Application: A.24-12-XXX
Exhibit No.: __________
Witness: Sonja N. Sax, ScD

PREPARED DIRECT TESTIMONY OF

SONJA N. SAX, ScD

ON BEHALF OF

SOUTHERN CALIFORNIA GAS COMPANY

(CHAPTER 6 – AIR QUALITY AND PUBLIC HEALTH BENEFITS OF ANGELES LINK)

BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

December 20, 2024

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PREPARED DIRECT TESTIMONY OF

SONJA N. SAX, ScD

(AIR QUALITY AND PUBLIC HEALTH BENEFITS OF ANGELES LINK)

I. INTRODUCTION

My name is Dr. Sonja Sax. I am the lead scientist in air quality at Epsilon Associates, Inc., and I have over twenty years of experience in exposure and health risk assessment. I have an Sc.D. and M.S. in Environmental Health from the Harvard T.H. Chan School of Public Health, and a B.A. in Biological Chemistry from Wellesley College.

My testimony supports Southern California Gas Company's (SoCalGas) Application for Authorization to Implement Revenue Requirement for Costs to Enable Commencement of Phase 2 Activities for Angeles Link. In this testimony, I describe how the human health impacts from exposure to pollutants such as fine particulate matter ($PM_{2.5}$), nitrogen oxides (NOx) and ozone (O_3) are well documented, and include increased risk of pulmonary disease such as asthma and bronchitis, increased cardiovascular disease, cancer and premature mortality. This testimony explains how reductions in exposure to these emissions can have significant health benefits. I also estimate the potential monetized health benefits associated with reduced NOx and $PM_{2.5}$ emissions that could result from Angeles Link.

SoCalGas proposes to develop a pipeline system to transport clean renewable hydrogen to end-users in Central and Southern California[1]. Phase 1 of Angeles Link was approved by the California Public Utilities Commission (CPUC) in December 2022 to track costs of conducting various feasibility studies.[2] One of the feasibility studies undertaken by SoCalGas in Phase 1 assessed the potential NOx emissions increases and reductions associated with Angeles Link and appropriate controls to mitigate any emissions increases as described in the Phase 1 NOx and Other Air Emissions Assessment (NOx Study). The NOx Study evaluated both potential NOx emissions increases and reductions associated with hydrogen infrastructure from transmission of clean renewable hydrogen, third party production and storage, and end-users in the mobility,

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1 Clean renewable hydrogen is defined as hydrogen produced such that it does not exceed 4 kilograms of carbon dioxide equivalent per kilogram of hydrogen produced on a lifecycle basis and is not produced using fossil fuels. *See* Decision Approving the Angeles Link Memorandum Account to Record Phase One Costs, Decision (D.) 22-12-055 (Phase 1 Decision).

2 *Id*.

power generation, and hard-to-electrify industries. The NOx Study focuses on NOx emissions, but other potential emissions were also evaluated, including direct emissions of $PM_{2.5}$.

As described in the NOx Study, NOx emission reductions far exceed any potential NOx emissions from the transmission of clean renewable hydrogen, third-party production and storage. The reduction of fossil fuels in the mobility sector (both diesel and gasoline) that are assumed to transition to fuel cells using clean hydrogen transported by Angeles Link accounts for the majority of NOx emission reductions. Only on-road medium- and heavy-duty vehicles, such as buses, are included in the emission estimates. Emission from off-road mobile sources were also evaluated including from agriculture, commercial harbor crafts, cargo handling equipment at ports, construction and mining, and ground support equipment at airports. Therefore, this health benefits analysis focuses on quantifying the benefits from using clean renewable hydrogen to reduce the use of diesel and gasoline fuel in on-road medium and heavy-duty vehicles as well as the off-road sector. The results of the analysis indicate that health benefits associated with avoided premature mortality (mainly respiratory and cardiovascular mortality) from reduced $PM_{2.5}$ and NOx emissions could range from approximately $183 million to $552 million (2018$) per year by 2045. Benefits are likely to be higher as this analysis does not quantify the health impacts from reduced emissions of other air pollutants (*e.g.,* O_3) or other potential avoided health outcomes (*e.g.*, respiratory and cardiovascular hospital admissions or emergency room visits). This health benefits assessment highlights the large economic benefits associated with the reduction of harmful air pollutants, particularly in large urban population centers, which have the worst air quality in the Nation. As discussed below, both the San Joaquin Valley Air Pollution Control District and the South Coast Air Quality Management District (SCAQMD) are in extreme nonattainment of health-based National Ambient Air Quality Standards (NAAQS) for O_3 and in nonattainment for the NAAQS for $PM_{2.5}$.[3] The SCAQMD alone is home to approximately 17 million people, which is about half the population of the whole state of California [4]. Importantly, the poor air quality in Central and Southern California disproportionately impacts disadvantaged communities. Forty-two percent of residents that live

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[3] US EPA, *Green Book Nonattainment Areas for Criteria Pollutants (Green Book)*, *available at:* https://www.epa.gov/green-book.

[4] SCAQMD, *Air Quality Management Plan (AQMP)*, *available at:* https://www.aqmd.gov/home/air-quality/air-quality-management-plans/air-quality-mgt-plan.

within the SCAQMD air basin are classified as living in disadvantaged communities (DACs).[5] In fact, as noted in the 2022 South Coast Air Quality Management Plan (referred to as the 2022 South Coast AQMP), achieving attainment of the NAAQS will require significant reductions in NOx emissions beyond what can be achieved by current programs and regulations. The 2022 South Coast AQMP states, "[t]he overwhelming majority of NOx emissions are from heavy-duty trucks, ships and other State and federally regulated mobile sources that are mostly beyond the South Coast AQMD's control" (SCAQMD 2022). Therefore, transitioning to clean renewable hydrogen that will specifically target these sources, is critical to attainment of the NAAQS and achieving healthier air quality and environmental equity especially for the residents of DACs.

In addition to improving air quality, California aims to achieve carbon neutrality by 2045. For nearly two decades, California has pursued a comprehensive, long-term approach to address climate change and carbon neutrality, including:

- Reducing GHG emissions to 40% below 1990 levels by 2030 (Senate Bill [SB] 32) and to 80% below 1990 levels by 2050 (Executive Order [EO] S-03-05);
- 100% carbon-free electricity by 2045 (SB 100);
- Attaining carbon neutrality by 2045 (EO B-55-18);
- 100% in-state sales of new passenger cars and trucks that are zero-emission by 2035 (EO N-79-20); and
- Mandating that 100% of the State's retail sales of electricity come from renewable and zero-carbon resources by 2045, with interim benchmarks of 60% by 2030, 90% by 2035 and 95% by 2045 (SB 1020).

As part of achieving these goals, decarbonizing transportation, which is the largest source of emissions of NOx and $PM_{2.5}$ in the state, is a critical component. Addressing the transportation sector has the added benefit of addressing other state goals such as improving air quality and environmental equity.

In December 2022, the California Air Resources Board (CARB) published the 2022 Scoping Plan for Achieving Carbon Neutrality (2022 Scoping Plan), which presents a sector-by-

[5] SCAQMD 2022, *Air Quality Management Plan (AQMP)*, *available at:* https://www.aqmd.gov/home/air-quality/air-quality-management-plans/air-quality-mgt-plan.

sector roadmap for achieving carbon neutrality goals by 2045. (CARB 2022a)[6] The plan is ambitious and aggressively targets the reduction of fossil fuel use, with the goal of not only reducing greenhouse gas emissions, but also improving air quality particularly in disadvantaged communities (*i.e.,* communities that bear a disproportionate burden of pollution and are more vulnerable to pollution effects) to attain a more equitable, healthier, and sustainable future. A major goal of the plan is to accelerate the move towards zero-emissions transportation both by electrifying and by finding alternative clean and renewable energy sources like clean renewable hydrogen.

A 2021 study[7] (Brown *et al*. 2021), evaluated different pathways for achieving a zero-carbon transportation system in California, highlighting the need to address the external costs (costs borne by everyone, and not the individual user) of transportation such as direct health impacts of air pollution and indirect greenhouse gas emissions that contribute to climate change. Consistent with the 2022 South Coast AQMP, Brown *et al*. (2021) noted that current regulations will not be sufficient to achieve California's ambitious carbon neutrality and air quality goals by 2045. In particular, as noted above, areas in Central and Southern California will not be able to attain health-based NAAQS without significantly addressing reductions in NOx emissions from the mobility sector.

Based on 2017 emissions estimates, mobile sources account for 75% of all NOx, and of this, 30% of the NOx is from medium and heavy-duty vehicles[8]. These vehicles include a diverse class of vehicles that range from large pickup trucks to large heavy-duty long-haul trucks. Transition to clean renewable hydrogen as an alternative zero-emission fuel, will be critical to achieving carbon neutrality, reducing dependence on fossil fuels, and reducing harmful air pollutant emissions from the medium and heavy-duty vehicle sector, which is harder to electrify compared to the light-duty vehicle sector (*i.e.*, cars and smaller trucks).

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[6] CARB, *2022 Scoping Plan for Achieving Carbon Neutrality*, *available at:* https://ww2.arb.ca.gov/sites/default/files/2022-12/2022-sp_1.pdf.

[7] University of California – Institute of Transportation Studies, *Driving California's Transportation Emissions to Zero* (2021), *available at: https://escholarship.org/uc/item/3np3p2t0.*

[8] CARB, *Statewide Emissions – CEPAM2019v1.03 Emission Projection Data* (2017), *available at:* https://ww2.arb.ca.gov/applications/statewide-emissions.

II. HUMAN HEALTH EFFECTS OF AIR POLLUTANTS ASSOCIATED WITH MOBILE SOURCES

The key air pollutants from vehicle exhaust include $PM_{2.5}$, which is directly emitted, NOx, and volatile organic compounds (VOCs). O_3 is not a directly emitted air pollutant, but is considered a secondary pollutant formed in ambient air from a reaction of NO_x and VOCs in the presence of sunlight, and therefore is also an air pollutant commonly associated with mobile source emissions. In addition, NOx contributes to the formation of $PM_{2.5}$, which is referred to as secondary $PM_{2.5}$. NO_x also denotes a larger group of air pollutants that includes nitrogen dioxide (NO_2). NO_2 concentrations are measured at monitoring sites and used as the health indicator for the larger group of NOx. Therefore, emissions of NOx contribute to several air pollutants including O_3, $PM_{2.5}$, and NO_2. Furthermore, diesel combustion generates PM, and is referred to as Diesel Particulate Matter (DPM). DPM is a subset of direct $PM_{2.5}$.

The health effects of these air pollutants have been extensively researched and summarized by United States Environmental Protection Agency (US EPA) in the Integrated Science Assessments for $PM_{2.5}$ (2019, 2022), O_3 (2020) and NO_2 (2016) as well as in the 2022 South Coast AQMP. Numerous health studies have also been conducted in California by the Office of Environmental Health Hazard Assessment (OEHHA)[9]. Some of the health effects associated with exposures to these pollutants are summarized in Table 1. These air pollutants are associated with many of the same health endpoints, including respiratory and cardiovascular endpoints and all-cause or cause-specific premature mortality. Effects are typically assessed for individual air pollutants, and when evaluated jointly, impacts of each individual air pollutant usually remain (*e.g.,* do not diminish and can be additive) when accounting for others. It is likely, however, that air pollutants could work synergistically to impact health, and this is currently an active area of research.

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[9] OEHHA, *Health Studies of Criteria Air Pollutants*, *available at:* https://oehha.ca.gov/air/health-studies-criteria-air-pollutants.

Table 1. Key Health Effects of Mobile Source Air Pollutants[10]

Air Pollutant	Key Health Effects
Ozone (O_3)	Increased risk of pulmonary disease (asthma, chronic obstructive pulmonary disease [COPD], respiratory infections), increased premature mortality; possible metabolic effects
Fine Particulate Matter ($PM_{2.5}$)	Short -term and long-term effects include increased premature mortality rates; increased respiratory disease (infections; asthma, COPD); increased cardiovascular disease; increased lung cancer (long-term exposures). Possible link to metabolic, nervous system, and reproductive and developmental effects.
Nitrogen Dioxide (NO_2)	Short-term respiratory effects (asthma exacerbation), longer-term risk of respiratory disease (asthma or COPD). Potential impacts on cardiovascular health and premature mortality

Particulate matter (PM) is a mixture of solid particulates of various sizes and diameters and liquid droplets found in the air. There are natural sources of PM as well as PM produced as a byproduct of human activities. Some examples of natural sources of PM include sea spray, windblown dust, and wildfire smoke. Examples of PM produced as a byproduct of human activities include burning of natural gas and vehicle exhaust from both gasoline and diesel engines. The health concerns regarding particles focus on whether the particles are small enough to be inhaled, where they can damage sensitive lung tissue, or can be absorbed into the body to affect other organ systems. Particle pollution is therefore characterized by size and is commonly focused only on particles that can be inhaled. The "coarse" PM_{10} particles up to 10 microns in size, and "fine" $PM_{2.5}$ particles no larger than 2.5 microns have different sources. PM_{10} particles are dust originating from unpaved roads, construction activities, and agricultural plowing, while $PM_{2.5}$ is typically produced from fuel combustion, including gasoline, diesel and natural gas. From a health perspective, $PM_{2.5}$ is considered to be more toxic because its size allows the particles to penetrate deeper into the lungs. Although all $PM_{2.5}$ has the potential to increase the risk of lung cancer, occupational studies of workers exposed to DPM suggest that DPM, in particular, may be linked to lung cancer risks.[11]

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[10] List of health effects is not comprehensive; detailed health effects information can be found in Appendix I: Health Effects (SCAQMD 2022) or in the US EPA NAAQS documentation, *see,* EPA, *Reviewing National Ambient Air Quality Standards (NAAQS): Scientific and Technical Information, available at:* https://www.epa.gov/naaqs.

[11] CARB, *Overview: Diesel Exhaust & Health*, *available at:* https://ww2.arb.ca.gov/resources/overview-diesel-exhaust-and-health.

NOx is a chief component of photochemical smog, and as noted above, contributes to the formation of O_3. Like $PM_{2.5}$, a common source of NO_x is fuel combustion (*i.e.,* diesel, gasoline, or natural gas), largely vehicle exhaust. NO_x is directly emitted, but as noted, also contributes to the secondary formation of $PM_{2.5}$ (secondary $PM_{2.5}$). Although the contribution of NOx to the secondary formation of $PM_{2.5}$ varies depending on meteorological conditions and other factors, studies have found that the majority of the secondary $PM_{2.5}$ comes from mobile sources (Watson *et al.* 1998). In fact, Zawacki *et al.* (1994) found that secondary $PM_{2.5}$ from mobile sources contributed more to overall $PM_{2.5}$ concentrations than primary $PM_{2.5}$ emissions ($PM_{2.5}$ directly emitted). In addition, the conditions that favor secondary formation of $PM_{2.5}$ are warmer climates and proximity to urban areas where the concentrations of both NOx and volatile organic compounds are abundant, such as in Southern California (Hodan and Barnard 2004). For the purposes of this analysis, the estimated benefits of reduced NOx emissions from Angeles Link are assumed to result in the reduced secondary formation of $PM_{2.5}$.

III. THE NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS) AND CALIFORNIA AMBIENT AIR QUALITY STANDARDS (CAAQS)

The 1970 Clean Air Act was enacted by Congress to protect the health and welfare of the public from the adverse effects of air pollution. As required by the Clean Air Act, the US EPA promulgated NAAQS for the following criteria pollutants: NO_2, sulfur dioxide (SO_2), PM_{10}, $PM_{2.5}$, carbon monoxide (CO), O_3, and lead (Pb). California has its own standards, the California Ambient Air Quality Standards (CAAQS), for the same criteria pollutants and several others. Although some CAAQS are similar to the NAAQS, others are more stringent or use different averaging times. These differences are due to the State's review of scientific evidence relating to pollutant exposures and health.

The NAAQS and CAAQS have been developed for various exposure durations. Short-term standards typically refer to pollutant levels that are not to be exceeded except for a limited number of times per year. Long-term standards typically refer to pollutant levels that are not to be exceeded on an annual average basis. These standards can be further broken down into primary and secondary standards. Primary standards are intended to protect human health, including the health of sensitive populations such as asthmatics, children and the elderly. The secondary standards are intended to provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings. For the purposes of this testimony the focus will be on the primary NAAQS/CAAQS. The primary NAAQS and CAAQS for the key criteria pollutants associated with vehicle emissions are shown in Table 2.

US EPA is mandated by the Clean Air Act to set the NAAQS and to review the standards every five years. The process is lengthy and involves several steps including planning, an integrated science assessment, a risk assessment and a policy assessment. For each step, a document is developed and reviewed by a panel of experts, internally by US EPA, and is open to comments from the public. The US EPA administrator, informed by the policy assessment, proposes a new rule that is also reviewed internally and externally before finalization. The final rule determines any changes to the NAAQS based on the most current scientific information and input from experts and the public.

One of the most basic goals set forth in federal and state air regulations is to ensure that ambient air quality, including the impact of background, existing sources, and new sources, complies with the NAAQS. All areas of the country are labeled with one of three classifications for each air pollutant. These three classifications are "attainment," "nonattainment," and "unclassified." In areas designated as attainment, the air quality with respect to the pollutant is equal to or better than the NAAQS. These areas are under a mandate to maintain, *i.e.,* prevent significant deterioration of air quality. In areas designated as unclassifiable, there is limited air quality data, and those areas are treated as attainment areas for regulatory purposes. In areas designated as nonattainment, the air quality with respect to the pollutant is worse than the NAAQS and is designated anywhere from marginal to extreme nonattainment, with these designations related to how far the measured concentrations are from the NAAQS. For example, an extreme classification means that the measured levels of that air pollutant are far above the health-based NAAQS, whereas a marginal classification is close to attainment of the NAAQS. Areas in nonattainment must take actions to improve air quality and attain the NAAQS within a certain period of time. This includes preparation of a State Implementation Plan (SIP) that specifies the strategy for achieving attainment. Due to changes in the NAAQS over the years, areas may be in nonattainment for both prior and current NAAQS.

Table 2. Ambient Air Quality Standards for Key Criteria Pollutants Associated with Vehicle Emissions[12]

Air Pollutant	Federal Standard (NAAQS) Concentration, Averaging Time, Year of AAQS Review	State Standard (CAAQS) Concentration, Averaging Time
Ozone (O_3)	0.070 ppm, 8-Hour (2015)	0.070 ppm, 8-hour 0.090 ppm, 1-hour
Fine Particulate Matter ($PM_{2.5}$)	35 µg/m^3, 24-Hour (2006) 9 µg/m^3, Annual (2024)	12 µg/m^3, Annual
Nitrogen Dioxide (NO_2)	0.100 ppm, 1-Hour (2010) 0.053 ppm, Annual (1971)	0.180 ppm, 1-hour 0.030 ppm, Annual

In California there are many areas that are in nonattainment of the NAAQS. The South Coast Air Basin (SCAB) and San Joaquin Valley Air Basin are the only areas in the county that are in extreme nonattainment for the new and prior O_3 NAAQS. The San Joaquin Valley and the SCAB are also in nonattainment for the $PM_{2.5}$ NAAQS (see Table 3). As a result, much of the SoCalGas service territory is in nonattainment of the new and prior O_3 and $PM_{2.5}$ NAAQS. The SoCalGas service territory areas that are in nonattainment of the 2015 8-hour O_3 and 2012 annual $PM_{2.5}$ NAAQS are also shown in Figures 1 and 2, respectively.[13] It is noteworthy that both the San Joaquin Valley and SCAQMD have the worst air quality in the Nation. Note that for some of the air districts, only part of the air district is in nonattainment. Attainment status with regards to the most recent annual $PM_{2.5}$ NAAQS that was promulgated in 2024 has not been determined by US EPA.

12 ppm - parts per million by volume; State standards are "not-to-exceed" values based on State designation value calculations. Federal standards follow the 3-year design value form of the NAAQS.

13 The annual $PM_{2.5}$ NAAQS was recently lowered from 12 to 9 µg/m^3 (*See* EPA, *Final Reconsideration of the National Ambient Air Quality Standards for Particulate Matter (PM), available at:* https://www.epa.gov/pm-pollution/final-reconsideration-national-ambient-air-quality-standards-particulate-matter-pm; Reconsideration of the National Ambient Air Quality Standards for Particulate Matter, 89 Fed. Reg. 16202 (March 6, 2024)), all of the regions that are currently in nonattainment for the 2012 annual $PM_{2.5}$ NAAQS will be in violation of the new lower NAAQS, and other counties currently in attainment may also be designated as nonattainment based on the new NAAQS.

The continued nonattainment in Central and Southern California is due to a number of factors including the large number of emission sources, meteorological conditions and topography that create "perfect storm" conditions for the formation of O_3 and $PM_{2.5}$. This is especially true of SCAB. Emissions in this area are associated with the nation's second largest urban area together with weather conditions such as low wind speeds, frequent temperature inversions, and high temperatures that lead to ideal conditions for the formation and trapping of air pollutants close to the ground. The presence of mountains also serves to trap the air pollution that is pushed inland by sea breezes. As several factors that contribute to poor air quality in nonattainment areas cannot be controlled (*e.g.,* weather and topography), addressing the factor that can be controlled, *i.e.,* the source of the air pollutants, is critical for improving air quality.

In 2022, CARB published its State SIP Strategy (CARB 2022b)[14]. The strategy includes a number of state-specific measures that are needed to achieve NAAQS attainment, but also identifies specific federal actions that will be critical to attainment. Specifically, to attain the O_3 standard of 70 ppb (2015 standard), the strategy entails a transition from fossil fuel combustion and a reduction of emissions through regulations, incentives and voluntary programs. Key state measures focus on regulating on-road and off-road sources, including the removal of on-road dirtier heavy-duty vehicles and incentive programs for on-road zero-emission trucks. Some of the off-road initiatives include more stringent off-road engine emissions standards and zero-emission harbor crafts and cargo handling equipment. At the federal level, CARB has determined that emissions regulations of out-of-state heavy-duty trucks, and many off-road sources such as construction equipment, locomotives, aviation and ocean-going vessels will also be needed to achieve attainment. As noted above, this is consistent with the findings described in the 2022 South Coast AQMP for a regional path to attainment of O_3. The 2022 South Coast AQMP strategy aligns with the State SIP Strategy. Importantly, Angeles Link could supply clean renewable hydrogen to on-road and off-road end-users, which are beyond the control of the SCAQMD, with clean renewable hydrogen and enable these areas to achieve attainment.

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[14] CARB, *2022 State Strategy for the State Implementation Plan (2022 State SIP Strategy)* (September 22, 2022), *available at:* https://ww2.arb.ca.gov/resources/documents/2022-state-strategy-state-implementation-plan-2022-state-sip-strategy.

Figure 1. 8-hour O_3 Non-attainment Areas (2015 Standard)

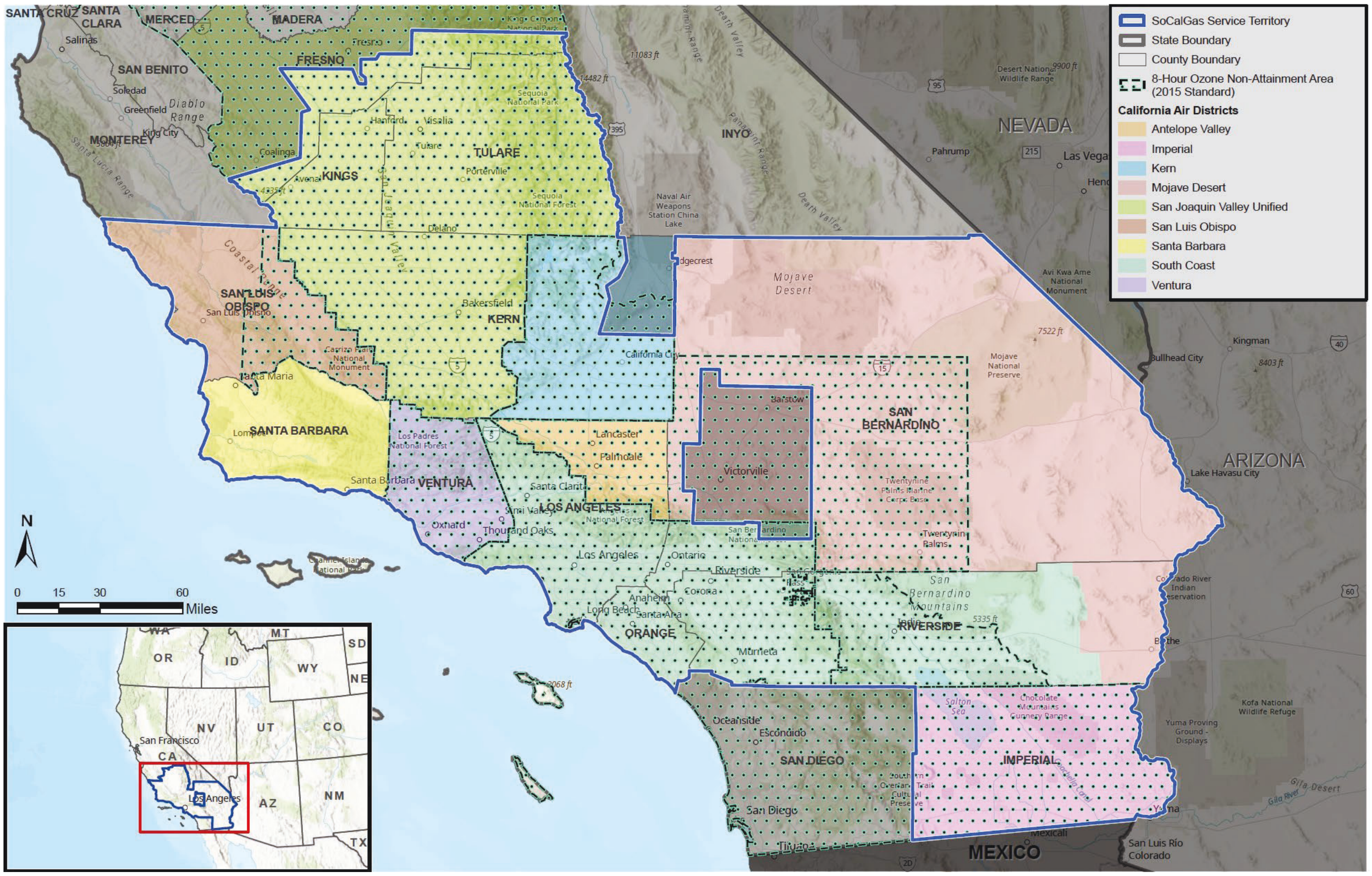
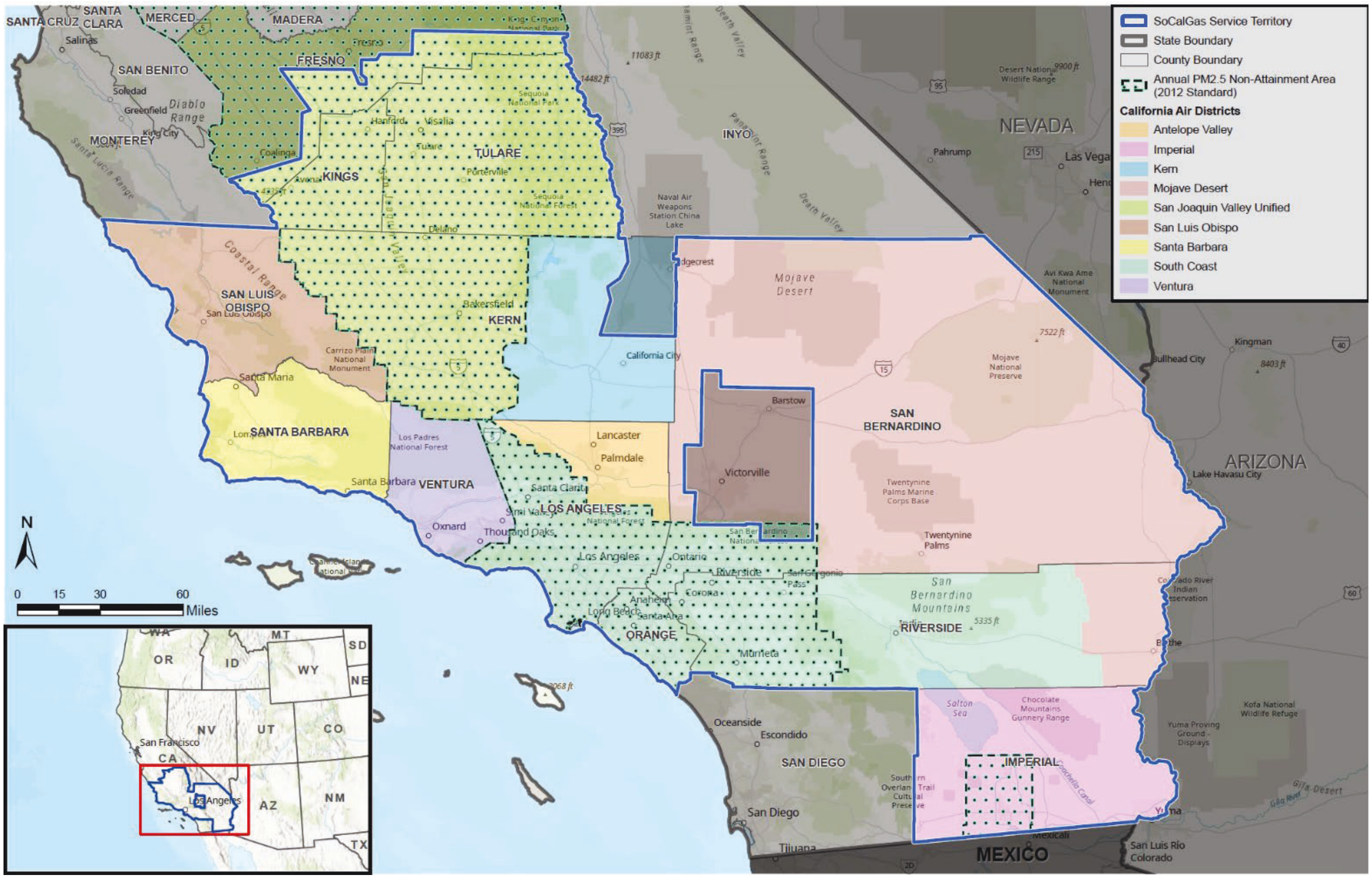


Figure 2. Annual $PM_{2.5}$ Non-attainment Areas (2012 Standard)[15]



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15 A new $PM_{2.5}$ standard was set in 2024, but attainment designations are not yet available based on the updated standard (US EPA 2024).

Table 3. National Ambient Air Quality Standards (NAAQS) Attainment Status Per EPA's Green Book[16]

Criteria Pollutant [1]	Averaging Time	Designation	Nonattainment Areas[17] in SoCalGas Service Territory[18] (nonattainment level)
Ozone (O_3)[1]	(1979) 1-hour (0.12 ppm)	Nonattainment	Imperial APCD (Section 185A) - whole South Coast AQMD (extreme) - part San Joaquin Valley APCD (extreme) - part Ventura APCD (severe) - whole
	(1997) 8-hour (0.08 ppm)	Nonattainment	Eastern Kern APCD (moderate) - part Imperial APCD (moderate) - whole South Coast AQMD (extreme) - part San Joaquin Valley APCD (extreme) - part Ventura APCD (serious) - part
	(2008) 8-hour (0.075 ppm)	Nonattainment	Eastern Kern APCD (severe) - part Imperial APCD (moderate) - whole South Coast AQMD (extreme) - part San Joaquin Valley APCD (extreme) - part San Luis Obispo APCD (marginal) - part Ventura APCD (serious) - part
	(2015) 8-hour (0.070 ppm)	Nonattainment	Eastern Kern APCD (serious) - part Imperial APCD (marginal) - whole South Coast AQMD (extreme) - part San Joaquin Valley APCD (extreme) - part San Luis Obispo APCD (marginal) - part Ventura APCD (serious) - part
$PM_{2.5}$ [1]	(1997) Annual (15 μg/m^3)	Nonattainment	South Coast AQMD (moderate) - part San Joaquin Valley APCD (serious) - part
	(2006) 24-hour (35 μg/m^3)	Nonattainment	Imperial APCD (moderate) - whole South Coast AQMD (serious) - part San Joaquin Valley APCD (serious) - part
	(2012) Annual (12 μg/m^3)	Nonattainment	Imperial APCD (moderate) - part South Coast AQMD (serious) - part San Joaquin Valley APCD (serious) - part

Furthermore, Central and Southern California have the most to gain from the reduction of air pollutant emissions, including the populations served by SoCalGas that are in nonattainment areas. In fact, as discussed below, analyses that have been conducted to assess the benefits from

16 The 1979 1-hour O_3 NAAQS (0.12 ppm) was revoked (6/15/2005), but many areas have not attained this standard (revised attainment date 2/6/2023). The 2008 8-hour O3 NAAQS (0.075 ppm) was revised to 0.070 ppm (12/28/2015), the 1997 8-hour O_3 NAAQS (0.08 ppm) was revoked (4/6/2015), but there are continuing obligations under the revoked 1997 and revised 2008 O3 NAAQS until attainment. Similarly, the Annual $PM_{2.5}$ NAAQS has been revised from 15 μg/m^3 to 12 μg/m3 and most recently to 9 μg/m^3 (effective May 6, 2024), and there are remaining obligations to attainment of the older standards.

17 US EPA, *Green Book Nonattainment Areas for Criteria Pollutants (Green Book), available at:* https://www.epa.gov/green-book; SCAQMD 2022.

18 The areas refer to the Air Pollution Control Districts (APCD) or Air Quality Management Districts (AQMD), collectively the "Air Districts".

reduced air pollutant emissions have found much higher benefits for these areas, and in particular the SCAQMD, than for other areas in California (CARB 2022a). In addition, as part of the NOx Study, a spatial evaluation was conducted to assess where the projected NOx emission reductions from Angeles Link are likely to occur based on end-user adoption of hydrogen (*see* Attachment A).[19] Areas that were shown to have the highest NOx reductions were found along the potential Angeles Link pipeline corridor in nonattainment areas that are most likely to benefit from these reductions. As described in more detail in Section VII, these areas also align with areas that have been designated as environmental justice (EJ) areas and/or DACs. This makes the transition away from fossil fuels, including the need for alternative fuels like clean renewable hydrogen, a critical part of attaining health-based air quality standards in these areas.

IV. ESTIMATING REDUCED EMISSIONS ASSOCIATED WITH ANGELES LINK

Estimates of reduced emissions associated with Angeles Link were obtained from the data underlying the NOx Study. As noted above, the benefits analysis focused on the reduced emissions resulting from replacement of diesel and gasoline with clean renewable hydrogen and delivered to end-users in the on-road and off-road sectors as part of Angeles Link. Specifically, the NOx emission reductions for medium and heavy-duty trucks (on-road diesel and gasoline) and for off-road diesel and gasoline sources were obtained from the data underlying of the NOx Study for the years 2030, 2035, 2040 and 2045. The NOx Study evaluated low, moderate, and high throughput scenarios for transportation and end users served by Angeles Link clean renewable hydrogen transportation. For the health benefits analysis the low and high throughput scenarios were used to evaluate the range of benefits for these two cases. The annual reduced NOx emissions estimated from Angeles Link are shown in Table 4.

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[19] *See* SS-Attachment A (Maps of Projected NOx Reductions and Environmental Justice Communities).

Table 4. Annual Reduced NOx Emissions (tons/year) from On-road and Off-road Diesel and Gasoline Sources Associated with Angeles Link (Low and High Scenarios)[20]

Year	Low Scenario		High Scenario	
	On-road	Off-road	On-road	Off-road
2030	250	50	1270	148
2035	1053	221	2563	355
2040	2105	427	3886	568
2045	3363	589	4948	716

The NOx Study also estimated the reduced direct $PM_{2.5}$ emissions associated with Angeles Link. The annual reduced direct $PM_{2.5}$ emissions for the years 2030, 2035, 2040 and 2045 are shown in Table 5.

Table 5. Annual Reduced $PM_{2.5}$ Emissions (tons/year) for On-road and Off-road Diesel and Gasoline Sources Associated with Angeles Link (Low and High Scenarios)[21]

Year	Low Scenario		High Scenario	
	On-road	Off-road	On-road	Off-road
2030	8	7	41	25
2035	39	37	91	57
2040	84	69	147	85
2045	136	94	194	109

V. METHODOLOGY FOR EVALUATION OF HEALTH AND ECONOMIC IMPACTS OF REDUCED EMISSIONS

Emissions from both on-road vehicles and off-road vehicles and equipment contribute to direct emissions of $PM_{2.5}$ and NOx emissions that contribute to secondary $PM_{2.5}$ and O_3. As discussed above, studies have found that human exposures to $PM_{2.5}$ are correlated with increased incidence of premature mortality and respiratory and cardiovascular morbidity[22]. Calculating the benefits of reduced emissions is a widely accepted methodology employed by US EPA and states, including California, for evaluating regulatory actions that aim to improve air quality. A full-scale benefits analysis consists of a number of complex analytical steps needed for each stage of emissions to impacts assessment, including quantifying emissions, changes in air

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20 NOx Study at 8.10 (Tables 25 and 26).

21 *Id.* at 10.11-10.13 (Tables 35A and 36A).

22 See *e.g.,* Krewski *et al*. 2009, Lepeule *et al.* 2012, US EPA 2019, 2022.

pollutant concentrations, population exposures, health risks, and an economic valuation. Estimating the impacts of emissions on ambient air pollutant concentrations is typically conducted using atmospheric chemistry and transport models such as the Comprehensive Air Quality Model with Extensions (CAMx) or the Community Multi-Scale Air Quality (CMAQ) model. Calculating the health impacts and conducting the economic evaluations involves separate benefits modeling tools, such as the US EPA Benefits Mapping (BenMAP) model. These tools use population distribution, baseline incidence rates, health impact functions, and health costs data to quantify the health benefits associated with changes in air quality. Importantly, these full-scale analyses are data, time, and resource intensive.

In contrast, reduced-form approaches are simpler to conduct and can provide reasonable high-level estimates that approximate full-scale modeling results. Benefits per ton (BPT) estimates are one example of a reduced-form approach that can provide an estimate of the monetary benefit of reducing a ton of an air pollutant's emissions from a particular source sector. Wolfe *et al*. (2019) calculated the benefit per ton of mobile source emissions for the contiguous United States using source apportionment modules available in CAMx. The authors estimated the premature mortality associated with direct emissions of $PM_{2.5}$ and secondary formation of $PM_{2.5}$ associated with NOx emissions and the costs associated with these health impacts. In addition, because regional differences in atmospheric composition, meteorological conditions, and the proximity of populations to sources can influence the relationship between pollutant exposures and emission reductions, Wolfe *et al*. (2019) presented regional estimates in addition to national estimates. The results show that the estimates of health-related impacts for the West are significantly higher than for the national and the East estimates. The authors note that this is due to the density of roads, vehicle traffic and the locations of high-density populations near these sources.

Wolfe *et al*. (2019) presents data derived from US EPA's 2011 v 6.2 emissions modeling platform that uses data from the 2011 National Emissions Inventory. Emissions are categorized into 17 sectors. California on-road emission estimates were provided by the state for the Wolfe *et al*. (2019) modeling. Emissions are only from direct combustion emissions and do not include any production or downstream contributions. The Benefits Mapping and Analysis Program-Community Edition (BenMAP-CE) was used to quantify the health impacts and costs that were used to develop the incidence per ton and benefit per ton estimates. The BenMAP-CE model calculates the estimated incidence for a number of health endpoints, including mortality, that are associated with a change in air quality for an exposed population in a given geographic region based on the baseline incidence in that population and region. Modeling relies on a concentration-response function (CRF) that is obtained from epidemiological studies.

Wolfe *et al*. (2019) used a CRF from two of the largest and most often used epidemiological studies for benefits calculations, the studies by Krewski *et al*. (2009) and Lepeule *et al*. (2012). Krewski *et al.* (2009) reported results from an extended follow-up of the second American Cancer Society Cancer Prevention Study cohort evaluating the correlations between $PM_{2.5}$ and premature mortality. The authors used the CRF derived from the random effects Cox statistical model that controlled for 44 individual and seven ecological variables. This CRF was based on exposures in 1999-2000 in 116 US cities (relative risk [RR] of 1.06, 95% confidence interval of 1.04-1.08), which means that the authors found a 6% increase in mortality for every 10 $\mu g/m^3$ increase in $PM_{2.5}$ concentrations. The study by Lepeule *et al*. (2012) is an extended follow-up of a different cohort study, the Harvard Six Cities study, which also evaluated mortality correlations with $PM_{2.5}$ exposures. The authors reported a higher mortality risk associated with exposures (RR= 1.14, 95% CI of 1.07-1.22), or a 14% increase in mortality for every 10 $\mu g/m^3$ increase in $PM_{2.5}$ concentrations. These two studies provide a range of impacts and reflect differences in study populations, exposures and statistical methodologies that can contribute to different results. Importantly, these studies and specifically the results from these two large cohort studies are the bases of most of the health benefits analyses conducted by US EPA[23] and states like California (CARB 2022).

Wolfe *et al*. (2019) present monetized values of mortality based on the value of a statistical life (VSL) approach, which represents a measure of the willingness to pay for a decrease in mortality risk across a population group. This approach is the same approach used by US EPA and California in their benefits analyses and represents best practices methodology. The VSL is typically adjusted for inflation and economic growth. A 3% and 7% discount rate are typically assumed.

[23] *See i.e.,* EPA, *Regulatory Impact Analyses for Air Pollution Regulations, available at:* https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/regulatory-impact-analyses-air-pollution.

The focus in the Wolfe *et al*. (2019) analysis is mortality, as this health outcome typically accounts for over 95% of health benefits. The national benefits per ton and incidence per ton for mortality from Wolfe *et al.* (2019) associated with direct $PM_{2.5}$ and secondary $PM_{2.5}$ from NOx emissions have been updated by US EPA to adjust for future income growth in 2018$ and are available for the years 2030, 2035, 2040, and 2045.[24] These updated estimates were used in this analysis. US EPA did not provide regional (West/East) estimates as presented by Wolfe *et al.* (2019), only national estimates. As noted above, the estimates presented by Wolfe *et al.* (2019) for the West were found to be higher than the national estimates. In addition, US EPA did not provide benefits per ton for other health impacts such as hospital admissions, emergency room visits, *etc*., that are also associated with exposures to these air pollutants. Lastly, based on available data, the benefits per ton estimate for on-road heavy-duty diesel vehicles was applied to NOx and $PM_{2.5}$ emissions for all on-road diesel vehicle categories in the NOx Study. Similarly, the benefits per ton estimate for on-road heavy-duty gasoline vehicles was applied to all on-road gasoline vehicle categories included in the NOx Study. As noted in the NOx Study, the majority of the NOx emission reductions for on-road vehicles are from heavy-duty vehicles (*e.g.,* 77% in 2045 for the high throughput scenario).

VI. HEALTH AND ECONOMIC IMPACT RESULTS

Using the US EPA updated mortality incidence per ton and benefits per ton estimates available for mobile sources along with the estimates of reduced direct $PM_{2.5}$ and NOx emissions from on-road vehicles and the off-road sector, the mortality incidence and associated economic estimates were calculated. Tables 6 and 7 show the range of premature mortality estimated for the reduced emissions for the low and high throughput scenarios, respectively, and using the two CRFs from the two epidemiological studies as described above.

As the tables show, the avoided premature mortality estimates increase with every year as there is an increase in reduced NOx and $PM_{2.5}$ emissions for each year. In addition, the estimates are about double when considering the study by Lepeule compared with Krewski, and they are significantly greater in the high throughput scenario. Overall, the avoided premature mortality ranges from 17 (Krewski, low scenario) to 50 (Lepeule, high scenario) avoided deaths in 2045.

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[24] EPA, *Mobile Sector Source Apportionment - Air Quality and Benefits Per Ton* (2018), *available at:* https://www.epa.gov/benmap/mobile-sector-source-apportionment-air-quality-and-benefits-ton.

Table 6. Avoided Premature Mortality Associated with Reductions in $PM_{2.5}$ and NOx Emissions (On-road and Off-road Diesel and Gasoline) from Angeles Link

(Low Scenario)

Year	Krewski	Lepeule
2030	1	2
2035	5	11
2040	10	24
2045	17	37

Table 7. Avoided Premature Mortality Associated with Reductions in $PM_{2.5}$ and NOx Emissions (On-road and Off-road Diesel and Gasoline) from Angeles Link

(High Scenario)

Year	Krewski	Lepeule
2030	4	9
2035	10	22
2040	16	37
2045	22	50

Similarly, there is a wide range of monetized benefit associated with these avoided deaths. As shown in Tables 8 and 9, in the low scenario the maximum yearly monetary benefits range from about $183 million based on the Krewski study to about $412 million based on the Lepeule study in 2045. In the high scenario the maximum yearly monetary benefit (in 2045) ranges from about $245 million to over $552 million based on Krewski and Lepeule, respectively. All estimates are in 2018$ and assume a 3% discount rate.

Table 8. Benefits of Reduced On-road and Off-road Diesel and Gasoline Emissions from Avoided Premature Mortality Due to Reductions in $PM_{2.5}$ and NO_x from Angeles Link

(Low Scenario)

Year	Krewski	Lepeule
2030	$10,000,000	$22,000,000
2035	$51,000,000	$115,000,000
2040	$113,000,000	$254,000,000
2045	$183,000,000	$412,000,000

Table 9. Benefits of Reduced On-road and Off-road Diesel and Gasoline Emissions from Avoided Premature Mortality Due to Reductions in $PM_{2.5}$ and NO_x from Angeles Link (High Scenario)

Year	Krewski	Lepeule
2030	$42,000,000	$95,000,000
2035	$103,000,000	$232,000,000
2040	$175,000,000	$395,000,000
2045	$245,000,000	$552,000,000

VII. ENVIRONMENTAL JUSTICE

California has been at the forefront of the EJ movement. The California Environmental Protection Agency (CalEPA) notes that "the principles of environmental justice call for fairness, regardless of race, color, national origin or income, and the meaningful involvement of the community in the development of laws and regulations that affect every community's natural surroundings, and the places people live, work, play and learn."[25] Along with the climate change goals, California has set forth goals to align with EJ principles that ensure the health of people by restoring, protecting, and improving the environment.

To help identify communities that may be disproportionately burdened by the cumulative impacts of pollution and may be more vulnerable to the effects of pollution, CalEPA developed the California Communities Environmental Health Screening Tool (CalEnviroScreen).[26] CalEnviroScreen is a screening tool that produces scores based on a number of pollution burden indicators (*e.g.,* concentrations of O_3 and $PM_{2.5}$, exposure to drinking water contaminants, toxic releases from facilities) as well as population characteristics (health vulnerabilities, socioeconomic factors) for each census tract in California[27]. The census tracts are then ranked by score and percentiles are calculated based on the score and mapped (see Figure 3). The higher the percentiles, the higher the score.

Figures 3 and 4 show that there are a large number of highly impacted communities, *i.e.,* the communities with the highest pollution burdens and most vulnerable groups (shown in red

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[25] CalEPA, *Environmental Justice Program, available at:* https://calepa.ca.gov/envjustice/.

[26] OEHHA, *CalEnviroScreen 4.0* (May 1, 2023), *available at:* https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-40.

[27] CalEnviroScreen is specific to California, at the national level there are several screening tools that are used to identify EJ or DACs including US EPA's EJ Screen and the Climate and Economic Justice Screening Tool (CEJST).

and orange) located in the San Joaquin Valley and in the SCAQMD air basin within the SoCalGas Service Territory. The San Joaquin Valley is home to about 4.3 million people[28], and more than half (about 2.2 million) that live in communities classified as DAC[29], and in the SCAQMD air basin, the population is approximately 17 million people, of which about 7 million (42%) live in communities classified as DAC (SCAQMD 2022).

DACs were first defined by CalEPA as a requirement of SB 535[30], and the definition was based on geographic, socioeconomic, public health and environmental criteria. SB 535 establishes minimum funding levels for DACs from California Climate Investments, which receives proceeds from the State's Cap and Trade program. The funding is aimed at improving the health and quality of life of overburdened communities.

In 2022, CalEPA revised the designation of DACs[31] for the purposes of SB 535 as:

- Census tracts in the highest 25th percentile of overall scores in CalEnviroScreen 4.0
- Census tracts in the highest 5th percentile for cumulative pollution burden in CalEnviroScreen 4.0, but with no overall score due to data gaps
- Census tracts identified as DACs in the 2017 designation regardless of CalEnviroScreen 4.0 score
- Lands associated with a federally recognized tribes (even if not identified in the CalEPA DAC map.

Figure 5 presents a map of the 2022 SB 535 DACs as defined above in the SoCalGas Service Territory, including the recognized tribes. This map aligns with the results from the CalEnviroScreen overall scores and highlights the San Joaquin Valley and the Los Angeles urban area as having a substantial number of DACs.

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28 Public Policy Institute of California (PPIC), *2020 Census: Counting the San Joaquin Valley* (August 30, 2018), *available at:* https://www.ppic.org/blog/2020-census-counting-the-san-joaquin-valley/.

29 CalEPA, *SB 535 Disadvantaged Communities Map* (2022), *available at:* https://experience.arcgis.com/experience/1c21c53da8de48f1b946f3402fbae55c/page/SB-535-Disadvantaged-Communities/.

30 SB 535 (De León, 2012), *available at:* https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201120120SB535.

31 CalEPA, *California Climate Investments to Benefit Disadvantaged Communities*, *available at:* https://calepa.ca.gov/envjustice/ghginvest/.

Figure 3. CalEnviroScreen 4.0 Results in the SoCal Service Territory

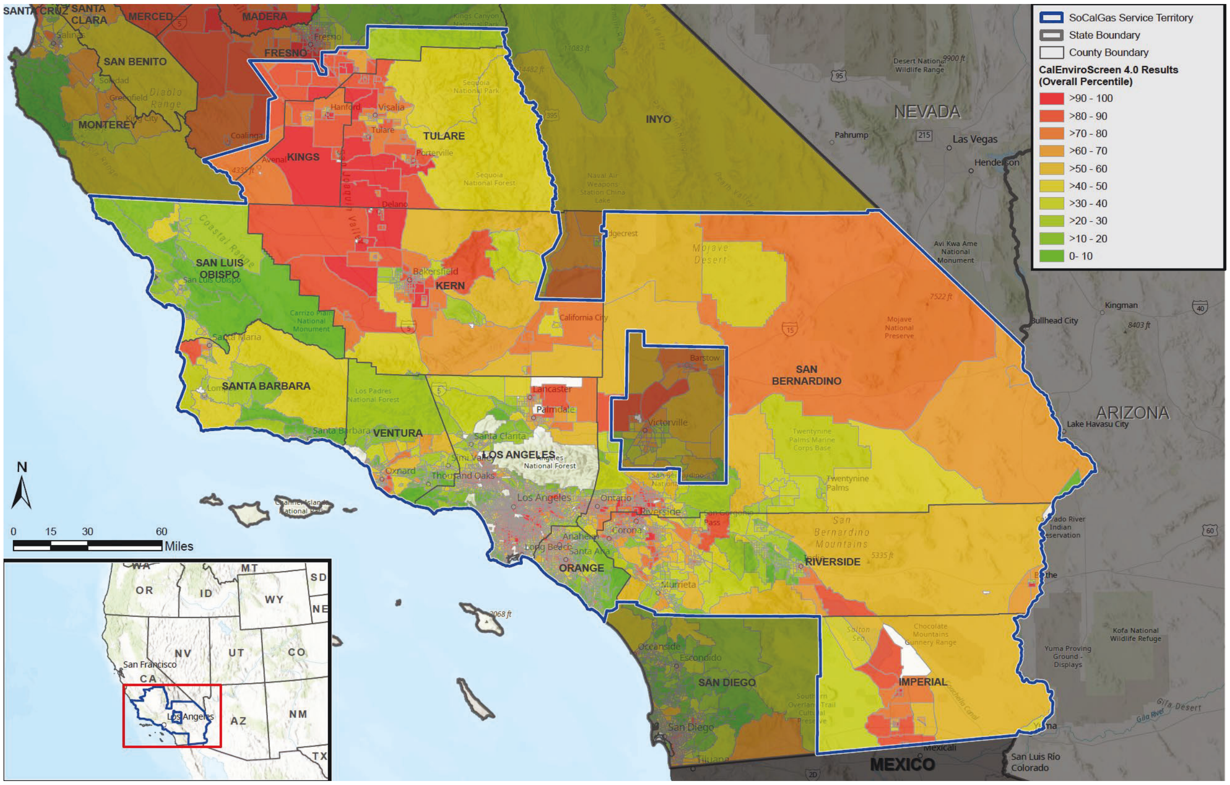


Figure 4. CalEnviroScreen 4.0 Results in the Los Angeles Area

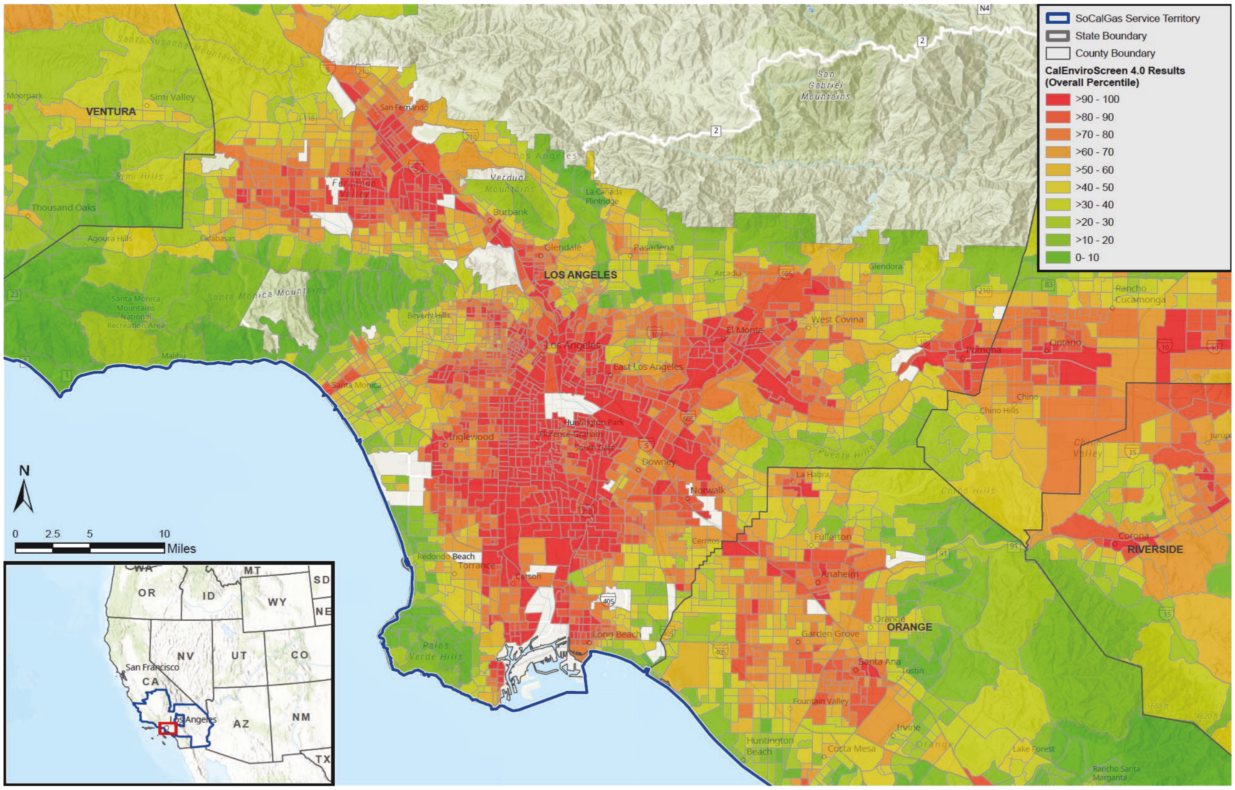
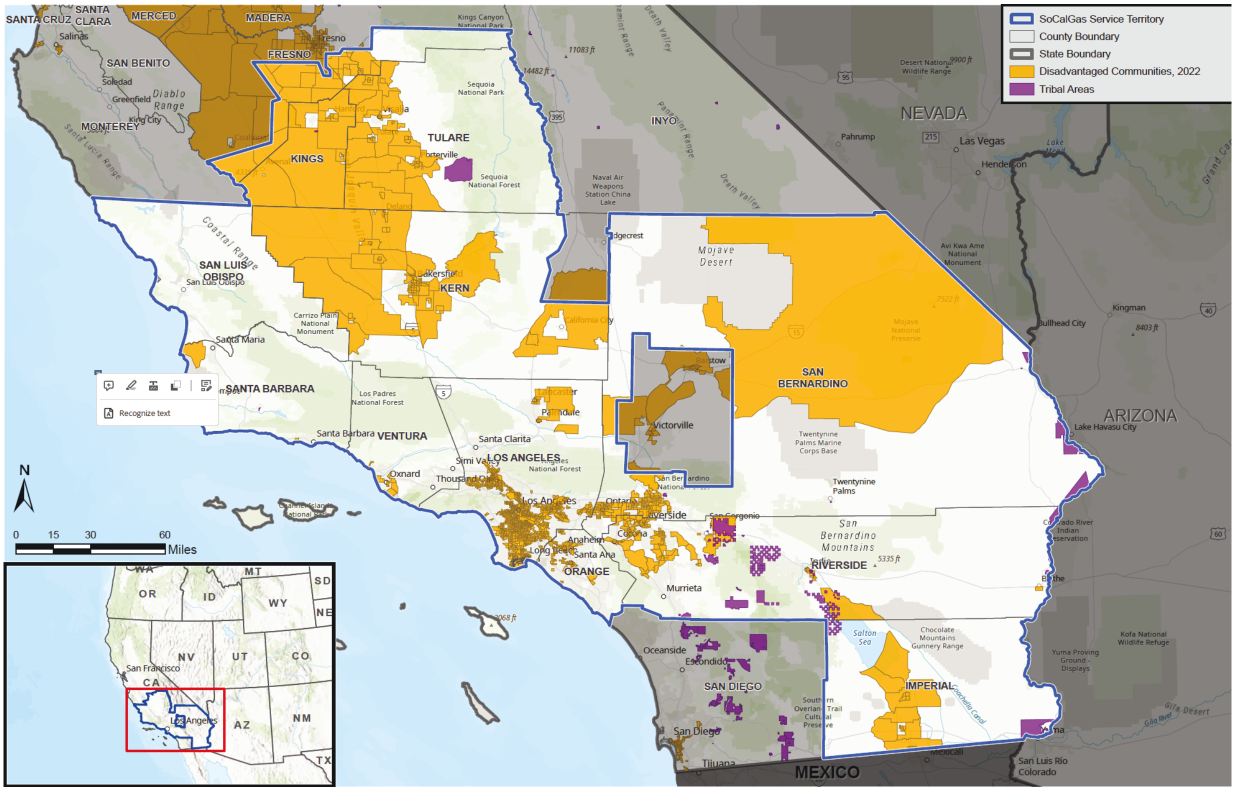


Figure 5. Disadvantaged Communities within the SoCal Service Territory

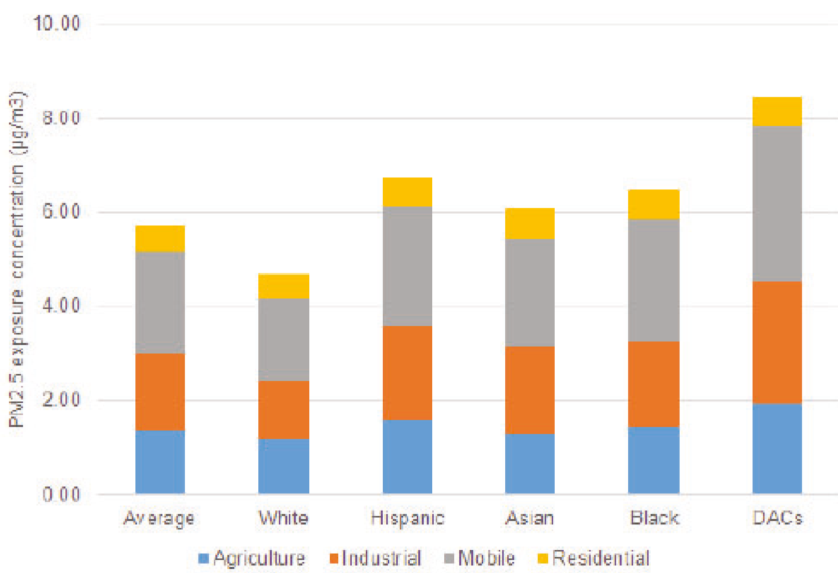


Note: DACs are defined by CalEPA as a requirement under SB 535

EJ was a key consideration and helped inform the CARB 2022 Scoping Plan with the assistance of the AB 32 Environmental Justice Advisory Committee, which was created by statute and was critical to ensuring that EJ was incorporated into the 2022 Scoping Plan. As noted in the 2022 Scoping Plan, there are large disparities in air pollutant exposures between white and non-white populations in California and between low-income and higher-income communities. This is because DACs are disproportionately located near pollution sources such as highways, *e.g.*, along highways in the San Joaquin Valley. For example, whereas mobile sources may account for about 30% of $PM_{2.5}$ exposures on average, DACs are likely to experience a higher percentage of exposure. In fact, based on results from CalEnviroScreen, CARB reported that mobile sources accounted for the largest air pollution disparity in communities based on race, accounting for 45% of exposure disparity in Black populations, and in DACs, accounting for 37% of the disparity (see Figure 6, depicting Figure G-4 from the 2022 Scoping Plan, reproduced below). These results indicate that there is likely to be a larger benefit to these EJ communities by reducing mobile source emissions, particularly from the elimination of emissions from heavy-duty diesel trucks.

These results also align with the findings from the spatial analysis that was conducted as part of the NOx Study that show that EJ communities and DACs are in areas that are projected to have the highest NOx reductions due to Angeles Link and therefore would benefit the most from a move to using clean hydrogen in the mobility sector.[32]

Figure 6. Top Sources of PM 2.5 and Their Contribution to Exposures by Race



Source: 2022 Scoping Plan (CARB 2022a); Appendix G, Figure G-4

[32] *See* SS-Attachment A (Maps of Projected NOx Reductions and Environmental Justice Communities).

VIII. BENEFITS COMPARISON WITH OTHER ESTIMATES

The Alliance for Renewable Clean Hydrogen Energy Systems (ARCHES) is the sponsor of the California-based H2Hub designated by the US Department of Energy (DOE) for up to $1.2 billion in federal funding as part of DOE's hydrogen hub program under the Infrastructure Investment and Jobs Act (also known as the Bipartisan Infrastructure Law) to advance the production and use of clean renewable hydrogen in order to achieve California's ambitious goals of a net-zero carbon future. ARCHES estimated that the California H2Hub projects will ultimately result in health and health-cost savings of billions of dollars from reduced air pollution.[33] Also, as noted in the ARCHES's Community Benefits Plan Fact Sheet the projects are estimated to result in 13,292 fewer days of work lost/year, 2,097 fewer hospitalizations/year for respiratory illness, and 48 fewer premature deaths/year. ARCHES has identified projects supporting the use of clean renewable hydrogen in several end-user sectors that are hard to electrify including heavy-duty vehicles, power plants, industries (cement, steel and refineries) and ports. Angeles Link has been recognized by ARCHES as an integral part of the California H2Hub.

As part of its 2022 Scoping Plan, CARB also evaluated the health benefits associated with improved air quality[34]. The modeling includes an evaluation of the Scoping Plan Scenario as well as different technology and fuel option alternatives for reducing dependence on fossil fuels and includes scaling up renewable hydrogen as a new option for hard to electrify end uses. Emission projections for stationary, area and mobile sources to 2035 and 2045 are obtained based on a 2020 CARB base year of pollutant emission inventory (and other sources such as EMFAC 2021 for on-road vehicles and OFFROAD2021 for other sectors) and spatial and temporal resolution were obtained using the Sparse Matrix Operator Kernel Emissions (SMOKE) model. CMAQ is then used to estimate air pollutant concentrations associated with the emission estimates relative to a reference scenario. As with other analyses, the concentration differences were then used in BenMAP to quantify health and associated economic impacts.

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[33] ARCHES H2, *Meet ARCHES* (October 2023), *available at:* https://archesh2.org/wp-content/uploads/2023/10/Meet-Arches_October-2023.pdf.

[34] *See* CARB 2022, Appendix H – AB32 GHG Inventory Sector Modeling, *available at:* https://ww2.arb.ca.gov/sites/default/files/2024-01/nc-2022-sp-appendix-h-ab-32-ghg-inventory-sector-modeling.pdf.pdf.

CARB reported that implementation of the 2022 Scoping Plan would result in a benefit estimated to be $75 billion in 2035 and $189 billion in 2045 for avoided $PM_{2.5}$ alone.

An important finding in the 2022 Scoping Plan was that the total benefits are not equally distributed across California. As shown in Figure 7 below, depicting Figure H-10 from the 2022 Scoping Plan, the large majority of the health benefits in both 2035 and 2045 were associated with air quality improvement in the South Coast AQMD. As discussed above, the South Coast AQMD has had challenges in the attainment of health-based NAAQS and would have the most to gain from a transition from fossil fuels in the transportation sector. CARB further evaluated the health impacts using an EJ framework, and quantified the health benefits for DACs identified using CalEnviroScreen 4.0 (see Section VII). CARB estimated that the DAC community benefits would be $22 billion in 2035 and $61 billion in 2045. Similar to the total benefits as shown in Figure 7 below, the highest portion of the benefits are observed in DACs in South Coast.

In 2022, the California Public Utilities Commission published a report conducted by Energy and Environmental Economics, Inc. (E3 2022) in collaboration with Commission staff and the researchers at the University of California, Irvine. The report, "Quantifying the Air Quality Impacts of Decarbonization and Distributed Energy Programs in California"[35] analyzed emissions associated with burning fossil fuels and quantified the health benefits associated with eliminating these emissions, including from the transportation sector. The approach is similar to the approach used for the benefits analysis in the CARB 2022 Scoping Plan discussed above including the use of the full atmospheric transport modeling of emissions from each sector to estimate both primary air pollutant concentrations as well as secondary air pollutant concentrations. As noted in the E3 report, in California 40-60% of $PM_{2.5}$ concentrations are from secondary formation. As with the analysis presented in the 2022 Scoping Plan, modeling was conducted using the SMOKE model to determine emissions and CMAQ with a 4 km x 4 km resolution for estimating air pollutant concentrations. The granular analysis allowed for the determination of air quality impacts in different communities, including to DACs identified using CalEnviroScreen 3.0. To quantify the health benefits the authors modeled the removal of

[35] E3, *Quantifying the Air Quality Impacts of Decarbonization and Distributed Energy Programs in California* (2021) , *available at:* https://www.ethree.com/wp-content/uploads/2022/01/CPUC-Air-Quality-Report-FINAL.pdf

all emissions from a given sector (*e.g.*, on-road transportation) relative to a reference scenario, which was a "business as usual" scenario for 2035 using US EPA's BenMAP model.

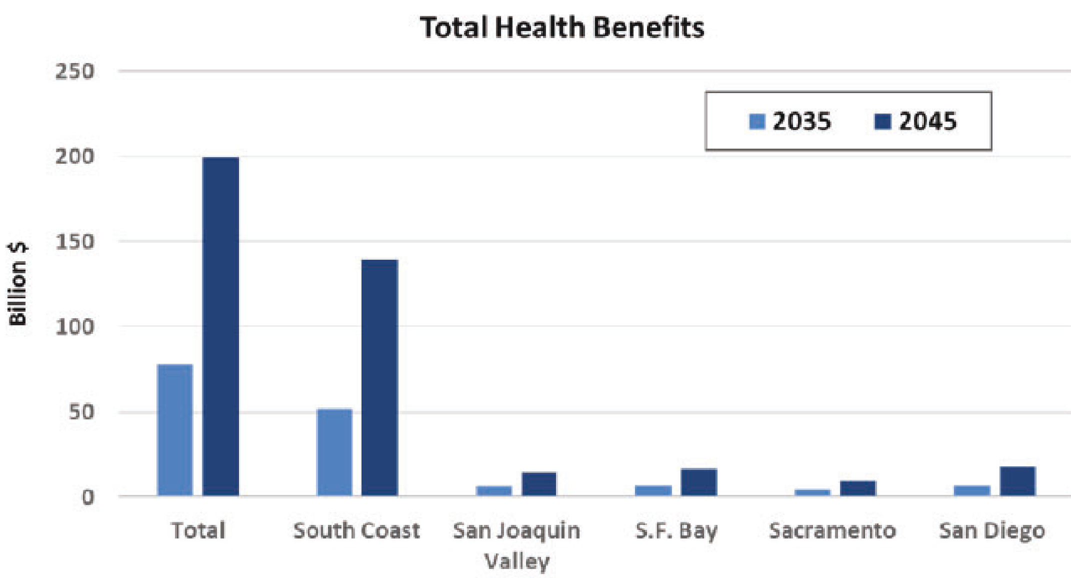
The authors reported that the largest emissions reduction for NOx was for the on-road transportation sector (including light, medium and heavy-duty vehicles, but not buses or motorcycles), with about 40% of the emissions associated with the SCAQMD, and 60% in the rest of California. Direct $PM_{2.5}$ emissions were primarily associated with the burning of natural gas from buildings and generators. With regards to improvements in air quality, however, the on-road sector was associated with the largest reductions of $PM_{2.5}$ concentrations, in particular in the SCAQMD, which highlights the importance of considering secondary $PM_{2.5}$ contributions from mobile sources. That is, even though the on-road sector had relatively low *direct* $PM_{2.5}$ emissions, large reductions resulted from reducing the NOx emissions that contribute to *secondary* $PM_{2.5}$.

The authors also conducted episodic analyses focused on a winter and summer period and transportation subsectors (light-duty, medium-duty, and heavy-duty). In both summer and winter, the largest $PM_{2.5}$ reductions were associated with eliminating the heavy-duty vehicle emissions and in the winter, these reductions were concentrated in the San Joaquin Valley and SCAQMD.

The health benefits analysis reflected the modeling results, with the largest avoided premature mortality associated with the on-road transportation sector, largely due to reductions in direct and secondary $PM_{2.5}$. For the on-road sector alone, the E3 report estimated the value of avoided premature mortality from reduced $PM_{2.5}$ would be $18.9 billion per year in 2020$ in 2035, with about 75% of the benefits estimated for the SCAQMD alone. Importantly, the authors noted that in census tracts designated as DACs, reductions in the on-road sector results in $7.8 billion 2020$ per year in 2035, or about 38% of the total health benefits.

The benefits analyses presented here are more modest compared to the results of other studies, but still show a significant benefit for one important sector of end-user that would transition to using clean renewable hydrogen for fuel. Additional reductions in air pollutant emissions for other end-users would increase these health benefits numbers. In addition, due to limited data, the analysis focused solely on mortality, and the addition of the morbidity benefits (*e.g.*, hospitalizations, emergency room visits etc.) would also increase these benefits estimates. Additional benefits would result from reductions in other air pollutants associated with fuel combustion including O_3.

Figure 7. Total Health Benefits Estimated for Air Quality Improvements in the Scoping Plan Scenario



Source: 2022 Scoping Plan (CARB 2022a) – Appendix H, Figure H-10

IX. UNCERTAINTY AND LIMITATIONS

Health benefits assessments, including monetizing the benefits, are a widely used methodology. US EPA uses this methodology in Regulatory Impact Assessments (RIAs), and states like California use these methods to evaluate the benefits and costs of air pollution regulations as described above. There are a number of uncertainties in estimating health impacts from air pollutant exposures.

The benefits analysis presented here is limited to specific mobile sources, and does not account for the full scope of potentially reduced emissions, although it provides a fair estimate of the largest contributing sectors (*i.e.,* medium and heavy-duty on-road and off-road sectors). In addition, the analysis does not quantify morbidity impacts, which although relatively smaller, would increase the estimates. Also, the analysis does not include an evaluation of potential cancer risks. In particular, SCAQMD found that DPM is the largest contributor to air toxics cancer risk in California[36].

The analysis is also based on national-level estimates, whereas using regional estimates would yield higher benefits. Also, the analysis does not account for the potential benefits of reductions in other air pollutant concentrations, including O_3 and VOCs (many of which are associated with their own potential health effects). Lastly, the benefits analysis does not quantify the impacts from reducing greenhouse gas emissions, which would prevent or reduce global climate impacts beyond the air quality improvements. As reported in the Angeles Link Phase 1 Greenhouse Gas (GHG) Emissions Evaluation, clean renewable hydrogen is estimated to result in the removal of about 4.5 and 9 million metric tons of carbon dioxide equivalents per year from the SoCalGas geographic service territory by end-users in 2045 for the low and high scenarios, respectively. Most of the GHG reductions are from the mobility sector, which accounts for 72.5% and 50.3% of the overall GHG reductions for the low and high scenarios, respectively.

There are a number of uncertainties associated with the benefits analyses. One important uncertainty associated with estimating $PM_{2.5}$ health impacts stems from the assumption that all $PM_{2.5}$, regardless of composition, is equally potent in causing health effects such as premature mortality. This is important because $PM_{2.5}$ varies significantly in composition depending on the source. Several reviews have evaluated the scientific evidence of health effects from specific particulate components (*e.g*., Rohr and Wyzga 2012, Kelly and Fussell 2007). These reviews indicate that the evidence is strongest for combustion-derived components of PM including elemental carbon (EC), organic carbon (OC) and various metals (*e.g.,* nickel and vanadium). However, there is still no definitive data that points to any particular component of PM as being more toxic than other components. Various studies have also shown the importance of considering particle size, composition, and particle source in determining the health impacts of PM (US EPA 2019). By not considering the relative toxicity of PM components, BenMAP analyses are likely to be somewhat conservative, and therefore estimates may be lower than observed.

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[36] SQAQMD, *2. Overview of Goals, Summary of Previous MATES Studies, and Projected Timeline - Presentation by S.A. Epstein* (October 26,2023), *available at:* https://www.aqmd.gov/docs/default-source/planning/mates-vi/mates-tag-1-presentations.pdf?sfvrsn=8.

Another important source of uncertainty is the assumption of a log-linear response between exposure and health effects, without consideration for a threshold below which effects may not be measurable. The issue of a threshold for $PM_{2.5}$ and other air pollutants is highly debated and can have significant implications for health impacts analyses as it requires consideration of current air pollution levels and calculating effects only for areas that exceed threshold levels. Without consideration of a threshold, effects of any change in air pollution below or above the threshold are assumed to have an equal impact on health. Interestingly, although US EPA traditionally does not consider thresholds in its cost-benefit analyses, the NAAQS itself is a health-based threshold level that US EPA has developed based on evaluating the most current evidence of health effects. Most epidemiological studies do not indicate that a threshold exists, but these studies often do not have the statistical power to detect thresholds. If a threshold exists, then any impact below the threshold may not be as large. In the case of California, where levels of air pollutants exceed health-based standards, the benefits are more likely to be larger.

A limitation of epidemiological studies, including the studies by Krewski and Lepeule, is a lack of information regarding population exposures, which are typically estimated based on outdoor monitor data (*e.g.*, measurements made at one to a few monitors across a wide area) but may not represent personal exposures experienced by people in their everyday lives (*e.g.,* exposures at home, at work, while commuting). This can introduce error in the estimated associations between exposure and mortality. The error could increase or decrease the association between exposure and mortality.

Also, epidemiological studies cannot always account for other factors or exposures that could contribute to or account for the observed health effects. For example, many other air pollutants have been shown to be associated with the same health effects as those associated with $PM_{2.5}$. Epidemiological studies often cannot distinguish between the effects attributed to one air pollutant from those of others. Lifestyle factors, such as smoking, diet and exercise, can also be important contributing factors to mortality. If these factors are not properly considered in the analyses, the results could be lower. Both epidemiological studies included estimates of many of the factors that could be associated with both the exposures and mortality in order to properly account for these factors. Lastly, poor air quality can also impact lifestyle factors, such as the ability to exercise outdoors in poor air quality conditions, and these would indirectly affect health and well-being of populations.

Therefore, as the US EPA did in developing the $PM_{2.5}$ and other NAAQS, when assessing the health impacts of $PM_{2.5}$ it is important to consider information from other all health effects studies, including from animal and cell-based studies, in the interpretation of health effects data. BenMAP analyses, however, rely only on individual epidemiological studies. The epidemiological studies included in this analysis were selected because of their size and quality, and they are the studies commonly used by US EPA and other states in benefit-cost analyses for mortality. However, there are numerous other epidemiological studies, and it is not uncommon to find different results across different studies because each evaluates different populations and air quality data from different time periods, and uses different statistical methods. Because there is no scientific consensus on the single best method for doing these analyses, it is important to consider whether results across studies are consistent. Sensitivity analyses are often warranted using different CRFs from different studies in order to evaluate the potential variability and/or uncertainty in health estimates. In this analysis, mortality estimates for two different epidemiological studies were used to provide a range of potential benefits, taking into account study differences.

X. CONCLUSIONS

This testimony presents a high-level estimate of some of the potential health benefits associated with Angeles Link. A reduced-form approach is used along with estimates from the data underlying the NOx Study and US EPA benefits per ton figures to quantify the potential benefits of reduced direct emissions of $PM_{2.5}$ and secondary $PM_{2.5}$ formed as a result of NOx emissions. Benefits were calculated for both the low and high throughput scenarios as presented in the NOx Study to provide a range of estimates. In addition, values based on two epidemiological studies are presented to provide additional context for the possible range of estimates.

These estimates indicate that health benefits associated with avoided premature mortality associated with Angeles Link could range from approximately $183 million to $552 million (2018$) per year by 2045. Benefits are likely to be higher as this analysis only includes estimates from avoided premature mortality for exposures to direct $PM_{2.5}$ and secondary formation of

$PM_{2.5}$ associated with NOx emissions, and no other air pollutants (*e.g.,* O_3) that will also be reduced by the transition to clean renewable hydrogen. The analysis also does not quantify all other potential morbidity outcomes avoided (*e.g.,* respiratory and cardiovascular hospital admissions or emergency room visits) or cancer. Other health benefits associated with climate impacts, which are harder to quantify, have not been included in these estimates. Importantly, a large majority of the 21 million residents that are served by SoCalGas will benefit from this project, including many DACs that bear a disproportionate impact from air pollution and live in a region of the country that experiences the worst air quality in the Nation, primarily due to mobile sources.

This concludes my prepared direct testimony.

XI. QUALIFICATIONS

My name is Dr. Sonja Sax. I am the lead scientist in air quality at Epsilon Associates, Inc. My business address is 3 Mill & Main Place, Suite 250, Maynard, Massachusetts 01754. I have over twenty years of exposure and health risk assessment experience. I have served as a consultant for the Clean Air Advisory Committee on ozone and particulate matter National Ambient Air Quality Standards (2019). I have an ScD and M.S. in Environmental Health from the Harvard T.H. Chan School of Public Health, and a B.A. in Biological Chemistry from Wellesley College. A copy of my resume is attached as Attachment B.

I have not previously testified before the Commission.

REFERENCES

Alliance for Renewable Clean Hydrogen Energy Systems (ARCHES). Available at: https://archesh2.org/wp-content/uploads/2023/10/Meet-Arches_October-2023.pdf.

Angeles Link Phase 1 Nitrogen Oxides (NOx) and other Air Emissions Assessment. November 2024.

Angeles Link Phase 1 Greenhouse Gas (GHG) Emissions Evaluation. November 2024.

Angeles Link Phase 1: Maps of Projected NOx Reductions and Environmental Justice Communities. July 2024

Brown, A. L; Sperling, D.; Austin, B.; DeShazo, JR; Fulton, L.; Lipman, T., et al. (2021). Driving California's Transportation Emissions to Zero. *UC Office of the President: University of California Institute of Transportation Studies*. http://dx.doi.org/10.7922/G2MC8X9X Retrieved from https://escholarship.org/uc/item/3np3p2t0

California Air Resources Board (CARB). 2022a. 2022 Scoping Plan for Achieving Carbon Neutrality. Available at: https://ww2.arb.ca.gov/our-work/programs/ab-32-climate-change-scoping-plan/2022-scoping-plan-documents.

CARB. 2022b. 2022 State Strategy for the State Implementation Plan. Available at: https://ww2.arb.ca.gov/resources/documents/2022-state-strategy-state-implementation-plan-2022-state-sip-strategy

CARB 2017. Statewide Emissions – CEPAM2019v1.03 Emission Projection Data, available at: https://ww2.arb.ca.gov/applications/statewide-emissions.

California Public Utilities Commission (CPUC) Decision Approving the Angeles Link memorandum Account to Record Phase One Costs. A.22-02-007 December 15, 2022. Available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M499/K891/499891989.PDF

Energy Environmental Economics (E3) 2022. Quantifying the Air Quality Impacts of Decarbonization and Distributed Energy Programs in California. Available at: https://www.ethree.com/wp-content/uploads/2022/01/CPUC-Air-Quality-Report-FINAL.pdf.

Hodan WM, Barnard WR. (2004). Evaluating the Contribution of $PM_{2.5}$ Precursor Gases and Re-entrained Road Emissions to Mobile Source $PM_{2.5}$ Particulate Matter Emissions.

Kelly FJ, Fussell JC. 2012. Size, source and chemical composition as determinants of toxicity attributable to ambient particulate matter. Atmospheric Environment. Volume 60. Pages 504-526. SSN 1352-2310. https://doi.org/10.1016/j.atmosenv.2012.06.039.

Krewski D, Jerrett M, Burnett RT, Ma R, Hughes E, Shi Y, Turner MC, Pope CA 3rd, Thurston G, Calle EE, Thun MJ, Beckerman B, DeLuca P, Finkelstein N, Ito K, Moore DK, Newbold KB, Ramsay T, Ross Z, Shin H, Tempalski B. Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality. Res Rep Health Eff Inst. 2009 May;(140):5-114; discussion 115-36. PMID: 19627030.

Lepeule J, Laden F, Dockery D, Schwartz J. Chronic exposure to fine particles and mortality: an extended follow-up of the Harvard Six Cities study from 1974 to 2009. Environ Health Perspect. 2012 Jul;120(7):965-70. doi: 10.1289/ehp.1104660. Epub 2012 Mar 28. PMID: 22456598; PMCID: PMC3404667.

Rohr AC, Wyzga RE. 2012. Attributing health effects to individual particulate matter constituents. Atmospheric Environment. Volume 62. Pages 130-152. ISSN 1352-2310. https://doi.org/10.1016/j.atmosenv.2012.07.036.

Southern California Gas Company (SoCalGas) 2024. Angeles Link Phase 1 Final Environmental Social Justice Community (ESJ) Final Engagement Plan and ESJ Screening.

South Coast Air Quality Management District (SCAQMD). 2022. South Coast Air Quality Management Plan. Available at: https://www.aqmd.gov/home/air-quality/air-quality-management-plans/air-quality-mgt-plan.

SCAQMD. 2023. Overview of Goals, Summary of Previous MATES Studies, and Projection Timeline, Presentation by S.A. Epstein, October 26, TAG Meeting #1 Available at: https://www.aqmd.gov/home/air-quality/air-quality-studies/health-studies/mates-vi.

University of California – Institute of Transportation Studies 2021. *Driving California's Transportation Emissions to Zero*. Available at: https://escholarship.org/uc/item/3np3p2t0.

United States Environmental Protection Agency (US EPA). 2019. Integrated Science Assessment for Particulate Matter (Final Report). EPA/600/R-19/188, 2019. Available at: https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter#history.

US EPA. 2018. Mobile Sector Source Apportionment - Air Quality and Benefits Per Ton (2018). Available at: https://www.epa.gov/benmap/mobile-sector-source-apportionment-air-quality-and-benefits-ton.

US EPA. 2022. Supplement to the 2019 Integrated Science Assessment for Particulate Matter (Final Report). EPA/635/R-22/028.Available at: https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter#history.

US EPA. 2020. Integrated Science Assessment for Ozone and Related Photochemical Oxidants (Final Report). EPA/600/R-20/012. Available at: https://www.epa.gov/isa/integrated-science-assessment-isa-ozone-and-related-photochemical-oxidants#history.

US EPA. 2016. Integrated Science Assessment for Oxides of Nitrogen – Health Criteria (Final Report). EPA/600/R-15/068. Available at: https://www.epa.gov/isa/integrated-science-assessment-isa-oxides-nitrogen-health-criteria#history.

US EPA. 2024. Final Reconsideration of the National Ambient Air Quality Standards for Particulate Matter. Available at: https://www.epa.gov/pm-pollution/final-reconsideration-national-ambient-air-quality-standards-particulate-matter-pm.

US EPA. 2024. Green Book. Available at: https://www.epa.gov/green-book

Watson JG, Fujita EM, Chow JC, Zielinska B, Richards LW, Neff W, Dietrich D. Northern front range air quality study final report. Prepared for Colorado State University, Fort Collins, CO, and EPRI, Palo Alto, CA, by Desert Research Institute, Reno, NV. 1998 Jun 30.

Wolfe P, Davidson K, Fulcher C, Fann N, Zawacki M, Baker, KR. 2019. Monetized health benefits attributable to mobile source emission reductions across the United States in 2025. Science of The Total Environment. Volume 650, Part 2, Pages 2490-2498. ISSN 0048-9697. https://doi.org/10.1016/j.scitotenv.2018.09.273.

Zawacki M, Baker KR, Phillips S, Davidson K, Wolfe P. Mobile source contributions to ambient ozone and particulate matter in 2025. Atmospheric Environment. 2018 Sep 1;188:129-41.

Attachment A

Maps of Projected NOx Reductions and Environmental Justice Communities

Figure No.
A-9

Title
NOx Emissions Reductions Associated With Angeles Link (AL) 2030 Total, Low Throughput

Client/Project 203723235
Southern California Gas Company (SoCalGas)
Phase One NOx Study

Project Location
California
Prepared by BS on 2024-07-19

N

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(At original document size of 11x17)
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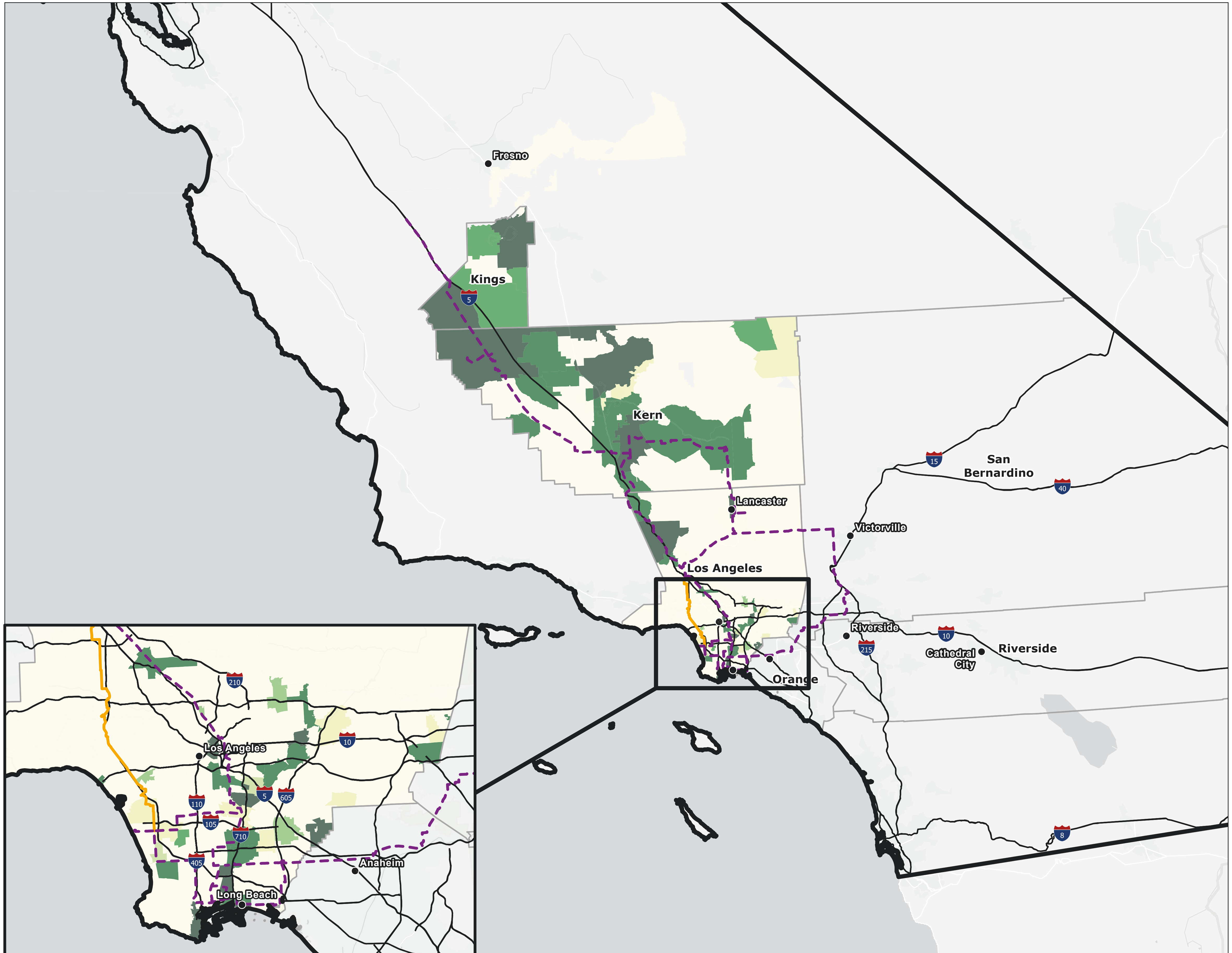
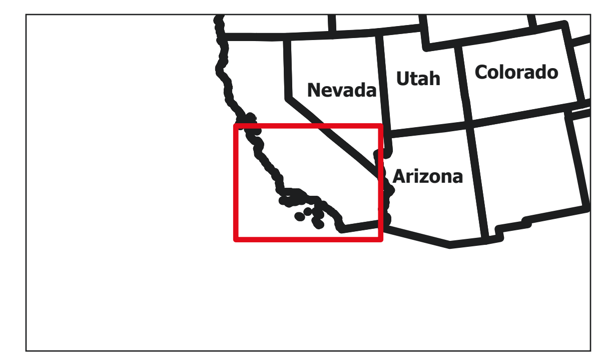


Legend

- Major Cities
- State Boundary
- Counties
- Interstate/Highway
- Preferred Routes (combined)
- Route Variation 1

Reduction in NOx Emissions Attributable to AL in 2030, Low Scenario

- 0.00 - 0.05 tons/year NOx
- 0.05 - 0.12 tons/year NOx
- 0.12 - 0.23 tons/year NOx
- 0.23 - 0.37 tons/year NOx
- 0.37 - 0.55 tons/year NOx
- 0.55 - 5.7 tons/year NOx
- >5.7 tons/year NOx



Notes
1. Coordinate System: NAD 1983 StatePlane California II FIPS 0402 Feet
2. Data Sources: USGS, OEHHA, CalEPA, CEQ
3. Background: ESRI Basemap
4. Figure depicts overall NOx emission reductions allocated by zip code
5. NOx emissions reductions by zip code are based on Demand Study hydrogen data
6. The NOx emissions reduction benefits depicted on the map are focused within the counties through which the Angeles Link would potentially pass. These benefits could potentially extend beyond these boundaries

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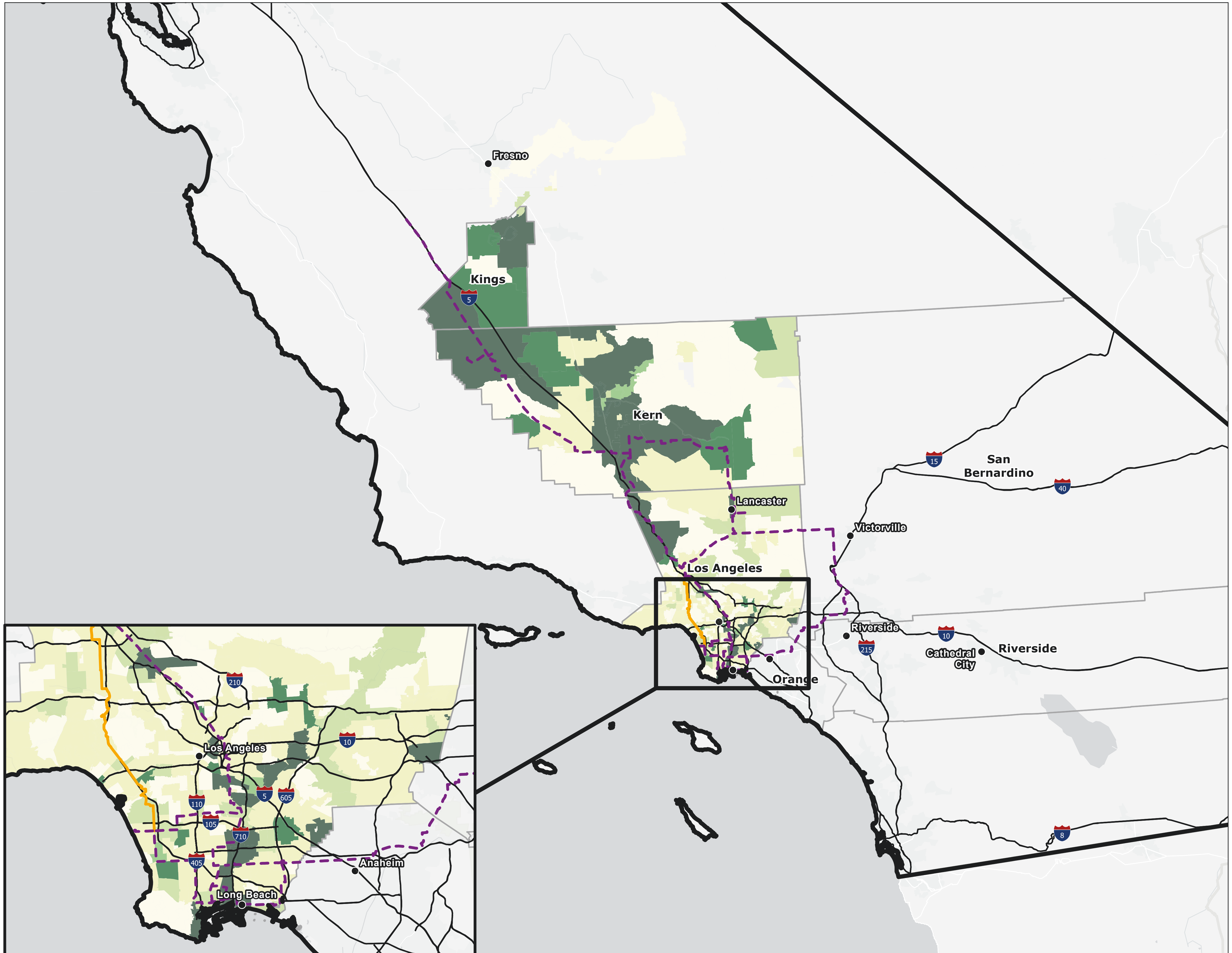

Figure No.

A-10

Title

NOx Emissions Reductions Associated With Angeles Link (AL) 2035 Total, Low Throughput

Client/Project 203723235

Southern California Gas Company (SoCalGas)
Phase One NOx Study

Project Location
California

Prepared by BS on 2024-07-19

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(At original document size of 11x17)
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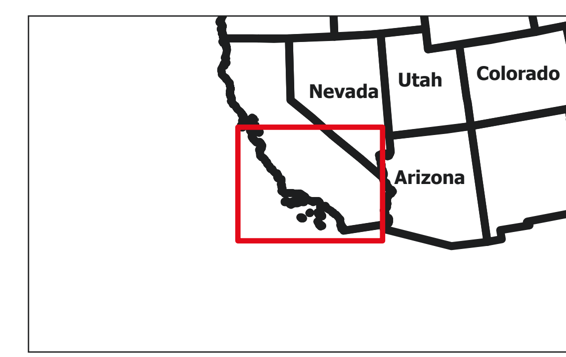
Legend

- Major Cities
- State Boundary
- Counties
- Interstate/Highway
- Preferred Routes (combined)
- Route Variation 1

Reduction in NOx Emissions Attributable to AL in 2035, Low Scenario

- 0.00 - 0.05 tons/year NOx
- 0.05 - 0.12 tons/year NOx
- 0.12 - 0.23 tons/year NOx
- 0.23 - 0.37 tons/year NOx
- 0.37 - 0.55 tons/year NOx
- 0.55 - 5.7 tons/year NOx
- >5.7 tons/year NOx



Notes
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3. Background: ESRI Basemap
4. Figure depicts overall NOx emission reductions allocated by zip code
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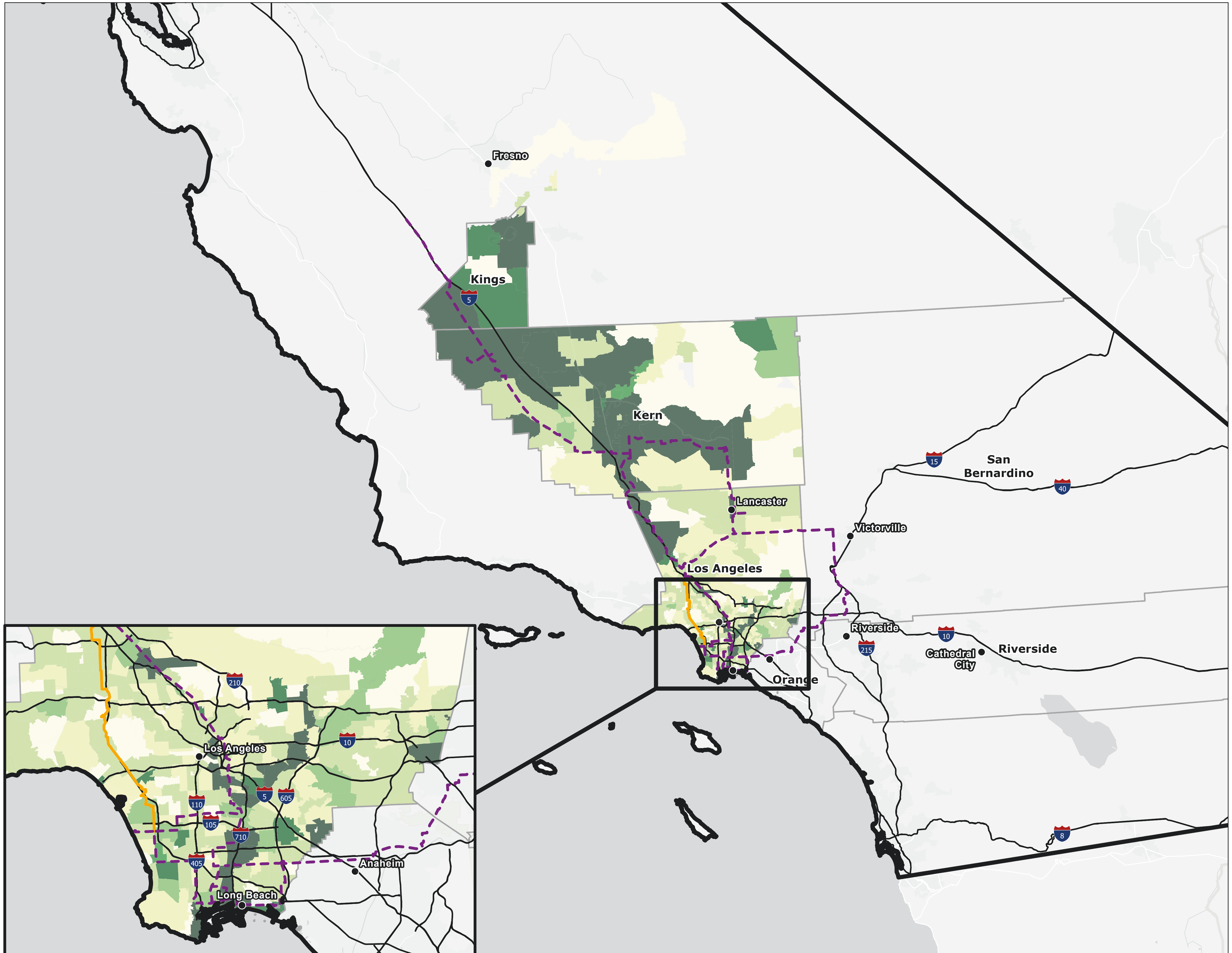

Figure No.
A-11

Title
NOx Emissions Reductions Associated With Angeles Link (AL) 2040: Total, Low Throughput

Client/Project 203723235
Southern California Gas Company (SoCalGas)
Phase One NOx Study

Project Location
California

Prepared by BS on 2024-07-19

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(At original document size of 11x17)
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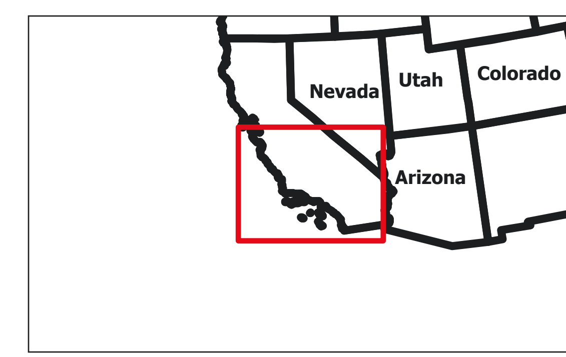
Legend
- Major Cities
- State Boundary
- Counties
- Interstate/Highway
- Preferred Routes (combined)
- Route Variation 1

Reduction in NOx Emissions Attributable to AL in 2040, Low Scenario
- 0.00 - 0.05 tons/year NOx
- 0.05 - 0.12 tons/year NOx
- 0.12 - 0.23 tons/year NOx
- 0.23 - 0.37 tons/year NOx
- 0.37 - 0.55 tons/year NOx
- 0.55 - 5.7 tons/year NOx
- >5.7 tons/year NOx



Notes
1. Coordinate System: NAD 1983 StatePlane California II FIPS 0402 Feet
2. Data Sources: USGS, OEHHA, CalEPA, CEQ
3. Background: ESRI Basemap
4. Figure depicts overall NOx emission reductions allocated by zip code
5. NOx emissions reductions by zip code are based on Demand Study hydrogen data
6. The NOx emissions reduction benefits depicted on the map are focused within the counties through which the Angeles Link would potentially pass. These benefits could potentially extend beyond these boundaries

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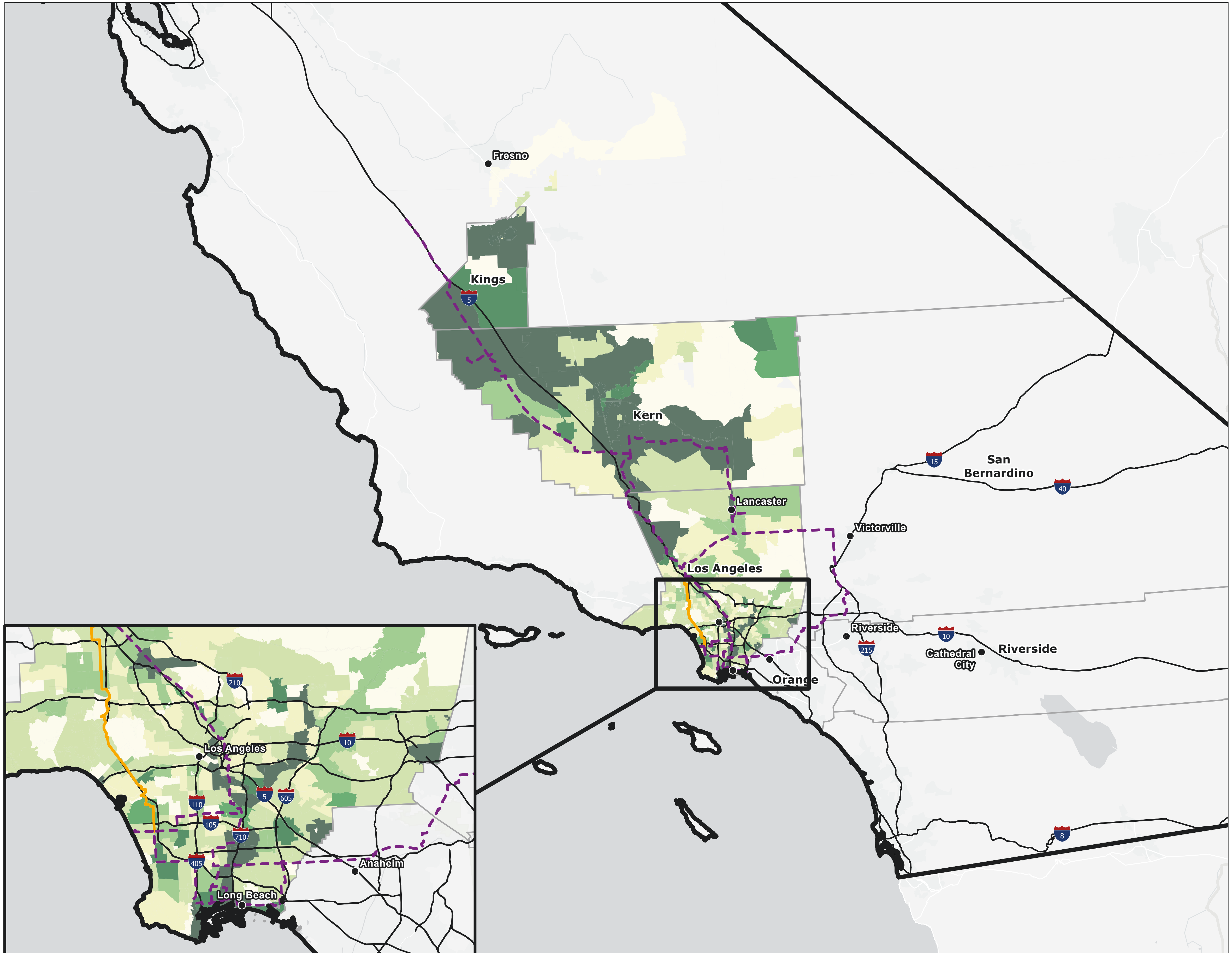
Figure No.
A-12

Title
NOx Emissions Reductions Associated With Angeles Link (AL) 2045: Total, Low Throughput

Client/Project 203723235
Southern California Gas Company (SoCalGas)
Phase One NOx Study

Project Location
California

Prepared by BS on 2024-07-19



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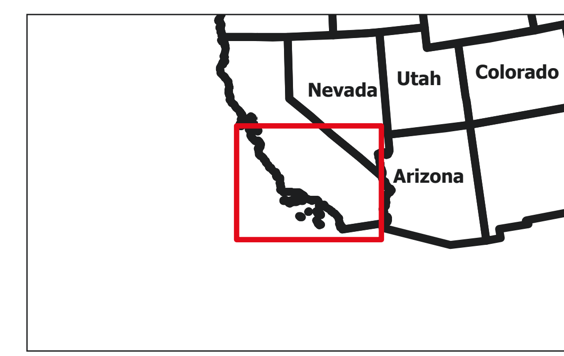
Legend
- Major Cities
- State Boundary
- Counties
- Interstate/Highway
- Preferred Routes (combined)
- Route Variation 1

Reduction in NOx Emissions Attributable to AL in 2045, Low Scenario
- 0.00 - 0.05 tons/year NOx
- 0.05 - 0.12 tons/year NOx
- 0.12 - 0.23 tons/year NOx
- 0.23 - 0.37 tons/year NOx
- 0.37 - 0.55 tons/year NOx
- 0.55 - 5.7 tons/year NOx
- >5.7 tons/year NOx



Notes
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2. Data Sources: USGS, OEHHA, CalEPA, CEQ
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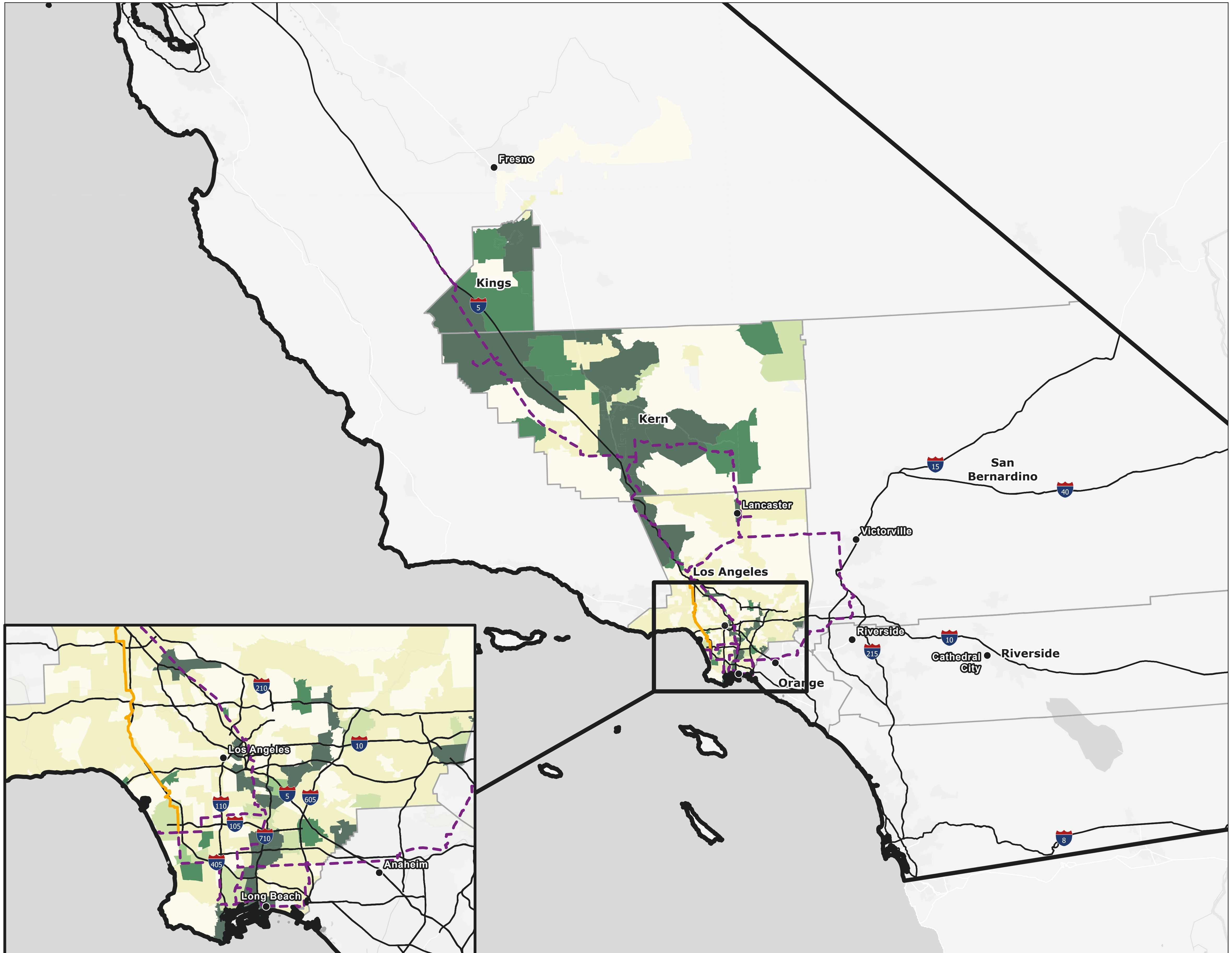

Figure No.
A-13

Title
NOx Emissions Reductions Associated With Angeles Link (AL) 2030 Total, High Throughput

Client/Project 203723235
Southern California Gas Company (SoCalGas)
Phase One NOx Study

Project Location
California

Prepared by BS on 2024-07-19

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0 20 40 Miles
(At original document size of 11x17)
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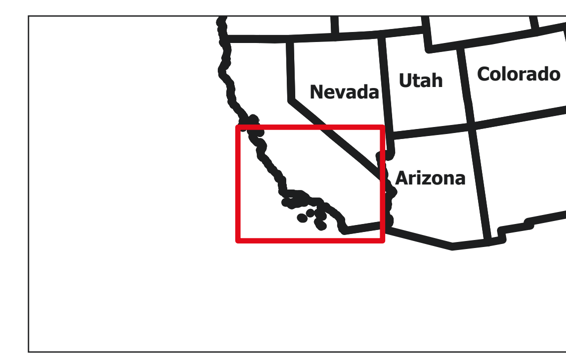
Legend
- Major Cities
- State Boundary
- Counties
- Interstate/Highway
- Preferred Routes (combined)
- Route Variation 1

Reduction in NOx Emissions Attributable to AL in 2030, High Scenario
- 0.00 - 0.06 tons/year NOx
- 0.06 - 0.16 tons/year NOx
- 0.16 - 0.32 tons/year NOx
- 0.32 - 0.51 tons/year NOx
- 0.51 - 0.78 tons/year NOx
- 0.78 - 7.7 tons/year NOx
- >7.7 tons/year NOx



Notes
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2. Data Sources: USGS, OEHHA, CalEPA, CEQ
3. Background: ESRI Basemap
4. Figure depicts overall NOx emission reductions allocated by zip code
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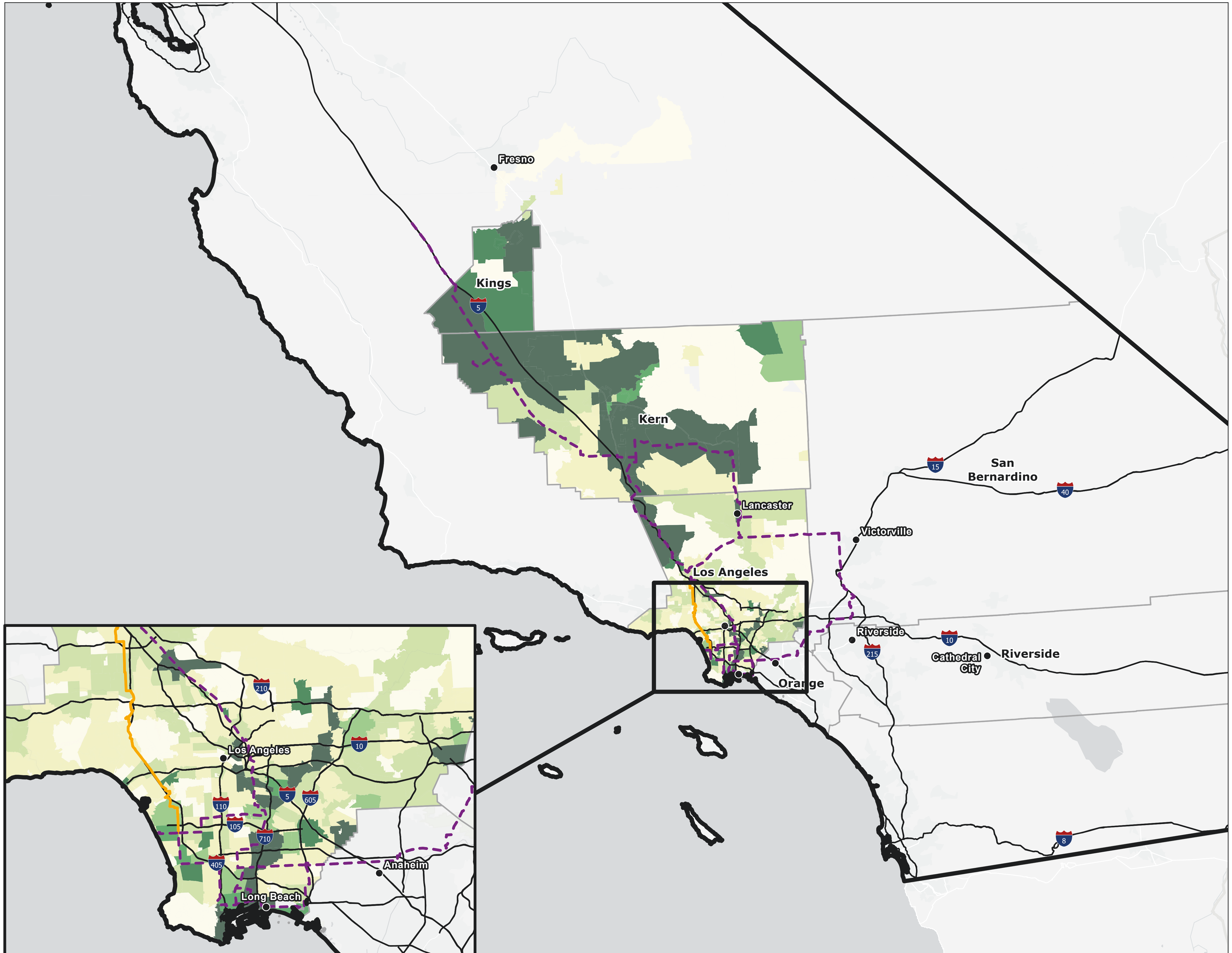

Figure No.
A-14

Title
NOx Emissions Reductions Associated With Angeles Link (AL) 2035 Total, High Throughput

Client/Project 203723235
Southern California Gas Company (SoCalGas)
Phase One NOx Study

Project Location
California

Prepared by BS on 2024-07-19

N

0 20 40 Miles
(At original document size of 11x17)
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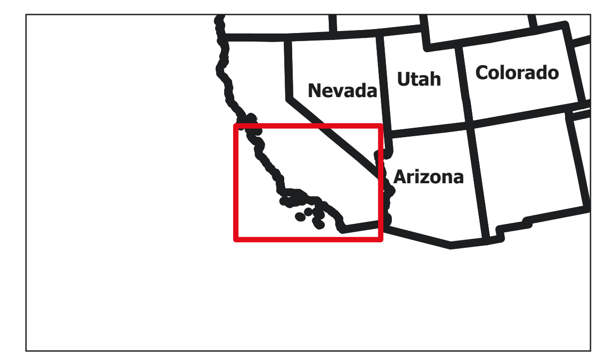
Legend
- Major Cities
- State Boundary
- Counties
- Interstate/Highway
- Preferred Routes (combined)
- Route Variation 1

Reduction in NOx Emissions Attributable to AL in 2035, High Scenario
- 0.00 - 0.06 tons/year NOx
- 0.06 - 0.16 tons/year NOx
- 0.16 - 0.32 tons/year NOx
- 0.32 - 0.51 tons/year NOx
- 0.51 - 0.78 tons/year NOx
- 0.78 - 7.7 tons/year NOx
- >7.7 tons/year NOx



Notes
1. Coordinate System: NAD 1983 StatePlane California II FIPS 0402 Feet
2. Data Sources: USGS, OEHHA, CalEPA, CEQ
3. Background: ESRI Basemap
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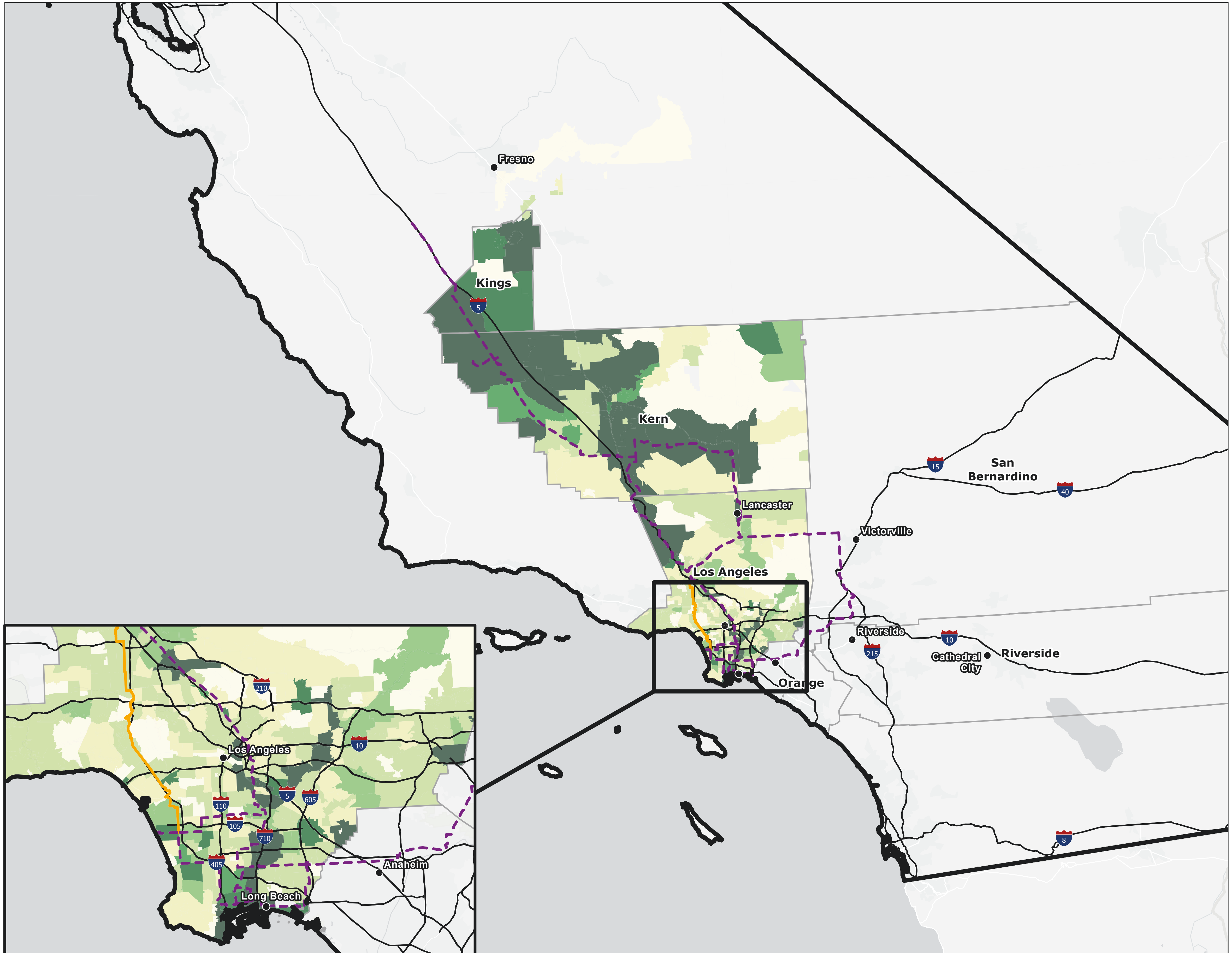


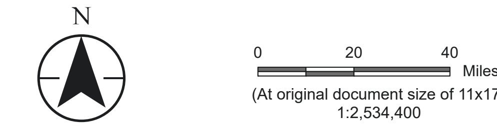
Figure No.
A-15

Title
NOx Emissions Reductions Associated With Angeles Link (AL) 2040: Total, High Throughput

Client/Project 203723235
Southern California Gas Company (SoCalGas)
Phase One NOx Study

Project Location
California

Prepared by BS on 2024-07-19

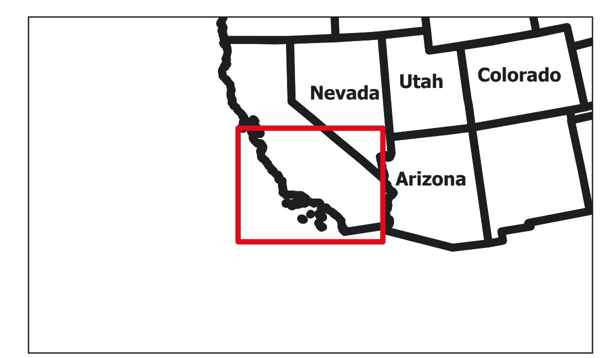


Legend

- Major Cities
- State Boundary
- Counties
- Interstate/Highway
- Preferred Routes (combined)
- Route Variation 1

Reduction in NOx Emissions Attributable to AL in 2040, High Scenario

- 0.00 - 0.06 tons/year NOx
- 0.06 - 0.16 tons/year NOx
- 0.16 - 0.32 tons/year NOx
- 0.32 - 0.51 tons/year NOx
- 0.51 - 0.78 tons/year NOx
- 0.78 - 7.7 tons/year NOx
- >7.7 tons/year NOx



Notes
1. Coordinate System: NAD 1983 StatePlane California II FIPS 0402 Feet
2. Data Sources: USGS, OEHHA, CalEPA, CEQ
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Figure No.

A-16

Title

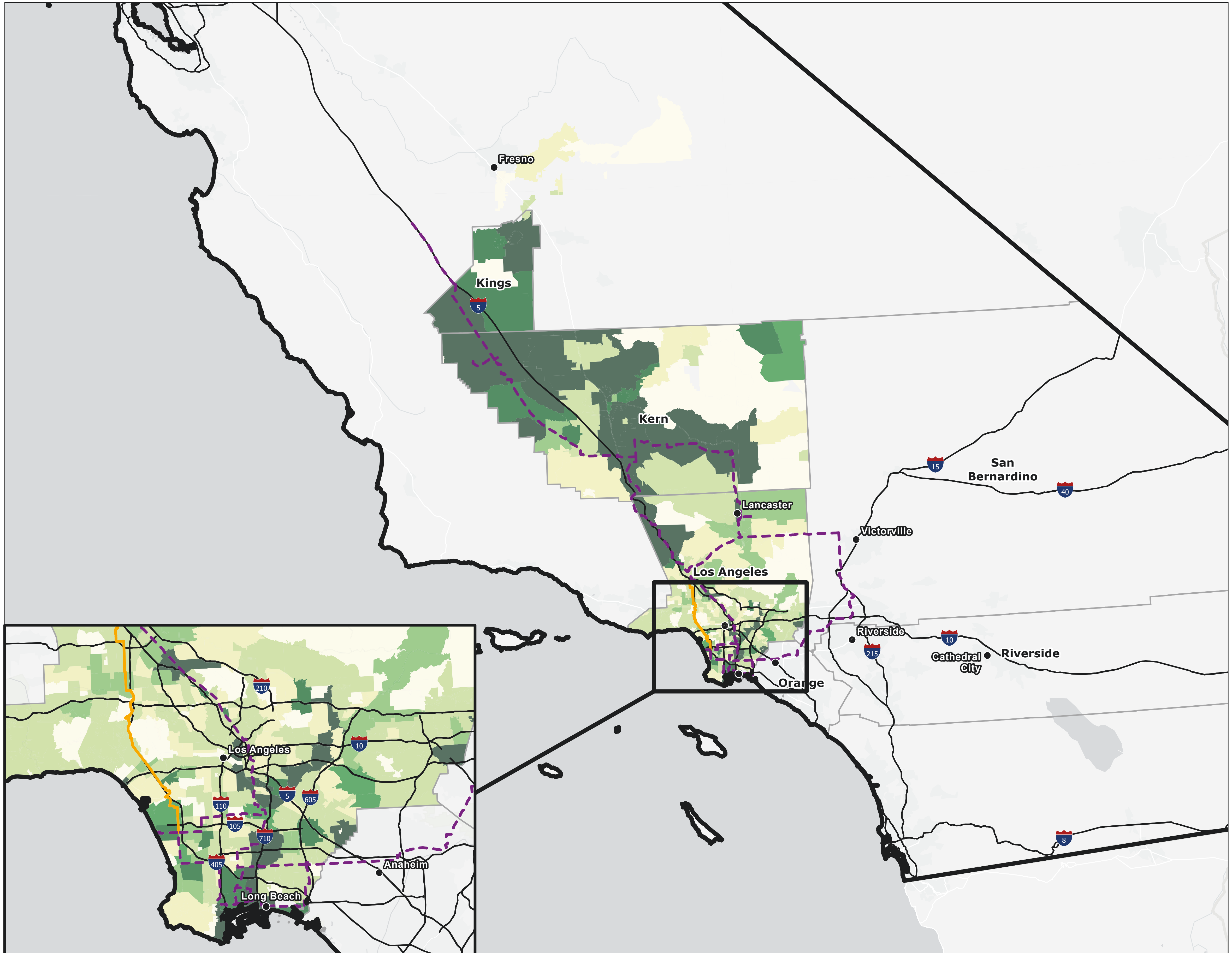
NOx Emissions Reductions Associated With Angeles Link (AL) 2045: Total, High Throughput

Client/Project 203723235

Southern California Gas Company (SoCalGas)
Phase One NOx Study

Project Location
California

Prepared by BS on 2024-07-19



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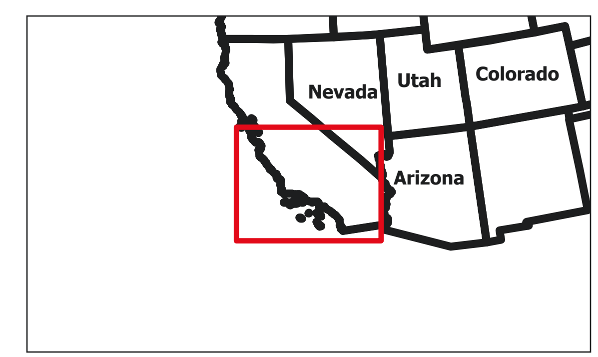
Legend

- Major Cities
- State Boundary
- Counties
- Interstate/Highway
- Preferred Routes (combined)
- Route Variation 1

Reduction in NOx Emissions Attributable to AL in 2045, High Scenario

- 0.00 - 0.06 tons/year NOx
- 0.06 - 0.16 tons/year NOx
- 0.16 - 0.32 tons/year NOx
- 0.32 - 0.51 tons/year NOx
- 0.51 - 0.78 tons/year NOx
- 0.78 - 7.7 tons/year NOx
- >7.7 tons/year NOx



Notes
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2. Data Sources: USGS, OEHHA, CalEPA, CEQ
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Stantec

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Attachment B

Dr. Sonja Sax Resume

Epsilon
ASSOCIATES INC.

Sonja Sax, Sc.D.

LEAD SCIENTIST, AIR QUALITY

EDUCATION

Sc.D., Environmental Health Sciences, Harvard T.H. Chan School of Public Health

M.S., Environmental Health Management, Harvard T.H. Chan School of Public Health

B.A., Biological Chemistry, Wellesley College

PROFESSIONAL ACTIVITIES

Air & Waste Management Association (AWMA)

Society for Risk Analysis (SRA)

International Society of Exposure Science (ISES)

PROFESSIONAL SUMMARY

Sonja Sax, Sc.D. is an environmental health scientist with 20 years of exposure and health risk assessment experience. Dr. Sax has particular expertise in evaluating exposures and health impacts of airborne gases and particles.

Throughout her consulting career Dr. Sax has managed large, complex environmental projects with tight deadlines, conducted critical evaluations of health risk and toxicological assessments, and prepared technical and expert reports. She has extensive knowledge of air pollution regulations and has aided clients in issues related to air permitting and compliance, including review of air modeling and air quality data. She has authored and co-authored several publications, presented her research at various conferences and testified before scientific panels. She also served as a consultant for the Clean Air Science Advisory Committee (CASAC) on ozone and particulate matter National Air Quality Standards in 2019.

Highlights of Dr. Sax's experience include:

- Regulatory support and development of scientific comments
- Exposure and human health risk assessments
- Environmental Justice Analyses
- Cost-benefit analyses
- Regulatory dispersion modeling
- Critical and systematic reviews of health effects of hazardous pollutants
- Litigation support

PROFESSIONAL EXPERIENCE

2022—Present, Epsilon Associates, Maynard, MA. Lead Scientist. Manage and work on permitting projects, including air modeling and risk assessment to support the permitting process. Conduct environmental justice (EJ) analyses to support projects across several states including Massachusetts, New York, and New Jersey. Conducted multiple air quality analyses, including modeling impacts of mobile sources to assess impact on EJ communities.

2016 — 2022, Ramboll, Amherst, MA. Senior Project Manager. Managed large environmental projects, conducted critical evaluations of the toxicity of various chemical (e.g., chloroprene), conducted cost-benefits analyses associated with ozone and particulate matter exposures.

2005 – 2016, Gradient Corporation, Cambridge, MA. Senior Project Manager. Evaluated human exposures and health risks associated with environmental pollutants. Conducted air dispersion modeling and exposure assessments. Provided technical support for human health risk assessments. Reviewed and interpreted epidemiological studies. Assisted in preparing expert reports, peer-reviewed publications, regulatory comments, and risk communications.

2003 – 2005 Harvard T.H. Chan School of Public Health, Boston, MA. Postdoctoral Fellow. Managed two large exposure assessment projects, developed study protocols, organized field studies, and managed staff. Additional duties included writing grants, analyzing data, and publishing manuscripts in peer-reviewed journals.

1998 – 2003 Harvard T.H. Chan School of Public Health, Boston, MA. Research/Teaching Assistant. Designed, conducted, and managed large air pollution exposure assessment studies of inner-city teenagers in New York City and Los Angeles; measured and analyzed indoor, outdoor, and personal concentrations of volatile organic compounds (VOCs), carbonyls, PM2.5, and particle-associated metals. Teaching assistant for an introductory environmental health course.

1994 – 1997 Harvard School of Public Health, Boston, MA. Research Assistant. Proposed, designed, and implemented an indoor air quality study of a green community of homes.

1995 – 1995 Environmental Protection Agency, Boston, MA. Intern. Analyzed health effects data to assess the impact of ozone concentrations on hospital admissions in Massachusetts.

1991 – 1994 Repligen Corporation, Boston, MA. Research Associate. Managed the peptide chemistry lab. Conducted research to improve the synthesis of peptides. Trained and supervised laboratory staff.

PROJECT EXPERIENCE

Regulatory Support and Development of Scientific Comments

American Waterways Operators (AWO). Reviewed and commented on the California Air Resources Board (CARB) Commercial Harbor Craft Regulations. Review included an assessment of the CARB emissions inventory for tug boats and tow boats and a critical review and comments on the CARB Health Benefits Analysis used to support the regulations. Comments were incorporated into the commentary submitted by AWO to CARB.

Trade Organization. Provided written and oral comments on several occasions to the Clean Air Scientific Advisory Committee (CASAC) on human exposure, epidemiology, toxicology, and mechanistic studies and their bearing on US EPA's National Ambient Air Quality Standards (NAAQS) for particulate matter and ozone.

Utility Air Regulatory Group. Provided a critical review of the scientific basis for revisions to the NAAQS for ozone, specifically focusing on the epidemiological and human health evidence.

Confidential Industrial Client. Assisted ethylene oxide production facilities in preparing commentary on the proposed NESHAPs Risk and Technology Reviews. Prepared a presentation on ethylene oxide health risks for a town hall meeting.

Exposure and Human Health Risk Assessments

Physical Rehabilitation Network (PRN). Provided assistance in tracking the latest research on COVID-19 infection data and helped develop policies for the health workers and patients as the science evolved.

Teck Chile. Managed a project for a mining company in Andacollo, Chile. Assisted in the development of a health study to evaluate potential impacts to a community from exposures resulting from mining activities, including exposures to particulate matter and heavy metals. Developed of an exposure study and provided exposure and health effects information to various stakeholders, including the mining community.

Electric Power Research Institute (EPRI). Co-authored a report summarizing the human health and ecological health effects of molybdenum found in coal combustion products, focusing on the use of this information in risk assessment and current regulatory standards and criteria.

EPRI. Co-authored a review of the role of non-chemical stressors in cumulative risk assessment that was published in a peer-reviewed journal.

Trade Organization. Performed an ozone mortality risk assessment using US EPA's Environmental Benefits Mapping and Analysis Program (BenMAP). Evaluated mortality risks by conducting a series of sensitivity analyses to assess how alterative model inputs impact risk results. Presented results to US EPA.

Electric-Power Generating Companies. Prepared technical analyses on exposures and potential health effects associated with particulate matter from airborne emissions of coal-fired electric utility power generating plants. Conducted air dispersion modeling and risk analyses using the HEM-3 model. Evaluated the results of the model and summarized the findings in a technical report.

Trade Organization. Evaluated the latest version of the US EPA Air Pollutants Exposure (APEX) model by conducting a series of sensitivity analyses to assess how alterative model inputs impacted exposure and risk assessment results.

Manufacturing Client. Reviewed the scientific literature on indoor dust levels of and potential exposure to several flame-retardant chemicals. Developed exposure estimates using probabilistic analyses and co-authored a peer-reviewed publication.

Large Electrical Utility. Performed a health risk evaluation of the possible relationship between measured airborne concentrations of sulfuric acid and sulfur dioxide in the vicinity of a large coal-fired power plant and acute health symptoms (e.g., irritation of the eyes, nose, and throat; shortness of breath; asthma-like symptoms). Reviewed regulatory, medical, and research information on the potential health effects of sulfur dioxide and sulfuric acid. Aided in the preparation of both a technical report and a public communication document.

EPRI. Evaluated potential inhalation risks from mercury associated with the beneficial use of coal combustion products in wallboard, concrete, and structural fill. Characterized indoor off-gassing of mercury from building materials, as well as ambient mercury volatilization and wind-blown dust emissions for coal ash structural fills. Presented results at a conference meeting and co-authored a peer-reviewed paper.

Pesticide Manufacturer. As part of a comprehensive program of risk assessment support to an industry research task force, evaluated the risks associated with background exposure to inorganic arsenic in food, water, and soil in the US using a probabilistic (Monte Carlo) exposure model and a margin of exposure (MOE) toxicity assessment approach. Results were published in the peer-reviewed literature.

Harvard School of Public Health. Helped design a large study to assess the exposures of volatile organic compounds (VOCs), carbonyls, PM2.5, and particle-associated metals of inner-city teenagers in New York City and Los Angeles, measuring indoor, outdoor, and personal concentrations. Implemented a sampling and quality assurance plan for the project, including building necessary field equipment and testing different sampling methodologies for VOCs. Trained field personnel in field activities. Analyzed all carbonyl samples using solvent extraction techniques and an HPLC method that I developed and implemented to analyze the samples. Compiled field and analytical datasets to compute concentrations, developed statistical models for data analysis, prepared a final report for the funding agency, and prepared several manuscripts for peer-reviewed journals.

Harvard School of Public Health. Conducted an in-depth literature review to assess the research needs for the design and construction of healthy and sustainable housing. Proposed, designed, and implemented an indoor air quality study of a green residential community, including recruitment of participants, setup, and collection of air pollution samples (VOCs, carbonyls, and NO2), and analysis of samples. Compiled and analyzed data and prepared a final report that was presented and distributed to all participants, as well as at a conference (Indoor Air).

US EPA. Collected and analyzed Massachusetts's hospital admissions data to assess correlations with ozone levels and determine respiratory health impacts of ozone exposures based on epidemiological findings. Prepared a report on the health impacts of ozone in Massachusetts based on the findings. Results were presented at the Clean Air and Public Health Conference.

Environmental Justice Analyses

Lincoln Property Company, Industrial Park, Boxborough, MA. Completed an environmental justice analysis, including modeling of air quality impacts from vehicles and trucks related to the project using US EPA MOVES model to develop emission estimates, and US EPA AERMOD to estimate concentrations of nitrogen dioxide and particulate matter. Maximum modeled concentrations of mobile emissions associated with the project were compared against air quality standards to show that the project would not contribute to adverse or disproportionate impacts to EJ communities.

Vineyard Northeast, Outer Continental Shelf. Assisted in writing the environmental justice (EJ) section of the Construction and Operations Plan (COP) for Vineyard Northeast, an offshore wind development in Lease Area OCS-A 0522. The section included evaluating the project impacts to EJ communities across different states along the Northeast of the US.

Franciscan Children's Hospital, Brighton, MA. Completed the environmental justice (EJ) and air quality analyses for the project which includes three projects to update the aging campus: (1) the construction of a new, approximately 289,500 square foot (sf) inpatient building for both medical and behavioral health with state-of-the-art clinical spaces in which to care for patients (Inpatient Building); (2) a new gymnasium with a connector to the existing Kennedy Day School (Gym and Connector); and (3) a new parking garage with approximately 475 parking spaces. Air modeling was conducted to show that there were no adverse or disproportionate impacts on EJ communities.

Tyngsborough Warehouse Development, Tyngsborough, MA. The redevelopment of the Project Site included the construction of a state-of-the-art 492,750 SF warehouse / distribution / logistics cross-dock facility set back from Middlesex Road and a 26,000 SF retail building that will front directly on Middlesex Road. Conducted an environmental justice and air quality analysis, to support the MEPA review process for this project. Air modeling was conducted to show that the Project, including the diesel truck trips, would not adversely impact air quality in the region and would not disproportionally impact EJ communities.

1414 Massachusetts Avenue, Boxborough, MA. Conducted an environmental justice (EJ) and air quality analysis for the Project, which consisted of a light industrial park and included four single-story, light manufacturing buildings with associated loading docks, access drives, parking lots (513 total spaces), landscaping, and stormwater management infrastructure. Air modeling was conducted to show that air quality would not exceed health-based standards and would not adversely impact EJ communities near the site.

22 Drydock Avenue (ISQ3), Boston, Massachusetts. Conducted an environmental justice (EJ) and air quality analysis for the project, which consisted of approximately 319,750 square foot building with research laboratory/office, accessory eating and drinking space, and space for the Gloucester Marine Genomics Institute, along with below-grade parking and site improvements. The required review consistent with requirements of a Special Review Procedure under MEPA. Air modeling was conducted to show that the project would not adversely impact EJ communities.

Cost-benefit Analyses

California State University, California. A technical report was prepared to address health effects of criteria air pollutants from the construction and operation of the California State University Dominguez Hills Project in support of an Environmental Impact Report. For the health effects analysis, spatially and temporally allocated emissions, photochemical grid modeling using the CAMx program, and application of concentration-health response functions through the BenMAP program were used to quantify health effects from incremental ozone and fine particulate matter concentrations resulting from the Project.

Port of Seattle Terminal 5 Facility, Seattle, WA. Lead the health risk assessment for the Sustainable Airport Master Plan on behalf of the Ports of Seattle and various stakeholders. Worked on a health impact evaluation to support the Environmental Impact Statement for air quality impacts. Air dispersion modeling was used to estimate the contributions from Airport activities to the communities' air quality, including particulate matter ($PM_{2.5}$) and hazardous air pollutants (HAPs) for different scenarios. The health impact evaluation included a HAP inhalation risk assessment and a $PM_{2.5}$ health impact evaluation using BenMAP.

City of San Antonio, Texas. Lead the health and economic impact assessment on behalf of the City of San Antonio to estimate the health and economic impacts of ozone for current and future (5-10 years) air quality scenarios using BenMAP. Worked closely with stakeholders to develop the plan, review results, and develop materials for presentation of study results, including presentations and a final report to interested parties.

Trade Organization. Conducted a sensitivity analyses using BenMAP to quantify the health benefits of reducing ozone concentrations in several urban cities across the US. The analyses were conducted to determine how changes in BenMAP model inputs would impact health benefit estimates. Results were presented in a white paper that was submitted to US EPA as part of regulatory comments, as well as at a scientific conference.

Trade Organization. Reviewed and critiqued the assumptions and uncertainties associated with the statistical models on which US EPA's 2011 Benefits and Costs of the Clean Air Act Report was based. Specifically, the underlying assumptions and the uncertainties associated with the US EPA BenMAP methodology were evaluated and opinions on the current scientific data to support the report conclusions were developed.

Regulatory Dispersion Modeling

Aries Clean Technologies, Sanford, Maine. Conducted air modeling to support permitting of a biosolids processing plant to show compliance with air quality standards including for criteria air pollutants and hazardous air pollutants.

Parallel Products of New England, New Bedford, MA. Evaluated air and odor impacts and conducted environmental justice analyses to support development of a waste management complex.

Newark Energy Center, Newark, NJ. Conducted air modeling using EPA's AERMOD model and developed a risk assessment report to support a Title V renewal and comply with new air toxics regulations in New Jersey,

Vicinity Energy, Trenton, NJ. Conducted air modeling using EPA's AERMOD model and a risk assessment of air toxics to support a Title V renewal of the facility.

Critical and Systematic Reviews of Health Effects of Hazardous Pollutants

Denka Performance Elastomers, LaPlace, LA. Served as Project Manager for a multi-year project to help a manufacturing facility that makes neoprene address community concerns regarding the facility emissions. Worked with a team to evaluate the scientific information related to the carcinogenic effects of chloroprene. The results of our analysis were published in the peer-reviewed literature and were used to communicate with US EPA and help develop a "Request for Correction" of the chloroprene risk assessment published by US EPA in 2010.

Asphalt Institute. Conducted a meta-analysis and drafted a technical report on the cancer risks associated with exposures to bitumen and bitumen fumes. The technical report was also published as a peer-reviewed article.

Manufacturing Client. Conducted an extensive literature search on the toxicity and health effects of cobalt and cobalt alloys found in dental materials. Compiled and summarized the literature to determine the potential health risks from potential exposures.

Battery Council International. In response to an OSHA request for information for re-evaluating standards for lead, analyzed lead particle size distribution data and prepared a white paper summarizing the results and discussing the implications for lead workplace standards.

International Carbon Black Association. As part of a team, provided analyses of health effects data on carbon black, a manufactured substance generated as an airborne fine particulate of elemental carbon. Reviewed toxicological and epidemiological studies of carbon black-exposed populations, and evaluated the evidence for the carcinogenicity of carbon black. Co-authored a peer-reviewed publication summarizing the findings.

Connecticut Siting Council. Conducted in-depth review of most current health effects information of exposures to low-frequency magnetic fields from epidemiological, animal, and mechanistic studies. Provided detailed reviews of most recent literature in support of guidelines for power line siting projects.

Litigation Support

Coal Processing Facility. For a toxic tort, analyzed ambient particulate matter monitoring data, assessing the appropriateness of the measurement method, how the measured levels compared to background exposure levels, and implications for potential community exposures to coal dust.

Electric Utility. Evaluated the scientific basis of health claims associated with air quality regulations that would impact an electricity generation facility. Compared air quality data in the area around the facility to health-based National Ambient Air Quality Standards.

New Mexico Environment Department. Conducted air dispersion modeling using AERMOD software for a large mine tailings area in New Mexico to determine the air concentration contributions of various heavy metals from contaminated resuspended dust. Results were used to calculate risk from inhalation and were included in a comprehensive risk assessment for the area.

Law Firm. Provided technical support for determining health risks from vapor intrusion of contaminated soils into schools.

Smelter Company, Peru. Reviewed and provided comments on a health effects study conducted in Peru and written in Spanish.

Law Firm. Using AERMOD, conducted air dispersion modeling for a large manufacturing facility to determine air impacts of various volatile organic compounds from contaminated groundwater (area source) and from stack emissions (point sources).

Law Firm. In the context of litigation, conducted a comprehensive exposure and risk assessment of pesticide exposures via dermal, inhalation, and ingestion routes.

EXPERT TESTIMONY EXPERIENCE

On September 11, 2012, provided written and oral testimony before US EPA's Clean Air Science Advisory Committee (CASAC) regarding issues with the Third Draft Ozone Integrated Science Assessment (ISA). Comments submitted to CASAC Ozone Review Panel.

On September 11, 2012, provided written and oral testimony before US EPA's CASAC regarding issues with the First Draft Ozone Risk and Exposure Assessment. Comments submitted to CASAC Ozone Review Panel.

On January 9, 2012, provided written and oral testimony before US EPA's CASAC regarding issues with the Second Draft Ozone ISA. Comments submitted to CASAC Ozone Review Panel.

On May 7, 2010, provided written and oral testimony before US EPA's CASAC regarding issues related to the Policy Assessment for the Review of the Particulate Matter National Ambient Air Quality Standards. Comments were submitted to Docket No. EPA-HQ-OAR-2007-0492.

On March 10, 2010, provided written and oral testimony before US EPA's CASAC regarding issues with the Quantitative Health Risk Assessment for Particulate Matter: Second External Review Draft, released February 2010. Comments were submitted to Docket No. EPA-HQ-ORD-2010-3518.

PUBLICATIONS

Sax, S, Sabato, J, Stefanescu, T, Holland, B. 2023 “Environmental Justice and Air Permitting in the United States.” EM Magazine. Air & Waste Management Association. February

Sax SN, Gentry PR, Van Landingham C, Clewell HJ III, Mundt KA. 2020. “Extended Analysis and Evidence Integration of Chloroprene as a Human Carcinogen.” Risk Anal. 40(2):294-318.

Mundt KA, Dell LD, Crawford L, Sax SN, Boffetta P. 2018. “Cancer Risk Associated with Exposure to Bitumen and Bitumen Fumes: An Updated Systematic Review and Meta-Analysis.” J. Occup. Environ. Med. 60(1):e6-e54.

Goodman JE, Zu K, Loftus CT, Lynch HN, Prueitt RL, Mohar I, Shubin SP, Sax SN. 2018. “Short-term ozone exposure and asthma severity: Weight-of-evidence analysis”. Environ. Res. 160:391-397.

Petito Boyce C, Sax SN, Cohen JM. 2017. “Particle size distributions of lead measured in battery manufacturing and secondary smelter facilities and implications in setting workplace lead exposure limits.” J. Occup. Environ. Hyg. 14(8):594-608.

Goodman JE, Sax SN, Lange S, Rhomberg LR. 2015. “Are the elements of the proposed ozone National Ambient Air Quality Standards informed by the best available science?” Regul. Toxicol. Pharmacol. 72(1):134-40.

Petito Boyce C, Goodman JE, Sax SN, Loftus CT 2015. “Providing Perspective for Interpreting Cardiovascular Mortality Risks Associated with Ozone Exposures.” Regul. Toxicol. Pharmacol. 72(1):107-116.

Goodman JE, Petito Boyce C, Sax SN, Beyer LA, Prueitt RL. 2015. “Rethinking Meta-analysis: Applications for Air Pollution Data and Beyond.” Risk Anal. 35(6):1017-1039.

Goodman JE, Prueitt RL, Sax SN, Pizzurro DM, Lynch HN, Zu K, Venditti FJ. 2015. “Ozone Exposure and Systemic Biomarkers: Evaluation of Evidence for Adverse Cardiovascular Health Impacts.” Crit. Rev. Toxicol. 45(5):412-452

Goodman JE, Prueitt RL, Sax SN, Lynch HN, Zu K, Lemay JC, King JM, Venditti FJ. 2014. “Weight-of-evidence Evaluation of Short-term Ozone Exposure and Cardiovascular Effects.” Crit. Rev. Toxicol. 44(9):725-790.

Prueitt RL, Lynch HN, Zu K, Sax SN, Venditti FJ, Goodman JE. 2014. “Weight-of-evidence Evaluation of Long-term Ozone Exposure and Cardiovascular Effects.” Crit. Rev. Toxicol. 44(9):791-822.

Sax, SN; Zu, K; Goodman, JE. 2013 "Letter to the editor Re: Air pollution and lung cancer incidence in 17 European cohorts: Prospective analyses from the European Study of Cohorts for Air Pollution Effects (ESCAPE)." Lancet Oncol. 14(11):e439-440

Sax, SN; Goodman JE. 2014. "Letter to the editor Re: Long-Term Residential Exposure to Air Pollution and Lung Cancer Risk." Epidemiology. 25 (1): 159.

Goodman, JE; Prueitt, RL; Chandalia, J; Sax, SN. 2014. "Evaluation of adverse human lung function effects in controlled ozone exposure studies." J. Appl. Toxicol. 34(5):516-24.

Sax, SN; Goodman, JE. 2013. Letter re: "Is the Relation Between Ozone and Mortality Confounded by Chemical Components of Particulate Matter? Analysis of 7 Components in 57 US Communities Letter]." Am. J. Epidemiol. 177(12):1460

Goodman, JE; Sax, SN. 2013. Letter re: article, 'Controlled Exposure of Healthy Young Volunteers to Ozone Causes Cardiovascular Effects.' Circulation 127(4):e432.

Long, CM; Sax, SN; Lewis, AS. 2012. "Potential indoor air exposures and health risks from mercury off-gassing of coal combustion products (CCPs) used in building materials." Coal Combustion and Gasification Products 4:68-74.

Lewis, AS; Sax, SN; Wason, SC; Campleman, SL. 2011. "Non-chemical stressors and cumulative risk assessment: An overview of current initiatives and potential air pollutant interactions." Int. J. Environ. Res. Public Health. 8(6):2020-2073.

Hesterberg, TW; Long, CM; Sax, SN; Lapin, CA; Bunn, WB; Valberg, PA; McClellan, RO. 2011. "Human health hazards of exposure to new technology diesel exhaust (NTDE)." Toxicologist - Supplement to Toxicological Sciences 120(Suppl. 2).

Dodge, DG; Pollock, MC; Sax, SN; Petito Boyce, C; Goodman, JE. 2011. "Risk characterization of the brominated flame retardant decabromodiphenyl ethane in indoor dust." Toxicologist - Supplement to Toxicological Sciences 120(Suppl. 2):271.

Petito Boyce, C; Lewis, AS; Sax, SN; Beck, BD; Eldan, M; Cohen, SM. 2010. Letter re: Xue et al. (2010) article addressing probabilistic modeling of dietary arsenic exposure and dose. Environ. Health Perspect. 118(8). E-pub ahead of print doi:10.1289/ehp.1002328.

Petito Boyce, C; Sax, SN; Dodge, DG; Pollock, MC; Goodman, JE. 2009. "Human exposure to decabromodiphenyl ether, tetrabromobisphenol A, and decabromodiphenyl ethane in indoor dust." J. Environ. Protection Sci. 3:75-96.

Hesterberg, TW; Long, CM; Bunn, WB; Sax, SN; Lapin, CA; Valberg, PA. 2009. "Non-cancer health effects of diesel exhaust (DE): A critical assessment of recent human and animal toxicological literature." Crit. Rev. Toxicol. 39:195-227.

Petito Boyce, C; Lewis, AS; Sax, SN; Eldan, ME; Cohen, SM; Beck, BD. 2008. "Probabilistic analysis of human health risks associated with background concentrations of inorganic arsenic: Use of a margin of exposure approach." Human Ecol. Risk Asses. 14:1159-1201.

****Winner of the HERA Human Risk Assessment Paper of the Year Award in 2008.**

Sax, SN; Koutrakis, P; Rudolph, PA; Cereceda-Balic, F; Gramsch, E; Oyola, P. 2007. "Trends in the elemental composition of fine particulate matter in Santiago, Chile, from 1998 to 2003." J. Air Waste Manag. Assoc. 57(7):845-855.

Valberg, P; Long, CM; Sax, SN. 2006. "Integrating studies on carcinogenic risk of carbon black: Epidemiology, animal exposures, and mechanism of action." J. Occup. Environ. Med. 48(12):1291-1307.

Sax, SN; Bennett, DH; Chillrud, SN; Kinney, P; Ross, J; Spengler, JD. 2006. "A cancer health risk assessment of a cohort of inner-city teenagers in New York City and Los Angeles." Environ. Health Perspect. 114(10):1558-1566.

Koutrakis, P; Sax, SN; Sarnat, JA; Coull, B; Demokritou, P; Oyola, P; Garcia, J; Gramsch, E. 2005. "Analysis of PM10, PM2.5, and PM2.5-10 concentrations in Santiago, Chile, from 1989 to 2001." J. Air Waste Manage. Assoc. 55(3):342-351.

Sax, SN; Bennett, DH; Chillrud, SN; Kinney, PL; Spengler, JD. 2004. "Differences in source emission rates of volatile organic compounds in inner-city residences of New York City and Los Angeles." J. Exp. Anal. Environ. Epidemiol. 14:S95-S109.

Chillrud, SN; Epstein, D; Ross, JM; Sax, SN; Pederson, D; Spengler, JD; Kinney, PL. 2004. "Elevated airborne exposures to manganese, chromium and iron from steel dust in New York City's subway system." Environ. Sci. Technol. 38:732-737.

Kinney, PL; Chillrud, SN; Ramstrom*, S; Ross, J. 2002. "Exposures to multiple air toxics in New York City." Environ. Health Perspect. 110(Suppl. 4):539-546.

PRESENTATIONS

Sax, S. 2024. “Air Modeling to Assess Air Quality Impacts in Environmental Justice Communities.” Presentation at the Air & Waste Management Association. Raleigh, NC. November 14th

Sax, S 2024. “Cumulative Impact Analyses to Address Environmental Justice in Massachusetts.” Presentation at the Boston Bar Association. Boston, MA. March 30th.

Sax, S 2024. “Cumulative Impact Analyses to Address Environmental Justice in Massachusetts.” Virtual webinar. Northeast Energy and Commerce Association. April 9th.

Sax, S, Weiss, I. 2023. “Cumulative Impact Analyses to Address Environmental Justice in Massachusetts.” Presentation at the Air & Waste Management Association. Arlington, VA. October 23-24.

Sax, S, Sabato, J. 2022 “ The Challenges of Evaluating Cumulative Impacts from Projects Located Near Environmental Justice Areas.” Tampa FL. December 4-8.

Sax, S; Dell, L, Lewis, RJ. 2021“Risk of Bias Analysis of Ozone Studies used in BenMAP”. Presentation at the Society for Risk Analysis.

Sax, S. 2021. “US EPA’s BenMAP Model for Health Impact Analysis of Air Pollution : the Good, the Bad and the Challenging.” Virtual Presentation at the America’s Air Quality Biennial Technology Transfer Conference. February 10th.

Sax, S. 2019. “Wind Turbines and Health: Review of the Literature.” Presentation at the North American Wind Energy Academy (NAWEA) WindTech Conference. October 14th.

Sax, S, Dell, L, Mundt, K. 2018. “Risk of Bias Analysis of Ozone Epidemiological Studies Used in BenMAP Analyses.” Presentation at the Society of Risk Analysis, New Orleans, LA. December 2nd -6th.

Sax, S, Bonyoung, K, Kemball-Cook, S. 2018. “Using BenMAP for Assessing Health Impacts of Ozone Exposure: A Case Study in San Antonio.” Poster Presentation at the International Society of Exposure Science, Ottawa, Canada. August 26-30.

Sax, S, Mundt, K, Dell, L, Crawford, L, Boffetta, P. 2017. “Cancer and Bitumen Exposures: An Updated Meta-Analysis” Presentation at the Society of Risk Analysis. Arlington, VA. December 10-13th.

Sax, S., Mundt, K, Gentry, R. 2017 “Re-evaluating the Inhalation Unit Risk for Chloroprene” Poster Presentation at the International Society of Exposure Science, Research Triangle Park, NC. October 15-19.

Sax, S. 2015. “Strengths and Limitations of EPA’s Ozone Risk and Exposure Assessment” Independent Workshop on Ozone NAAQS Science and Policy. Texas Commission on Environmental Quality. April 8th.

Sax, SN; Lau, J; Goodman, J. 2012. "Evaluation of the BenMAP Model for Estimating Mortality Impacts of Lower Ozone Concentrations." Poster Presentation at the International Society of Exposure Science, Seattle, WA, October 28-November 1.

Long, CM; Lewis, AS; Sax, SN. 2011. "Indoor Air Inhalation Risks of Mercury Off-gassed from Building Materials Containing Coal Combustion Products (CCPs)." Platform Presentation at the Air & Waste Management Association's Annual Conference & Exhibition, Orlando, FL, June 21-24.

Hesterberg, TW; Bunn, WB; Long, CM; Sax, SN; Valberg, PA; Lapin, CA. 2011. "New Technology Diesel Exhaust (NTDE) Is Distinctly Different From Traditional Diesel Exhaust (TDE)." Platform Presentation at the Air & Waste Management Association's Annual Conference & Exhibition, Orlando, FL, June 21-24.

Hesterberg, TW; Long, CM; Sax, SN; Lapin, CA; Bunn, WB; Valberg, PA; McClellan, RO. 2011. "Human Health Hazards of Exposure to New Technology Diesel Exhaust (NTDE)." Poster Presentation at the Health Effects Institute (HEI) Annual Conference, Boston, MA, May 1-3.

Long, CM; Lewis, AS; Sax, SN. 2009. "Mercury Inhalation Risks in Indoor Air from Use of Coal Combustion Products (CCPs) in Building Materials." Poster Presentation at the World of Coal Ash (WOCA) 2009 Conference, Lexington, KY, May 4-7

Lewis, AS; Sax, SN; Long, CM. 2009. "Mercury Inhalation Risks from Use of Coal Combustion Products (CCPs) as Structural Fill and from Disposal of CCP-Containing Wallboard and Concrete in Landfills." Poster Presentation at the World of Coal Ash (WOCA) 2009 Conference, Lexington, KY, May 4-7.

Lewis, A; Sax, S; Thakali, S; Beck, BD. 2009. "Evaluation of Risk for Fetal Limb Defects from Occupational Exposure to Mancozeb and Ethylene Thiourea During Pregnancy." Poster presented at Society of Toxicology 48th Annual Meeting, Baltimore, MD, March 15-19.

Sax, SN; Lewis, AS; Long, CM. 2009. "Inhalation Risks of Mercury from Use of Coal Combustion Products (CCPs) as Structural Fill and from Disposal of CCP Building Materials in Landfills." Poster Presentation at the 48th Annual Meeting of the Society of Toxicology, Baltimore, MD, March 15-19.

Long, CM; Lewis, AS; Sax, SN. 2009. "Inhalation Risks of Mercury in Indoor Air from Beneficial Use of Coal Combustion Products (CCPs) in Building Materials." Poster Presentation at the 48th Annual Meeting of the Society of Toxicology, Baltimore, MD, March 15-19.

Valberg, P; Sax, S; Long, C. 2006. "Inhalation Health Risk Assessment: Extrapolating from Macromaterials to Nanomaterials." Poster presentation at Overcoming Obstacles to Effective Research Design in Nanotoxicology, Cambridge, MA, April 24-25.

Sax, S; Spengler, JD; Chillrud, S; Kinney, P. 2003. "Concentrations and Emission Rates of VOCs in New York City and Los Angeles Homes." Presented at the 13th Annual Conference of the International Society of Exposure Analysis (ISEA), Stresa, Italy.

Ramstrom*, S; Spengler, JD; Chillrud, S; Kinney, P. 2002. "Seasonal Variation in Indoor and Outdoor Concentrations of VOCs in New York City." Presented at the 9th International Conference on Indoor Air Quality and Climate, Monterey, CA.

Ramstrom*, S; Chillrud, S; Kinney, P; Spengler, J. 2002. "Personal Exposures to VOCs in a Population of Inner-City Teenagers in New York City: A Preliminary Health Risk Assessment." Presented at the ISEA/ISEE Conference, Vancouver, BC, Canada. Abstract in Epidemiology 13(4):365.

Ramstrom*, S; Chillrud, S; Aggarwal, M; Spengler, J; Kinney P. 1999. "Exposure Assessment of Urban Air Pollutants in Teenagers in New York City: Winter Study Results." Presented at ISEA/ISEE Conference, Athens, Greece. Abstract in Epidemiology 10(4):850.

Ramstrom*, S; Chillrud, S; Spengler, J; Kinney, P. 1999. "Field Validation of VOC Thermal Desorption Tubes by Triplicate Comparisons." Presented at ISEA/ISEE Conference, Athens, Greece. Abstract in Epidemiology 10(4):3020.

Ramstrom*, S; Spengler, JD. 1999. "A Pilot Study of VOCs, Aldehydes, and NO2 Measurements in Environmentally Innovative Homes." Presented at the 8th International Conference on Indoor Air Quality and Climate, Edinburgh, Scotland. Volume 4:165.

TECHNICAL REPORTS

Kinney, P; Chillrud, SN; Sax, S; Ross, J; Pederson, D; Johnson, D; Aggarwal, M; Spengler, JD. 2004. "The Los Angeles TEACH Study." Final Report to the Mickey Leland Urban Air Toxics Research Center.

Kinney, P; Chillrud, SN; Ramstrom*, S; Ross, J; Pederson, D; Johnson, D; Aggarwal, M; Spengler, JD. 2002. "The New York City TEACH Study." Final Report to the Mickey Leland Urban Air Toxics Research Center.

*SONJA N. SAX FORMERLY SONJA S. RAMSTROM