associates. 2014. "Review of the SCAQMD Socioeconomic Assessment." Bethesda, MD: Abt Associates Inc.

[17] A comparison of DCF and LCF methods, as well as more information for the methodology used, can be found in Appendix 2-B.

[18] The Carl Moyer Formula evaluates emissions using NOx + VOC + [20 x PM2.5].

using the DCF method should not be compared with another cost-effectiveness value calculated using the LCF method. In the interest of transparency and comparability South Coast AQMD staff began providing both values since the rulemaking process that led to the 2015 NOx RECLAIM amendments.

The stationary source measures for NOx are expected to cost between $1,500 and $2,400,000 per ton of emissions reduced, as calculated using the Modified LCF method. South Coast AQMD's VOC controls have cost-effectiveness values between $20,000 and $30,000 per ton (DCF method), and $28,000 to $48,000 (LCF method). These values are consistent with estimations for previous VOC regulations. CARB's sole VOC measure has a cost-effectiveness value of about $6,000 per ton.

Many control measures' cost per ton of NOx reduced exceed costs identified for measures in the 2022 AQMP due to relatively smaller emission reduction potential compared with the cost of equipment. However, many technologies implemented through rule development in the future are expected to benefit from cheaper, more efficient technology not yet available for implementation. These potential future cost savings in equipment are not included in the analysis of South Coast AQMD measures presented here. South Coast AQMD mobile source measures would cost between $87,000 and $334,000 per ton of NOx reduced using the Modified LCF method. Both mobile source measures use incentive spending, and the cost to consumers is subsidized through government funding.

As demonstrated in the Modified LCF method values in Table 2-4, most of CARB's control measures for mobile sources are more cost-effective than South Coast AQMD's control measures for stationary sources. CARB's less cost-effective mobile source measures are those that require turnover of the existing fleet while emissions standards for new engines/vehicles are more cost-effective. Some of CARB's measures (in particular for federal sources) do not have readily available cost data and so average cost-per-ton from all other measures have been applied (about $85,000 per ton).

The reason why South Coast AQMD controls for stationary sources are generally less cost-effective relative to CARB's mobile source controls is largely related to two factors. First, stationary sources have been significantly controlled over several decades of air quality regulation, and the cost of applying additional controls to this lower level of remaining emissions is high. However, the 2022 AQMP demonstrates that given the very low level of NOx allowed in the region to meet the federal ozone standard, even these remaining lower levels of stationary source emissions must continue to be controlled.

Second, most South Coast AQMD stationary source controls include significant penetration of zero-emissions equipment. Based on currently available information, these zero-emissions controls are more expensive that low and ultra-low NOx technologies in these applications. Potential future cost savings for some of this equipment may occur, however it is speculative to project what those costs will be in the future. As rulemaking proceeds for each measure, updated cost information will be used to inform the development for each rule (see Chapter 4 of the 2022 AQMP for further discussion of how costs and cost-effectiveness will be addressed in future rulemaking). Even though these zero-emissions technologies are more expensive, they are critical to include in the control measures to achieve the level of emission reductions required for attainment of the ozone standard.

The 2022 AQMP relies on mobile source controls to reduce emissions between 60% to 80% beyond the 2037 baseline, depending on the mobile source sector. Stationary source controls (totaling about 22 tons per day of NOx) are also about 60%. However, even this significant level of control is not sufficient to achieve the ozone standard and the 2022 AQMP calls for an additional 3 tons per day of 'black box' reductions from stationary sources. This indicates that even greater reductions will be required beyond the zero emissions controls already included in the South Coast AQMD control measures. However, based on information currently available, it is not clear how to feasibly incorporate even more zero emissions technology than currently specified by 2037 for stationary sources. Future rulemaking will evaluate the feasibility of greater levels of zero emission technology penetration at that time.

TABLE 2-4: COST-EFFECTIVENESS OF 2022 AQMP MEASURES

Control Measures	**Targeted Pollutant**	**Discounted Cash Flow Method*** (2021$/ton)	**Levelized Cash Flow Method**** (2021$/ton)	**Modified Levelized Cash Flow Method***** (2021$/ton)	**Modified LCF based on Carl Moyer Formula****** (2021$/weighted ton)
South Coast AQMD					
C-CMB-03: Commercial Cooking	NOx	$751,100	$1,136,300	$1,116,400	NC
C-CMB-05: Miscellaneous Small Commercial Combustion Equipment (Non-permitted)	NOx	$110,000	$176,100	$176,100	NC
L-CMB-01: NOx RECLAIM	NOx	$9,500	$16,900	$19,000	NC
L-CMB-02: Large Boilers and Process Heaters	NOx	$865,400	$1,270,300	$2,078,800	NC
L-CMB-03: Large Internal Combustion Prime Engines	NOx	$321,500	$549,200	$606,700	NC
L-CMB-04: Large Internal Combustion Emergency Standby Engines	NOx	$592,900	$1,024,300	$1,027,200	NC
L-CMB-05: Large Turbines	NOx	$723,800	$1,158,300	$1,158,300	NC
L-CMB-06: Electric Generating Facilities	NOx	$1,512,300	$2,420,000	$2,420,100	NC
L-CMB-07: Petroleum Refining	NOx	$43,700	$70,000	$70,000	NC
L-CMB-08: Landfills and POTWs	NOx	$79,000	$126,400	$126,400	NC
L-CMB-09: Incineration	NOx	$900	$1,500	$1,500	NC
L-CMB-10: Miscellaneous Combustion	NOx	$28,700	$51,100	$84,800	NC
R-CMB-03: Residential Cooking	NOx	$144,400	$214,900	$217,500	NC
R-CMB-04: Residential Other Combustion	NOx	$235,400	$357,000	$357,100	NC
FUG-01: Improved Leak Detection and Repair	VOC	$30,000	$47,800	$50,400	NC
CTS-01: Further Emission Reduction from Coatings, Solvents, Adhesives, and Sealants	VOC	$20,800	$27,600	$27,600	NC
C-CMB-04: Small Internal Combustion Engines (Non-permitted)	NOx	$446,100	$628,100	$744,000	NC
MOB-05: Accelerated retirement of older light-duty and medium-duty vehicles	NOx	NC	NC	$334,300	$298,300
MOB-11: Emission reductions from incentive programs	NOx	NC	NC	$87,000	$52,900

TABLE 2-4 (CONTINUED): COST-EFFECTIVENESS OF *2022 AQMP* MEASURES

Control Measures	Targeted Pollutant	Discounted Cash Flow Method* (2021$/ton)	Levelized Cash Flow Method** (2021$/ton)	Modified Levelized Cash Flow Method*** (2021$/ton)	Modified LCF based on Carl Moyer Formula**** (2021$/weighted ton)
CARB					
Advanced Clean Fleets Regulation	NOx	NC	NC	$194,800	$107,800
Zero-Emissions Trucks Measure	NOx	NC	NC	$194,800	$106,600
On-Road Motorcycle New Emissions Standards	NOx	NC	NC	$51,500	$14,700
Clean Miles Standard	NOx	NC	NC	($2,590,000)	($2,590,000)
Tier 5 Off-Road Vehicles and Equipment	NOx	NC	NC	$30,600	$29,300
Amendments to the In-Use Off-Road Diesel-Fueled Fleets Regulation	NOx	NC	NC	$87,900	$47,800
Transport Refrigeration Unit Regulation Part 2	NOx	NC	NC	$77,300	$67,800
Commercial Harbor Craft Amendments	NOx	NC	NC	$52,700	$32,300
Cargo Handling Equipment Amendments	NOx	NC	NC	$621,800	$270,900
Spark-Ignition Marine Engine Standards	NOx	NC	NC	$14,200	$4,200
Consumer Products Standards	VOC	NC	NC	$6,200	
Zero-Emission Standard for Space and Water Heaters	NOx	NC	NC	$496,600	$429,500
In-Use Locomotive Regulation	NOx	NC	NC	$47,600	$33,800
On-Road Heavy-Duty Vehicle Low-NOx Engine Standards	NOx	NC	NC	$8,200	$4,700
Off-Road Equipment Tier 5 Standard for Preempted Engines	NOx	NC	NC	$34,300	$32,800
Off-Road Equipment Zero-Emission Standards Where Feasible	NOx	NC	NC	$77,300	$77,300
Cleaner Fuel and Visit Requirements for Aviation	NOx	NC	NC	$84,200	$50,500
Airport Aviation Emissions Cap	NOx	NC	NC	$84,200	$50,500
More Stringent NOx and PM Standards for Ocean-Going Vessels	NOx	NC	NC	$84,200	$84,200
Cleaner Fuel and Vessel Requirements for Ocean-Going Vessels	NOx	NC	NC	$95,900	$95,900

NC = Not calculated

* Incremental costs discounted to the beginning of first implementation year assumed for cost analysis, divided by cumulative emission reductions over equipment life

** Annual average amortized costs, divided by annual average emission reductions over equipment life

*** Annual average amortized costs, divided by annual average emission reductions over the period of 2023-2037

**** Annual average amortized costs, divided by annual average weighted emission reductions over the period of 2023-2037. The weighted emission reductions are calculated using the Carl Moyer formula: NOx reductions + ROG (proxied by VOC) reductions + 20 x PM2.5 reductions.

Zero-Emission (ZE) Technology & Infrastructure Considerations

The prevalence of measures targeting the reduction of NOx emissions in the 2022 AQMP2022 AQMP Socioeconomic Report, particularly from combustion sources, involves the transition to a number of electric and fuel-cell technologies. The impacts of implementing such technology on the existing infrastructure presents challenges in quantifying cost and determining the level of uncertainty in scale and distribution. A September 2022 memorandum prepared by Industrial Economics, Inc (IEc) (included in Appendix 2-C) explored currently available literature regarding zero-emission fueling infrastructure. The studies and analysis summarized in this memo describe potential factors to consider when developing the cost of future implementation of zero emission technologies at the scale outlined in the scope of the 2022 AQMP2022 AQMP. Three broad categories of expenditures are expected in future zero emission infrastructure including zero emission equipment, energy systems, and soft costs. Examples of costs within these main categories are shown in Figure 2-2 below.

FIGURE 2-2: THREE CATEGORIES OF COSTS FOR ZERO EMISSIONS INFRASTRUCTURE

ZE Equipment

- Hardware
- Installation
- Operations and maintenance
- Building electrification
- Stationary source zero emission equipment

Energy Systems

- Energy supply (e.g., power plants, microgrids)
- Regional transmission
- Local distribution

'Soft' Costs

- Land use (e.g., site acquisition, site re-design, easements, etc.)
- Opportunity costs (e.g., permitting delays, new technology malfunctions)
- Marketing
- Employee training
- Future-proofing (e.g., overbuilding infrastructure to prepare for future changes)
- Stranded assets (e.g., new plug technology replacing older plugs)
- Climate resiliency

There are many uncertainties in estimating costs for zero emission infrastructure. The current level of uncertainty in costs is generally lowest for zero emission equipment (for those categories where zero emission equipment is currently or imminently available), and highest for ‘soft’ costs. ‘Soft’ costs are often unique to each individual zero emission infrastructure project and commonly difficult to quantify, even at the beginning of project implementation. These ‘soft’ costs can present a significant hurdle to each project and further research is needed to determine how these costs for each project can be considered broadly when zero emissions technologies are deployed at the scale needed to meet air quality standards.

Energy system costs can include the overall cost of improvements to the electrical grid (power plants, transmissions lines, local distribution systems), as well as costs associated with switching fuels (e.g., switching from natural gas fueled equipment to electric equipment). Similar energy system costs may be incurred for hydrogen fuels. A significant and challenging question with energy systems is determining how much hydrogen fuels will be used, both in individual applications (e.g., vehicles, onsite power generation, etc.), as well as energy storage to support grid electricity. While electricity is expected to play a dominant role across broad sectors of the economy to support zero emissions technologies, the consensus from many reports and initiatives is that hydrogen will play a significant role in the deployment of zero emissions technologies. Key example reports and initiatives include:

- CA Energy Commission SB 100 Report (2021): https://efiling.energy.ca.gov/EFiling/GetFile.aspx?tn=237167&DocumentContentId=70349
- CARB 2022 Draft Scoping Plan: https://ww2.arb.ca.gov/sites/default/files/2022-05/2022-draft-sp.pdf
- CARB AB 8 Annual Report (2022): https://ww2.arb.ca.gov/sites/default/files/2022-09/AB-8-Report-2022-Final.pdf
- US DOE Hydrogen Program Plan: https://www.hydrogen.energy.gov/pdfs/hydrogen-program-plan-2020.pdf
- Bipartisan Infrastructure Law Regional Clean Hydrogen Hub program: https://www.energy.gov/oced/regional-clean-hydrogen-hubs

Zero emissions technologies included in CARB and South Coast AQMD control measures rely on a mix of hydrogen and electric technologies. Regardless of fuel type, the cost estimates for each control measure generally include the costs of zero emission equipment, and some of the energy system costs (e.g., switching from natural gas to hydrogen). 'Soft' costs are generally not included in current estimates. For energy system costs evaluated in South Coast AQMD control measures, the future price of fuels is assumed to be fixed using the values in Table 2-5 below.

TABLE 2-5: ASSUMED FUEL COSTS USED TO ESTIMATE SOUTH COAST AQMD CONTROL MEASURE COSTS

Fuel Type	Cost
Natural Gas (Residential)	$13.64/MMBTU
Natural Gas (Commercial)	$9.29/MMBTU
Natural Gas (Industrial, non-electric generation)	$7.20/MMBTU
Natural Gas (Electric Generation)	$3.22/MMBTU
Electricity (Residential)	$0.19/kWh
Electricity (Commercial)	$0.16/kWh
Electricity (Industrial)	$0.14/kWh
Hydrogen	$6.50/kg

Source: Costs based on Energy Information Agency data adjusted for our region

The future cost of fuels is difficult to predict. These energy system costs may change substantially, either higher or lower, based on how zero emissions technologies are deployed. Due to the high uncertainty, these speculative future energy system costs are not considered in the socioeconomic analysis conducted here. As described in control measure MOB-15 (see Appendix IV-A of the 2022 AQMP), there are many other agencies (e.g., Energy Commission, Public Utilities Commission, CARB, US Department of Energy, etc.) taking the lead in developing zero emissions policies, as well as tools and methods to estimate the potential cost of those policies. South Coast AQMD will continue to partner with these agencies and organizations to contribute to their method development for estimating the full cost to transition to zero emissions technology.

Chapter 3

Public Health and Other Benefits

The 2022 AQMP contains a suite of control strategies that are designed to attain the 70 ppb 8-hour ozone standard in the South Coast Air Basin by 2037. Attaining the ozone standard will result in various benefits including better public health, improved visibility, and avoided damage to animals, crops, vegetation, and buildings. South Coast AQMD staff has worked closely with Industrial Economics, Inc. to provide an updated health benefits literature review and fine-tune the methodology used to quantify public health benefits and address the associated uncertainties in estimates. Despite these efforts, a full assessment of all clean air benefits in dollar terms is not possible until further advances occur in human health sciences, physical science, and economic disciplines that will allow monetary estimates to be made for currently unquantifiable areas. Other clean air benefits not directly related to public health are scientifically documented and are qualitatively discussed towards the end of this chapter.

Projected Emission Reductions and Changes in Pollutant Concentrations

Regional air quality modeling indicates that significant NOx reductions with additional strategic, limited VOC reductions will lead to the attainment of ozone standards. As shown in Table 3-1, the proposed control strategies in the 2022 AQMP were projected to significantly reduce NOx emissions by 44 and 124 tons per day (tpd) and strategically reduce VOC emissions by 7 and 17 tpd, in 2032 and 2037 respectively. In addition to reducing exposure to ozone pollution, these control strategies were also projected to generate significant PM2.5 co-benefits by reducing emissions of precursors (e.g. NOx) for secondary PM2.5 formation as well as directly emitted PM2.5 emissions from mobile sources (2 and 3 tpd in 2032 and 2037). Those reductions will reduce health risk associated with exposure to PM2.5.

TABLE 3-1: PROJECTED EMISSION REDUCTIONS BY POLLUTANT[1]

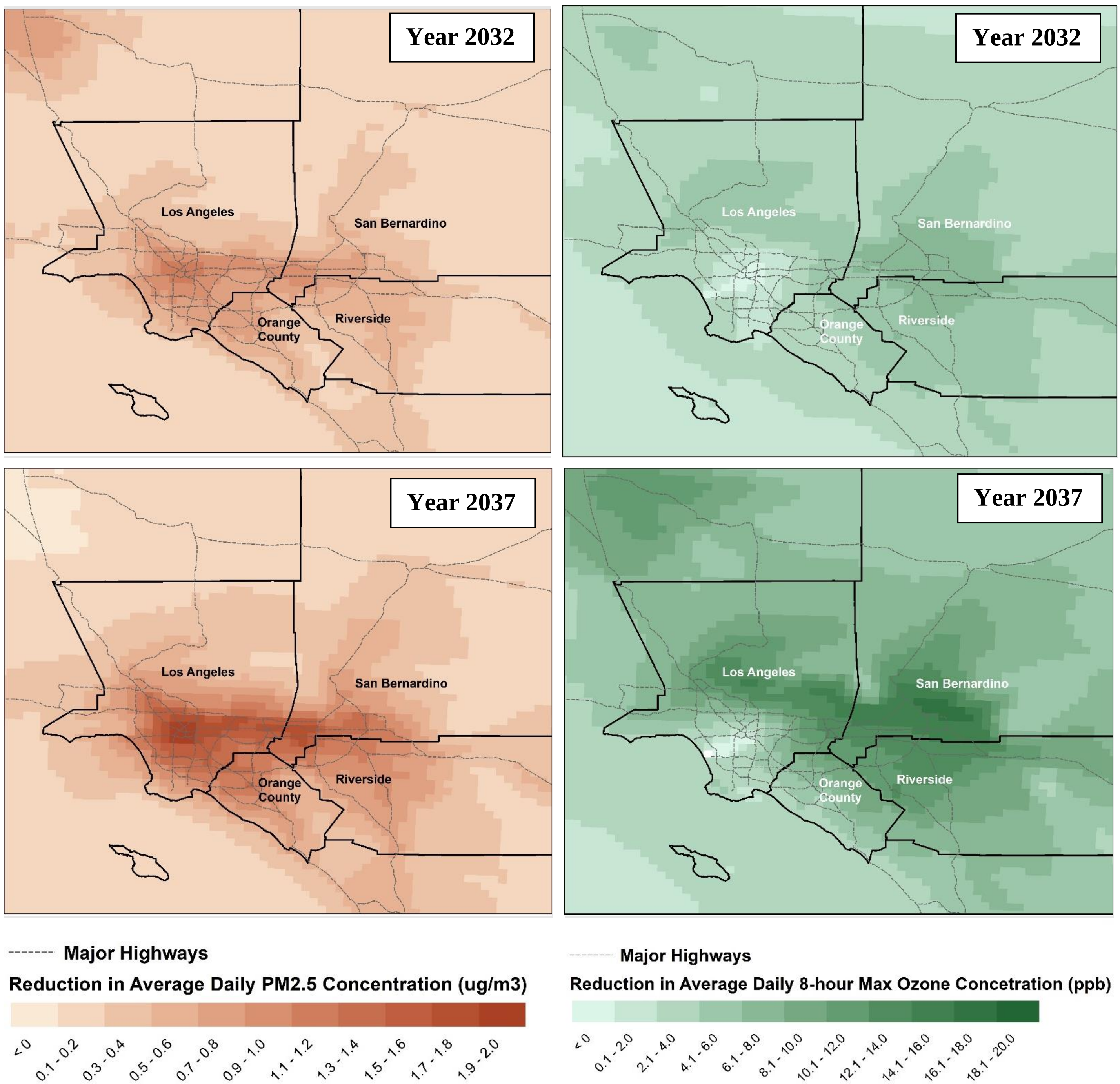
NOx Emissions (tons per day)	**Year 2032**	**Year 2037**
Baseline Inventory	199	184
Reductions from Final Control Strategies	44	124
Remaining Emissions	155	60
VOC Emissions (tons per day)	**Year 2032**	**Year 2037**
Baseline Inventory	345	339
Reductions from Final Control Strategies	7	17
Remaining Emissions[2]	338	321
PM2.5 Emissions (tons per day)	**Year 2032**	**Year 2037**
Baseline Inventory	58	59
Reductions from Final Control Strategies	2	3
Remaining Emissions[2]	56	55

[1]Projected emission reductions are the average of the summer planning period (May 1 to September 30). The NOx emission reductions reported in this table reflect the latest regional air quality modeling results.
[2]Numbers may not sum due to rounding.

Although each attainment demonstration is performed with respect to the worst air quality site, the benefit assessment herein analyzed the changes in the projected air pollutant concentrations between the baseline scenario (without 2022 AQMP) and the control or policy scenario (with 2022 AQMP) in each air quality modeling grid of four kilometer by four kilometer. Thus, the quantified public health benefits discussed in this report are based on where projected air quality changes are expected to occur. Figure 3-1 shows the modeled changes in ozone and PM2.5 concentrations based on control measures proposed in the 2022 AQMP, which will move beyond the already adopted regulations and already implemented programs to the level needed to attain the federal ozone standard. Air quality modeling methods account for background concentrations of pollutants and thus concentrations projected in the control scenarios are above backgound concentration levels.[1]

[1] Background concentrations of chemical species are calculated with a global chemistry transport model Community Atmosphere Model with Chemistry, CAM-chem. Species concentrations from this model are fed into the modeling domain along the model boundaries. Temporally- and spatially-dependent CAM-Chem data are used to capture the variability in background concentrations throughout the entire modelling year. Biogenic and Anthropogenic emissions from within the modeling domain are simulated with the CAM-Chem-derived boundary conditions to estimate pollutant concentrations within the Basin. Therefore, the PM concentrations modeled for future years in this analysis are above the background levels.

FIGURE 3-1: MODELED REDUCTIONS IN PM2.5 AND OZONE CONCENTRATIONS, 2032 AND 2037



Note: Ozone concentarations shown here are the summer planning period average of daily 8-hour maxima, whereas $PM_{2.5}$ concentrations are the annual average of 24-hour means.

Quantified Public Health Benefits

Numerous epidemiological as well as controlled laboratory studies have demonstrated a positive association between ambient air pollution exposure and increases in illness and other health effects (morbidity endpoints) and increases in death rates from various causes (mortality endpoints) (U.S. EPA 2019; U.S. EPA 2020). Groups that are most sensitive to the effects of air pollution are children, elderly persons, and people with certain respiratory and heart conditions.

Table 3-2 summarizes the causal determinations documented in the U.S. EPA Integrated Science Assessments (ISAs), based on the current weight of evidence regarding ozone and PM2.5 exposure (U.S. EPA 2020; U.S. EPA 2019 and 2022).[2] Exposure to other pollutants, such as NO_2 and SO_2, has also been found to cause adverse respiratory effects.[3] However, based on the recommendation by Industrial Economics, Inc., this analysis does not quantify these effects to avoid potentially double counting benefits with reduced PM2.5 exposure (Industrial Economics, and Thurston 2016b). Similarly, due to concerns of potentially double counting over the same health endpoint, not all causal or likely causal relationships listed in Table 3-2 are quantified in this report.

TABLE 3-2: SUMMARY OF U.S. EPA'S CAUSAL DETERMINATIONS FOR OZONE AND PM2.5 EXPOSURE

Health Category	Causal Determination	Quantified?
Short-Term Exposure to Ozone		
Total Mortality	*Suggestive of a causal relationship*	N
Cardiovascular Effects	*Suggestive of a causal relationship*	N
Respiratory Effects	**Causal relationship**	**Y**
Central Nervous System Effects	*Suggestive of a causal relationship*	N
Metabolic Effects	**Likely to be a causal relationship**[1]	N
Effects on Cutaneous and Ocular Tissues	*Inadequate to infer a causal relationship*	N
Long-Term Exposure to Ozone		
Total Mortality	*Suggestive of a causal relationship*	N
Cardiovascular Effects	*Suggestive of a causal relationship*	N
Respiratory Effects (including respiratory mortality)[2]	**Likely to be a causal relationship**	**Y**
Reproductive and Developmental Effects	*Suggestive of a causal relationship*	N
Central Nervous System Effects	*Suggestive of a causal relationship*	N
Cancer	*Inadequate to infer a causal relationship*	N

[2] Descriptions for Weight of Evidence for Causal Determinations are provided in Appendix 3-A.

[3] See the 2022 AQMP Appendix I for a discussion of health effects of ambient air pollution.

TABLE 3-2 (CONTINUED): SUMMARY OF U.S. EPA'S CAUSAL DETERMINATIONS FOR OZONE AND PM2.5 EXPOSURE

Health Category	Causal Determination	Quantified?
Short-Term Exposure to PM2.5		
Mortality	**Causal relationship**[3]	N
Cardiovascular Effects	**Causal relationship**	**Y**
Respiratory Effects	**Likely to be a causal relationship**	**Y**
Central Nervous System Effects	*Suggestive of a causal relationship*	N
Long-Term Exposure to PM2.5		
Mortality	**Causal relationship**	**Y**
Cardiovascular Effects	**Causal relationship**[4]	N
Respiratory Effects	**Likely to be a causal relationship**	**Y**
Central Nervous System Effects	**Likely to be a Causal Relationship**	**Y**
Reproductive and Developmental Effects	*Suggestive of a causal relationship*	N
Cancer, Mutagenicity, Genotoxicity	***Likely to be a causal relationship***	**Y**

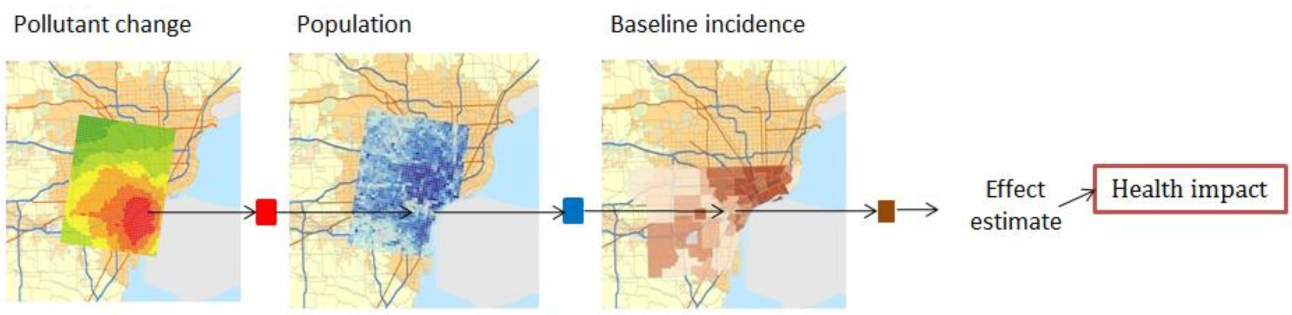
Notes:

1. The ISA determination of likely causal for metabolic effects is based on a synthesis of evidence from toxicology studies in animals, controlled human exposure studies, and epidemiological studies. Due to the more limited epidemiological evidence currently available, the U.S. EPA has not yet identified a suitable epidemiological study from which to derive a health impact function for use in a domestic air quality benefit analysis.
2. The ISA includes cause-specific respiratory mortality as a subset of the respiratory effects category.
3. We do not quantify mortality due to short-term exposure to PM2.5 since mortality due to long-term exposure to PM2.5 is expected to be inclusive of any short-term exposure impacts.
4. Although we do not quantify cardiovascular morbidity effects using risk models with long-term exposure to PM2.5 a number of cardiovascular effects modeled based on short-term exposure to PM2.5 are likely to have chronic impacts following the initial event (e.g., stroke, out-of-hospital cardiac arrest, and AMI). Our valuation of the short-term cardiovascular endpoints reflects long-term, multi-year costs-of-illness.

Source: U.S. EPA ISAs (2019; 2020)

The first step of a public health benefits analysis is the health effects quantification. Appropriate concentration-response (C-R) functions need to be selected, which numerically characterize the causal and likely causal relationships between exposure to a pollutant and various health endpoints. Specifically, the C-R function used in this analysis relates changes in ambient air pollution concentration with changes in mortality or morbidity incidence, the magnitude of which also depends on the baseline incidence rate and the population exposed to a specific health risk being analyzed (see Figure 3-2 for a graphic illustration).

FIGURE 3-2: HEALTH EFFECTS QUANTIFICATION



Source: U.S. EPA BenMAP Community Edition User's Manual.

C-R functions were determined based on a systematic review of the epidemiological literature, where studies were evaluated for quality and applicability according to numerous criteria (See Appendix ; Industrial Economics and Thurston 2016a; Industrial Economics and Thurston 2016b). These criteria included: peer-review, date of the study, geography and population characteristics, and study design. Thus, the C-R functions applied in this analysis were found from recent, peer-reviewed articles, derived from local studies of the Basin or studies that report separate estimates using sub-samples pertaining to the Basin, where feasible. The 2020 RTP/SCS population forecast was provided by SCAG for each air quality modeling grid. When feasible, local health data based on public administrative records were utilized to obtain baseline incidence rates. Appendix 3-B describes in detail the input data and methodology used, as well as analytical assumptions such as cessation lags for mortality effects associated with long-term PM2.5 exposure that will have implications for monetizing health benefits. The public health benefit analysis is implemented using U.S. EPA's Environmental Mapping and Analysis Program – Community Edition (BenMAP-CE).

Table 3-3 reports the health effect estimates for each health endpoint by pollutant. In total, it was estimated that nearly 1,600 premature deaths will be avoided in 2032, and nearly 3,000 premature deaths avoided in 2037, or an average of about 1,500 avoided premature deaths per year due to improved air quality as a result of implementing the 2022 AQMP control measures. Figure 3-3 shows that mortality risks will be reduced in each of the four counties, with the largest number of avoided premature deaths concentrated in the densely-populated Los Angeles County area. Morbidity incidence is also reduced as a result of the Plan. It is estimated that reductions in ozone and PM2.5 concentrations will result in about 350 fewer asthma-related emergency department visits annually.[4] In addition, the number of hospital admissions from all endpoints considered (asthma, cardiovascular, respiratory, and ischemic stroke) are estimated to decrease by about 8,750 per year.

[4] Full scale regional air quality modeling was conducted for 2032 and 2037, with the health benefits interpolated for all interim years. Based on the implementation schedule of control measures, staff conservatively assumes that 2025 is the first year when health benefits associated with improved ozone and PM2.5 are expected. For the sake of simplicity, linear interpolations between 2024-2032 and 2032-2037. Staff is well aware of the complexity and non-linearity of ozone and PM2.5 chemistry. However, without full scale modeling and detailed control scenarios for in-between years, it is not feasible to estimate the progress for each year.

TABLE 3-3: HEALTH EFFECT ESTIMATES*

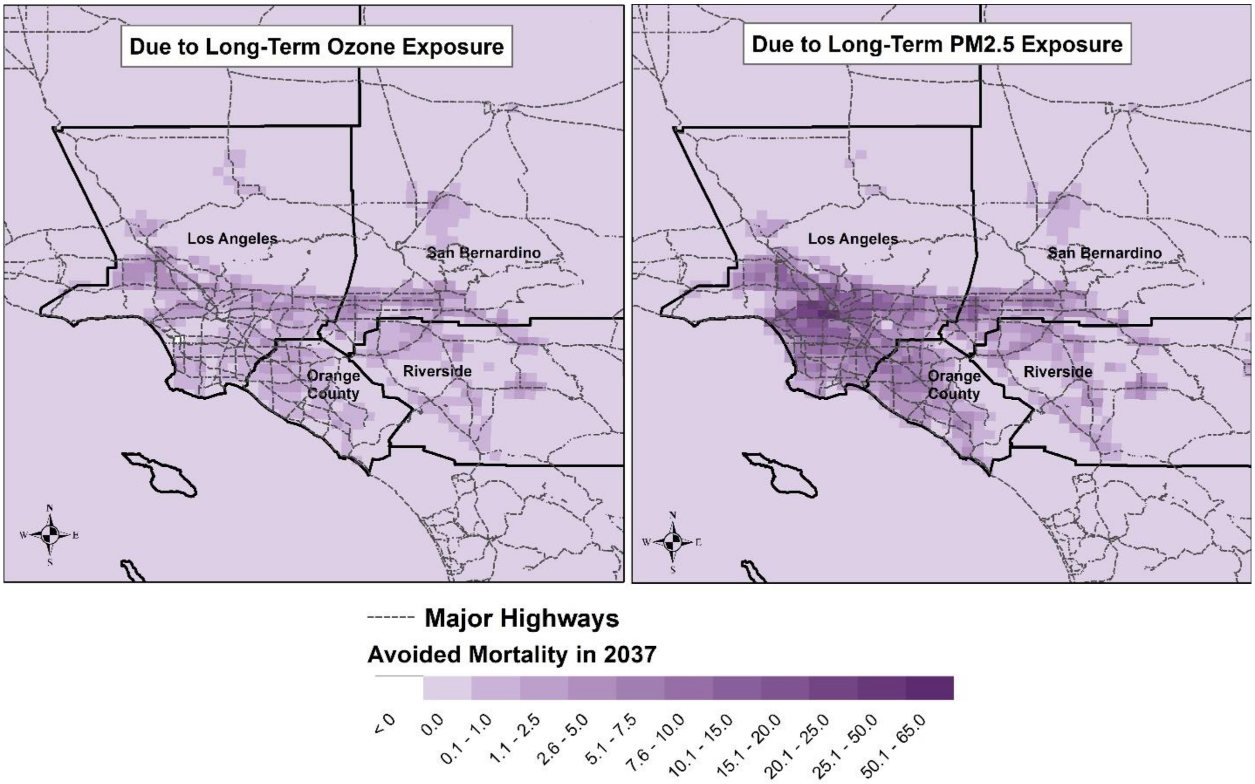
	2032	2037	Annual Average, 2025-2037
Premature Deaths Avoided, All Cause			
Long-Term Ozone Exposure[1]	339	744	341
Long-Term PM2.5 Exposure	1,280	2,287	1,168
Reduced Morbidity Incidence			
Long-Term Ozone Exposure			
Asthma, New Onset	4,506	9,501	4,445
Short-Term Ozone Exposure[1]			
Asthma Symptoms (Chest Tightness, Cough, Shortness of Breath, and Wheeze)	795,164	1,741,652	799,502
Emergency Room Visits (ED), Asthma	286	649	293
ED Visits, All Respiratory Minus Asthma	655	1,501	674
HA, Asthma	8,244	18,292	8,343
Minor Restricted Activity Days	318,008	710,412	322,945
School Loss Days, All Cause	96,176	208,938	96,304
Long-Term PM2.5 Exposure			
Asthma, New Onset	1,903	3,280	1,708
HA, Alzheimer's Disease	131	239	120
HA, Parkinson's Disease	54	100	50
Incidence, Hay Fever/Rhinitis	9,024	15,726	8,141
Incidence, Lung Cancer (non-fatal)	107	191	97
Short-Term PM2.5 Exposure			
Acute Myocardial Infarction, Nonfatal	18	35	17
Asthma Symptoms, Albuterol use	316,362	554,968	286,250
ED Visits, Asthma	66	117	60
ED Visits, All Cardiac Outcomes	138	255	128
ED Visits, All Respiratory Minus Asthma	325	582	297
Emergency Hospitalizations (EHA), Asthma	3	6	3
HA, All Cardiac Outcomes	47	87	43
HA, All Respiratory	132	245	123
Incidence, Ischemic Stroke	73	138	68
Incidence, Out-of-Hospital Cardiac Arrest	13	23	12
Minor Restricted Activity Days[2]	430,241	755,830	389,543
Work Loss Days[2]	73,341	129,022	66,445

* Each health effect represents the point estimate of a statistical distribution of potential outcomes. Please see Appendix 3-B where the 95-percent confidence intervals are reported. The study population of each C-R function utilized can be found in Appendix 3-B.

1 Health effects of ozone exposure are quantified for the summer planning period only (i.e., May 1 to September 30). There are potentially more premature mortalities and morbidity conditions avoided outside the ozone peak season.

2 Expressed in person-days. Minor Restricted Activity Days (MRAD) refer to days when some normal activities are avoided due to illness.

FIGURE 3-3: SPATIAL DISTRIBUTION OF ESTIMATED PREMATURE DEATHS AVOIDED (YEAR 2037)



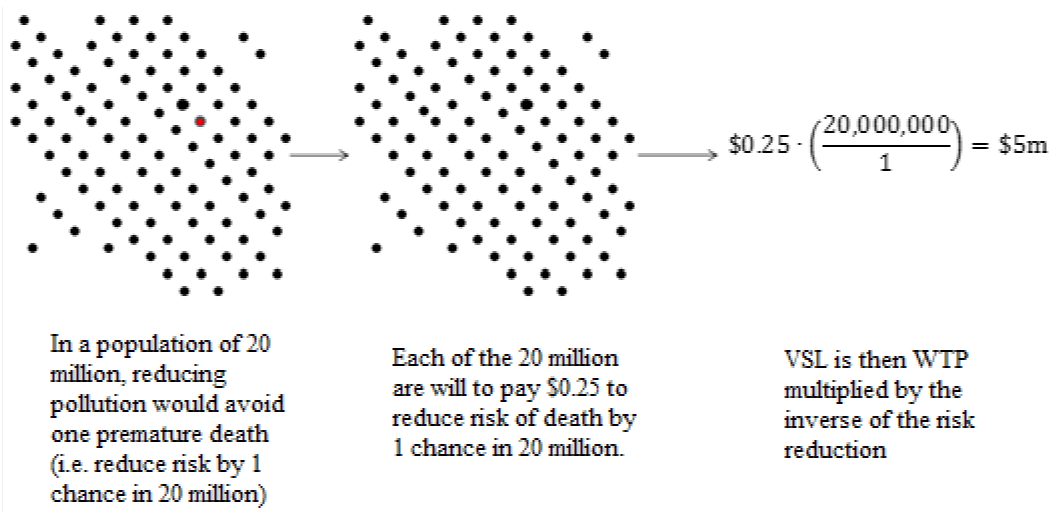
Basin residents are also expected to benefit from the avoidance of large numbers of hospital admissions, emergency room visits, school and work loss days, as well as various respiratory and cardiovascular symptoms. The respiratory mortality effects related to long-term ozone exposure were estimated based on a national C-R function from Turner et al. (2016), and the adult all-cause mortality effects associated with long-term PM2.5 exposure were estimated based on pooling C-R functions estimated in Jerrett et al. (2005), Jerrett et al. (2013), and the kriging and land use regression results from Krewski et al. (2009). Details of these selected functions and the C-R functions used for morbidity effect estimates can be found in Appendix 3-B.

It should be noted that the health effect estimation does not use a concentration threshold below which the affected population would stop benefiting from further reduced exposure to ambient air pollution. In the analysis, health benefits will continue to accrue due to reduced exposure at all levels of pollutant concentration, even at levels below the latest NAAQS.[5] This practice was recommended by Industrial

[5] Note that the control scenario being analyzed here is based on the 2022 AQMP control strategies which are designed to bring the Basin into attainment of the federal ozone standards. Due to the nature of emissions and air quality dynamics, there are spatial variations of pollutant concentrations across the Basin (see Chapter 5 of the 2022 AQMP for detailed discussions). In the baseline scenario (without 2022 AQMP), there are certain areas in the Basin where the modeled pollutant concentrations are already below the federal standards; however, there are also many other areas with modeled pollutant concentrations still exceeding the standards by attainment deadlines. In the control scenario, pollutant concentrations in all areas are expected to fall below the standards, with some falling slightly below and others significantly below. By not employing a threshold in the analysis, public health benefits are

Economics, Inc. and based on the latest scientific evidence, including those summarized in the ISAs (U.S. EPA 2019; U.S. EPA 2020). It is also consistent with the current analytical approach adopted by the U.S. EPA in its regulatory impact analyses (U.S. EPA 2021).[6] It should also be noted that long-term health effects related to ozone exposure are quantified for the entire year, while short-term health effects associated with ozone exposure are quantified for the summer planning period of May 1 to September 30. The temporal differences between the long-term and short-term ozone health effects reflects the temporal scale for which the health effects were originally derived in the supporting epidemiological literature. There are potentially more premature mortalities and morbidity conditions avoided outside the peak ozone season.

FIGURE 3-4: ILLUSTRATIVE EXAMPLE OF VALUE OF STATISTICAL LIFE



Source: U.S. EPA, modified by Industrial Economics, Inc. and South Coast AQMD staff

After health effects are quantified, they are then translated into dollar values using two types of valuation methodologies.[7] Monetized benefits associated with avoided premature deaths are monetized based on a population's willingness-to-pay (WTP) for a small reduction of mortality risk in a year and generally expressed as the "value of statistical life (VSL)." As illustrated in Figure 3-4, the concept of VSL does not place a monetary value on saving a life with certainty; instead, it is an aggregate WTP of a population so that the associated risk reductions across this population are statistically equivalent to one case of premature death avoided.[8] The total monetized benefits of avoided premature deaths were derived by multiplying the number of premature mortalities reduced by the VSL. For morbidity effects, WTP was the preferred valuation method, but in many cases when such estimates are not yet available or reliable, cost

being quantified for all reductions in pollutant concentrations between the baseline and the control scenarios that are attributable to the 2022 AQMP.

[6] There was no threshold used in quantifying public health benefits of reduced ozone exposure in the 2021 Regulatory Impact Analysis (RIA) of the Final Revised Cross-State Air Pollution Rule (CSAPR) Update for the 2008 Ozone NAAQS.

[7] Health effects quantification and valuation in this analysis rely on existing high quality studies whose results are applicable and suitable for a benefits analysis of the 2022 AQMP. This "benefit transfer" from existing studies to the analysis herein is necessary as it is not feasible for staff to conduct original research for all necessary inputs.

[8] For more details, please see Industrial Economics and Robinson (2016a) and Robinson and Hammitt (2016).

of illness (COI) avoided were used to monetize morbidity risk reductions. Avoided COI is conceptually regarded as a conservative estimate of monetized health benefits, as it only accounts for avoided resource costs including direct medical costs and indirect productivity losses, but generally cannot fully account for the benefits of preventing pain and suffering associated with health-related issues.

As shown in Table 3-4, the overall quantifiable and monetized annual public health benefits are estimated to be $20 billion in 2032 and $40.5 billion in 2037 with an average annual of $19.4 billion. About 97 percent of these benefits are attributable to mortality-related benefits, among which the avoided premature deaths due to reduced long-term exposure to PM2.5 were estimated to account for over 70 percent of total monetized public health benefits. The estimates were based on the VSL of $11.1 million[9] and the assumption that the WTP for mortality risk reductions will increase as per-capita income grows; specifically, a one percent increase in income was assumed to raise VSL by 1.1 percent (i.e., an income elasticity of 1.1) (Industrial Economics and Robinson 2016a). These values correspond to a present value of quantified benefits of $129.6 billion at a four percent discount rate or $207 billion at a one percent discount rate, cumulatively from 2025-2037. The values in Table 3-4 are presented in 2021 U.S. dollars and reflect projected income levels in 2032 and 2037. Sensitivity and uncertainty analyses regarding these public health benefits estimations can be found in Appendix 3B.

TABLE 3-4: MONETIZED PUBLIC HEALTH BENEFITS (BILLIONS OF 2021 DOLLARS)

	2032	2037	Annual Average (2025-2037)	Present Value (2025-2037)
Mortality-related benefits	$19.3	$39.1	$18.7	$129.6
Long-Term Ozone Exposure	$4.0	$9.6	$4.2	$29.4
Long-Term PM2.5 Exposure	$15.3	$29.5	$14.4	$100.2
Morbidity-related benefits	$0.7	$1.4	$0.7	$4.7
Grand Total	**$20.0**	**$40.5**	**$19.4**	**$134.3**

Note:

1) Numbers may not sum up due to rounding, and the present value was calculated using a four-percent discount rate.
2) The monetized public health benefits reported in this table were estimated for the four-county region, which includes areas that are located outside the Basin. However, staff estimated that mortality-related benefits accrued to the areas within the Basin would account for 99 percent of the total. In other words, the difference is minimal between quantifying public health benefits for the Basin and for the four-county region.
3) Present Value is discounted to year 2022.

See Appendix 3-B for a detailed discussion regarding morbidity-related public health benefits.

In this chapter, the quantifiable public health benefits associated with improved air quality were assessed relative to reduced morbidity conditions and premature mortalities from exposure to ozone and PM2.5, respectively. The analysis is careful in avoiding potentially double counting health effects by using C-R functions that minimize overlapping health endpoints for the same age group or by subtracting health

[9] All VSL values presented here are in 2021 dollars and 2013 income levels, health benefits results estimated from them are converted to 2032 and 2037 income levels using published CA Wages & Salaries for consistency with this report.

benefits from a health endpoint that could be potentially part of benefits associated with another broader health endpoint (for example, the avoided ED Asthma benefits are deducted from the avoided ED All Respiratory benefits). However, it needs to be emphasized that the health benefits presented here may be underestimating the total actual health benefits. This is because not enough information is currently available in scientific literature to allow for all adverse health effects identified to be measured and valued in dollars, mainly because sufficient data are not available to establish a quantitative relationship between these pollutant levels and some of these health effects.

Moreover, improved public health can generate direct economic benefits other than increased productivity and fewer lost work days in the short-term. As an example of other health benefits that can occur, but are not quantified here, a 2017 study (Isen et al. 2017) showed that improvement in early-childhood health has long-term economic benefits throughout adulthood. Reductions of in-utero and early-infancy exposure to air pollution were found to increase labor participation among the affected individuals 30 years later; that is, working-age adults are more likely to hold a job when they were less exposed to air pollution as an infant.

Public Welfare Benefits

NAAQSs for criteria pollutants, set pursuant to the CAA, include both primary standards designed to protect public health and secondary standards to protect public welfare, including preventing damage to agriculture, ecology, visibility, buildings, and materials. In the previous section, the public health benefits associated with the 2022 AQMP, which is designed to attain the federal ozone and PM2.5 standards, were quantified. The 2022 AQMP is additionally expected to provide benefits protective of public welfare. Although these additional benefits are not specifically quantified for this AQMP, we provide a qualitative description of these public welfare benefits. We additionally include a discussion of the benefits estimated in these categories from the Socioeconomic Reports of previous AQMPs and the scientific literature that provided the methodological basis for quantification. The 2014 report by Abt Associates recommended that the literature and methodologies be updated to reflect the latest advancement in scientific knowledge and that the sufficiency of data and information should also be evaluated. Implementation of these recommendations will be conducted for future AQMPs.

Agricultural Benefit

Agriculture is an integral part of the economy in the Basin. Riverside and San Bernardino counties are ranked in the top 25 counties in California in value of agricultural commodity production. The total value of agricultural production in the four-county region was $2.3 billion, comprised of $1.36 billion from Riverside, $527 million from San Bernardino, $230 million from Los Angeles, and $132 million from Orange (CDFA 2015). Some of the leading commodities produced in these counties include: milk, nursery, grapes (table), hay (alfalfa), eggs, and cattle (milk cows).

Ozone damages vegetation and many crops more than all other pollutants combined. Since the early 1970s, numerous studies have shown that ozone inhibits crop productivity in California, resulting in reductions in crop yield (Larsen and Heck 1976; Oshima et al. 1976; CARB 1987). Improvements in air quality, in particular reductions in ozone concentrations, can improve the productivity of crops. The benefits to agriculture from improved air quality have been quantified in the Socioeconomic Report of previous AQMPs. Using results from more recent studies on the effects of ozone on crop yield (Olszyk and Thompson 1989; Randall and Soret 1998), combined with land-use and economic data, the cash value of increased crop yields that would result from implementation of the 2007 AQMP was estimated. It was projected that the 2007 AQMP would result in a cash value of $23.2 million (in 2000 dollars) for the year 2023. Since the 2012 AQMP was a PM2.5 plan, ozone concentrations were not modeled to derive agricultural benefits. In addition to the benefits to crops from reducing ozone, air contaminants can also damage livestock as they do humans. This livestock benefit was not quantified in previous AQMPs and is also not quantified here.

Implementation of the Final 2016 AQMP was projected to result in agricultural benefits such as increased productivity of agricultural crops in the four counties. However, these benefits were not quantified in that plan as recommended updates to the economic methods to quantify those benefits could not be implemented at that time. Similarly, agricultural benefits are expected through implementing the 2022 AQMP, but the needed updates to the economic methods have not been completed. These updates are planned for future socioeconomic assessments.

Material Benefit

Material benefit is the benefit accrued by the reduction of damage to materials from air pollution. Studies have identified the types of damage that can occur from air pollution and estimated their monetary value. For total suspended particulate matter (TSP) in particular, it causes accelerated wear and breakdown of painted wood and stucco surfaces of residential and commercial properties (Murray et al. 1985). In addition, TSP leads to additional household cleaning costs due to soiling damages (Cummings et al. 1985). Using the results from these studies, the benefits of air pollution controls under previous AQMPs were estimated. The monetary benefit, as a result of implementing the 2007 AQMP, from decreases in cost for repainting stucco and wood surfaces, and cleaning and replacing damaged materials was projected to be $308 million (in 2000 dollars) for the year 2023. Material benefits due to the 2012 AQMP was projected to be about $13 million (in 2005 dollars) for the year 2023. The large difference between the benefits estimated from these two previous AQMPs is due to the 2007 AQMP being an ozone attainment plan with more PM2.5 co-benefits, whereas the 2012 AQMP was a PM2.5 attainment plan with fewer PM2.5 reductions.

In addition to the these damages, a link exists between several pollutants (ozone, sulfur dioxide, PM2.5, and nitrogen oxides) and ferrous metal corrosion; erosion of cement, marble, brick, tile, and glass; and the fading of fabric and coated surfaces (Cummings et al. 1985; Murray et al. 1985). The damage and conversely the potential benefits from reducing the exposure to these items currently cannot be quantified and valued in dollars.

There will also be benefits of reduced damage to materials as a result of the 2022 AQMP, which will reduce PM2.5 and correspondingly TSP. However, the studies used previously to quantify these benefits are outdated, and the Abt report (2014) recommended not quantifying these benefits until a systematic literature review of current research on this topic could be conducted and the sufficiency of data and information could be reevaluated. This literature review is planned for socioeconomic assessments in future AQMPs.

Visibility Benefit

Visibility benefits are the benefits individuals place on the ability to see distant vistas, in places where they live, work, and travel. In qualitative terms, an example of this for the Basin is the value people place on being able to see the San Gabriel Mountains, which were designated a National Monument, from much greater distances, more often. Studies have found that individuals place a monetary value on being able to see distant vistas (Smith and Osborne 1996). A local study by Beron et al. (2001), which estimated parameters that could quantify the value of these visibility benefits,[10] was applied to valuation of the visibility improvements of previous AQMPs. The visibility benefit of the 2007 AQMP was projected to be $5.2 billion (in 2000 dollars) for the year of 2020, and $649 million (in 2005 dollars) as a result of the 2012 AQMP for the year of 2023. The larger benefit from the 2007 AQMP is due to a greater reduction of PM2.5 concentrations than those achieved in the 2012 AQMP.

There will also be benefits to visibility as a result of the air quality improvements achieved from implementing the 2022 AQMP. However, quantification of these benefits was not performed in this analysis based on a recommendation from Abt Associates (2014). The Abt report argued that the local study used to monetize the visibility benefits in previous AQMPs had shortcomings and was dated;[11] therefore, an updated methodology is needed to accurately estimate these benefits. This methodology update is planned for socioeconomic assessments in future AQMPs.

[10] This study used a method called hedonic price analysis, which uses property values along with a diverse set of attributes to estimate the implicit prices of attributes that are associated with a good exchanged in the market.

[11] The methodological improvements since Beron et al. (2001) was published would address issues such as endogeneity in spatial sorting of communities, choice of functional form for the econometric model, and the difficulty of measuring amenities from available data that are likely present in that research.

Chapter 4

Macroeconomic Job Impacts

Chapters 2 and 3 of this report estimated the incremental costs and quantified the public health benefits associated with the 2022 AQMP control measures, respectively. The control measures are designed to provide a path to clean air targets and address federal CAA requirements for the 2015 ozone standard. The costs and benefits of the 2022 AQMP are expected to alter, to various degrees, the economic decisions made by households, businesses, and other economic actors. Some businesses would see production costs go up while other businesses would benefit from a greater demand for their services and technologies. For consumers who consider purchasing or replacing household appliances, for example, the proposed control strategies would also in some cases change or widen the range of product, that differ in fuel types, energy efficiencies, effective unit prices, and thus potential payback periods. In the meantime, improved public health would contribute to higher labor productivity and reduce healthcare-related expenditures. All these direct effects would then cascade through the regional economy and produce indirect and induced macroeconomic impacts. The immediate and subsequent effects may not just occur in the short-term, but some of them may also have lasting impacts that would subside only after a long period of time.

These direct, indirect, and induced macroeconomic impacts were assessed through a multi-year, multi-sector, and multi-region economic model customized by REMI for the South Coast AQMD.[1] This model contains 21 sub-county regions within the four-county area of Los Angeles, Orange, Riverside, and San Bernardino, and the rest of California, rest of the United States outside of California, and the rest of the world. The production of the model economy is comprised of 70 public and private sectors. The regionalized input-output framework used in the REMI model depicts the inter-industry relationships and interactions between different sectors of the model economy. The structure of each sub-county region's economy is represented through production, sales, and purchases between sectors; demand and supply of products in each sector; expenditures made by consumers, businesses, and governments; and trades of goods and services which occur between one sub-county region, the rest of the sub-county regions, the rest of California, rest of the U.S., and the rest of the world. REMI is a dynamic model which simulates the difference in jobs and other macroeconomic variables annually. REMI simulates annual job impacts, resulting in a projection of either jobs gained or foregone. Jobs foregone consist of two conceptually distinctive components: loss of existing jobs and forecasted jobs not created, but they cannot be numerically separated.

The macroeconomic impacts associated with the 2022 AQMP were simulated and projected relative to the baseline forecast for the regional economy, which excludes the implementation of the proposed control strategies in the 2022 AQMP. Consistent with the baseline air quality modeling and emission inventory analysis in the 2022 AQMP, the baseline economic forecast utilizes the 2020 SCAG Growth Forecast (SCAG 2020), specifically its population and job projections.[2] The regional job impacts were simulated for incremental costs only, public health benefits only, and a combined scenario. The REMI model provides policy variables through which the incremental costs and public health benefits can be entered as changes to the economic variables or parameters in the model equations.

[1] REMI Policy Insight Plus (PI+) South Coast Sub County Model v3.0.0 (Build 6083). For a full description of the REMI methodology, please refer to the REMI documentation available at http://www.remi.com/products/pi.

[2] Appendix 4-A describes the procedures to adjust and update the default REMI baseline forecasts based on SCAG projections and the modeling implications of this update.

Job Impacts Explained

Cost and revenue impacts to each industry sector are estimated for every year during the analysis horizon (2023-2037). For example, if an industry is anticipated to invest in air pollution controls, they will need to temporarily reallocate or increase spending to procure and install those controls, and may either forego creating a new job, remove an existing job, or forego spending on other aspects of their business. This would in turn have cascading indirect and induced economic impacts throughout the economy as explained in Appendix 4B. Conversely, industries that benefit from increased sale and revenue associated with air pollution control investments may add more jobs to meet the increased demand for their product and services which then generate their own indirect and induced economic impacts. The analysis simulates the economy-wide effects for each year over the analysis horizon, while also taking into account dynamic effects through time. It is not appropriate to sum job gains or foregone jobs across years, unless total employment is also summed. A more appropriate measure is therefore average annual jobs gained/foregone. Total job impact also takes into account potential economic benefits from the AQMP such as improved public health. In addition to job impacts, potential impacts on regional competitiveness are simulated as part of this analysis and included in Appendix 4C.

It should be emphasized that the REMI model is designed and used mainly to assess the potential macroeconomic impacts on the overall regional economy and the various sectors within the economy. It is not designed to predict potential impacts on an individual business or facility. Moreover, due to data limitations, the analysis does not fully take into account the air quality management plans being concurrently proposed by other air districts, such as the 2020 ozone plan by the San Joaquin Valley Air Pollution Control District. However, to the extent control measures in these plans are part of the 2022 State Implementation Plan (SIP), the model would capture these effects through incremental costs impacting the rest of California. The federal actions proposed by CARB in the 2022 SIP would concurrently affect the four-county region, other regions in the state, and the rest of the nation. However, the potential effects for the rest of the U.S. related to the proposed federal actions are outside the scope of this report.[3]

Projected Job Impacts Due to Estimated Incremental Costs

As discussed in Chapter 2, the total incremental costs associated with the 2022 AQMP control strategies was estimated to be $2.85 billion per year on an amortized annual average between 2023 and 2037, based on a four-percent real interest rate. Almost all private industry sectors in the regional economy are expected to

[3] Effects occurring in the rest of the nation may change relative prices and other relative conditions between the four-county regional economy, other regions in California, and the rest of the U.S. However, these potential changes are not analyzed in this report due to data limitation.

incur varying amounts of cost increases as a direct result of implementing the proposed control strategies. The additional cost is modeled as a higher cost of doing business, which would result in a projected decrease in industry output. In some cases, the proposed control strategies may lead to the adoption of more energy efficient technologies, which would result in fuel-savings or less operating and maintenance costs, such that the cost of doing business may be partially offset.

The 2022 AQMP also include multiple measures that would reduce emissions from residential combustion sources, such as cooktops, ovens, dryers, heaters, and so on. Such measures are assumed to directly affect consumer spending on goods and services. Certain measures may impact industries that have limited presence in California. An example is the proposed federal action to require cleaner marine fuel and cleaner vessel engines for ocean-going vessels visiting U.S. ports. The increased cost for the vessel owner or operator located outside of California are projected to increase prices of goods typically imported as ocean cargos. Overall, these measures that would directly or indirectly affect consumers will then impact how individuals and households allocate their budget.

These direct changes in the cost of doing business are accompanied by an increased demand for zero-emission or low NOx technologies which are necessary to bring the region into attainment. At the same time, consumer spending is also expected to increase on residential appliances using zero-emission or low NOx technologies. These changes would result in increased output and sales for the suppliers of this equipment which would additionally benefit the upstream suppliers who provide intermediate inputs to manufacture such equipment. These potential beneficial impacts flowing from the increased demand on suppliers would highly depend on the location(s) of the potential suppliers. Due to lack of such information in many cases, staff largely relied on REMI's embedded assumption regarding the share of increased local demand met by local *versus* outside suppliers.

The government sector is impacted in multiple ways. Some control measures would impact combustion sources operated by public entities, therefore potentially increasing the cost for their operation, similar to how they would impact private industries. In the meantime, the 2022 AQMP includes limited incentive measures (e.g., C-CMB-04, MOB-05, and MOB-11), which are devised to accelerate the deployment of zero and low NOx emission technologies. Assuming no additional revenues are raised, the estimated government spending to provide clean air incentives would need to be appropriated from unallocated and non-earmarked funds or from funds for discretionary programs that are supported by existing revenue sources. To be conservative about the prospect of securing additional public revenue from new sources, the REMI analysis assumes that all incentive programs would be funded by existing revenue sources for the state and local government budget. This scenario would require a government budget reallocation and affects the provision of public services in the REMI model.

All of these different cost and demand changes are entered into the appropriate REMI policy variables. Overall, the incremental costs from implementation of the 2022 AQMP are projected to result in, on average, about 29,000 jobs foregone per year during the period from 2023 to 2037. The number of jobs foregone includes both potential job losses and forecasted jobs not created, and 29,000 jobs foregone would represent a 0.26 percent decrease from the baseline total of jobs in the four-county region. Table 4-1 shows the job impacts by industry sector for the initial implementation year of the 2022 AQMP (2023), the milestone year for ozone attainment demonstration (2032 and 2037), as well as the annual average between 2023 and 2037.

All but two sectors – utilities and construction – are expected to provide fewer jobs relative to the baseline forecast. The jobs forgone projected for each of these sectors represent a decrease of less than one percent from each sector's baseline job counts with the exception of the sector of agriculture, forestry, fishing, and related activities, which would see an average decline of eight percent between 2023 and 2037. However, this sector is tied for the lowest baseline job numbers with 11,000 workers, thus an eight-percent decrease amounts to only 900 jobs, a fraction of jobs foregone in other sectors. The average annual job impacts show that the sectors of transportation and warehousing, healthcare and social assistance, and accommodation, food, and other non-public services together would account for nearly half of overall jobs foregone in the region.

TABLE 4-1: ANNUAL REGIONAL JOB IMPACTS OF INCREMENTAL COSTS BY SECTOR

(Relative to Baseline)

Sector	NAICS	Jobs			Average Annual (2023-2037)		
		2023	2032	2037	Jobs	Baseline Jobs	% Change
Agriculture, Forestry, Fishing, and Related Activities	11	-15	-1,207	-745	-940	11,346	-8.32%
Mining, Oil and Gas Extraction	21	-13	-95	-156	-89	11,346	-0.78%
Utilities	22	-3	817	1,807	701	20,837	3.50%
Construction	23	-586	1,572	-794	159	557,007	0.03%
Manufacturing	33	501	-582	-1,802	-474	567,408	-0.09%
Wholesale Trade	42	-29	-824	-554	-449	412,280	-0.11%
Retail Trade	44-45	-269	-2243	-4,141	-2,236	887,573	-0.25%
Transportation and Warehousing	48-49	-131	-5,268	-6,573	-3,936	716,631	-0.54%
Information	51	-42	-373	-661	-350	283,925	-0.12%
Finance and Insurance	52	-108	-1,298	-2,138	-1,165	508,223	-0.23%
Real Estate and Rental and Leasing	53	-207	-1,387	-2,783	-1,426	605,162	-0.23%
Professional, Scientific, and Technical Services	54	-98	-1,477	-1,365	-1,102	868,486	-0.13%
Management of Companies and Enterprises	55	11	-206	-309	-166	133,655	-0.12%
Administrative and Waste Management Services	56	-94	-2,345	-3,679	-1,970	823,234	-0.24%
Educational Services	61	-51	-687	-1,408	-540	276,979	-0.19%
Health Care and Social Assistance	62	-321	-3,190	-6,213	-3,090	1,468,188	-0.21%
Arts, Entertainment, and Recreation	71	-68	-650	-1083	-608	292,339	-0.21%
Accommodation and Food Services	72	-166	-2,423	-4783	-2,199	795,452	-0.28%
Other Services, except Public Administration	81	-201	-5715	-9209	-4,378	687,075	-0.63%
State and Local Government	92	-289	-4,530	-12,174	-4,522	984,812	-0.45%
Total		**-2,179**	**-32,123**	**-58,773**	**-28,779**	**11,058,489**	**-0.26%**

Projected Job Impacts of Quantified Public Health Benefits

Similar to the job impacts of incremental costs, the job impacts due to public health improvements were also simulated annually for the period of 2023 to 2037. Public health improvements consist of two components: avoided premature deaths and reduced morbidity incidence. These improvements were quantified and monetized as described in Chapter 3. The largest amount of public health benefits comes from the aggregated willingness-to-pay for a lower risk of premature deaths as a result of decreased exposure to PM2.5 and ozone, based on Value of Statistical Life (VSL). These monetized benefits, while not occurring in the market economy through direct transactions of goods and services, were considered to enhance the quality of life or amenity in the region. In the modeled economy, an increase in a region's amenity, which includes but is not limited to better environmental quality such as cleaner air, acts to attract more economic migrants into the region. Therefore, it directly increases local labor supply as well as local demand for housing, which in turn produces ripple effects throughout the regional economy.

As discussed in Chapter 4 of the 2022 AQMP Socioeconomic Report, there are remaining uncertainties surrounding the macroeconomic modeling of non-market benefits and whether the amount of the benefits should be adjusted before being entered into REMI to enact regional amenity improvements (Abt Associates 2014; Lahr 2016). In consideration of these uncertainties and that the majority of health benefits related to avoided premature deaths accrue to older-age population, the primary analysis scenario inputs only 25 percent of the estimated health benefits as increased amenity.[4] Sensitivity analysis at 50 and 100 percent are included in Appendix 4B.

The other component of the public health benefits is derived from reduced morbidity incidence, such as fewer hospital admissions and visits to emergency departments, fewer absences from work and school, and fewer episodes of experiencing cardiovascular and respiratory symptoms. The monetized morbidity-related benefits are estimated based on the willingness-to-pay for a lower morbidity risk, and where those estimates are not available, the avoided cost of illness was used.[5] The portion of morbidity-related benefits associated with avoided work loss days and school loss days was valued based on the market price of a worker's productivity (i.e., hourly earnings) that results from less work absences due to fewer illnesses for adult workers and their children. These benefits were modeled in REMI as an increase in labor productivity for all industries in the region. Other morbidity-related benefits were considered to result in less spending on healthcare and related services, thus allowing households to reallocate their budget and increase spending on other goods and services. The change in healthcare-related expenditures was modeled as a decrease in consumer spending for six categories in the REMI model, including spending on hospitals, health insurance, nursing homes, paramedical services, pharmaceutical and other medical products, and physician services.

Table 4-2 shows the annual regional job impacts of quantified public health benefits for the milestone years for ozone attainment demonstration (2032 and 2037), as well as the annual average between 2023 and 2037. Under the primary scenario, the public health benefits are projected to increase the number of jobs in the region by about 14,000 in 2032 and 32,000 in 2037 relative to the baseline. The annual job impacts for the analysis horizon of 2023-2037 correspond with an average annual increase of 11,500 jobs, which is about 0.11 percent above the baseline regional total jobs. The mortality-related benefits contribute the largest share to

[4] This is the same share of total mortality-related health benefits inputted as increased amenity in the primary scenario for the Final 2016 AQMP Socioeconomic Report.

[5] This specific methodology was recommended by IEc (Industrial Economics and Robinson 2016).

the number of jobs gained, at nearly 11,000 on average per year, while morbidity-related benefits (increased labor productivity and reduced healthcare costs) contribute fewer than 800 jobs per year on average.

TABLE 4-2: ANNUAL REGIONAL JOB IMPACTS OF QUANTIFIED PUBLIC HEALTH BENEFITS

(Relative to Baseline)

	Jobs		Average Annual (2023-2037)	
Primary Scenario	2032	2037	Jobs	% Change
Quantified Public Health Benefits	13,848	31,945	11,490	0.11%
Mortality-Related Benefits	12,866	30,104	10,695	0.10%
Morbidity-Related Benefits	981	1,840	793	0.01%

Note: REMI model results are not additive, so the total job impact can not necessarily be found from adding the individual components. Several proposed clean air strategies in the 2022 AQMP will be implemented beginning in 2023. However, to be conservative and in consideration of the transition from VOC-limited to NOx-limited ozone formation regime for several areas in the South Coast Air Basin, it is assumed that there would be minimum clean air benefits during the first two years of 2022 AQMP implementation, and health benefits of implementing the 2022 AQMP would begin accruing only in 2025.

As discussed above, the regional job impacts of quantified public health benefits are driven by three forces at work. First, increased economic migration into the region, due to improved regional amenities (or “quality of life”), would result in a larger labor supply and also higher demand for goods and services, thus creating ripple effects throughout the regional economy. Second, the benefits related to avoided morbidity incidence would decrease healthcare-related consumer spending, thus directly resulting in reduced jobs and output in healthcare industries; these healthcare savings can then be spent on other goods and services, which would result in positive job impacts when these goods and services are supplied by local businesses and industries. Third, increased labor productivity due to fewer absences from work would make the region more competitive, thus driving up output and jobs in all sectors.

Table 4-3 shows the distribution of job impacts from quantified health benefits across all major sectors under the primary scenario. All sectors are projected to experience job gains relative to the baseline. The largest job gain, in both absolute and percentage terms, is expected in the construction sector. This is mainly due to increases in various infrastructure investments and related services in the region to accommodate a larger population due to increased migration into the area. For the same reason, the state and local Government and real estate and rental leasing, and accommodation and food services sector are also projected to see large gains in jobs.

TABLE 4-3: ANNUAL REGIONAL JOB IMPACTS OF QUANTIFIED PUBLIC HEALTH BENEFITS BY SECTOR

(Relative to Baseline)

Sector	NAICS	Jobs		Average Annual (2023-2037)		
		2032	2037	Jobs	Baseline Jobs	% Change
Agriculture, Forestry, Fishing, and Related Activities	11	7	16	23	11,346	0.05%
Mining, Oil and Gas Extraction	21	15	31	45	11,346	0.11%
Utilities	22	35	78	109	20,837	0.14%
Construction	23	2,586	5,227	7,806	557,007	0.36%
Manufacturing	33	458	997	1,341	567,408	0.07%
Wholesale Trade	42	310	721	957	412,280	0.06%
Retail Trade	44-45	1,149	2,713	3,613	887,573	0.11%
Transportation and Warehousing	48-49	689	1,632	2,169	716,631	0.08%
Information	51	71	177	216	283,925	0.02%
Finance and Insurance	52	321	777	1,000	508,223	0.05%
Real Estate and Rental and Leasing	53	1,179	2,760	3,776	605,162	0.16%
Professional, Scientific, and Technical Services	54	682	1,573	2,122	868,486	0.06%
Management of Companies and Enterprises	55	34	79	103	133,655	0.02%
Administrative and Waste Management Services	56	743	1,776	2,349	823,234	0.07%
Educational Services	61	307	751	994	276,979	0.09%
Health Care and Social Assistance	62	1,032	2,722	3,331	1,468,188	0.06%
Arts, Entertainment, and Recreation	71	106	292	336	292,339	0.03%
Accommodation and Food Services	72	1,456	3,423	4,679	795,452	0.15%
Other Services, except Public Administration	81	;474	1,216	1,497	687,075	0.06%
State and Local Government	92	2,194	4,983	7,043	984,812	0.18%

TABLE 4-3 (CONTINUED): ANNUAL REGIONAL JOB IMPACTS OF QUANTIFIED PUBLIC HEALTH BENEFITS BY SECTOR

(Relative to Baseline)

Sector	NAICS	Jobs		Average Annual (2023-2037)		
		2032	2037	Jobs	Baseline Jobs	% Change
Total		13,848	31,945	11,490	11,058,489	**0.10%**

Projected Job Impacts of the 2022 AQMP

The simulation of the regional economy with all of the incremental cost and benefit-related policy variables combined together represents the regional economic impact of the 2022 AQMP. Figure 4-1 illustrates how the net job impacts of the 2022 AQMP change over time, along with the job impacts attributable separately to incremental costs and public health benefits. Overall, the regional economy is projected to experience jobs forgone in the first years because the negative effects, mainly associated with the incremental costs of proposed control measures, would dominate the positive effect that largely stems from public health benefits. Over time, while incremental costs continue to increase, public health benefits also increase, and offset close to half of the expected jobs lost.

On an annual average, the combined effects of public health benefits and incremental costs associated with the 2022 AQMP are expected to result in a loss of 17,000 jobs per year from 2023 to 2037, relative to the baseline job forecast. This represents an annualized job growth rate of 0.41 percent, or a 0.03 percentage point deceleration from the baseline job growth during the same period. Table 4-4 reports the average annual net job impacts by sector. It is projected that the negative job impacts would spread among most of the public and private sectors and increase over time.

FIGURE 4-1: REGIONAL NET JOB IMPACTS OF THE 2022 AQMP, 2023-2037

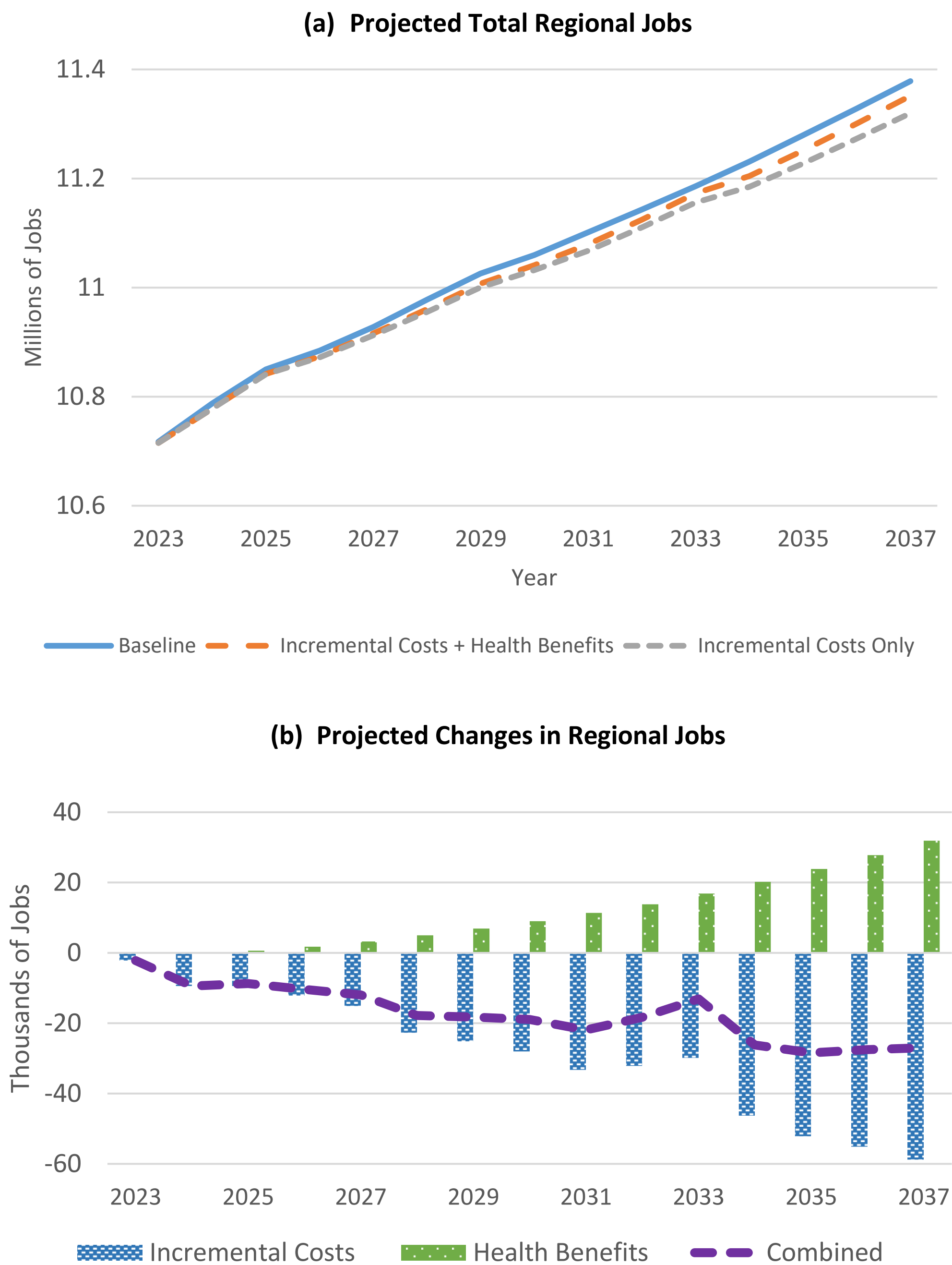


TABLE 4-4: ANNUAL NET JOB IMPACTS BY SECTOR

(Relative to Baseline)

Sector	NAICS	Jobs			Average Annual (2023-2037)		
		2023	2032	2037	Jobs	Baseline Jobs	% Change
Agriculture, Forestry, Fishing, and Related Activities	11	-15	-1202	-731	-935	11,346	-8.28%
Mining, Oil and Gas Extraction	21	-13	-80	-125	-77	11,346	-0.67%
Utilities	22	-3	851	1883	729	20,837	3.64%
Construction	23	-586	4152	4398	2195	557,007	0.39%
Manufacturing	33	501	-126	-815	-104	567,408	-0.02%
Wholesale Trade	42	-29	-515	163	-192	412,280	-0.05%
Retail Trade	44-45	-269	-1096	-1440	-1279	887,573	-0.14%
Transportation and Warehousing	48-49	-131	-4583	-4954	-3363	716,631	-0.46%
Information	51	-42	-303	-485	-290	283,925	-0.10%
Finance and Insurance	52	-108	-977	-1365	-894	508,223	-0.18%
Real Estate and Rental and Leasing	53	-207	-210	-33	-448	605,162	-0.07%
Professional, Scientific, and Technical Services	54	-98	-796	199	-539	868,486	-0.06%
Management of Companies and Enterprises	55	11	-172	-231	-138	133,655	-0.10%
Administrative and Waste Management Services	56	-94	-1604	-1912	-1,347	823,234	-0.16%
Educational Services	61	-51	-380	-660	-280	276,979	-0.10%
Health Care and Social Assistance	62	-321	-2159	-3504	-2189	1,468,188	-0.15%
Arts, Entertainment, and Recreation	71	-68	-544	-793	-514	292,339	-0.17%
Accommodation and Food Services	72	-166	-970	-1377	-990	795,452	-0.12%
Other Services, except Public Administration	81	-201	-5243	-8004	-3,969	687,075	-0.57%
State and Local Government	92	-289	-2340	-7210	-2,711	984,812	-0.27%
Total		**-2,179**	**-18,294**	**-26,994**	**-17,334**	**10,911,958**	**-0.16%**

Table 4-5 shows the distribution of net job impacts in 2023, 2032, and 2037 among five groups categorized by industry earnings within REMI. The range of industry wage rates are listed in Table 4-5. All groups are projected to see small numbers of jobs foregone in 2023 which mirrors the negative job impacts among various sectors. In 2037, all but one group are projected to experience jobs foregone of between 0.13 and 3.13 percent, relative to the baseline forecast. Some groups will recover from a low around 2032 due to the increasing public health benefits, including the lowest income group making on average $163 - $1,118 per week.

TABLE 4-5: NET JOB IMPACTS BY INDUSTRY EARNINGS GROUP

Group	2022 Average Weekly Earnings*	% Impact from Baseline			No. of Industries
		2023	2032	2037	
1	$163-$1,118	-0.09%	-5.07%	-3.13%	14
2	$1,141-$1,501	-0.02%	-0.30%	-0.78%	14
3	$1,579-$2,070	-0.02%	-0.14%	-0.13%	14
4	$2,072-$2,653	0.00%	-0.12%	0.01%	14
5	$2,694-$7,630	0.13%	-0.38%	-0.62%	14

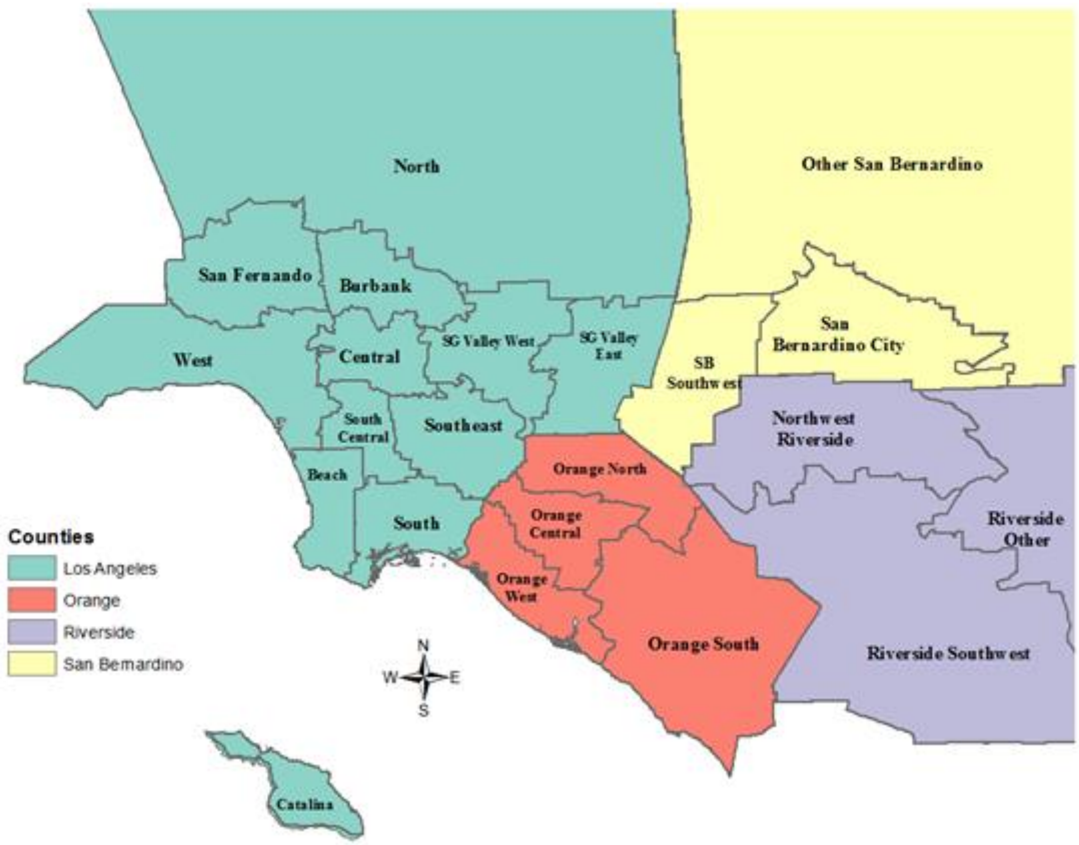
*Source: REMI. For the list of industries by earning group, see Appendix 4B.

Chapter 5

Sub-Regional Distribution

This chapter assesses the sub-regional distribution of incremental costs, public health benefits, and job impacts to provide information on how the 2022 AQMP may affect different communities within the four-county region of Los Angeles, Orange County, Riverside and San Bernardino. As Figure 5-1 shows, there are 11 sub-county regions within Los Angeles County, four within Orange County, and three each within Riverside and San Bernardino counties. The four counties are divided into these sub-county regions based on socioeconomic characteristics found in the U.S. Census Bureau's American Community Survey (Lieu, Dabirian, and Hunter 2012). The REMI model used to simulate regional macroeconomic impacts based on the incremental costs and public health benefits of the 2022 AQMP was customized according to these same sub-county definitions.

FIGURE 5-1: 21 SUB-COUNTY REGIONS



Note: For readability, this map does not show the entire subregions of North (of the Los Angeles County), Other San Bernardino, Riverside Southwest, and Riverside Other.

Description of the 21 Sub-County Regions

With six commercial airports, the nation's two largest marine ports, and over 10 million workers generating $1.2 trillion dollars in GDP,[1] the regional economy of Los Angeles, Orange, Riverside, and San Bernardino counties is one of the largest and most productive in the United States. This section provides a snapshot of how different communities within the four-county region vary according to key demographic and economic indicators. All indicators discussed below are based on the adjusted REMI baseline based on the 2020 RTP/SCS.[2]

The four-county region is home to about 17.6 million people. About 75 percent of the region's population, or about 13 million people, reside in the coastal counties of Los Angeles and Orange, while the remaining 25 percent, or about 4.6 million people, live further inland in Riverside and San Bernardino counties. Figure 5-2 (a) demonstrates the population distribution among 21 sub-county regions projected for 2023, while Figure 5-2 (b) shows widely varying population density in each of the sub-regions.

The densest populated areas in the region are the South Central and Central sub-regions in Los Angeles County. South Central is home to more than 1.1 million people, or roughly 16,000 people per square mile. The Central sub-region in Los Angeles also has a population over 1.4 million and a density of 14,000 people per square mile. The densest populated areas in Orange County are the Central and Western sub-regions, which have a population density of 10,000 and 5,900 people per square mile, respectively. In comparison, the sub-regions further inland are much less densely populated. The inland subregions with the highest population densities are San Bernardino City, San Bernardino Southwest, and Northwest Riverside. However, their population densities of 2,900-3,600 people per square mile are about only one fifth of the population density in South Central Los Angeles.

[1] U.S. Bureau of Economic Analysis, 2020 GDP and 2020 total job estimates (including payroll jobs and self-employment) for Los Angeles-Long Beach-Anaheim and Riverside-San Bernardino-Ontario metropolitan statistical areas.

[2] See Appendix 4A for a detailed discussion.

FIGURE 5-2 (a): PROJECTED POPULATION BY SUB-COUNTY REGION, 2023

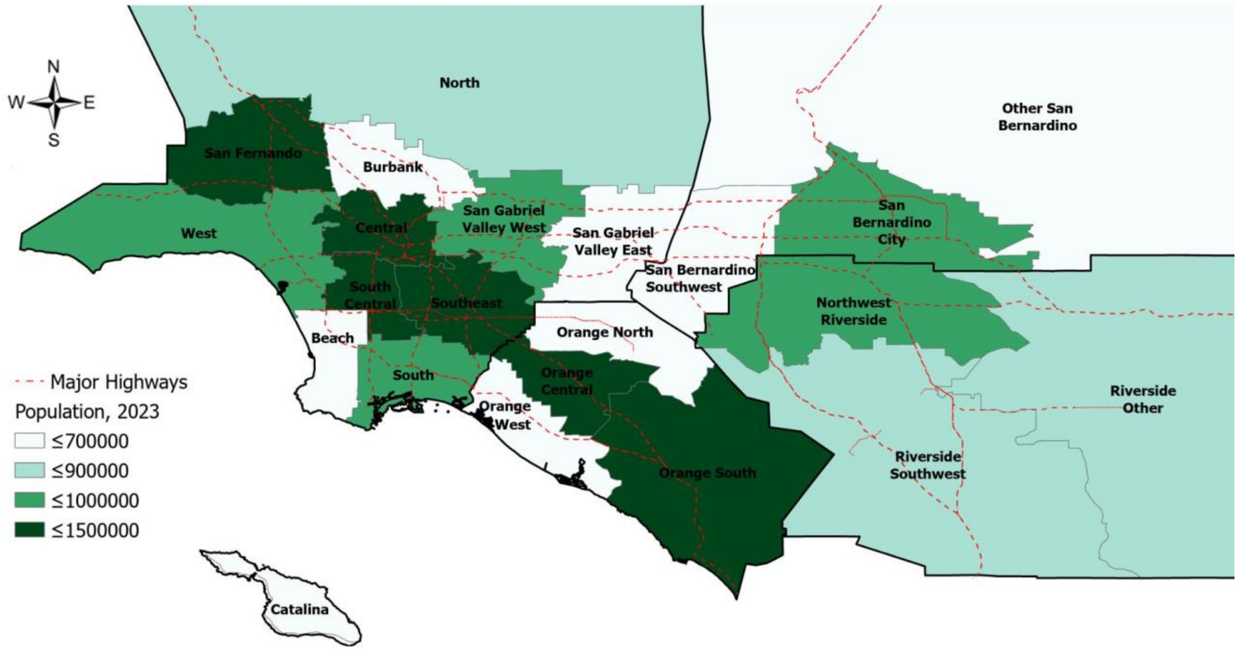
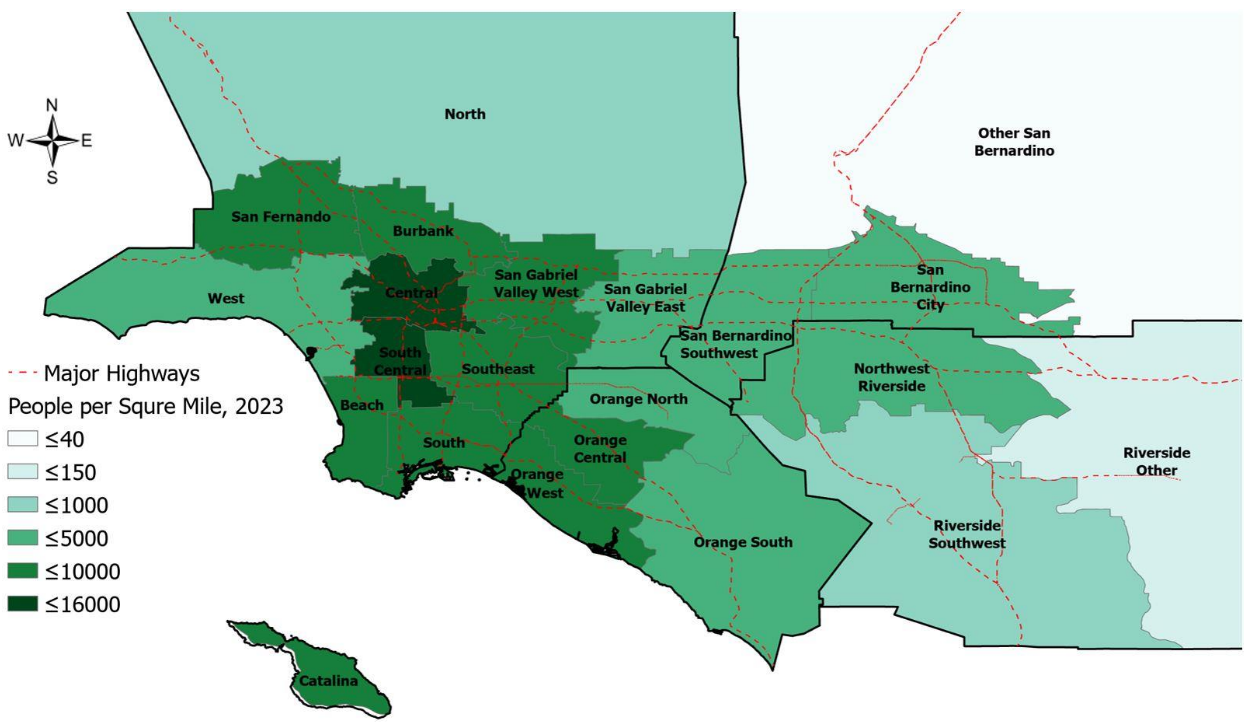


FIGURE 5-2 (b): PROJECTED POPULATION DENSITY BY SUB-COUNTY REGION, 2023



As seen in Figure 5-3, the region's jobs are largely concentrated in the Central and Western sub-regions of Los Angeles, which collectively will provide 2.2 million jobs or about one out of every five jobs in the region in 2023. In Orange County, the Orange Central subregion is projected to host 680,000 jobs. In the Inland area, the largest concentration of jobs is found along the San Bernardino and Riverside border. This cluster of San Bernardino Southwest, San Bernardino City, and Northwest Riverside together will supply nearly 1.5 million jobs or about one out of every seven jobs in the region.

FIGURE 5-3: PROJECTED JOB COUNTS BY SUB-COUNTY REGION, 2023

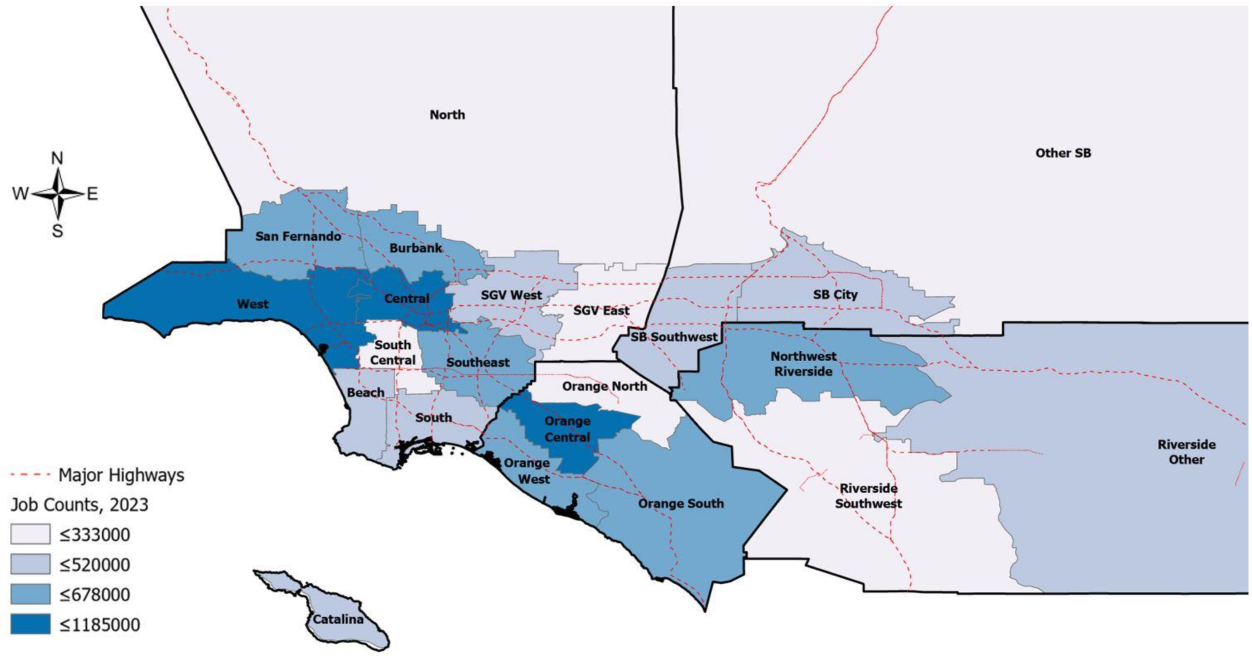


Figure 5-4 (a) shows the number of jobs per working-age adult (25 to 64 years old). Most sub-county regions have about one job per working-age adult, with a few exceptions. South Central and Northern Los Angeles, Riverside Southwest, and Other San Bernardino regions have relatively scarce employment opportunities, with less than one job per two working-age adults. In comparison, residents in the Burbank and West subregions of Los Angeles have better employment prospects, with approximately three jobs for every two working-age adults.

Figure 5-4 (b) illustrates the age-dependency ratio, defined as the number of those too young or elderly to work per working-age adult. The West subregion of Los Angeles has the lowest age-dependency ratio of 32 dependents per 100 workers; whereas, the South Central subregion of Los Angeles has the largest at 176 dependents per 100 workers. Higher age-dependency ratios found in the inland area than typically found in Los Angeles and Orange counties is largely a result of proportionally more families with young children and relatively more affordable family housing, but it also indicates more pressure on workers in these areas—as well as in certain areas in Los Angeles such as its North, San Fernando, and South Central subregions—to provide for those not in the workforce. Such pressure is especially high in regions such as South Central Los Angeles, Riverside Southwest, and Other San Bernardino where jobs are harder to come by, as indicated in Figure 5-4 (a).

FIGURE 5-4 (a): PROJECTED JOBS PER WORKING-AGE ADULT BY SUB-COUNTY REGION, 2023

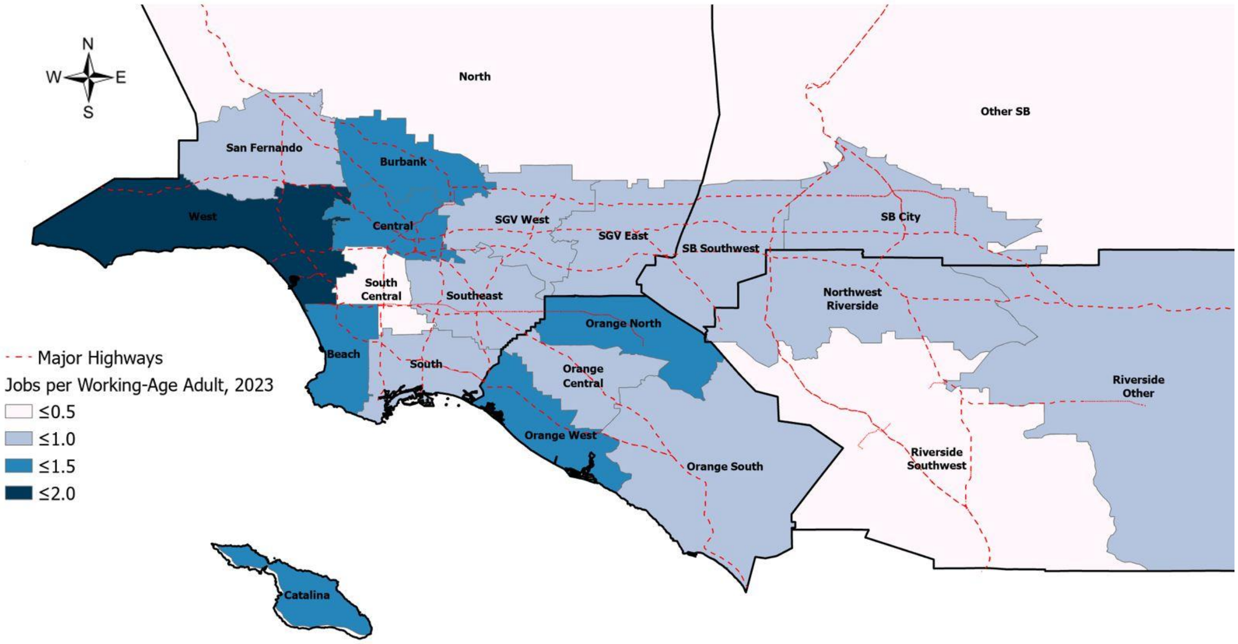
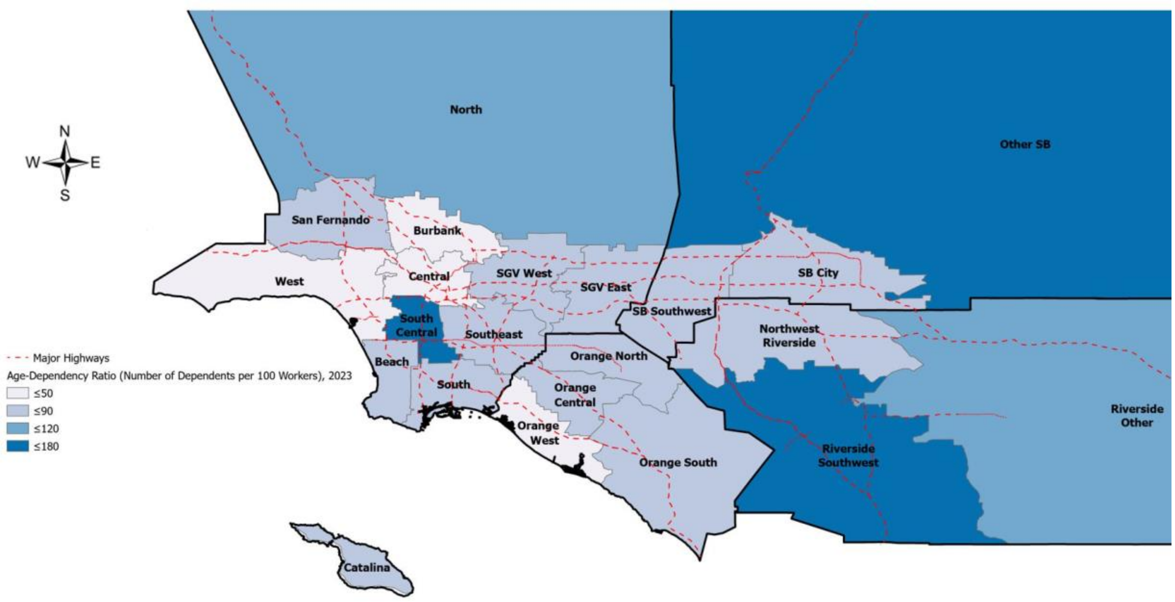


FIGURE 5-4 (b): PROJECTED AGE-DEPENDENCY RATIOS BY SUB-COUNTY REGION, 2023



In terms of economic output, Figure 5-5 (a) shows the distribution of industry output by sub-county region, with all dollar amounts being expressed in 2021 dollars. More than one-fifth of the region's output, or about $445 billion, is projected for Central and West Los Angeles; whereas, all sub-regions in Riverside and San Bernardino combined are projected to produce about $367 billion, or approximately 17 percent of the regional economic output. Figure 5-5 (b) illustrates labor productivity defined as output per worker across sub-county regions. Output per worker is highest in the Burbank area of Los Angeles, at about $251,000. Output per worker in the inland area are lower, ranging from $160,000 to $185,000. The differences largely reflect the very different industry structures across the four-county region, with more capital-intensive industries tending to locate in the coastal counties and more labor-intensive industries in the inland area. It should be noted however that productivity and output have increased for inland regions since the 2016 AQMP.

FIGURE 5-5 (a): PROJECTED ECONOMIC OUTPUT BY SUB-COUNTY REGION, 2023

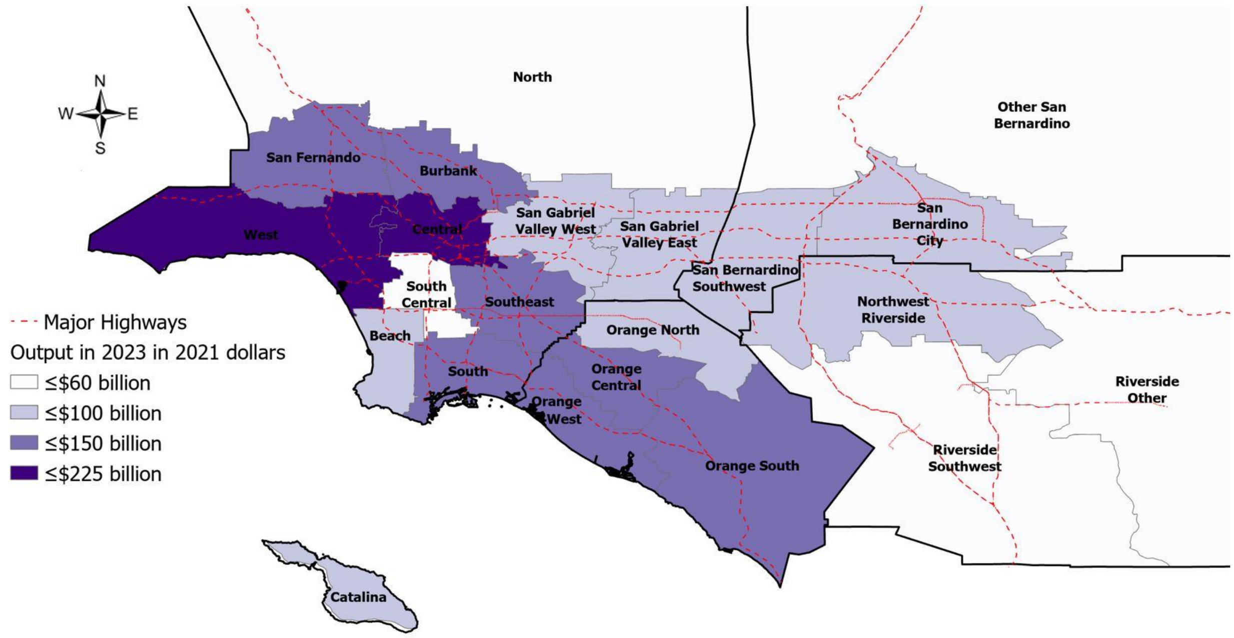
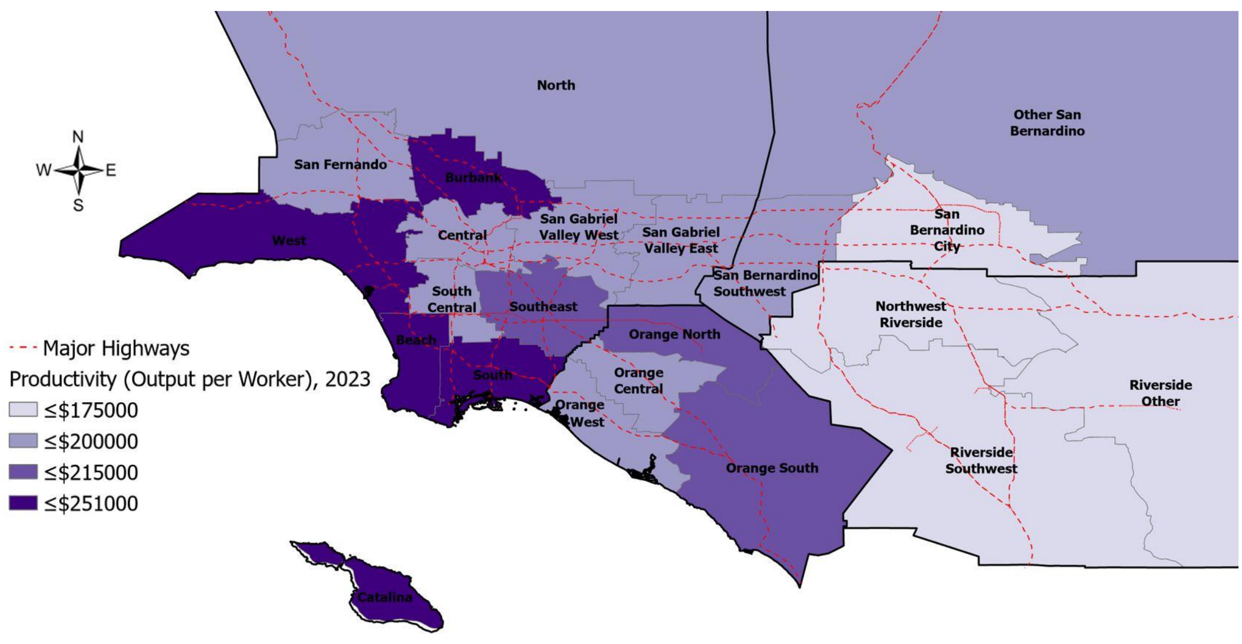


FIGURE 5-5 (b): PROJECTED WORKER PRODUCTIVITY BY SUB-COUNTY REGION, 2023



Sub-County Distribution of Estimated Incremental Costs

As reported in Chapter 2, the total incremental costs associated with the 2022 AQMP will directly affect private industries, consumers and households, and the public sector. Table 5-1 reports the average annual total incremental costs by sub-county region, which is also illustrated in Figure 5-6. The distribution of incremental costs largely reflects the population in each sub-county region.[3]

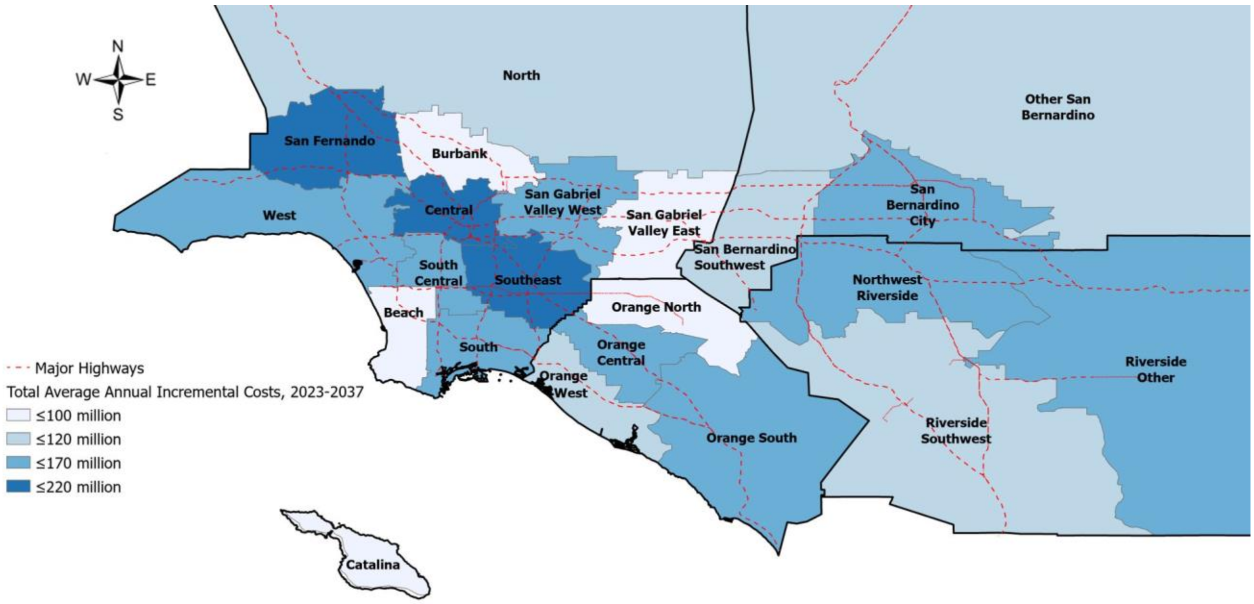
TABLE 5-1: INCREMENTAL COST BY SUB-COUNTY REGION (AVERAGE ANNUAL, 2023-2037)

County	Sub-county Region	Average Annual Incremental Cost (Millions of 2021$)
Los Angeles	Beach & Catalina	89
Los Angeles	Burbank	91
Los Angeles	Central	210
Los Angeles	North	113
Los Angeles	San Fernando	214
Los Angeles	San Gabriel Valley East	100
Los Angeles	San Gabriel Valley West	145
Los Angeles	South	134
Los Angeles	South Central	167
Los Angeles	Southeast	180
Los Angeles	West	140
Orange	Orange Central	166
Orange	Orange North	69
Orange	Orange South	159
Orange	Orange West	103
Riverside	Northwest Riverside	150
Riverside	Riverside Other	143
Riverside	Riverside Southwest	120
San Bernardino	San Bernardino City	145
San Bernardino	Other San Bernardino	107
San Bernardino	San Bernardino Southwest	108
All Sub-County Regions		**2,851**

Note: Total average annual incremental cost may not sum up to the total in Table 2-1 due to rounding.

[3] It should be noted that the cost distribution presented here is for informational purposes only and was allocated based on sub-county population. It may not reflect the actual cost distribution under all plausible cost scenarios. Staff expects to be able to gather more detailed information during the program implementation and rulemaking process.

FIGURE 5-6: TOTAL INCREMENTAL COSTS BY SUB-COUNTY REGION (AVERAGE ANNUAL, 2023-2037)

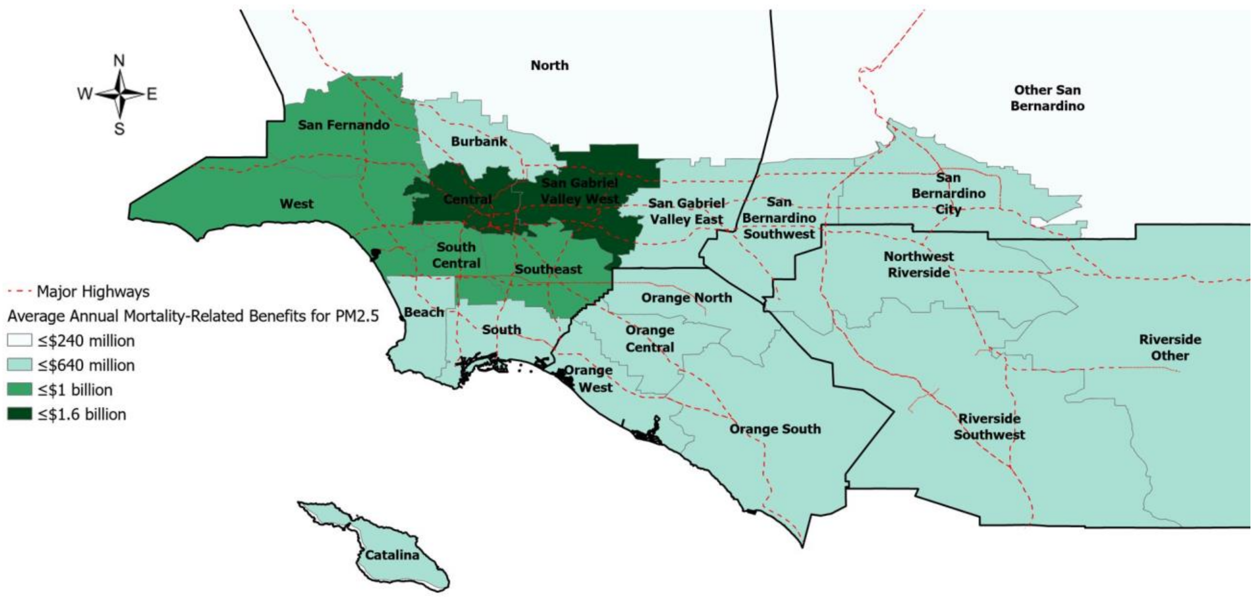


Sub-County Distribution of Monetized Public Health Benefits

As discussed in Appendix I of the 2022 AQMP, air pollution continues to be linked to increases in death rates (mortality) and increases in illness and other health effects (morbidity). Based on the quantification of health benefits in Chapter 3, it has been estimated that the four-county region will gain an average annualized benefit of $19.4 billion from 2025 to 2037 for avoided premature deaths, asthma and other respiratory illness, cardiovascular disease, and so.[4]

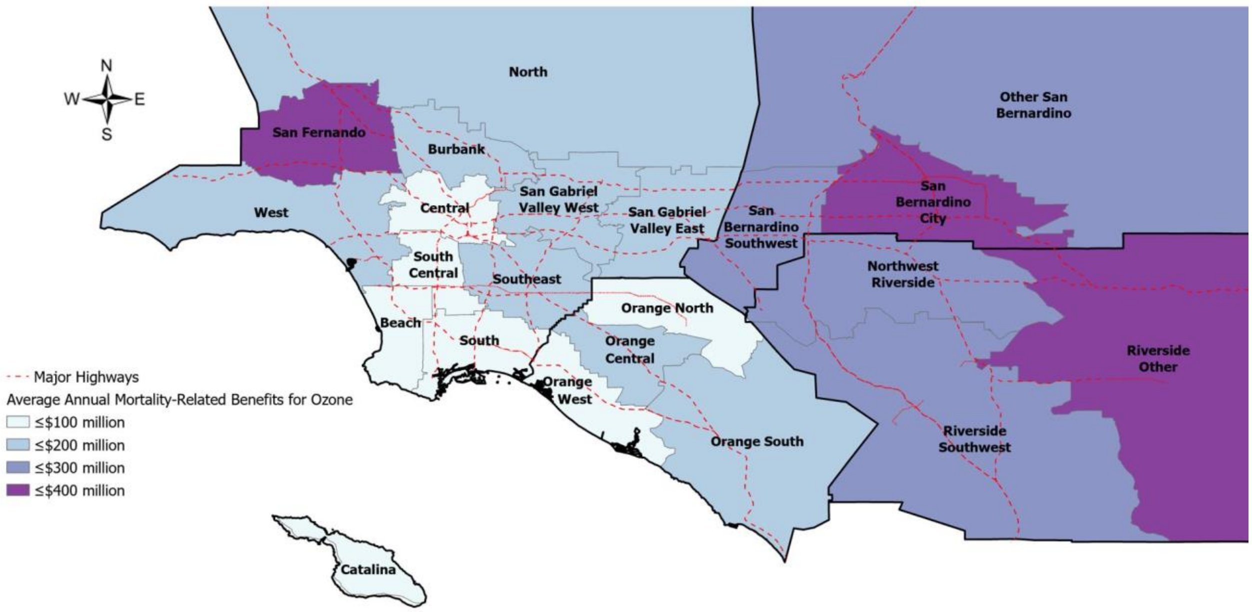
Figures 5-7 (a) and (b) provide a visualization of how mortality-related benefits are distributed in the region. Figure 5-7 (a) shows that the largest average annual mortality-related benefits associated with decreased PM2.5 exposure are projected for Central Los Angeles and San Gabriel Valley West; whereas, Figure 5-7 (b) shows that the largest average annual mortality-related benefits associated with decreased ozone exposure occur mostly in downwind areas including San Bernardino City, Riverside Other, as well as the San Fernando Valley within Los Angeles County. Morbidity-related benefits related to decreased PM2.5 and ozone exposure are much lower than mortality-related benefits and are similar to the spatial distributions shown in Figures 5-7(a) and (b), respectively.

FIGURE 5-7 (a): DISTRIBUTION OF MORTALITY-RELATED BENEFITS FOR PM2.5 BY SUB-COUNTY REGION (AVERAGE ANNUAL, 2023-2037)



[4] As discussed in Chapter 3, it is conservatively assumed that little health benefits would accrue in the first two years of the 2022 AQMP implementation.

FIGURE 5-7 (b): DISTRIBUTION OF MORTALITY-RELATED BENEFITS FOR OZONE BY SUB-COUNTY REGION (AVERAGE ANNUAL, 2023-2037)



Tables 5-2 reports the per capita annual average public health benefits for each of the 21 sub-county regions. It ranges from about $410 per person in Orange North to nearly $2,200 per person in San Bernardo City.[5] The per capita public health benefits will be further analyzed between EJ and non-EJ communities in Chapter 6.

[5] Per capita calculation uses average projected population for 2023-2037 in the SCAG-adjusted REMI baseline. Therefore, differing population growth in each sub-county region may also contribute to the differences of annual average per capita public health benefits observed across the sub-county regions.

TABLE 5-2: PER CAPITA PUBLIC HEALTH BENEFITS BY 21 SUB-COUNTY REGION (AVERAGE ANNUAL, 2023-2037)

County	Sub-county Region	Per Capita Average Annual PM2.5 Benefits (2021$)		Per Capita Average Annual Ozone Benefits (2021$)		Total Annual Average Benefits Per Capita ($)
		Mortality	Morbidity	Mortality	Morbidity	
Los Angeles	Beach & Catalina	584	5	129	10	728
Los Angeles	Burbank	774	7	179	13	973
Los Angeles	Central	1,106	10	58	4	1178
Los Angeles	North	196	2	186	30	414
Los Angeles	San Fernando	1,077	11	451	45	1,583
Los Angeles	San Gabriel Valley East	562	6	189	19	776
Los Angeles	San Gabriel Valley West	1,033	10	152	14	1,209
Los Angeles	South	599	6	97	10	713
Los Angeles	South Central	745	10	21	3	780
Los Angeles	Southeast	1,295	15	152	18	1,480
Los Angeles	West	1,201	9	190	11	1,412
Orange	Orange Central	810	10	183	29	1,032
Orange	Orange North	307	3	93	10	413
Orange	Orange South	478	5	169	20	670
Orange	Orange West	367	3	79	7	457
Riverside	Northwest Riverside	329	4	176	29	538
Riverside	Riverside Other	443	3	390	25	862
Riverside	Riverside Southwest	315	3	195	24	536
San Bernardino	Other San Bernardino	193	2	204	20	418
San Bernardino	San Bernardino City	1,256	12	818	100	2,187
San Bernardino	San Bernardino Southwest	581	6	241	27	856
All Sub-County Regions		14,250	142	4,354	467	**19,214**

Sub-County Distribution of Projected Job Impacts

As discussed in Chapter 4, the costs and benefits of the 2022 AQMP are expected to alter, to various degrees, the economic decisions made by households, businesses, and other economic actors. Some businesses would see production costs go up while other businesses would benefit from a greater demand for their services and technologies. For consumers who consider purchasing or replacing household appliances, for example, the proposed control strategies would also in some cases change or widen the range of product, that differs in fuel types, energy efficiencies, effective unit prices, and thus potential payback periods. In the meantime, improved public health would contribute to higher labor productivity and reduce healthcare-related expenditures. All these direct effects would then cascade through the regional economy and produce indirect and induced macroeconomic impacts. Given this, the region is expected to see, on average, about 17,000 jobs foregone when compared to the annual average baseline workforce between 2023 and 2037, as a result of implementing the 2022 AQMP.

Figure 5-8 (a) shows the distribution of the annual average net job impacts by sub-county region. All regions except Riverside Southwest are expected to experience net jobs forgone over the period of 2023-2037. Central Los Angeles followed by South Los Angeles is expected to have the largest numbers of jobs foregone at approximately 3,200 and 1,900 on an annual average. Riverside Southwest is expected to have a modest gain of 15 jobs on an annual average. Figure 5-8 (b) shows the average annual percent change in jobs compared to the baseline, which represents job impacts that would occur regardless of whether the 2022 AQMP is implemented. The largest percent changes are concentrated in Riverside Southwest and South Los Angeles with 0.36 percent annual average net jobs forgone below the baseline, followed by West Los Angeles with 0.31 percent below the baseline.

`FIGURE 5-8 (a): DISTRIBUTION OF NET JOB IMPACTS BY SUB-COUNTY REGION (ANNUAL AVERAGE, 2023-2037)

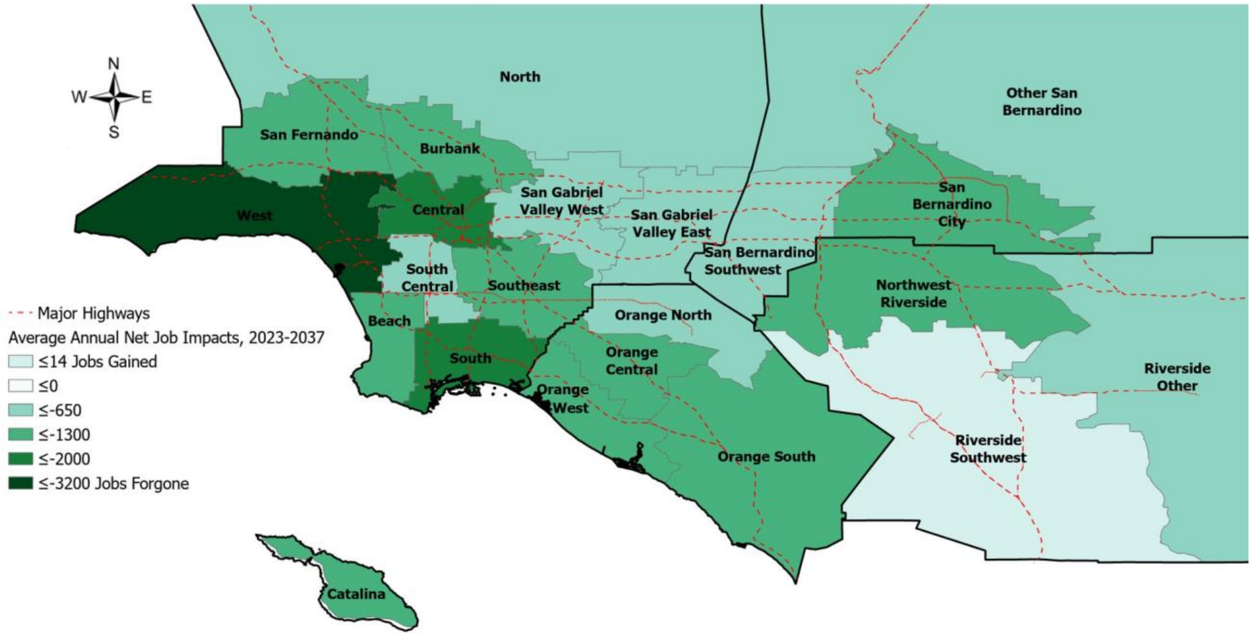
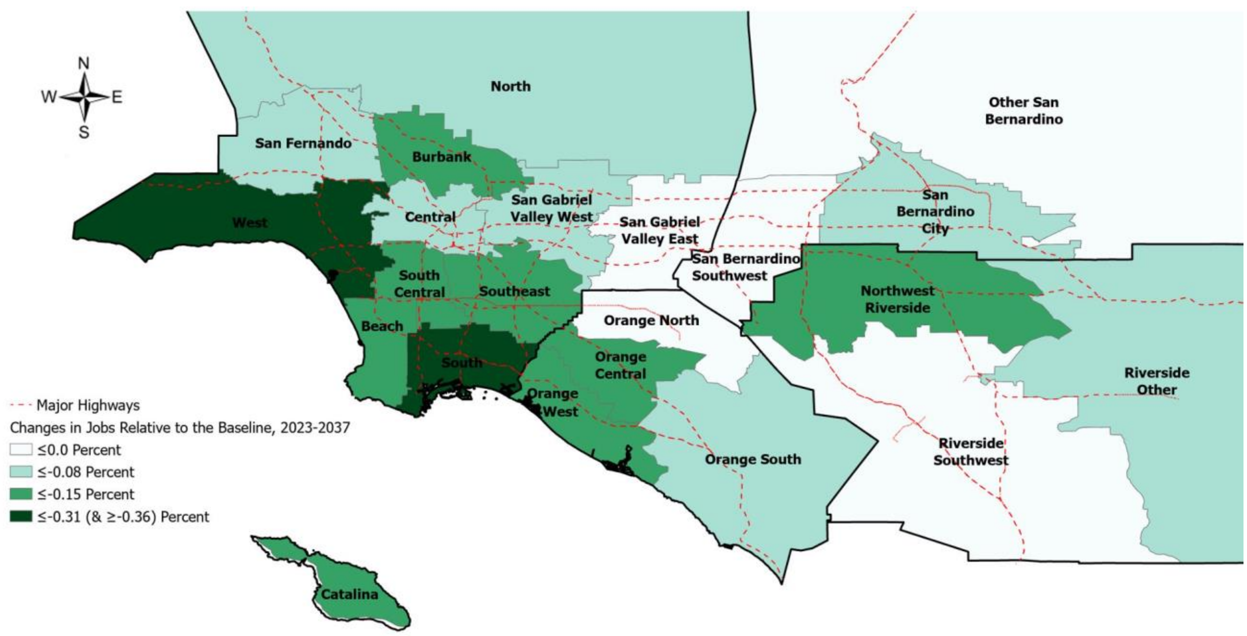


FIGURE 5-8 (b): PERCENT CHANGE RELATIVE TO THE BASELINE BY SUB-COUNTY REGION (ANNUAL AVERAGE, 2023-2037)



Chapter 6
Environmental Justice

Introduction to Environmental Justice and Disadvantaged Communities in South Coast Air Basin

The environmental justice (EJ) movement began in the 1960s as individuals sought to address the inequity of environmental protection in their communities.[1] Locally, the South Coast AQMD defines EJ as "equitable environmental policymaking and enforcement to protect the health of all residents, regardless of age, culture, ethnicity, gender, race, socioeconomic status, or geographic location, from the health effects of air pollution."[2] California state law defines EJ as “the fair treatment and meaningful involvement of people of all races, cultures, incomes, and national origins, with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies.”[3] Separately, though similar to the state of California’s definition, the United States Environmental Protection Agency (U.S. EPA) defines EJ as “the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.”[4]

While the definitions provide a marker for EJ goals, determining which communities can be identified as “areas of concern” or “EJ communities” requires measurable fit-for-purpose information about these places. As an example, in 2012 California Senate Bill (SB) 535 established funding requirements for “disadvantaged communities (DACs).”[5] In May 2022, the California Environmental Protection Agency (CalEPA) updated its designation of DACs for SB535, including:

1. Census tracts receiving the highest 25 percent of overall scores in CalEnviroScreen4.0 (CES),
2. Census tracts lacking *overall* scores in CES due to data gaps, but ranking among the highest 5 percent of the cumulative pollution burden scores,
3. Census tracts identified in the 2017 DAC designation as disadvantaged, regardless of their CES scores,[6]
4. Lands under control of federally recognized Tribes.

CalEPA created and updates the list of DACs using CalEnviroScreen 4.0 (CES), which “is a mapping tool that helps identify California communities that are most affected by many sources of pollution, and where people are often especially vulnerable to pollution’s effects.”[7] In addition, prior to SB 535, South Coast AQMD developed its own guidelines for EJ area designation for grant allocation purposes, based on a combination of PM2.5 concentrations, toxic cancer risk, and poverty rate. Since the adoption of SB 535 and the corresponding application of SB 535 within the statewide CES tool, South Coast AQMD has moved towards using the latest

[1] See https://www.epa.gov/environmentaljustice/environmental-justice-timeline.
[2] See http://www.aqmd.gov/nav/about/initiatives/environmental-justice.
[3] California Government Code § 65040.12(e)(1). See https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=GOV&sectionNum=65040.12.
[4] See http://www3.epa.gov/environmentaljustice/.
[5] California Senate Bill 535, De León, Chapter 830, Statutes of 2012.
[6] The 2017 DAC designation included the top 25% of census tracts from CalEnviroScreen3.0, as well as tracts that do not have an overall CES score but fall in the highest 5% of CES pollution burden scoring. See https://calepa.ca.gov/wp-content/uploads/sites/6/2017/04/SB-535-Designation-Final.pdf.
[7] See https://oehha.ca.gov/calenviroscreen/about-calenviroscreen.

designation of SB 535 DACs as its definition of EJ communities.[8] See Chapter 8 of the 2022 AQMP for a detailed discussion.[9]

The examples above provide quantifiable and defined methods for determining which communities face disproportional environmental burdens, in the context of identifying how government funding should be directed. This chapter will present a quantified analysis that evaluates how environmental justice communities would be impacted by the proposed control strategies in the 2022 AQMP.

Introduction to EJ and Distributional Analysis

Based on recommendations provided by Abt Associates in 2014 and scientific advising and methods provided by Industrial Economics, Inc. (IEc) in 2016, South Coast AQMD staff implemented its first EJ and distributional analysis as part of the Final 2016 AQMP Socioeconomic Assessment. [10] The methods and analyses used as part of the Final 2016 AQMP Socioeconomic Assessment were:

1. Review and sensitivity analysis of five alternative EJ screening and designation methods in the Basin;
2. Analysis of the public health impacts across "EJ" and "non-EJ" communities for each alternative definition; and
3. Distributional analysis of public health impacts in "EJ" and "non-EJ" communities using inequality indicators to understand whether the Final 2016 AQMP further exacerbated or reduced inequities between and within communities.

We provide an update to these analyses based on the 2022 AQMP and describe up-to-date methods and results in the following sections. Additional details on the background and methods can be found within the Final 2016 AQMP Socioeconomic Report.[11]

Alternative EJ Screening and Designation Methods

Various EJ definitions are analyzed in this chapter. Alternative definitions are shown in Table 6-1, all based on the CES structure for defining EJ communities using indicator data. Definition 1 begins with a narrower definition of pollution burden, focusing on a community's exposure to higher ozone and PM2.5 concentrations. The following definitions then include a progressively broader set of population and pollution indicators, with Definition 3 being the same as the designation method used for the SB 535 DACs.[12]

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[8] It is important to note that disadvantaged communities and environmental justice communities are not always defined in the same way; however, South Coast AQMD is using the state's DAC definition to identify EJ communities within the Basin.

[9] See http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2022-air-quality-management-plan/revised-draft-2022-aqmp/revised-draft-2022-aqmp-chapter-8.pdf.

[10] The final EJ and distributional analysis report is available on the South Coast AQMD website at http://www.aqmd.gov/docs/default-source/clean-air-plans/socioeconomic-analysis/scaqmdfinalejreport_113016.pdf.

[11] See http://www.aqmd.gov/docs/default-source/clean-air-plans/socioeconomic-analysis/final/sociofinal_030817.pdf.

[12] Additional details on how indicators are combined can be found in Appendix 6A and in the CES documentation at https://oehha.ca.gov/media/downloads/calenviroscreen/report/calenviroscreen40reportf2021.pdf.

TABLE 6-1: ALTERNATIVE DEFINITIONS FOR EJ COMMUNITY DESIGNATION

Alternative Definition	Population Characteristics Indicators		Pollution Burden Indicators	
	Socioeconomic	Sensitive	Exposure	Environmental Effects
1 (Poverty and air quality)	Poverty	-	PM2.5, ozone	-
2 (Socioeconomic and air quality)	Education, housing burden, linguistic isolation, poverty, unemployment	Asthma, cardiovascular disease (CVD), low birth weight	PM2.5, ozone, diesel PM, traffic impacts	-
2a (Definition 2 plus race/ethnicity)	Education, housing burden, linguistic isolation, poverty, unemployment, race/ethnicity	Asthma, CVD, low birth weight	PM2.5, ozone, diesel PM, traffic impacts	-
3 SB 535 Definition (Socioeconomic, health, environmental, and air quality)	Education, housing burden, linguistic isolation, poverty, unemployment	Asthma, CVD, low birth weight	Ozone, PM2.5, diesel PM, traffic impacts, drinking water contaminants, children's lead risk from housing, pesticide use, toxic releases from facilities	Cleanup sites, groundwater threats, hazardous waste, impaired waters, solid waste sites
3a (Definition 3 plus race/ethnicity)	Education, housing burden, linguistic isolation, poverty, unemployment, race/ethnicity	Asthma, CVD, low birth weight	Ozone, PM2.5, diesel PM, traffic impacts, drinking water contaminants, children's lead risk from housing, pesticide use, toxic releases from facilities	Cleanup sites, groundwater threats, hazardous waste, impaired waters, solid waste sites

Notes:

1. For Alternative Definitions 3 and 3a, consistent with the SB 535 DAC definition, additional census tracts have been added including those that lack overall scores in CES but receive the highest 5% of CES pollution burden scores, those that were identified in the 2017 DAC designation, regardless of their CES scores, and lands under the control of federally recognized Tribes.
2. Race/ethnicity is not included as an indicator in CalEnviroScreen 4.0. It is expressed as the percent of population within a census tract with minority status using the U.S. Census Bureau's American Community Survey five-year estimates for 2019. Based on the federal National Environmental Policy Act (NEPA) Guideline, "minority" is defined as "[i]ndividual(s) who are members of the following population groups: American Indian or Alaskan Native; Asian or Pacific Islander; Black, not of Hispanic origin; or Hispanic." We recognize the term "minority" can be problematic but include it in our analyses and in this document in reference to the Census Bureau's designation.
3. Consistent with CalEnviroScreen 4.0 methods, the "environmental effects" indicators are given half weight when calculating the overall score.

The definitions in Table 6-1 vary with respect to which indicators of disadvantage they include. We group these indicators using component designations in CES: the Pollution Burden component is made of Exposure and Environmental Effects indicators, and the Population Characteristics component is made of Socioeconomic and Sensitive population indicators. Indicator data are provided at the census tract level, allowing us to designate EJ communities at the census tract scale within the Basin.[13]

Definition 1 (poverty and air quality) is the simplest definition and consists of poverty status and the air quality indicators of PM2.5 and ozone concentrations.

Definition 2 (socioeconomic and air quality) includes other socioeconomic indicators available in CES, such as educational attainment, housing burdened low-income households, linguistic isolation, and unemployment. It also includes more air quality indicators as part of exposure category, namely diesel PM and traffic impacts. Further, Definition 2 adds indicators related to sensitive populations, including asthma emergency department (ED) visits, cardiovascular disease, and low birth weight infants. Definition 2a includes the same indicators that are used in Definition 2 and additionally includes race/ethnicity into the socioeconomic indicators, measured as the percent of minority population living in a census tract (see Note 2 of Table 6-1).

Definition 3 (socioeconomic, health, environmental, and air quality) uses the latest SB 535 DAC designation to identify EJ communities within the South Coast Air Basin. Definition 3 expands Definition 2 to include the full suite of indicators from CES, plus tracts that have been designated as DACs within the Basin per SB 535. Compared to Definition 2, additional indicators from CES include an expanded set of exposure indicators plus the subcategory of environmental effects, which includes toxic cleanup sites, groundwater threats, hazardous waste facilities, impaired water bodies, and solid waste sites. CES assigns half weight to the environmental effects category in the CES calculation to reflect the difference between actual pollutant levels evaluated in exposure category relative to potential risks associated with proximity to potential environmental threats. Definition 3a encompasses all the indicators included in Definition 3 plus percent minority as a socioeconomic indicator.

Definitions 2a and 3a include the percent minority variable in their definition. Race, ethnicity, and percent minority are not included in CES4.0. However, percent minority is included in this analysis as an additional socioeconomic indicator based on state-of-the-science literature and input from the 2016 EJ Working Group. South Coast AQMD includes definitions that include percent minority (2a and 3a) and that do not include percent minority (2 and 3) to allow for circumstances where there may be legal prohibitions to including or not including indicators of race and ethnicity in the analysis.

For Definitions 1 and 2, each census tract within the Basin was ranked from the most to the least impacted areas, based on a tract's overall screening score, where each tract's score is calculated using the CES4.0 equation and underlying data (see Appendix 6-A for an example). South Coast AQMD then selected the top 25 percent and top 50 percent of tracts statewide according to each of these scores and designated those located within the South Coast Air Basin as EJ communities for this analysis, consistent with the Final 2016 AQMP Socioeconomic Report. This creates two variants within Definitions 1 and 2: one that selects the top 25 percent of CES scores, and the other that selects the top 50 percent of CES scores. Definition 3 includes the top 25 percent of scores from CES statewide plus census tracts that meet the criteria described for SB 535, and therefore only designates communities located within the South Coast Air Basin as "EJ" or "non-EJ" (rather than providing 25 and 50 percent cutoff values). Table 6-2 shows the EJ population distribution across the four

[13] Additional details about indicators, their units, and how missing data are handled are provided in the CalEnviroScreen4.0 report. See https://oehha.ca.gov/media/downloads/calenviroscreen/report/calenviroscreen40reportf2021.pdf.

counties within the Basin for Definitions 1, 2, and 3 (SB 535 definition). Compared to the SB 535 definition, Definitions 1 and 2 have a smaller share of EJ communities within Los Angeles County and larger share of EJ communities within Orange and Riverside Counties.

TABLE 6-2: EJ POPULATION DISTRIBUTION BY DEFINITION AND DESIGNATION THRESHOLD

County	Definition 1 (poverty and air quality)		Definition 2 (socioeconomic and air quality)		Definition 3 (SB 535 Definition: socioeconomic, health, environmental, and air quality)
	Top 50%	Top 25%	Top 50%	Top 25%	Top 25% and additional SB 535 DAC
Los Angeles	57.8%	59.0%	61.0%	66.6%	67.6%
Orange	13.6%	8.2%	12.3%	7.2%	7.6%
Riverside	14.8%	16.8%	14.2%	11.4%	11.4%
San Bernardino	13.7%	15.9%	12.4%	14.8%	13.5%
Total	100%	100%	100%	100%	100%

Note: Definition-specific values may not sum to 100 percent due to rounding.

Figures 6-1 and 6-2 present maps that show EJ communities according to Definitions 1 and 2, respectively, where each map compares the alternative definition shown in blue to that of Definition 3, the SB 535 definition employed by South Coast AQMD, shown in yellow. Consistent with the distribution of communities in Table 6-2, communities that have been designated as EJ communities based on the SB 535 designation largely overlap with those designated as EJ communities by Definitions 1 and 2. According to Definition 1 (Figure 6-1), which prioritizes poverty and regional air pollutants, census tracts in the northwestern part of the Basin in Los Angeles County are in the top 50% of EJ areas. The map for Definition 1 also includes rural census tracts in the northeastern portion of the Basin in San Bernardino County. Additional tracts in the northern part of Los Angeles County are also included. In comparison, Definition 2’s EJ communities (Figure 6-2) are more concentrated in the central part of the Basin with fewer areas to the north included. The differences are largely due to the addition of burden indicators associated with impact occurring closer to the emissions source (e.g., diesel PM emissions, traffic impacts). Both Definitions 1 and 2 include several census tracts in Orange County along the Santa Ana Freeway portion of Interstate 5, as well as census tracts in Riverside County adjacent to Interstate 15. Compared with Definitions 1 and 2, Definition 3 (SB 535) includes large rural census tracts with smaller population in the southeastern corner of the Basin. Residents in these census tracts are impacted by water- and hazardous waste-related environmental burdens in addition to air pollution.

FIGURE 6-1: EJ COMMUNITIES USING DEFINITION 1 (POVERTY AND AIR QUALITY) VERSUS SB 535 DESIGNATION

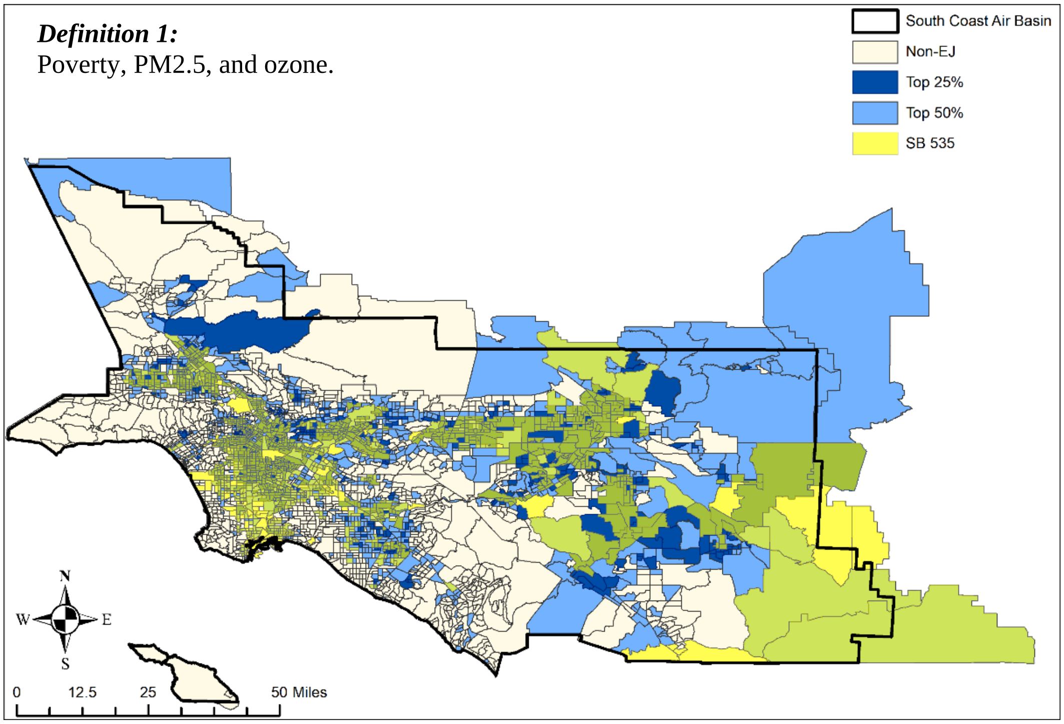


FIGURE 6-2: EJ COMMUNITIES USING DEFINITION 2 (SOCIOECONOMIC AND AIR QUALITY) VERSUS SB 535 DESIGNATION

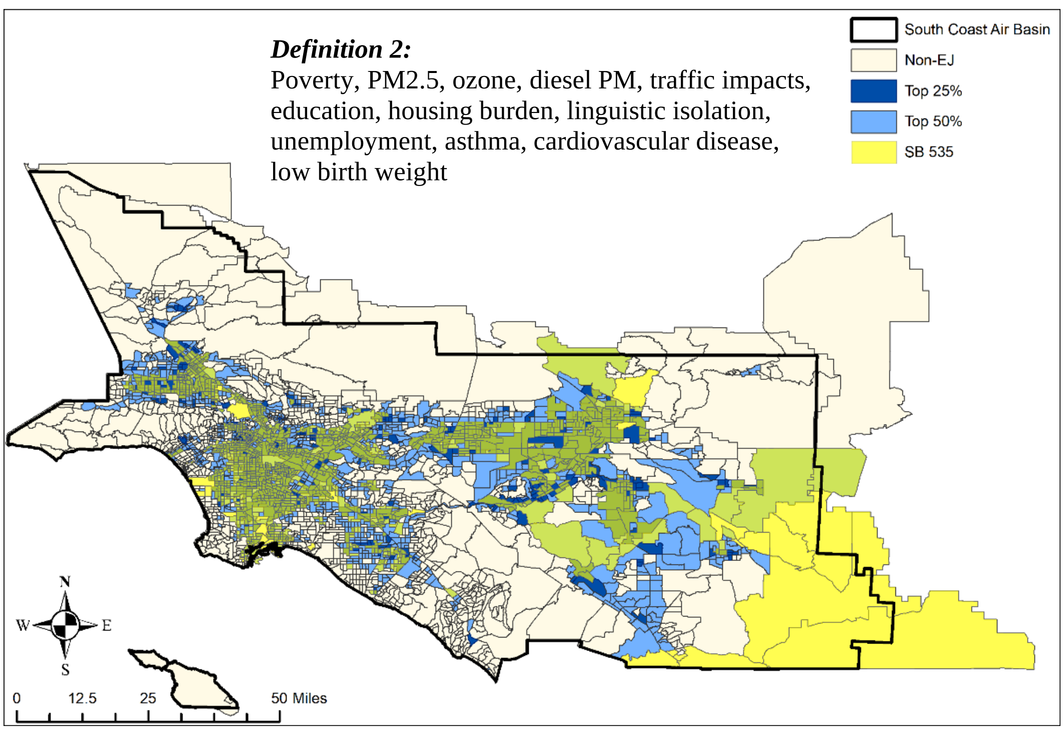


Table 6-3 illustrates the impact of adding percent minority to Definitions 2 and 3 on the EJ population distribution across the four counties. Table 6-3 allows the comparison of population distributions between EJ definitions without and with percent minority (i.e., between Definitions 2 and 2a and between Definitions 3 and 3a). The addition of the percent minority indicator does not in the aggregate significantly change the distribution of EJ communities across counties within the Basin.

TABLE 6-3: IMPACT OF INCLUDING THE PERCENT MINORITY ON EJ POPULATION DISTRIBUTION

County	Top 50%		Top 25%		Top 25% and additional SB 535 DAC	
	Def. 2	Def. 2a (incl. % minority)	Def. 2	Def. 2a (incl. % minority)	Def. 3	Def. 3a (incl. % minority)
Los Angeles	61.0%	61.2%	66.6%	66.9%	67.6%	67.7%
Orange	12.3%	12.4%	7.2%	7.3%	7.6%	7.8%
Riverside	14.2%	14.1%	11.4%	10.9%	11.4%	11.2%
San Bernardino	12.4%	12.4%	14.8%	15.0%	13.5%	13.3%
Total	100%	100%	100%	100%	100%	100%

Note: County-specific values may not sum to 100 percent due to rounding.

Similarly, marginal changes in EJ designations are observed in Figures 6-3 and 6-4, where percent minority was added to the existing list of demographic indicators under Definitions 2 (in 2a) and 3 (in 3a). Under Definition 2, with the addition of the percent minority indicator in 2a, tracts in the Long Beach area are included as EJ communities; tracts near Santa Clarita to the north are removed. Under Definition 3, with the addition of the percent minority indicator in 3a, few tracts change, as Definition 3 already incorporates six socioeconomic indicators, and percent minority is just one more indicator within that component. These changes in census tracts between Definitions 2 and 2a and 3 and 3a suggest a correlation between percent minority in a census tract and many of the socioeconomic and environmental indicators that are already included under Definitions 2 and 3.

FIGURE 6-3: IMPACT OF ADDING PERCENT MINORITY INTO DEFINITION 2

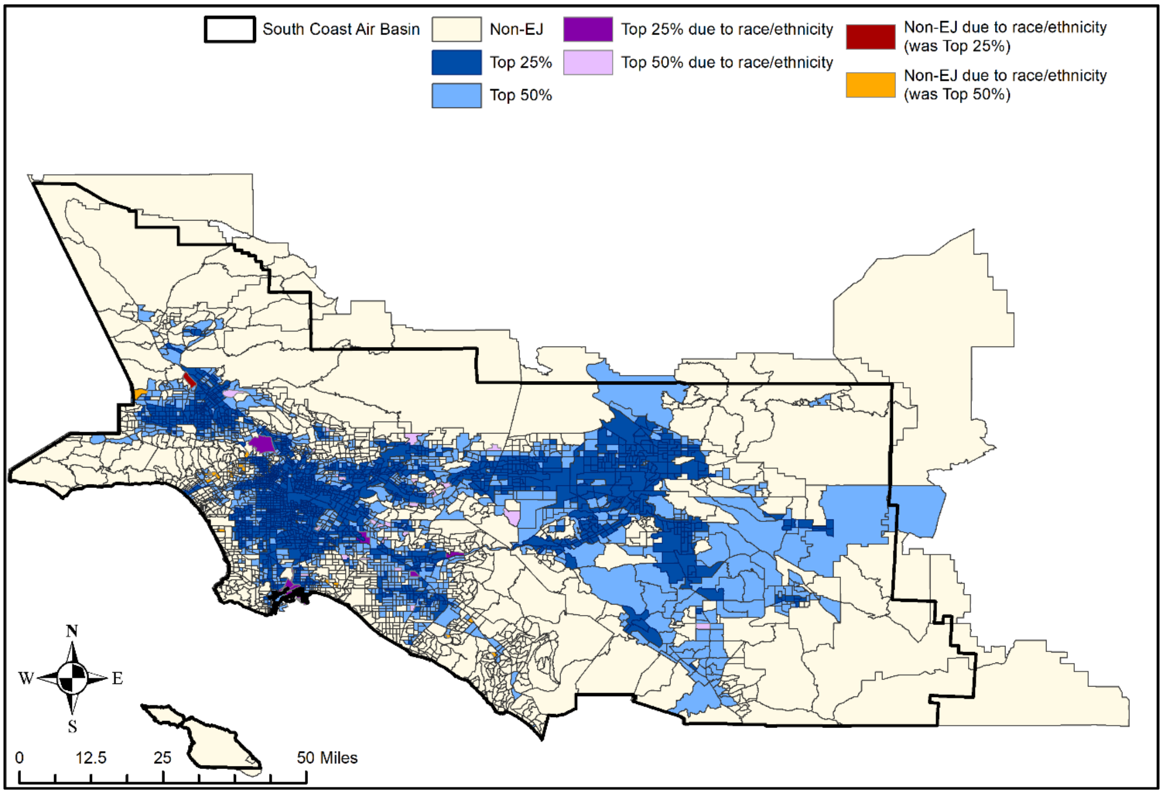
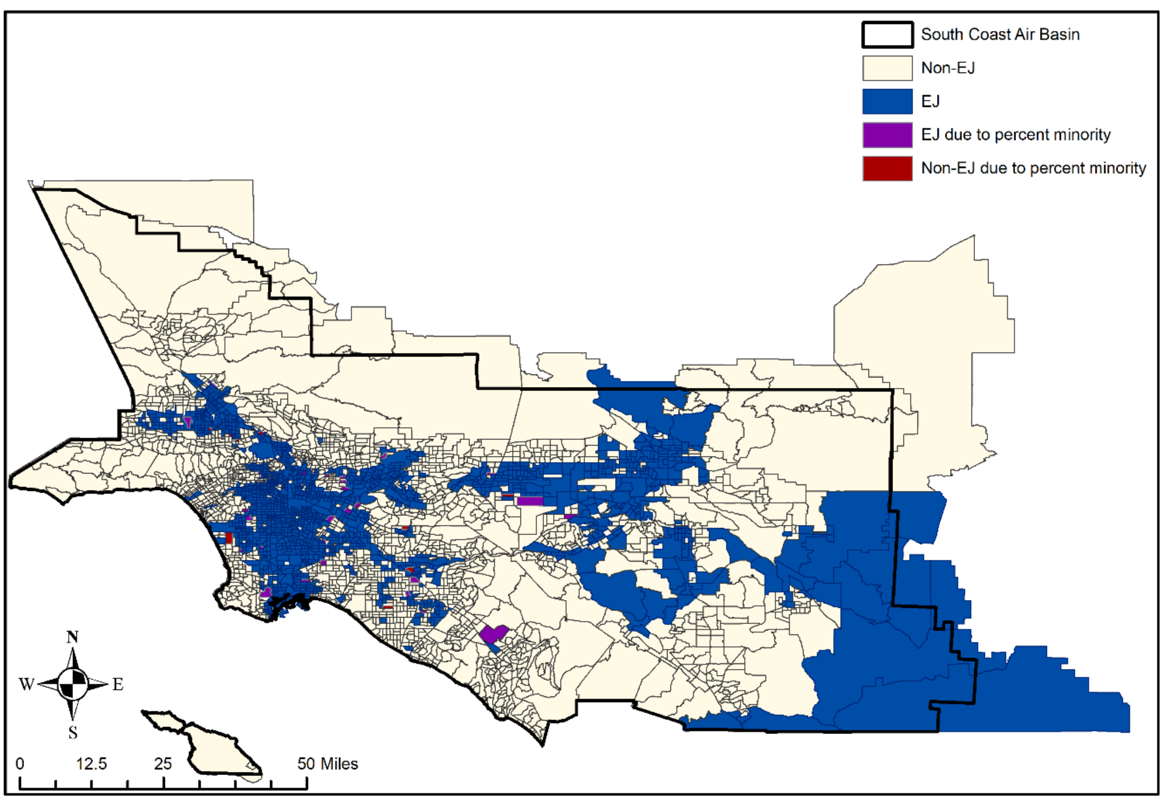


FIGURE 6-4: IMPACT OF ADDING PERCENT MINORITY INTO DEFINITION 3



Quantified Public Health Effects and Monetized Benefits in EJ and non-EJ communities

We next assess how implementation of the 2022 AQMP will affect health in communities designated as EJ or non-EJ according to the definitions described in the previous section, and whether the impacts of the 2022 AQMP are likely to reduce existing inequalities in air pollution-related health risks. We replicated the distributional analysis in the Final 2016 AQMP Socioeconomic Report using updated public health data associated with the 2022 AQMP.

To perform the distributional analysis, we first distributed the changes in health impacts across EJ and non-EJ communities. We present health impacts by endpoint, including premature mortality, asthma ED visits, and asthma incidence associated with both PM2.5 and ozone exposure. We analyzed the difference in health impacts between EJ and non-EJ communities in both per capita health impacts and as per capita monetized values.[14]

Table 6-4 compares the projected decreases in the number of premature deaths per million residents 30 years or older in 2037 in EJ and non-EJ communities due to implementation of the 2022 AQMP associated with changes in both PM.5 and ozone exposure. Table 6-4 shows on average greater mortality benefits in EJ communities compared with non-EJ communities for all EJ definitions. These findings consistently indicate better adult mortality related outcomes in EJ communities resulting from the 2022 AQMP.

TABLE 6-4: ANNUAL AVOIDED PREMATURE DEATHS AMONG ADULTS (30 YEARS OR OLDER)* ANTICIPATED THROUGH IMPLEMENTING THE 2022 AQMP

By EJ Designation and for Year 2037

		Number of Premature Deaths Avoided per Million Residents 30 Years and Older**		Difference
EJ Designation		EJ Communities	Non-EJ Communities	(EJ) – (Non-EJ)
Definition 1	Top 50%	262	211	51
	Top 25%	274	228	45
Definition 2	Top 50%	262	209	53
	Top 25%	268	229	39
Definition 3	Top 25% and additional SB 535 DAC	260	232	29

*Due to long-term exposure to both PM2.5 and ozone.
**Although the 'Top 50%' of tracts include 'Top 25%' tracts by definition, the values in this table represent per capita deaths avoided, allowing 'Top 50%' results to appear smaller than 'Top 25%' results.

Table 6-5 compares the projected decrease in the number of asthma-related ED visits per million residents in 2037 in EJ and non-EJ communities due to implementation of the 2022 AQMP associated with changes in both PM2.5 and ozone exposure. Similar to Table 6-4, Table 6-5 shows on average greater asthma-related ED visit benefits in EJ communities compared with non-EJ communities for all EJ definitions. These findings

[14] Differences in premature deaths avoided between EJ and non-EJ communities, as well as between different percent cutoff thresholds within the same definition, depend on the relative size of the communities/census tracts, and therefore, we present the comparison in per capita terms.

consistently indicate better asthma ED visit related outcomes in EJ communities resulting from the 2022 AQMP.

TABLE 6-5: ANNUAL AVOIDED ASTHMA RELATED ED VISITS (ALL AGES)* ANTICIPATED THROUGH IMPLEMENTING THE 2022 AQMP

By EJ Designation and for Year 2037

EJ Designation		Number of Asthma-Related ED Visits Avoided per Million Residents**		Difference
		EJ Communities	Non-EJ Communities	(EJ) – (Non-EJ)
Definition 1	Top 50%	42	24	18
	Top 25%	47	30	18
Definition 2	Top 50%	41	25	17
	Top 25%	45	30	15
Definition 3	Top 25% and additional SB 535 DAC	43	31	12

*Due to both long-term exposure to PM2.5 and short-term exposure to ozone.
** Although the 'Top 50%' of tracts include 'Top 25%' tracts by definition, the values in this table represent per capita asthma ED visits avoided, allowing 'Top 50%' results to appear smaller than 'Top 25%' results.

Table 6-6 compares the projected decrease in asthma incidence per million children 17 years old or younger in 2037 in EJ and non-EJ communities. Compared with the health impacts quantified in Tables 6-4 and 6-5, the implementation of the 2022 AQMP leads to a proportionally larger decrease in asthma incidence among the youngest residents. Similar to the pattern we see in Tables 6-4 and 6-5, Table 6-6 shows on average greater asthma incidence benefits in EJ communities compared with non-EJ communities for all EJ definitions with the exception of Definition 3, where EJ communities are defined based on a broader set of environmental indicators than in Definitions 1 or 2. Definitions 1 and 2 focus on air quality as the primary environmental indicator.

TABLE 6-6: ANNUAL AVOIDED ASTHMA INCIDENCE (AGE 0 TO 17)* ANTICIPATED THROUGH IMPLEMENTING THE 2022 AQMP

By EJ Designation and for Year 2037

		Number of Asthma Incidence Avoided per Million Residents Aged 0 to 17**		Difference
EJ Designation		EJ Communities	Non-EJ Communities	(EJ) – (Non-EJ)
Definition 1	Top 50%	2,923	2,485	438
	Top 25%	3,008	2,638	370
Definition 2	Top 50%	2,880	2,548	332
	Top 25%	2,878	2,715	163
Definition 3	Top 25% and additional SB 535 DAC	2,752	2,812	(60)

*Due to both long-term exposure to PM2.5 and short-term exposure to ozone.
** Although the 'Top 50%' of tracts include 'Top 25%' tracts by definition, the values in this table represent per capita asthma incidence avoided, allowing 'Top 50%' results to appear smaller than 'Top 25%' results.

Table 6-7 shows the per capita monetized public health benefits in EJ and non-EJ communities, respectively. As previously discussed in Chapter 3, these monetized benefits are largely driven by projected avoided premature deaths.

TABLE 6-7: MONETIZED ANNUAL PUBLIC HEALTH BENEFITS DUE TO AVOIDANCE OF PM2.5 AND OZONE-RELATED PREMATURE MORTALITY, ASHTMA ED VISITS, AND ASTHMA INCIDENCE

By EJ Designation and for Year 2037

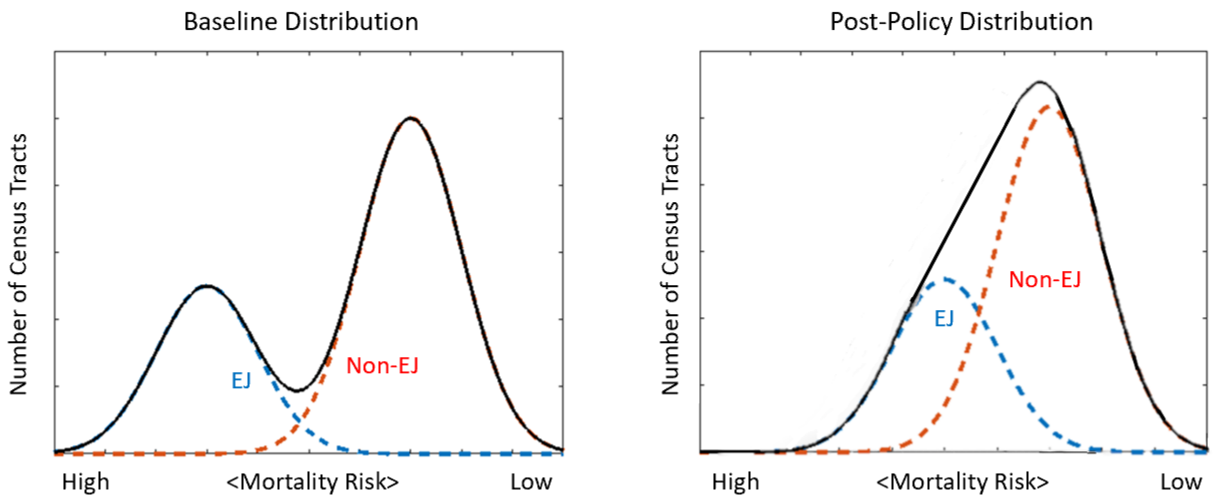
		Per Capita Monetized Benefits (in 2021 Dollars)		Difference in Per Capita Benefits
EJ Designation		EJ Communities	Non-EJ Communities	EJ - Non-EJ
Definition 1	Top 50%	$3,514	$2,831	$683
	Top 25%	$3,661	$3,059	$603
Definition 2	Top 50%	$3,503	$2,803	$700
	Top 25%	$3,589	$3,075	$515
Definition 3	Top 25% and additional SB 535 DAC	$3,481	$3,112	$369

The per capita monetized health benefits are on average higher within EJ communities compared to non-EJ communities for each EJ definition. Per capita benefits to EJ communities are very similar across all definitions and percent-thresholds, ranging approximately between $3,500 and $3,700 on average per resident, whereas the range for non-EJ communities varies from approximately $2,800 to $3,100 on average per resident. The greatest difference between EJ and non-EJ communities in per capita benefits is for the top 50 percent of communities identified by Definition 2 ($700); the smallest difference is in accordance with Definition 3, which incorporates EJ communities as defined by the most expansive list of indicators based on the SB 535 designation. Because Definition 3 is inclusive of environmental burden outside of air pollution, these communities may not experience as great of benefits compared with EJ communities defined based on air quality issues alone (as in Definitions 1 and 2). These findings indicate consistently greater monetized health benefits in EJ communities associated with the 2022 AQMP. Additional details describing the distributional analysis and additional results are included in Appendix 6-B.

Evaluating Distributional Impact of the 2022 AQMP via Health Risk Inequality Indices

According to the U.S. EPA's *Guidelines for Preparing Economics Analyses* (2016), examining the distribution of changes in health benefits alone may not completely reflect the distributional impact since "an unequal distribution of environmental improvements may actually help alleviate existing disparities (Maguire and Sheriff 2011)" (p. 10-7). This is demonstrated in the analysis above as greater per capita benefits are projected to accrue to EJ than non-EJ communities. The *Guidelines* recommend also the consideration of changes in distributions of health and environmental outcomes, such as health risk, between baseline and policy scenarios. Figure 6-5 is an illustration of this type of analysis.

FIGURE 6-6: ENVIRONMENTAL JUSTICE ANALYSIS ILLUSTRATION OF BASELINE DISTRIBUTION VERSUS POST-POLICY DISTRIBUTION FOR MORTALITY RISK IN EJ AND NON-EJ CENSUS TRACTS



Consistent with the Final 2016 AQMP Socioeconomic Report, we analyze the distributional impact of the 2022 AQMP by comparing the distributions of exposure-related mortality and morbidity risk between baseline and policy scenarios. The purpose of analyzing more than one health endpoint is two-fold: first, health risk for different health endpoints cannot easily be combined into one meaningful risk metric; second, different health endpoints may have varying impacts on different population groups, such as age cohorts. Therefore, we analyze the distribution of PM2.5 and ozone exposure related mortality risk, as premature death is the most severe effect of air pollution among all health endpoints. However, it is more likely that a larger effect of mortality risk changes will be experienced by the older age cohort. To complement the distributional analysis of mortality risk, the exposure related morbidity risk distribution is also analyzed for asthma-related ED visits across the entire population, and asthma incidence among children, whose lungs are not yet fully developed and are therefore more susceptible than adults to respiratory health impacts.

The distributional analysis consists of three main steps:[15]

[15] A similar methodology was used in Fann et al. (2011). See Appendix 6-B for further discussion.

1. Estimate health risk associated with the baseline and the 2022 AQMP policy scenario using BenMAP-CE and accounting for exposure to all emission sources of the pollutant (either PM2.5 or ozone), whether anthropogenic or biogenic.[16]
2. Calculate inequality index values, which summarize the distribution of exposure related health risk among all census tracts within the Basin, for the baseline and the policy scenario separately.[17]
3. Disaggregate the inequality index values calculated in Step 2 into the inequality *between* the EJ and the non-EJ group of communities and the inequality *within* EJ and non-EJ groups of communities.[18]

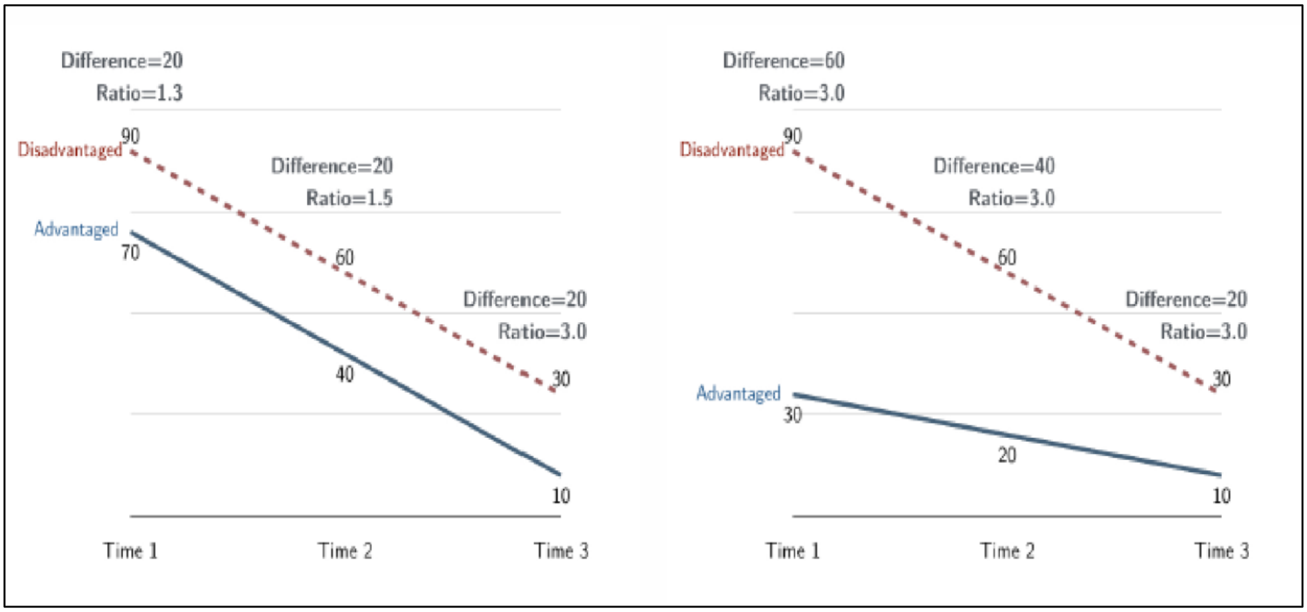
We analyze health risk inequalities using both the Atkinson and Kolm-Pollak inequality indices. The Atkinson Inequality Index is based on *relative* inequality (hereinafter referred to as "relative inequality index") whereas the Kolm-Pollak Inequality Index is based on *absolute* inequality (hereinafter referred to as "absolute inequality index"). Figure 6-6 demonstrates the general concept about how these two inequality indices differ from each other. The left panel shows no changes in absolute inequality (shown as difference) whereas the relative inequality (shown as ratio) declines over time. If we focus on relative inequality between groups on the right panel, however, the groups have different baseline values but improve proportionally so we will say the relative inequality does not change; however, the absolute inequality between those groups have reduced over time. Relative inequality allows us to determine if health impacts are disproportionately distributed, while absolute inequality allows us to determine if health impacts are different at all. For this reason, we consider both indices in the distributional analysis.

[16] BenMAP-CE was also used to quantify health benefits in Chapter 3. See Appendix 3-B for a discussion of BenMAP-CE operational steps.

[17] Studies have shown that using inequality index to summarize the distribution of a "bad" (e.g., health risk), as opposed to a "good" (e.g., income) can lead to violations of some mathematical axioms that an inequality index must satisfy. (See Industrial Economics et al. (2016) for a discussion of the axioms.) For this reason, South Coast AQMD staff analyzed the distributions of the complement of health risk (one minus the health risk), which is directly interpretable as a "good," i.e., the percent of population not expected to experience premature deaths, asthma-related ED visits, or asthma incidence (see Appendix 6-B for further discussion).

[18] Not all inequality indices can be disaggregated (or "decomposed" in the economics literature) into "between-group" and "within-group" values. An example is the oft-used Gini Index to measure income inequality, which—unlike the inequality indices use in this analysis—cannot be disaggregated.

FIGURE 6-6: COMPARISON OF ABSOLUTE (DIFFERENCE) AND RELATIVE (RATIO) INEQUALITY



An inequality index value is, in essence, a single number that indicates the statistical dispersion of a distribution. The index value and changes in index value cannot be compared across different inequality indices, and the directional change is much more meaningful than the precise value of an inequality index. .[19] Therefore, we present only the percent change in index values between baseline (no 2022 AQMP) and control (with 2022 AQMP) scenarios for 2037.

Table 6-8 reports the impact of the 2022 AQMP on the overall distribution of health risk within the Basin in 2037 when measured according to the SB 535 DAC Definition. Inequality associated with mortality and asthma health risks decreases in 2037 under the 2022 AQMP, as measured by both inequality indices, for combined PM2.5 and ozone-related risks.

Tables 6-9 and 6-10 separate the overall inequality of health risk, for relative inequality and absolute inequality Indices respectively, into two components: inequality *between* EJ and non-EJ groups of communities and a weighted average inequality *within* each group. The separation was conducted for all three alternative EJ definitions and two population thresholds for EJ designation.

We observe decreased inequality for most health risks using either *relative* (Table 6-9) or *absolute* (Table 6-10) inequality index. A decrease in inequality is consistent with our expectations based on the 2022 AQMP control measures. However, despite reduced health risks for both EJ and non-EJ communities as demonstrated in Tables 6-4 through 6-6, both the relative inequality index and absolute inequality index indicators suggest increased inequality between EJ and non-EJ communities in relation to children's asthma incidence under Definition 3 (SB 535). Upon further examination, the increase in between-group inequality for children's asthma incidence is driven by changes in health risk related to ozone exposure, and less so to PM 2.5 exposure (see Appendix 6-B) as ozone and PM2.5 health impacts do not necessarily occur in the same areas (see Chapter 3).

The projected increase in inequality for children's asthma incidence between EJ and non-EJ communities (only

[19] See Industrial Economics et al. (2016) for more technical discussion (https://www.aqmd.gov/docs/default-source/Agendas/STMPR-Advisory-Group/april-2016/ejwg2_iec-report_2b.pdf).

when EJ is defined using SB 535 designation) may reflect several underlying factors. First, the chemical mechanism of ozone formation in the Basin leads to greater reductions in ozone concentrations in the downwind suburban areas to the north of central Los Angeles and more rural areas further inland. Second, as discussed above, Definition 3 (SB 535) designates more inland communities as EJ and fewer communities to the north of Los Angeles fall under this EJ definition. Therefore, while the ozone-exposure related health risk is projected to decline nearly everywhere in the Basin, their relative decline between EJ and non-EJ communities can be sensitive to the EJ definition used. Additional distributional analysis results can be found in Appendix 6-B.

TABLE 6-8: OVERALL DISTRIBUTIONAL IMPACT OF THE 2022 AQMP IN 2037

UNDER SB 535-BASED EJ DEFINITION (DEFINITION 3)

	PM2.5 and Ozone Exposure Related Mortality Risk (Among Residents 30 Years or Older)		PM2.5 and Ozone Exposure Related Asthma ED Visits for Asthma (Among Residents of All Ages)		PM2.5 and Ozone Exposure Related Asthma Incidence (Among Residents 0 to 17 Years Old)	
	Relative Inequality Index	Absolute Inequality Index	Relative Inequality Index	Absolute Inequality Index	Relative Inequality Index	Absolute Inequality Index
% Change	-23%	-23%	-16%	-16%	-14%	-14%
Change	↓	↓	↓	↓	↓	↓

Note: We applied an inequality aversion parameter of 0.5 for each index. Inequality aversion parameters take on non-negative values only, and a higher value indicates that a society is more “inequality averse”. However, the same parameter value does not imply the same degree of inequality aversion between relative inequality and absolute inequality indices.

TABLE 6-9: DISAGGREGATED DISTRIBUTIONAL IMPACT OF THE 2022 AQMP IN 2037 USING RELATIVE INEQUALITY INDEX *(INEQUALITY AVERSION = 0.5)*

	PM2.5 and Ozone Exposure Related Mortality Risk (Among Residents 30 Years or Older)				PM2.5 and Ozone Exposure Related Asthma ED Visits for Asthma (Among Residents of All Ages)				PM2.5 and Ozone Exposure Related Asthma Incidence (Among Residents 0 to 17 Years Old)			
	Top 50%		*Top 25%*		*Top 50%*		*Top 25%*		*Top 50%*		*Top 25%*	
	Between	Within	Between	Within	Between	Within	Between	Within	Between	Within	Between	Within
Def. 1												
% Change	-44%	-23%	-51%	-23%	-21%	-15%	-21%	-15%	-26%	-12%	-25%	-12%
Change	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Def. 2												
% Change	-39%	-23%	-42%	-23%	-19%	-15%	-17%	-16%	-26%	-13%	-12%	-15%
Change	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Def. 3												
% Change			-31%	-23%			-13%	-18%			4%	-18%
Change			↓	↓			↓	↓			↑	↓

TABLE 6-10: DISAGGREGATED DISTRIBUTIONAL IMPACT OF THE 2022 AQMP IN 2037 USING ABSOLUTE INEQUALITY INDEX *(INEQUALITY AVERSION = 0.5)*

	PM2.5 and Ozone Exposure Related Mortality Risk (Among Residents 30 Years or Older)				PM2.5 and Ozone Exposure Related Asthma ED Visits for Asthma (Among Residents of All Ages)				PM2.5 and Ozone Exposure Related Asthma Incidence (Among Residents between 0 and 17 Years Old)			
	Top 50%		*Top 25%*		*Top 50%*		*Top 25%*		*Top 50%*		*Top 25%*	
	Between	Within	Between	Within	Between	Within	Between	Within	Between	Within	Between	Within
Def. 1												
% Change	-44%	-23%	-51%	-23%	-21%	-15%	-21%	-15%	-25%	-12%	-25%	-12%
Change	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Def. 2												
% Change	-39%	-23%	-42%	-23%	-19%	-15%	-17%	-16%	-21%	-13%	-11%	-15%
Change	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Def. 3												
% Change			-31%	-23%			-13%	-18%			4%	-18%
Change			↓	↓			↓	↓			↑	↓

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