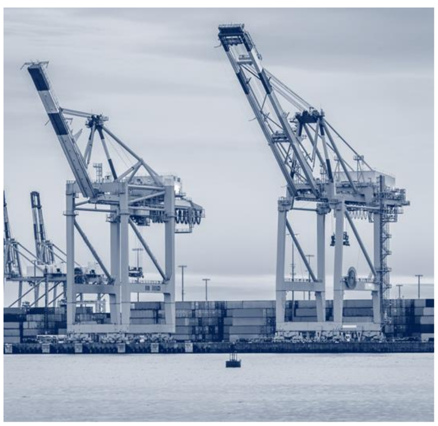
Newark Community Impacts of Mobile Source Emissions

A Community-Based Participatory Research Analysis





MJB & A

November 2020

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Funding for this report was provided by the Natural Resources Defense Council (NRDC). Lead manager for NRDC was Luke Tonachel.

About New Jersey Environmental Justice Alliance

The NJEJA (the Alliance, or NJEJA) is an alliance of New Jersey-based organizations and individuals committed to working together to create healthy, sustainable and just communities by eliminating environmental injustices in low income and communities Of Color. Together we support and work with communities through local, state, and national policy development, targeted campaigns and organizing, education, advocacy, training and technical assistance focused on critical environmental justice issues.

About M.J. Bradley & Associates

M.J. Bradley & Associates, LLC (MJB&A), founded in 1994, is a strategic consulting firm focused on energy and environmental issues. The firm includes a multi-disciplinary team of experts with backgrounds in economics, law, engineering, and policy. The company works with private companies, public agencies, and non-profit organizations to understand and evaluate environmental regulations and policy, facilitate multi-stakeholder initiatives, shape business strategies, and deploy clean energy technologies. In March 2020, MJB&A became a part of ERM, the world's leading sustainability consultancy. ERM has more than 5,500 technical experts and thought leaders in over 40 countries and territories.

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Introduction and Executive Summary

The transportation and mobile source sector in New Jersey significantly contributes to air quality issues within the state: in 2017, mobile sources contributed 71 percent of nitrogen oxides (NOx) and 27 percent of fine particulate matter ($PM_{2.5}$) statewide.[1] Transportation is also the largest contributor (42 percent) to the state's greenhouse gas (GHG) emissions.[2] Reducing emissions from this sector will be critical if the state is to meet its emissions reduction goals and improve air quality, especially within disproportionately burdened, environmental justice (EJ) communities which experience higher levels of air pollutants known to impact human health such as $PM_{2.5}$ and NOx.

There is an extensive body of empirical evidence detailing the health impacts of diesel and other goods movement related transportation emissions in environmental justice communities (communities Of Color and low-income communities). In New Jersey, there is a pattern of proximity to goods movement and transportation infrastructure largely in communities Of Color and low wealth areas of the state. For example, a recent study produced by the Union of Concerned Scientists found that communities Of Color throughout the Northeast and Mid-Atlantic are more likely to be exposed to high levels of $PM_{2.5}$, which contributes to higher levels of asthma, lung cancer, and heart disease within these communities.[3]

Efforts to drive down emissions in this sector are often focused on electrification of vehicles, especially passenger vehicles. However, passenger vehicles, or even transportation broadly, are not the only significant contributor of harmful air pollution across environmental justice communities. While electrification can have a meaningful impact across the transportation sector, electrification efforts should also carefully consider the equity and health implications that electrification scenarios will have on these particularly overburdened parts of the state: these same areas are also home to fossil fuel energy infrastructure that may be part of the electrification of the transportation sector.

Environmental justice communities are increasingly calling for the examination and prioritization of reducing co-pollutants in climate mitigation strategies.[4] The legacy of cumulative impacts from multiple sources of pollution in communities Of Color and low wealth communities requires that every opportunity to reduce health-harming emissions be explored. While climate mitigation efforts, including those targeting the transportation sector, are focused on GHG emissions, there are important opportunities to target the reduction of co-pollutants such as PM, NOx, sulfur dioxide and harmful air pollutants. This approach will appropriately center equity and immediate health impacts in considering policies to address climate change.

In New Jersey, while vehicle emissions contribute broadly to both GHG and harmful local air pollution, emissions from diesel trucks and buses emit higher levels of air pollution which can lead to even greater health concerns in populations who are more directly exposed to diesel emissions. Communities located adjacent to ports and related goods movement infrastructure (e.g., warehouses, logistics centers, railyards, etc.) experience higher levels of truck traffic, both from surrounding thruways and on local streets, which exacerbate health concerns. Since these emissions are local in their effects, policies to reduce transportation emissions from medium- and heavy-duty vehicles can significantly improve the health and well-being of communities in urban areas or around transportation corridors, which are often Of Color, low-income or otherwise vulnerable or disadvantaged communities.

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[1] https://www.nj.gov/dep/baqp/inventory.html

[2] https://www.nj.gov/dep/aqes/oce-ghgei.html

[3] Union of Concerned Scientists. (2019). Inequitable Exposure to Air Pollution from Vehicles in the Northeast and Mid-Atlantic Fact Sheet. https://www.ucsusa.org/sites/default/files/attach/2019/06/Inequitable-Exposure-to-Vehicle-Pollution-Northeast-Mid-Atlantic-Region.pdf

[4] Sheats, N. (2016). Achieving emissions reductions for environmental justice communities through climate change mitigation policy. Wm. & Mary Envtl. L. & Pol'y Rev., 41, 377.

This community-based participatory research project, completed in partnership with the New Jersey Environmental Justice Alliance (NJEJA) and the Natural Resource Defense Council (NRDC), evaluates the transportation-related pollution burden that environmental justice communities experience in and around port-adjacent communities in Newark, New Jersey. It highlights which transportation sources are the largest contributors to pollution exposure across the region generally and in specific hot spot areas. It then analyzes potential pathways, specifically focused on electrification, to reduce transportation-related emissions.

This analysis evaluates the distribution and intensity of vehicle emissions within the study area, and pathways for their reduction, by: 1) creating a comprehensive inventory of nearby vehicle emissions data across the marine and ground transportation sectors; 2) calculating relative emissions and emissions exposure within the entire study area as well as at specific locations determined by NJEJA and allies; and, 3) evaluating electrification pathways to reduce vehicle emissions.

Key Findings from Analysis

1) **The highest transportation emissions burden can be found in locations close to high density truck and bus routes and locations close to port facilities and rail yards.** However, the analysis shows that total emissions exposure, and relative contribution from different transportation sources, varies significantly across the study area.

2) **Emissions of $PM_{2.5}$, black carbon, and NOx from non-roadway sources, particularly locomotives and port operations, have the highest air quality impact in the total study area, followed by medium- and heavy-duty vehicles.** These sources far outweigh the emissions exposure from passenger vehicles and together contribute around 95 percent of the total emissions exposure modeled within the study area (from mobile source emissions).

3) **Population centers and residential areas in close proximity to roadway emissions would benefit from efforts to reduce emissions from medium- and heavy- duty vehicles which can significantly reduce air emissions of particulates and NOx within certain key locations in the study area.** The analysis shows that while electrification could be one path to these reductions, electrification of these vehicles must be accompanied by a focus on emissions reductions from electric generating units co-located within the same community in order to ensure a reduction in overall air pollution burden.

Study Design and Local Community Leadership and Engagement

This study was conducted in close consultation with the New Jersey Environmental Justice Alliance (NJEJA). NJEJA is a statewide alliance of organizations and individuals focused on a wide range of environmental justice issues.

Following a community-based participatory research model, this study built on strengths and resources within the community to integrate and achieve a balance between research and action for the mutual benefit of all partners. As an equal partner in the project, NJEJA provided critical guidance and input through their place-based experience and local data as well as helping to shape the study to ensure its usefulness for local applications. This guidance took many forms, including:

- Establishing study geographic scope;
- Determining included sources and emissions (within the analytical restrictions of this study);
- Identifying local hot spots (e.g. idling locations) and possible sensitive areas (e.g., schools) for deep analysis;
- Helping to prioritize pollutants and mobile sources of interest;
- Facilitating feedback of local residents and advocates through the Coalition for Healthy Ports (CHPS); and
- Shaping scenarios and highlighting local priorities for electrification analysis.

These elements are of vital importance to the communities located within the study area and were included because community leaders were able to bring these considerations to light. This bias to action approach to the research ensured that the aims of the study aligned with the goals of the groups advancing strategies for environmental justice with respect to transportation climate mitigation strategies. The results of this study help refine and prioritize the necessary interventions to reduce emissions with the greatest impact in environmental justice communities in close proximity to transportation infrastructure like seaports, airports, and highways.

Figure 1 Key Demographics of Study Area

	Study Area	New Jersey
Population	209,000	8,880,000
Population, % of Color	58%	32%
Median household income[1]	~$44,000	~$88,000
Burdened communities[2]	47 of 52 (90%)	662 of 1,987 (33%)

Adapted from U.S. Census Bureau 2014-2018 American Community Survey Estimates

[1] Population-weighted average estimate
[2] Defined as any census tract, as delineated in the most recent federal decennial census, that is ranked in the bottom 33 percent of census tracts in the State for median annual household income

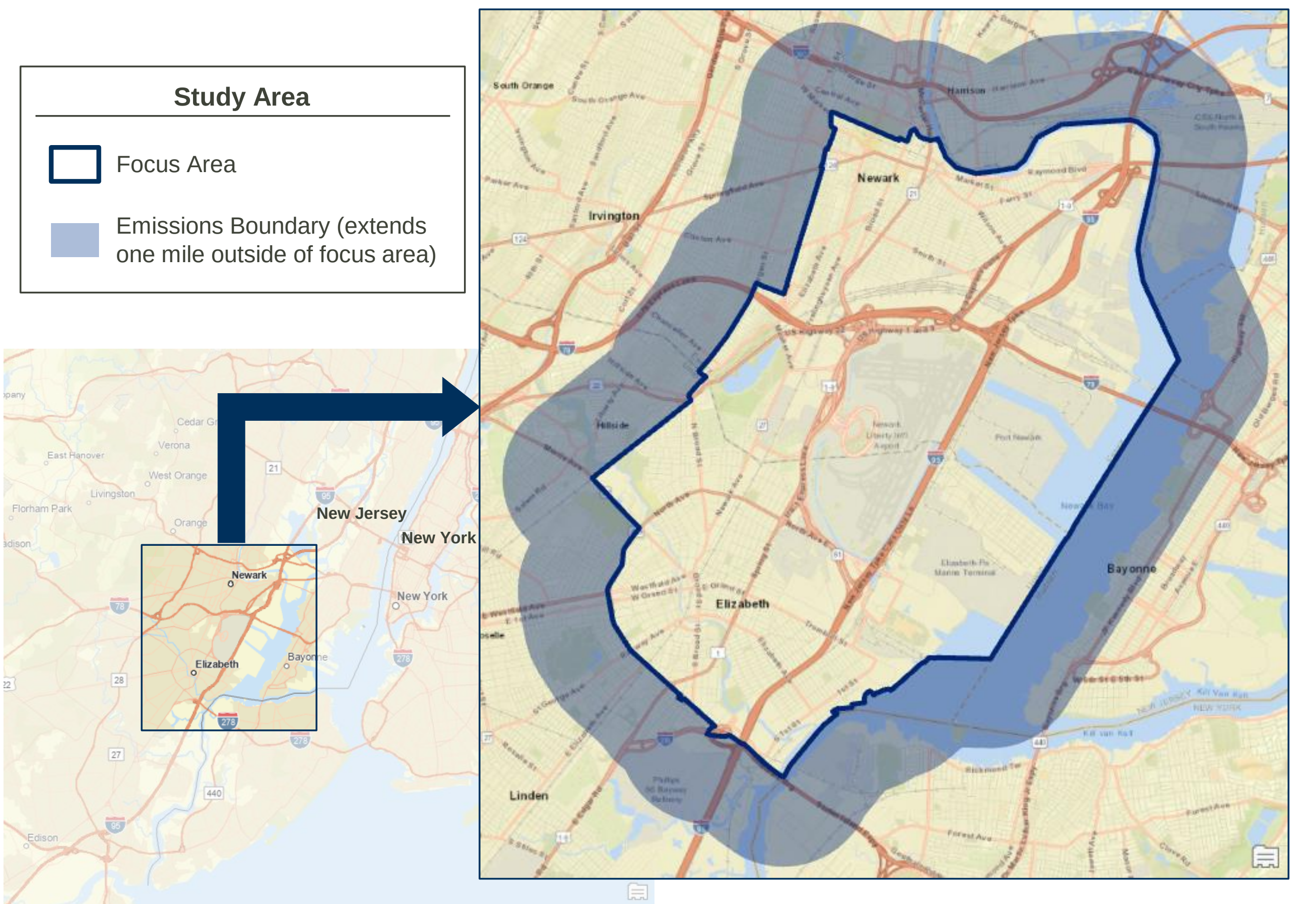
Methodology

MJB&A conducted a two-phase analysis in and around the ports of Newark and Elizabeth to evaluate transportation-related emissions and calculate how these emissions accumulate across the region to result in total emissions exposure. Phase One constituted developing a detailed inventory of roadway and non-roadway mobile source emissions, while Phase Two evaluated relative emissions and emissions exposure across the region and in particular in key areas.[5]

Working with NJEJA, MJB&A defined a study area that included much of southeast Newark and north Elizabeth, including Newark Airport and the ports of Newark and Elizabeth. By including both roadway and non-roadway sources, it covered key emissions known to negatively impact human health and the environment—specifically, NOx, fine particulate matter ($PM_{2.5}$), black carbon, and carbon dioxide (CO_2). To account for emission dispersion and ensure that emissions that may impact communities were included, a one-mile buffer (displayed in blue in Figure 2) was added to the analysis.

In this study, we use the term "emissions" to mean modeled emissions from transportation *sources in* the study area (or a subset of the study area). "Exposure" is a function of both emissions and dispersion and refers to the *cumulative (transportation) emissions impact* experienced at a location or area; that is, emissions from nearby transportation sources are included as well as those that have been carried by wind to a location from other sources.

Figure 2 Geographic Scope and Study Area



[5] See Appendix A for a detailed methodology.

Phase One: Emissions Inventory

Phase One created an inventory of local transportation emissions using both top-down and bottom-up approaches. This analysis was based on publicly available resources, purchased vehicle registration data, and adjustments using spatial analysis to account for local characteristics. Emission sources were disaggregated to the furthest extent possible to provide the most accurate and transparent representation of transportation-related emissions in the area. This inventory is comprised of a collection of 75 unique emission sources (48 roadway sources and 27 non-roadway sources) that have different emission factors, dispersion characteristics, and ultimately, contributions to emissions exposure.[6]

Roadway Emissions

MJB&A used a combination of spatial traffic datasets and Newark-specific summary traffic/vehicle data to create a traffic inventory that provided a detailed breakdown of vehicle miles traveled (VMT) by vehicle type, roadway type, county, and zip code, where applicable.

To translate VMT to emissions, MJB&A applied emissions factors to the most dominant vehicles stock at the state-, county-, and zip code-level for each roadway type. Figure 3 identifies each roadway sources captured within the emissions inventory and displays vehicle traffic on all roadways included in the analysis.

Figure 3 Roadway Mobile Emission Sources

Included Vehicles

Light-duty vehicles

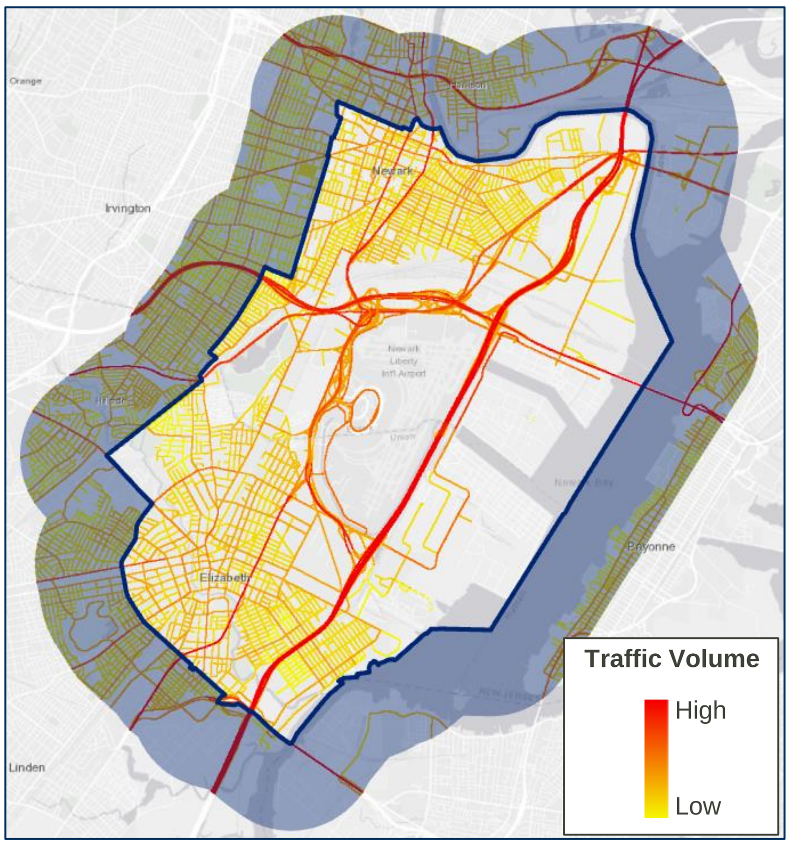
- Motorcycle
- Passenger car
- Light-duty truck

Medium-/Heavy-duty vehicles

- Single-unit truck
- Combination Truck

Buses

- School bus
- Intercity bus
- NJ Transit Bus (NJ Transit-designated routes only)



[6] Note that this emissions inventory and subsequential dispersion analysis are not comprehensive of all emission sources located within the study area. This analysis focused on select, transportation-related mobile sources and did not account for other potential sources of emissions, such as (but not limited to) electric generating units, industrial manufacturing facilities, oil refineries, buildings, construction, and airplanes (landing, taking off, and taxiing).

Non-Roadway Emissions

In addition to roadway emissions, this analysis focused on select non-roadway mobile emission sources located within railyards, port facilities, and the Newark International Airport; specific "hotspot" locations where heavy-duty diesel vehicles idle were also included.[7] MJB&A utilized data from the Port Authority of New York and New Jersey (PANYNJ) 2016 Greenhouse Gas and Criteria Pollutant Emissions Inventory for base port and airport emissions. Additional adjustments were required to allocate emissions from commercial marine vessels to specific ports. Using best available locomotive activity data for the relevant railyards, MJB&A performed detailed emissions analyses to estimate locomotive emissions within each railyard.

For each of these sources, all emissions within each source area were assumed to originate in an evenly distributed manner across the source (e.g., across the entire area of the railyard or port berth). Figure 4 identifies each non-roadway source captured within the emissions inventory and shows the boundaries and locations associated with each source.

Figure 4 Non-Roadway Mobile Emission Sources

Included Areas & Locations

Port[1]

1. Port Elizabeth
2. Port Newark
3. Howland Hook

Railyard[2]

4. ExpressRail Elizabeth
5. ExpressRail Staten Island
6. South Kearny
7. NS E-Rail
8. Oak Island
9. Trumbull

Airport[3]

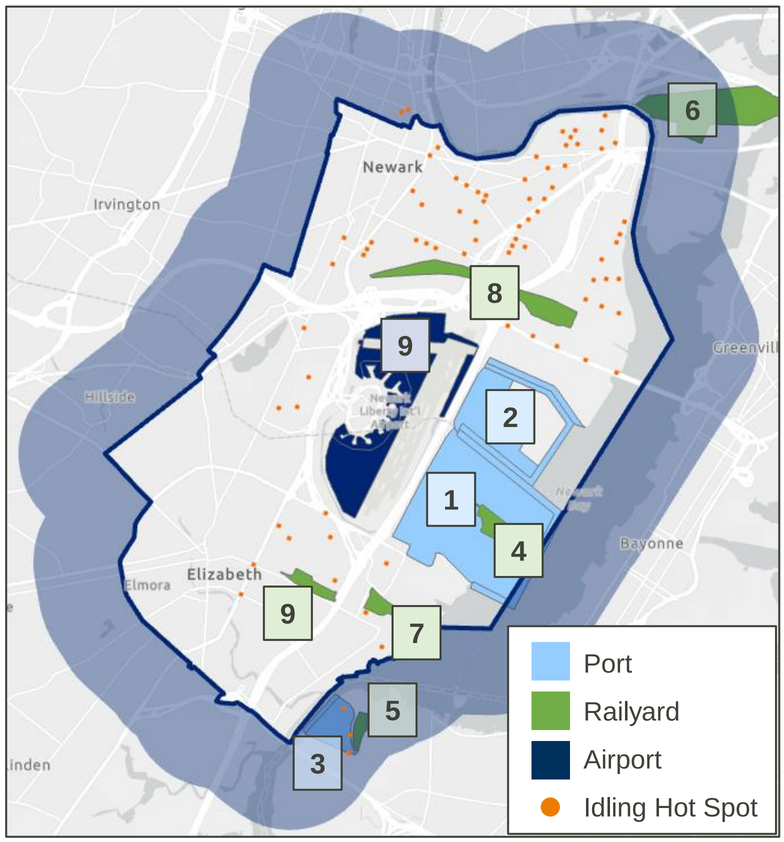
10. Newark International Airport

Heavy-duty diesel truck idling

- Identified hotspots

Emission Sources

[1] Cargo handling equipment, commercial marine vessels, & on-port heavy-duty diesel vehicles
[2] Switch & line-haul locomotives
[3] Ground support equipment & auxiliary power units



Phase Two: Emissions Evaluation

In Phase Two, MJB&A evaluated transportation emissions by utilizing the emissions inventory developed in Phase One to: 1) create heat maps of emissions exposure across the community and 2) evaluate the effect that policy interventions would have on emissions exposure under a range of electrification scenarios (e.g., low-to-high and in select policy-specific cases).

[7] Emissions from heavy-duty diesel vehicle idling are considered to be port-related activity (e.g., non-roadway) but occur on or along roadways and are referred to as roadway sources in the remaining report

To determine the level of emissions exposure experienced at any given location or area within the study area, MJB&A performed a dispersion analysis that modeled the movement of each pollutant. Although this analysis is a simplification of atmospheric dispersion modeling that can be used to develop air quality standards,[8] it does account for important factors that affect pollutant dispersion, such as fuel-source specific emission impact curves and wind direction. MJB&A utilized U.S. EPA AERSCREEN modeling tools to create engine-specific emission impact curves[9] to estimate the relative magnitude of emissions downwind from the source. These impact curves were combined with local wind data to create wind-adjusted impact functions that accounted for 360-degree dispersion out to one mile from the emissions source.

These impact functions were then applied to the emissions inventory created in Phase One to produce source-specific, spatial emission dispersion data. Ultimately, the outputs (or "exposure" values) of each dispersion analysis were aggregated to produce cumulative values; Figure 5 shows an illustrative example of how cumulative exposure values were calculated.

These spatial, cumulative exposure values enabled the ability to characterize relative pollution exposure at any location or within any defined area in the study area. To highlight the most impactful emission sources and identify emissions reduction interventions that could have the largest impact in the area, MJB&A performed detailed analyses at key "receptor sites" provided by NJEJA (displayed in Figure 6).[10] A case study of Hawkins Street Elementary School (receptor site #3) is further discussed on pages 12 and 13.

Figure 5 Illustration of Cumulative Exposure Calculation

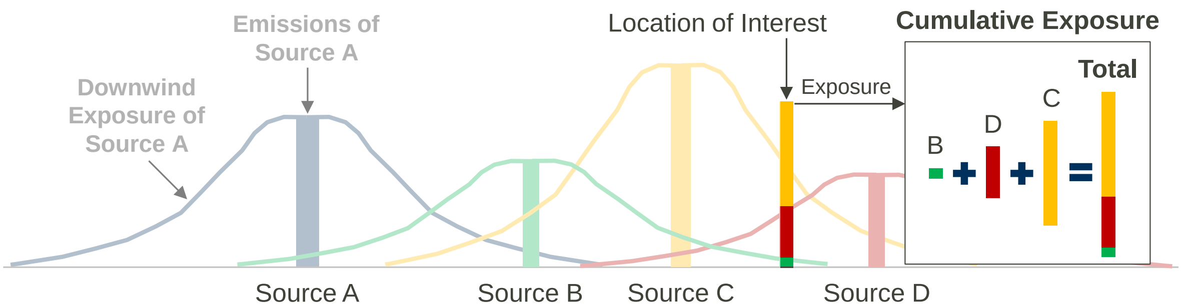
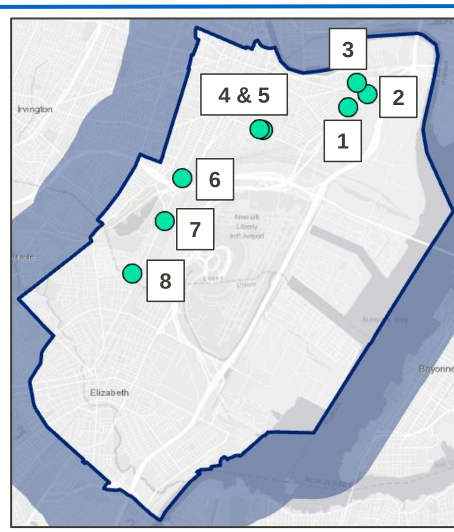


Figure 6 NJEJA Receptor Sites

Receptor Sites

1. Ironbound Aquatic Center
2. Newark Pre-School Council
3. Hawkins Street Elementary School
4. St. Justine II Pre-School
5. Fresenius Kidney Care Center
6. The Harbor
7. DaVita Parkside Dialysis Center
8. Kretchmer Senior Center



[8] Output of this analysis ("exposure" values) may be viewed as proportional to typical atmospheric dispersion model outputs (e.g., pollutant concentrations given as grams per cubic meter) but should not be directly compared

[9] Generic dispersion curves were modeled for all relevant engine types; see Appendix B for more information

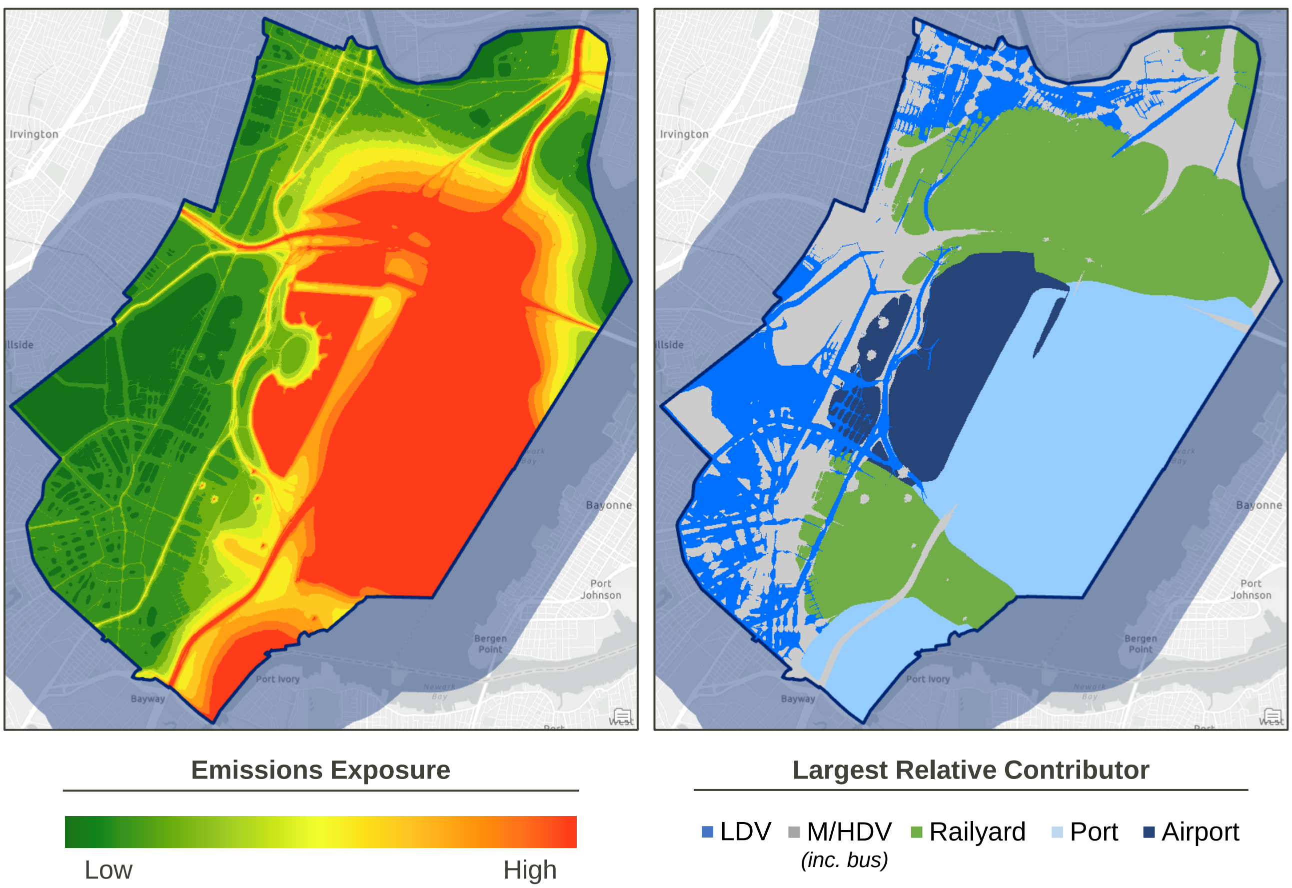
[10] See Appendix C for results from each receptor site.

Key Findings

Total emissions exposure, and relative contribution from different transportation sources, varies significantly across the study area.

This analysis finds that those emissions sources that contribute most to a location's exposure may be up to a mile away from the study area and that community exposure to pollution is affected by both nearby emissions and total exposure from sources that are not in the immediate vicinity.[11] Since pollutant exposure is a function of both emissions and dispersion, locations with the highest exposure are likely to be close to, and downwind from, port facilities, railyards, and high-density truck and bus routes. Figure 7 presents two different ways to visualize $PM_{2.5}$ emissions exposure experienced throughout the study area.[12] The leftward map represents the relative emissions exposure as a "heat map" to convey how $PM_{2.5}$ exposure varies across the area. The rightward map indicates the emissions source that is most responsible for $PM_{2.5}$ exposure experienced at any given location.[13]

Figure 7 $PM_{2.5}$ Emissions Exposure Across Study Area



[11] As a reminder, in this study, we use the term "emissions" to mean actual emissions from sources in the study area (or a subset of the study area). "Exposure" is a function of both emissions and dispersion and refers to the cumulative emissions impact experienced at a location or area; that is, emissions from nearby sources are included as well as those that have traveled to a location from other sources.

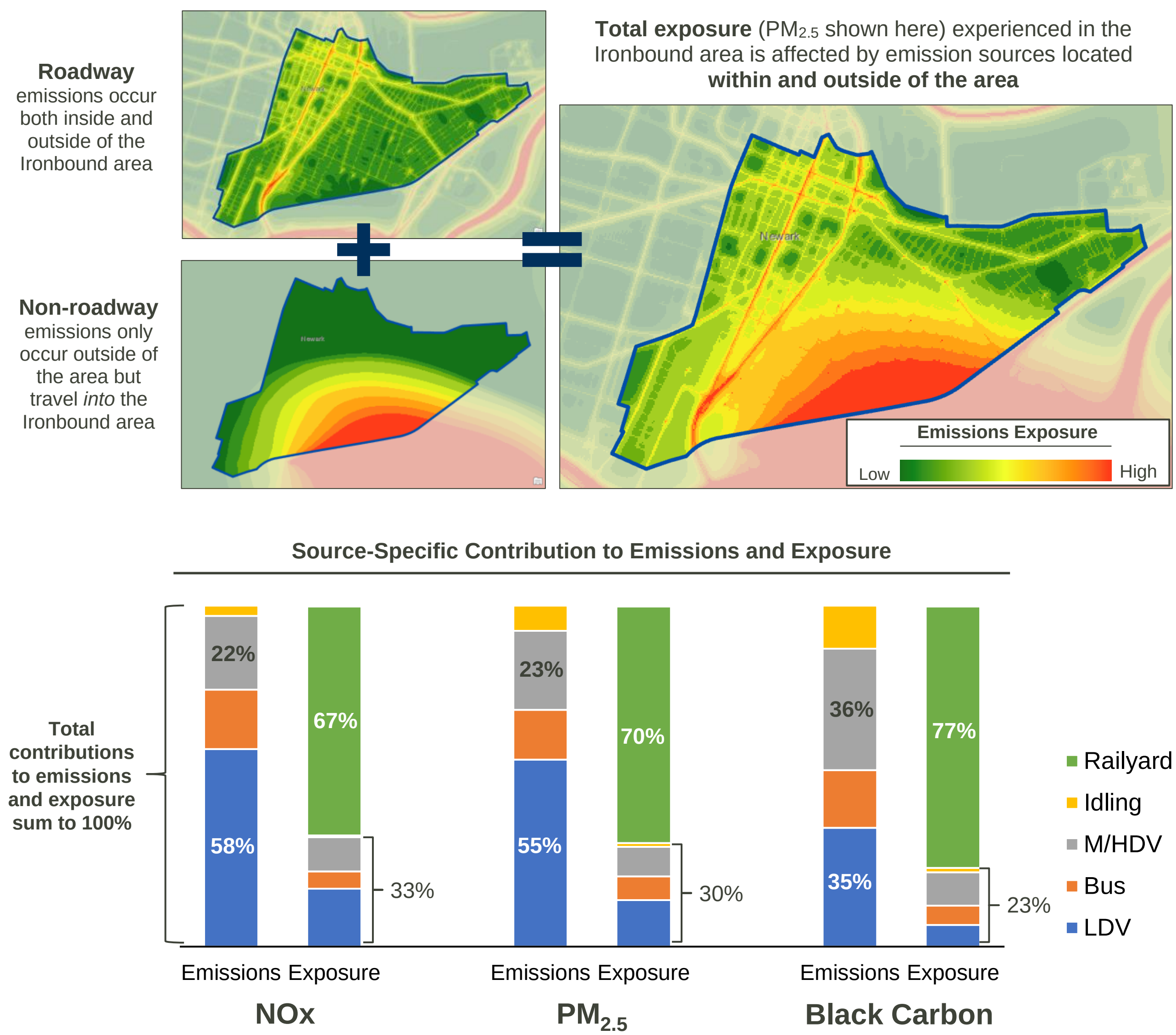
[12] See Appendix B for detailed emission exposure maps by emission source and pollutant (NOx, $PM_{2.5}$, and black carbon) for a more refined spatial visualization of contributing emission sources

[13] Emission sources aggregated as light-duty vehicles, medium-/heavy-duty vehicles (including buses), aggregated railyards, aggregated ports, and Newark International Airport.

As Figure 7 shows, location has a significant impact on the magnitude of exposure and the specific emission sources responsible for that exposure. Railyards, especially, are the primary source of exposure in many neighborhoods and communities around the study area, but high traffic bus and truck routes that travel through and around downtown Newark and Elizabeth are largely responsible for exposure in those areas.

The importance of accounting for pollutant dispersion and movement can also be seen in the Ironbound neighborhood and surrounding area of Newark. This study defined this area with a western border of Dr. Martin Luther King, Jr. Boulevard, extending through downtown and into the North and South Ironbound neighborhoods, bordered by U.S. Route 1 and Raymond Boulevard. Figure 8 shows a heat map of $PM_{2.5}$ emissions exposure within this defined area, which derives from both roadway and non-roadway sources. The chart in Figure 8 explores more detail on how each source contributes, on a relative basis, to emissions and exposure within the Ironbound area. The analysis shows that while total emissions emitted *within the area* primarily derive from light-duty vehicles (or medium- and heavy-duty vehicles for black carbon, specifically), emissions that originate from *outside the area* (in this case, Oak Island railyard to the southeast) are largely responsible for the total emissions exposure experienced within the area.

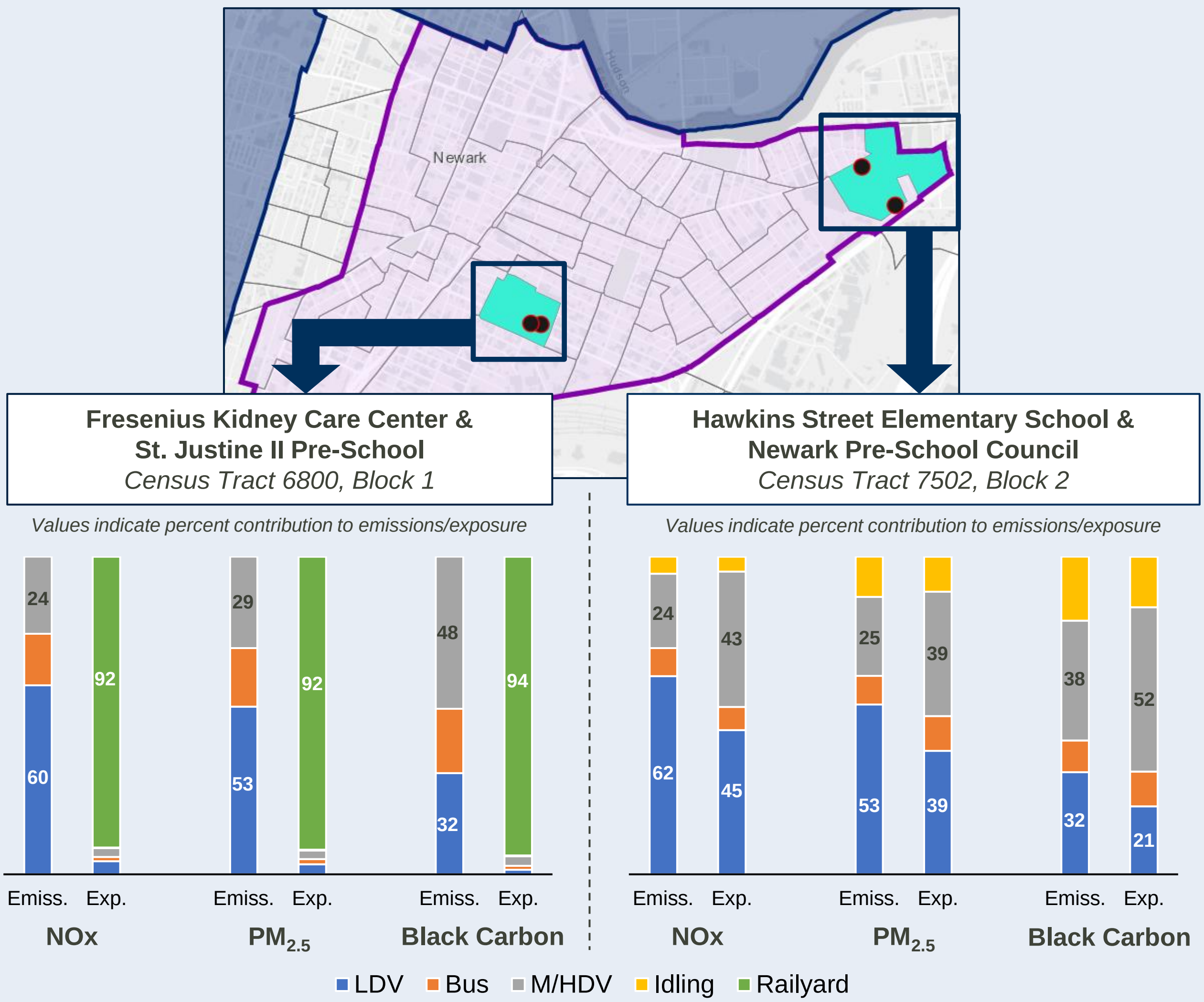
Figure 8 Emissions and Exposure in the Ironbound



Looking at specific locations within the total exposure heat map of Figure 8, one can see how certain points within the neighborhood, for example those around downtown Newark to the north and west, are more affected by exposure from roadway sources. Figure 9 illustrates a case study that was performed around key receptor sites to further highlight how nearby emissions can compare to exposure on a hyper local level. This case study also shows the significance of a location's proximity to emission sources; while non-roadway emissions have a significant impact on the emissions exposure experienced across the Ironbound area, vehicle emissions—particularly those from medium- and heavy-duty vehicles—can also have a major impact on local exposure in certain population centers.

Figure 9 Ironbound Receptor Site Case Studies: Emissions vs. Local Exposure

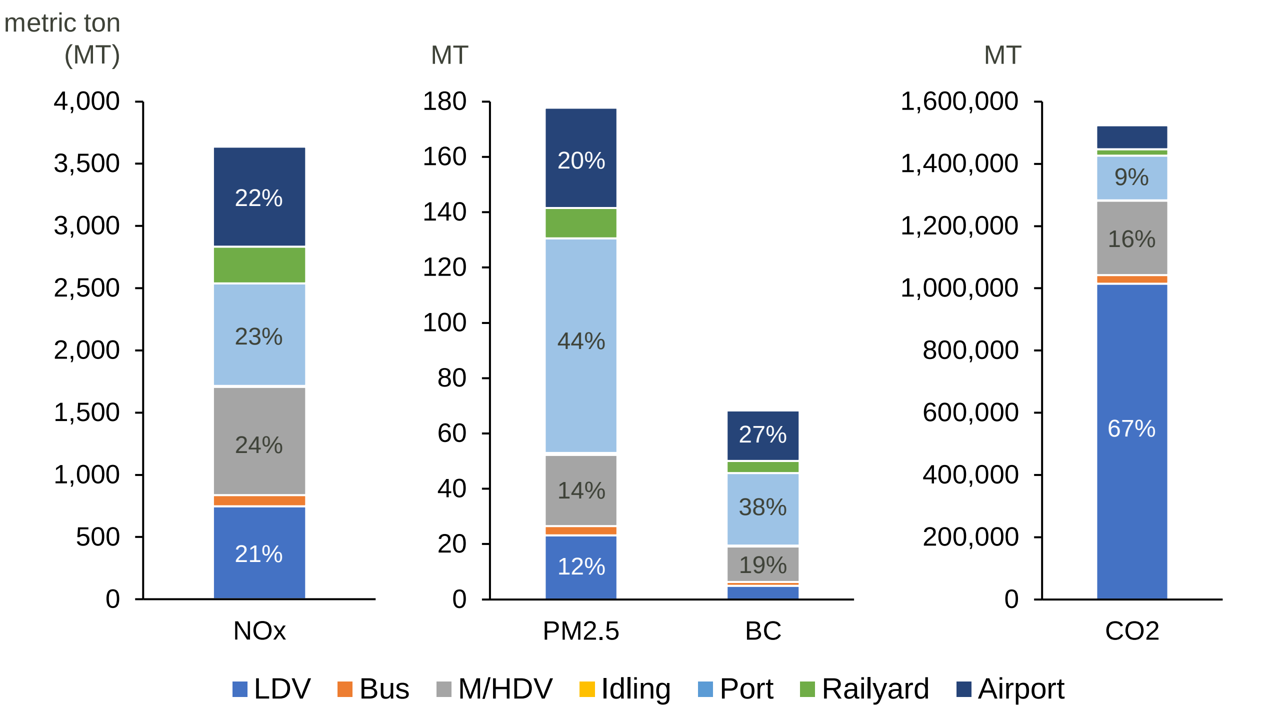
The highlighted areas below are both census tract blocks within the Ironbound and surrounding area. However, the key sources of emissions and exposure for each area vary significantly. Emissions that occur nearby Fresenius Kidney Care Center & St. Justine II Pre-School (within the tract block) derive largely from local traffic, but the pollution exposure experienced within the area is primarily caused by locomotives in Oak Island railyard, located approximately one-third of a mile away. Emissions near Hawkins Elementary and Newark Pre-School Council primarily come from local vehicle traffic, but idling emissions and truck traffic on surrounding highways (US-1 and the NJ Turnpike) contribute more significantly to exposure.



Emissions from non-roadway sources, particularly locomotives and ports operations, have the highest air quality impact in the total study area, followed by medium-and heavy-duty vehicles.

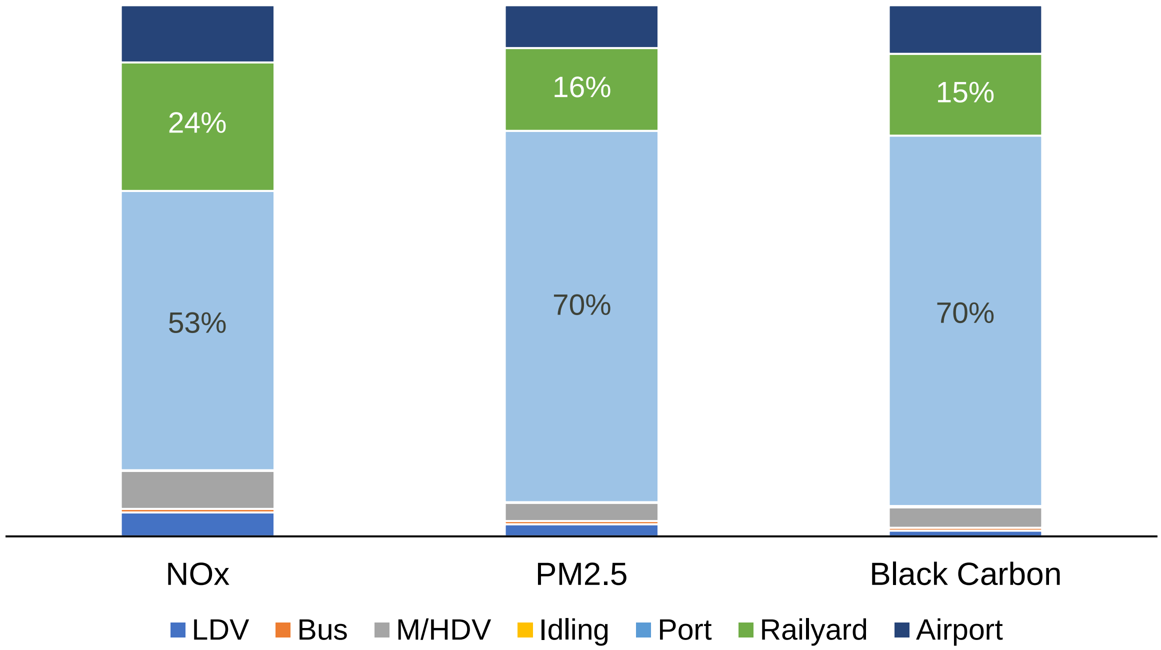
This analysis finds that non-roadway sources are responsible for the majority of $PM_{2.5}$ and black carbon emissions in the study area, while roadway vehicles produce similar NOx to non-roadway sources and much more CO_2. Figure 10 shows how light- and medium-/heavy-duty vehicles in the study area emit about the same amount of NOx as included sources in the airport and ports. However, non-roadway sources—particularly ports—are the dominant contributor to $PM_{2.5}$ and black carbon emissions in the area.

Figure 10 Total Emissions in Study Area, by Source



Although Figure 10 provides insight into emissions produced in the area, the dispersion analysis used to calculate total exposure reveals the even larger impact that ports and railyards have on local communities. As shown in Figure 11, these two sources alone are responsible for 77% of NOx exposure and around 85% of $PM_{2.5}$ and black carbon exposure. Buses and medium- and heavy-duty vehicles are the next largest sources of exposure, contributing jointly to around 8% of NOx and 4% of $PM_{2.5}$ and black carbon exposure.

Figure 11 Relative Contribution to Emissions Exposure within Study Area



While there are some policies in place to reduce the emissions from locomotives and marine vehicles, these vehicle classes have historically presented a much more difficult path for emissions reductions, including through electrification, due to limited policy attention and lack of funding. Policy intervention can help drive further development in this space. As discussed in the following finding, however, it is also important to look at emissions exposure on a very local basis when considering policy interventions.

Population centers and residential areas in close proximity to roadway emissions would benefit from efforts to reduce emissions from medium- and heavy-duty vehicles which can significantly reduce air emissions of particulates and NOx within certain key locations in the study area.

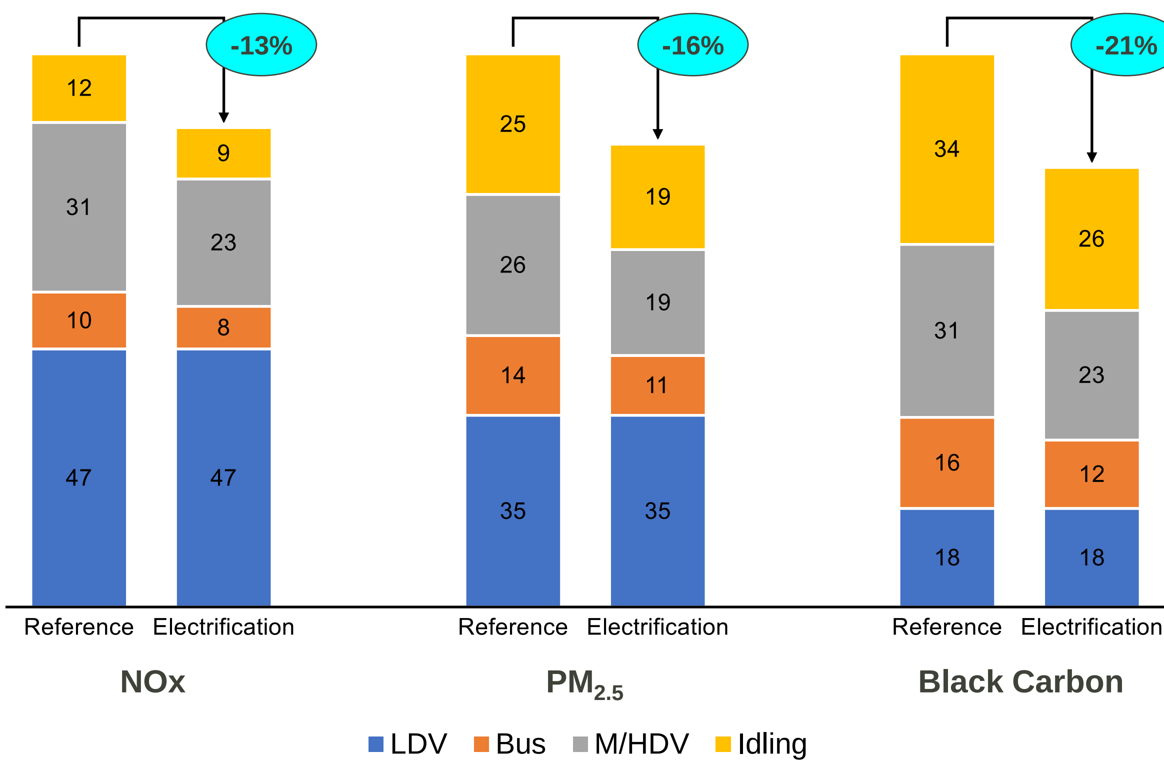
This analysis also includes an assessment of emission sources' relative contribution to exposure at a hyper local level—at a school, a hospital, or any other point within the study area. This highlights that many locations within the study area experience much lower relative exposure from non-roadway sources and may receive higher relative and total impact exposure from roadway sources depending on the location's proximity to a roadway.[14]

Because many population centers are severely impacted by roadway emissions, reducing emissions from high-emitting light-, medium- and heavy-duty vehicles can meaningfully reduce exposure in locations and areas near roadways. These benefits can be particularly local in nature if the emissions exposure at a specific location is dominated by emissions from a nearby truck or bus route or idling hot spot. The emissions exposure experienced at Hawkins Street Elementary School, for instance, is entirely from roadway sources, especially medium- and heavy-duty vehicle traffic and additional idling emissions from heavy-duty diesel trucks. Figure 12 shows how a 25 percent electrification of buses and medium- and heavy-duty vehicles can

[14] In short, this is because, among other things, the impact of non-roadway emissions is concentrated within one-mile of each source whereas roadway vehicle emissions are more evenly "spread" over the study area emissions. Although non-roadway sources disperse farther than roadway vehicles and distribute their emissions more substantially across a wider region, their relative impact on a specific location's exposure may be relatively small depending on that location's proximity to each type of emissions source.

reduce emissions at Hawkins St. Elementary School by 13 to 21 percent, depending on the pollutant.[15] Note that a significant share of these reductions come from a decrease in heavy-duty diesel vehicle idling emissions, which come from a nearby identified idling "hot spot." These emissions reductions could represent meaningful improvement in health outcomes for the children and staff attending this school in addition to those living and working in the surrounding areas. However, when assessed across the entire study area, this level of electrification of roadway vehicles would only reduce emissions exposure by 1 to 2 percent, simply because the magnitude of total port and railyard emissions affecting exposure in the study area is so high.[16]

Figure 12 Case Study: Effect of Electrification on Exposure at Hawkins St. Elementary School



[15] See Appendix C for results from each receptor site.

[16] A 60 percent electrification of all roadway vehicles (light-duty, buses, and medium-/heavy-duty) would reduce total area NOx emissions exposure by about 7 percent and $PM_{2.5}$ and black carbon by 3-4 percent when averaged across the study area, though it could have significant impacts on specific locations within the study area.

It is also critical that any analysis of electrification of transportation sources as an emissions reduction strategy take into account the potential impact of increased emissions from local power plants, which also contribute to the local pollution burden. In other words, if electrification is to be pursued for the light-, medium-, and heavy-duty transportation sector, to assure emissions reductions compared to the status quo, it must be paired with emissions reductions in local electric generating units (EGUs) as well, and across the broader power pools that dispatch generating units. To illustrate this point, MJB&A performed a preliminary emissions analysis of nearby EGUs, displayed in Figure 13.

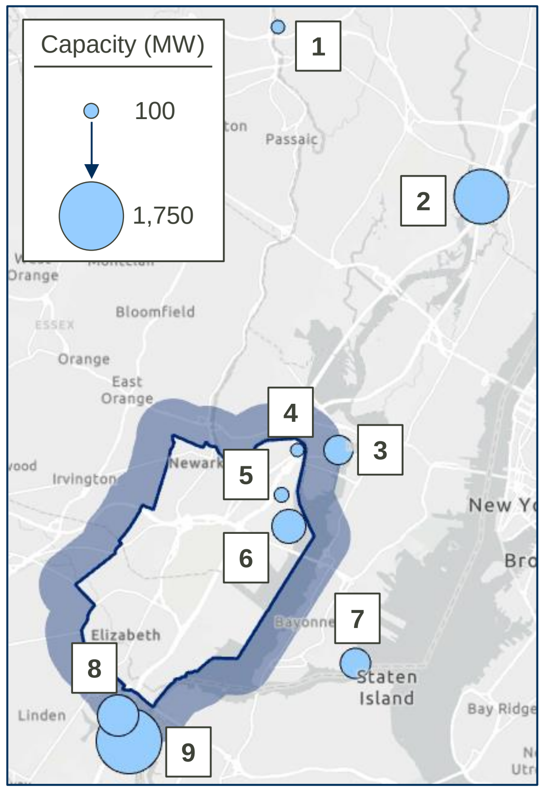
Figure 13 Electric Generating Units (EGUs) Included in Analysis

Included Power Plants*

1. Elmwood Power Park
2. Bergen Generating Station
3. PSEG Kearny Generating Station
4. PSEG Essex Generating Station
5. Newark Bay Cogeneration Plant
6. Newark Energy Center
7. Bayonne Energy Center
8. Linden Cogeneration Plant
9. PSEG Linden Generating Station

*All natural gas facilities

10. Elmwood Power Park
11. Bergen Generating Station
12. PSEG Kearny Generating Station



These EGUs exist within the PJM grid, a wholesale electricity market that operates in states throughout the mid-Atlantic. This analysis does not conduct a dispatch model to identify if these emitting EGUs, in particular, are likely to increase their output—and thus emissions—if electricity demand increases due to electrification of transportation. However, it does attempt to compare the relative emissions rates of transportation sources with the average emission rates of local EGUs to determine one possible scenario regarding the emissions effect of electrified transportation.

Figure 14 shows the emission rates of light-duty vehicles, buses, and medium- and heavy-duty vehicles under three conditions: 1) the average vehicle from the current fleet, 2) a new conventional internal combustion engine vehicle, and 3) an electric vehicle powered exclusively by the EGUs shown in Figure 13.

Figure 14 CO_2, NOx, and $PM_{2.5}$ Emissions Rates: Vehicles vs. EGUs

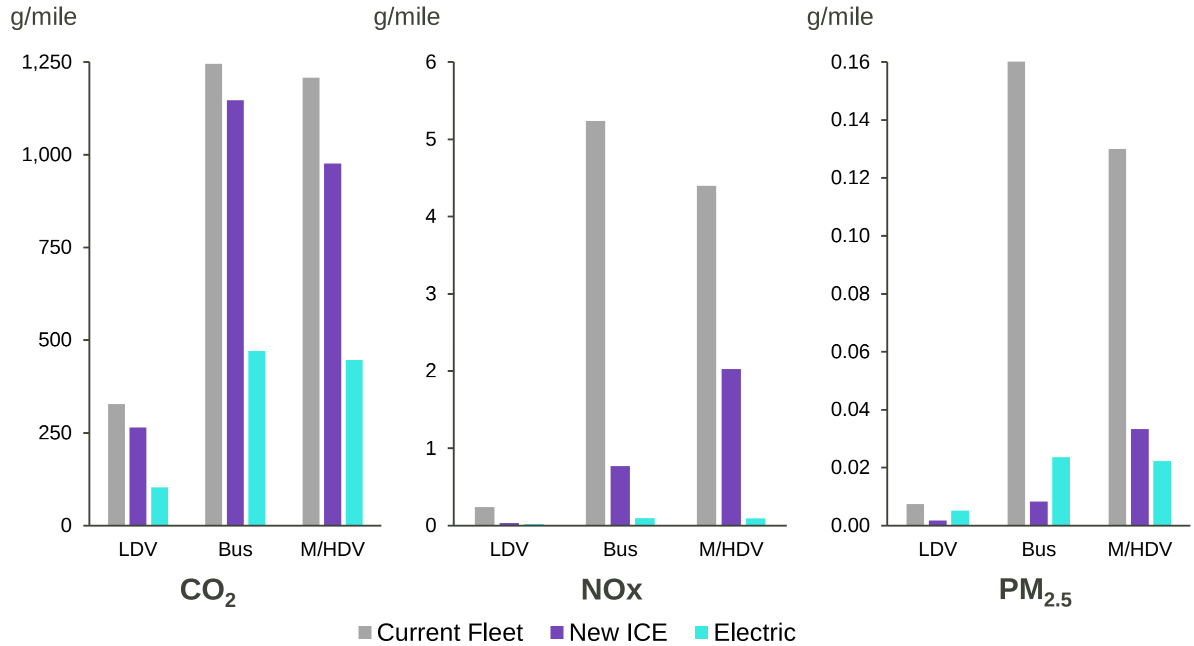


Figure 14 shows that the NOx and CO_2 emissions rates of these units are significantly lower than the rates of the vehicle fleet considered in this analysis. Accordingly, if one were to assume that 100 percent of the electricity needed to power a newly electrified truck, car, or bus were to come from these local EGUs, total NOx and CO_2 emissions would still decrease compared to prior emissions from a conventional gas- or diesel-powered vehicle. Of course, local emissions could be even lower if some portion of that electricity to power a new electric vehicle is produced by non-emitting generation or generation outside the region. However, a more detailed dispatch analysis is necessary to determine which, if any, EGUs in the area increase output and therefore determine local emissions impact. As with the transportation emissions exposure findings in this study, power plant emissions can have hyper local impacts that can be obscured when looking across broad areas.

Furthermore, the analysis finds that local EGUs have a lower $PM_{2.5}$ rate than the current vehicle fleets across all classes and than a new conventional truck, but higher emissions rates than that of the average new conventional light duty vehicle or bus. Accordingly, if a conventional bus is replaced with an electric bus, and all electricity to power that bus comes from local emitting EGUs, total local emissions (i.e., those from transportation sources affecting the study area and these local power plants) are likely to decrease. However, it is possible that somewhat greater $PM_{2.5}$ emissions reductions could be achieved through the purchase of a new conventional bus. Similarly, if a passenger vehicle is electrified and powered by exclusively local emitting EGUs, $PM_{2.5}$ emissions in the same locality could rise compared to a case in which that passenger vehicle was simply replaced by a new, cleaner conventional car.

One benefit of electrification, compared to replacing vehicles with new conventional vehicles, is that emissions can continue to decrease over time. The “electric” emissions in Figure 14 can be viewed as a ceiling on local emissions for electric vehicles, with room for improvement if and when the electric sector continues to reduce emissions through improving performance of emitting sources and replacing emitting resources with renewables, advanced energy storage, or other zero emitting resources.

In addition, further analysis could be conducted to assess the dispersion of NOx and $PM_{2.5}$ from electricity sources, as these impacts are often very local. As discussed above, because many population centers are severely impacted by very local roadway NOx and $PM_{2.5}$ emissions, electrifying high-emitting light-, medium- and heavy- duty vehicles can significantly reduce exposure in locations and areas near roadways.

However, those communities adjacent to EGUs may experience concurrent increases in emissions from the electric sector. Though outside of the scope of this study, more analysis should be conducted to identify the local impacts of these potential shifts in emissions.

In total, this study finds that the emissions impact of transportation electrification depends on which pollutant is being considered, what electricity generation sources are assumed to serve new demand, and how locally emissions are accounted for (i.e., averaged across a region or taking into account local emissions hot spots).

Discussion

This analysis displays the direct relationship between local air quality and pollution from transportation sources. While this is not a new finding—the literature on the impact of transportation emissions on human health and the environment is substantial—the street by street variation in the level of emissions impact that communities may experience sheds light on the direct impact that higher polluting vehicle routes have on local street and neighborhood air quality. This finding—and its implications—are critical for policymakers who are looking to create more equitable communities that do not disproportionately burden parts of the population with levels of air pollution that negatively impact health.

Historically, policies focused on reducing emissions from the transportation sector have been designed with the goal of reducing transportation pollution by either requiring—through vehicle emissions standards—or encouraging—through vehicle trade-in or scrappage programs—cleaner light-duty and medium-and heavy-duty vehicles. Within the medium- and heavy-duty space, vehicle trade-in programs and scrappage programs have led to some improvements in air quality. However, these policies have not gone far enough in reducing emissions, in particular in communities that are disproportionately burdened by poor air quality.

Many states across the country have shifted their transportation sector emissions policy, focusing instead on strategies to reduce climate-warming GHG emissions, often evaluating local air quality improvements as a co-benefit to CO_2 emissions reductions. The majority of policies implemented to reduce emissions within the transportation sector within the United States have focused primarily on the electrification of light-duty vehicles. These policies typically have a goal of broadly reducing GHG emissions from the transportation sector and focus less on local harmful air pollution.

New Jersey has followed this climate-centric path, and has implemented several policies as part of its climate and energy agenda to reduce GHG emissions from the transportation sector. This has included: signing the light-duty and medium- and heavy-duty zero-emissions vehicle electrification Memorandums of Understanding;[17]developing several incentive programs designed to encourage the procurement of light-duty electric vehicles; and, through the passage of SB 2252, codifying procurement targets, setting charging infrastructure targets, and creating transit bus electrification targets. These and other initiatives have placed New Jersey among the states actively pursuing transportation electrification, in particular for light-duty vehicles.

These policies, while constituting a meaningful step in reducing GHG emissions across the state, do not adequately focus on medium-and heavy-duty vehicle pollution or improving local air quality within environmental justice communities. For communities like those in the study area and especially those adjacent to the ports of Newark and Elizabeth, other types of vehicles in addition to light-duty vehicles have a significant impact on the emissions of local air pollution, like $PM_{2.5}$, black carbon, and NOx, that negatively impact human health the most.

Based on the findings of this analysis, when evaluating roadway transportation emissions sources, medium- and heavy-duty vehicles have an outsized impact on the harmful local pollutants that impact human health as well as contributing significantly to transportation sector GHG emissions. This analysis further found that reducing emissions from the medium- and heavy-duty vehicle sector would have meaningful and immediate impacts on air-quality within disproportionately burdened communities. These objectives, and programs specifically aimed at these communities' needs, should be centered alongside that of GHG reduction when developing transportation policies. This rebalancing is critical to ensure that GHG reduction policies, including those focused on electrification, are improving air quality within disproportionately burdened communities today in order to reduce the lifetime health burdens that community members face. For communities like those within the study area, the greatest opportunity for local air quality improvement

[17] In 2018, New Jersey joined eight other states in signing the state zero-emissions vehicle (ZEV) Memorandum of Understanding (MOU). New Jersey specifically set a target of 330,000 light-duty plug-in electric vehicles (PEV) in the state by December 2025. In 2020, New Jersey joined 15 other states and Washington DC in signing the state Medium- and heavy-duty Zero emission vehicle MOU.

comes when these emissions are directly targeted by policy, rather than arising as a co-benefit from policies focused on GHG reduction.

The State of California, in particular, has taken a leadership role in approving a number of policies in recent years designed to reduce emissions from medium- and heavy-duty vehicles, including the recent approval of two landmark rulings — the Advanced Clean Truck Rule and the Heavy-Duty Low NOx Omnibus Rule. Both of these rulings are designed to address medium- and heavy-duty vehicles emissions in distinct and complementary ways— with one program focused on developing a market for new zero-emitting medium- and heavy-duty vehicles and the other designed to reduce emissions from existing trucking fleets.

By addressing both local harmful air pollution in the short-term and developing a supply chain for zero-emitting trucks, the state is both considering the immediate and long-term needs of communities located in heavily trafficked areas. The California Air Resources Board (CARB) estimates that both of these policies will dramatically reduce emissions and improve air quality. Notably, CARB anticipates that the NOx Omnibus Rule is expected to reduce harmful NOx emissions in California by more than 24 tons per day once it is fully phased in by 2031.[18]

These policies, and those like them, represent a possible model for New Jersey to follow if it is serious about reducing community pollution exposure from the transportation sector. Several additional examples of how states are pursuing medium- and heavy-duty electrification are described below. Critical to implementing any policy similar to those described below is ensuring that reductions in medium- and heavy-duty vehicle emissions occur within environmental justice communities.

- **California Advanced Clean Trucks Rule**— The Advanced Clean Truck Rule focuses on developing a market for zero-emission MHDVs by requiring manufacturers of Class 2b-8 vehicles to sell zero-emission trucks at an increasing percentage of their annual California sales from 2024 to 2035 and by requiring large employers and fleet owners to report their existing fleet operations. California is also developing a partner regulation to the Advanced Clean Trucks rule that will require all medium and heavy-duty fleets to be 100% zero-emissions by 2045, per Executive Order N-79-20.
- **California Innovative Clean Transit—** All new transit buses in CA must be zero-emission, electric buses by 2029. By 2040, all public transit agencies must transition to 100% zero-emission bus fleets. Zero-emission bus technologies include all-electric or fuel cell electric buses.
- **California Heavy-Duty Low NOx Omnibus Rule—** The Heavy-Duty NOx Omnibus Rule increases exhaust emissions standards and test procedures, requiring engines to be approximately 75 percent below current standards beginning in 2024, and 90 percent below current standards in 2027.
- **California Port Electrification Goals—** A number of Ports in California have set aggressive truck electrification goals. The San Pedro Bay Port 2017 Clean Air Action Plan proposes to establish a new clean truck program with a goal to have a fully zero-emission drayage truck fleet by 2035 and to require all trucks entering the port to be zero-emission, meet the Low-NOx standard, or pay a fee by 2024. By 2035, trucks would need to be zero-emitting or would have to pay a fee. Additionally, the Ports of Los Angeles and Long Beach Clean Air Action Plan set a goal of 100 percent zero-emission drayage trucks by 2035. By 2035, all drayage trucks at California ports must be zero-emissions, per Executive Order N-79-20.

Importantly, this analysis also reveals the significant contribution to GHG and local harmful pollutant emissions from non-roadway sources in port-adjacent communities—specifically, from ports and railyards. However, strategies to reduce these emissions have not received the same amount of policy focus or investment as have roadway sources of emissions. While there are measures that can be taken in the short term to reduce some of these emissions (e.g., reducing vessel and locomotive idling or electrification of shore

[18] California Air Resources Board. (2020). Facts about the Low NOx Heavy-Duty Omnibus Regulation. https://ww2.arb.ca.gov/sites/default/files/classic//msprog/hdlownox/files/HD_NOx_Omnibus_Fact_Sheet.pdf

power sources), more dedicated action and research and development will be needed to have a meaningful impact on reducing emissions from these non-roadway sources. Some ports, such as Long Beach and Los Angeles, have reduced emissions under state regulation and long-term planning, but a more comprehensive approach is needed within ports in order to improve air quality in port-adjacent communities.

By taking a comprehensive approach to all modes of mobility and by keeping a focus on where air pollution exposure is most severe, policymakers in states like New Jersey can become leaders in equitably addressing emissions reductions within the transportation sector.

Conclusion

The damaging and significant health effects associated with exposure to local air pollutants such as NOx, black carbon, and $PM_{2.5}$ are well documented and significantly impact vulnerable populations in disproportionately burdened communities. This report contributes to this broader body of work by displaying the unequal emissions burden that roadway and non-road vehicles have on the port-adjacent communities of Newark. Notably, this report finds that a wide range of pollution sources dramatically impact the levels of exposure felt throughout a community— displaying the important role that bus and trucking routes, ports, and railyards have on the relative emissions exposure that community members experience.

Many population centers and residential areas, in particular, are highly impacted by roadway emissions—particularly those from medium- and heavy-duty vehicles. While it is critical to work towards addressing both roadway and non-road vehicle emissions, roadway gasoline and diesel vehicles have a cleaner alternative technology that is either already available (e.g., light-duty electric vehicles and transit buses) or is anticipated to be on the market within the next five years (e.g., box trucks). Investing in this technology today is not only feasible but is essential in order to make meaningful emissions reductions, improving air quality in disproportionately burdened communities and enabling the state to meet its short- and long-term emission reduction goals. Climate mitigation efforts in the transportation sector often focus primarily on the reduction of GHG in the sector, particularly through the electrification of passenger vehicles. This study illustrates the importance of prioritizing the reductions of harmful local air pollutants alongside CO_2 in this sector in order to realize the immediate health benefits such a reduction will have on areas most burdened by transportation sector emissions.

Appendix A: Analysis Methodology

Emissions Inventory

Emission data calculations applied both top-down and bottom-up approaches utilizing publicly available resources, purchased vehicle registration data, and adjustments using spatial analysis to account for local characteristics. Emission sources were disaggregated to the furthest extent possible to provide the most accurate and transparent representation of transportation-related emissions in the area. This inventory is comprised of a collection of 75 emission sources (48 roadway sources and 27 non-roadway sources) that have different emission factors, dispersion characteristics, and ultimately, contributions to emissions exposure. The analysis includes emissions and associated exposure from NOx, $PM_{2.5}$, and black carbon (CO_2 emissions are quantified but not dispersed).

To account for the spatial attribute of this inventory, MJB&A applied raster-based calculations[19] to perform all spatial analyses and modeling.

Roadway Sources

MJB&A used New Jersey-reported roadway data and summary traffic data to create a traffic inventory that provided a detailed breakdown of vehicle miles traveled (VMT) by vehicle type, roadway type, county, and zip code (where applicable).

<u>Non-Local Roadways</u>

Vehicle traffic was first modeled using the most recent New Jersey Highway Performance Monitoring System (HPMS)[20] spatial dataset provided by the Federal Highway Administration (FHWA). These data are reported by the State of New Jersey and provide total annual average daily traffic (AADT) and medium- and heavy-duty vehicle AADT (reported as single-unit and combination truck, respectively, on select roadways) on non-local roadways, such as:

- Interstates
- Principal and minor highways/arterials
- Major and minor urban collectors

Roadways captured by the HPMS dataset accounted for approximately 46% of the total roadway miles and 90% of the total vehicle miles traveled (VMT) analyzed in this study.

<u>Local Roadways</u>

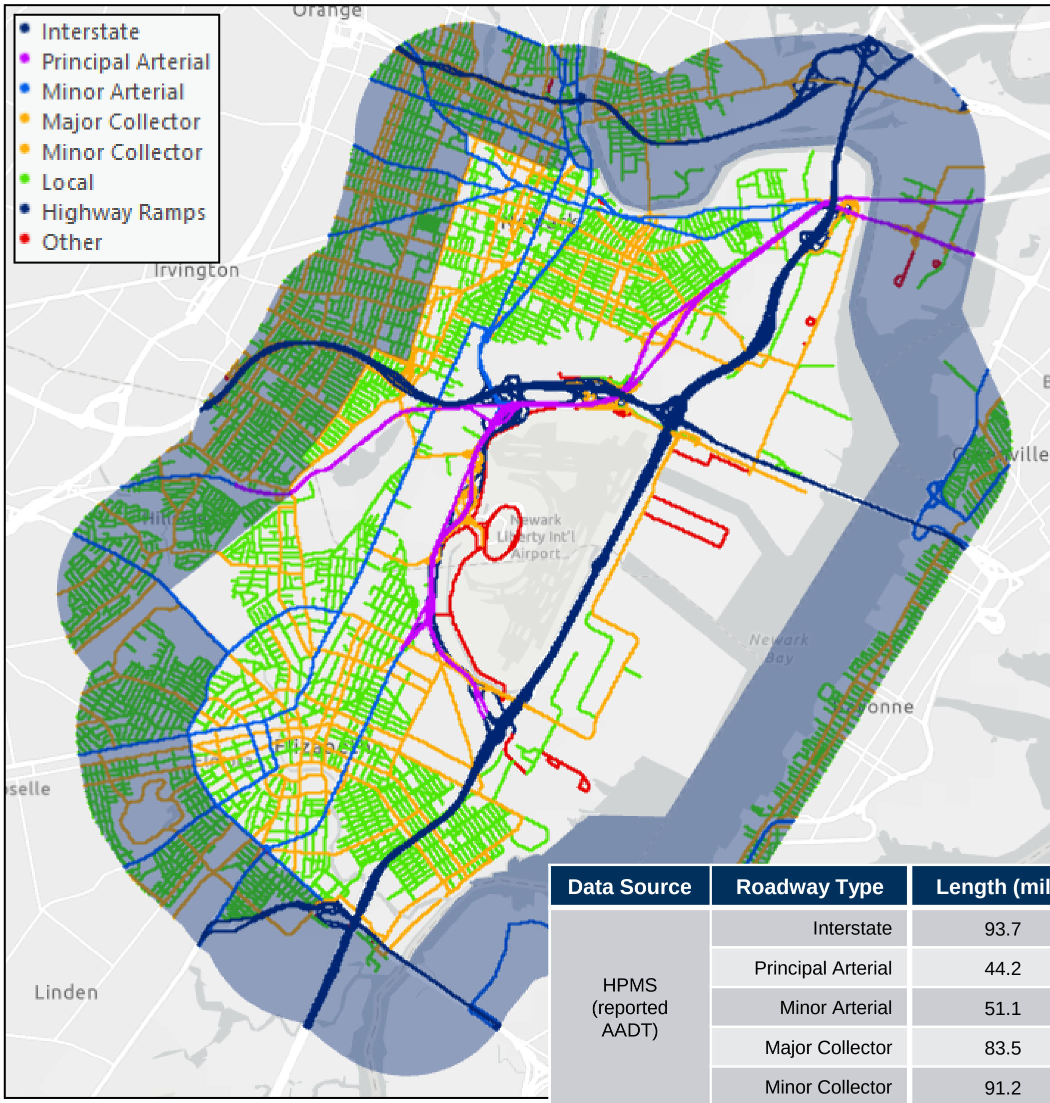
Because the HPMS only provides data for non-local roadways, MJB&A used publicly available data from the New Jersey state governmental resources to generate top-down estimates of local traffic patterns. The spatial attributes of local urban roadways[21] and summary traffic data were provided by the New Jersey Department of Transportation (NJDOT).[22,23] Together, these resources created county-specific summary data that captured:

- Roadway miles, VMT, and AADT by roadway type (functional classification) and county
- State-wide urban travel activity by vehicle and roadway type

[19] Using the New Jersey Department of Environmental Protection default projected coordinate system (NAD 1983 StatePlane New Jersey FIPS 2900); raster cell extent of 45 feet by 45 feet was chosen to provide high resolution
[20] https://www.fhwa.dot.gov/policyinformation/hpms/shapefiles.cfm
[21] https://njogis-newjersey.opendata.arcgis.com/datasets/road-centerlines-of-nj
[22] https://www.state.nj.us/transportation/refdata/roadway/pdf/hpms2018/TRAV_18.pdf
[23] https://www.state.nj.us/transportation/refdata/roadway/pdf/hpms2018/VMTFCC_18.pdf

Figure 1 shows all roadways included in the analysis, by roadway functional classification, and the approximate modeled length and VMT by roadway type.[24]

Figure 1. Included Roadways (by functional classification)



Data Source	Roadway Type	Length (mile)	Million VMT
HPMS (reported AADT)	Interstate	93.7	1,582
	Principal Arterial	44.2	436
	Minor Arterial	51.1	447
	Major Collector	83.5	296
	Minor Collector	91.2	213
NJ DEP Resources	Local Roadway	366.0	213
	Highway Ramp	12.0	47
	Other	42.7	85
	Total	**784.4**	**3,320**

[24] Due to inconsistent data aggregation across roadway types, roadway lengths shown in the table in Figure 1 may not provide an accurate estimation of undivided roadway length; major roadways may be divided into several parallel roadways (e.g., north- and south-bound I-95/NJ Turnpike have divided lanes restricted to light-duty vehicles in addition to unrestricted lanes), while two-way, local roadways may only be represented as one roadway. Because of this inconsistency and the multiple ways AADT can be reported (bidirectional for two-way roads, directional for one-way roads), roadway lengths should not be combined with modeled VMT to estimate average AADT across roadways.

Figure 2 displays traffic (AADT) of non-local (HPMS) and local roadways analyzed using these resources.

Figure 2. Traffic (AADT) of Included Roadways

Base Data Modeling

NJDEP and NJDOT documents provided average AADT on local roadways in the counties included in the study area (Essex and Union) and enabled preliminary local (NJDEP data) and non-local (HPMS data) roadway breakdown of AADT by the following vehicle types:

- Motorcycle
- Passenger Car
- Light-Duty Truck
- School & Intercity Bus
- Single-Unit Truck
- Combination Truck

To account for local roadway traffic variation, MJB&A used surrounding local roadway mileage and estimated registered vehicles[25] to create an adjusted AADT on a census block group-level. These adjusted traffic volumes were further adjusted based on proximity to and traffic of unrestricted roadways.

Non-local roadways were assumed to have vehicle traffic that reflected state-wide vehicle classification breakdowns (specific to roadway type); the vehicle breakdown of highway on- and off-ramps was

[25] U.S. Census Bureau 2018 American Community Survey (2013-2017 ACS 5-Year estimates)

determined by the functional classification of the destination roadway. Local roadway vehicle classification breakdowns were estimated using IHS Markit vehicle registration data for the following zip codes:

- Essex County (07102, 07103, 07114)
- Union County (07202, 07206, 07208)

The average vehicle breakdown of these zip codes (on a county-level) were applied to local roadways outside these zip codes but within each respective county (e.g. average of Essex County zip codes was applied to other local roadways in Essex County).

Additional Traffic Adjustments

Airport Travel

Roadway traffic into and out of Newark International Airport (EWR) was calculated using data and assumptions from the Port Authority of New York and New Jersey (PANYNJ) Annual Airport Traffic Report[26] and Greenhouse Gas and Criteria Air Pollutant Emissions Inventory.[27] MJB&A distributed the calculated AADT (non-transit bus, broken down by vehicle type) across the roadways that travel into and out of EWR. Transit bus traffic related to EWR was calculated separately.

Public Transit Bus

MJB&A utilized New Jersey Transit (NJ Transit) bus schedules and spatial route data to assign average daily bus traffic along each roadway with NJ Transit bus route(s). The Federal Transit Administration National Transit Database (NTD) 2018 Service Vehicle Inventory[28] was consulted to determine specifications (fuel type, model year) of the in-use transit bus fleet to inform emission calculations specific to NJ Transit.

School Bus

To calculate school bus traffic in the study area, the State of New Jersey Motor Vehicle Commission School Bus Inspection Reporting Program[29] was used to estimate the total number of school buses registered in the study area. This number was multiplied with the average annual VMT of school buses in the New York-Newark metropolitan area[30] to estimate the total school bus VMT in the study area. MJB&A then distributed VMT across roadways based on roadway type and applied spatial analyses to further adjust school bus traffic based to account for location and student enrollment[31] of nearby public and charter schools.

Intercity Bus

The U.S. Environmental Protection Agency (EPA) Motor Vehicle Emission Simulator (MOVES) was utilized to estimate the share of total VMT in Essex and Union Counties from intercity buses. This share was applied to the known total AADT/VMT of each roadway (non-local roadways only; intercity bus traffic on local roadways was considered negligible).

Single-Unit and Commercial Truck

When single-unit and commercial truck traffic was not provided by HPMS, modeled traffic was adjusted using a similar spatial analysis performed for school buses. MJB&A began with a base average single-unit/commercial AADT associated with each roadway type (calculated using NJDOT summary data) and

[26] https://www.panynj.gov/content/dam/airports/statistics/statistics-general-info/annual-atr/ATR2018.pdf
[27] https://www.panynj.gov/content/dam/port-authority/about/environmental-initiatives-/EY2016-Report-Final.pdf
[28] https://www.transit.dot.gov/ntd/data-product/2018-annual-database-service-vehicle-inventory
[29] http://pweb.nj-cleanair.com/SchoolBusInspection/pages/inspection/companySearch.jsf
[30] https://www.fhwa.dot.gov/policyinformation/tables/occupancyfactors/fhwa_pl_19_048.pdf
[31] https://www.nj.gov/education/data/enr/enr19/stat_doc.htm

performed spatial analyses to adjust for demand for commercial vehicles by considering all retail and/or commercial locations (OpenStreetMap supplemented with purchased commercial activity data).

Gasoline and Diesel Breakdown

MJB&A applied IHS Markit and U.S. EPA MOVES data to determine the gasoline and diesel share of VMT by vehicle type. For zip code-level vehicle stocks, IHS Markit vehicle registration data were used as a proxy to apportion VMT by fuel and vehicle type in each respective zip code; EPA MOVES data were used to estimate the gasoline/diesel VMT contribution associated with county- and state-level vehicle stocks.

Total Vehicle Miles Traveled

After making the necessary data adjustments, approximate VMT estimates for each vehicle type by roadway classification and area (state, county, and/or zip code) could be calculated. Table 1 provides a summary breakdown of VMT by vehicle class.

Table 1. Total VMT Included in Analysis

Roadway Type	Million VMT by Roadway				Percent of Roadway VMT			Percent of Total VMT		
	LDV	Bus	M/HDV	Total	LDV	Bus	M/HDV	LDV	Bus	M/HDV
Interstate	1,457	4.3	121.0	1,582	92.1%	0.3%	7.6%	43.9%	0.1%	3.6%
Principal Arterial	413	1.1	21.8	436	94.7%	0.3%	5.0%	12.4%	0.0%	0.7%
Minor Arterial	421	3.1	22.7	447	94.2%	0.7%	5.1%	12.7%	0.1%	0.7%
Major Collector	281	4.1	11.0	296	94.9%	1.4%	3.7%	8.5%	0.1%	0.3%
Minor Collector	198	5.3	10.0	213	92.8%	2.5%	4.7%	6.0%	0.2%	0.3%
Local Roadway	203	3.8	5.9	213	95.4%	1.8%	2.8%	6.1%	0.1%	0.2%
Highway Ramp	79	0.5	5.2	85	93.3%	0.6%	6.1%	2.4%	0.0%	0.2%
Other	47	0.5	0.1	47	98.8%	1.1%	0.2%	1.4%	0.0%	0.0%
Total	**3,099**	**22.8**	**197.6**	**3,320**				**93.4%**	**0.7%**	**6.0%**

Vehicle Emissions

MJB&A used U.S. EPA MOVES model to estimate NOx, CO_2, and $PM_{2.5}$ emission factors by fuel type, vehicle type, and model year. These emission factors (grams per VMT) were directly applied to the modeled VMT for each respective vehicle stock of the zip codes with known registration data (07102, 07105, and 07114 in Essex County; 07202, 07206, and 07208 in Union County) to generate a weighted average emission factor by vehicle type, by zip code. For local roadways with unknown vehicle stock characteristics i.e., outside known zip codes), MOVES emission factors were applied to county-level VMT data to estimate weighted average emission factors by vehicle type in Essex and Union counties. Additionally, weighted emission factors for vehicles on major roadway were calculated using state-level VMT data. As discussed earlier, NJ Transit bus emissions were calculated using emission factors specific to its in-service bus fleet. Further variation deriving from roadway type and location was accounted for by applying emission factors (state, county, or zip code-level traffic) based on the most dominant vehicle stock present on each roadway segment; Table 2 shows the applied emission factor associated with each vehicle type and roadway.

Table 2. Applied Vehicle Stock-Weighted Emission Factors by Vehicle Type and Roadway Type

Class	Type	Roadway Type			
		Major[1]	Collector[2]	Local[3]	Other Local[4]
Light-Duty Vehicles	Motorcycle	State			
	Passenger Car	State	County	Zip	County
	Light-Duty Truck	State	County	Zip	County
Buses	School Bus	State			
	Intercity Bus	State			
	NJ Transit Bus	NJ Transit			
Medium-/Heavy-Duty Vehicles	Single-Unit Truck	State	County	Zip	County
	Combination Truck	State	County	Zip	County

[1] Interstates, U.S./state highways, arterials, and inter-highway ramps/connectors
[2] Major/minor collectors & highway off-ramps
[3] Local roadways within primary zip codes
[4] Local roadways outside primary zip codes

These weighted emission factors were then applied to each applicable vehicle type at all source locations to generate the base roadway emissions inventory. Table 4 provides a breakdown of each roadway emission source that was analyzed.

Table 4. Roadway Emission Sources Included

Class	Vehicle Type	Roadway Subset	Roadway Location
LDV	Motorcycle	All Roadw ays	Study Area
LDV	Passenger Car	Major Highw ays & Arterials	Study Area
LDV	Passenger Car	Collectors & Off-Ramps	Essex County
LDV	Passenger Car	Collectors & Off-Ramps	Union County
LDV	Passenger Car	Local Roadw ays	Essex County (outside know n zips)
LDV	Passenger Car	Local Roadw ays	Union County (outside know n zips)
LDV	Passenger Car	Local Roadw ays	07102 (Essex County)
LDV	Passenger Car	Local Roadw ays	07105 (Essex County)
LDV	Passenger Car	Local Roadw ays	07114 (Essex County)
LDV	Passenger Car	Local Roadw ays	07202 (Union County)
LDV	Passenger Car	Local Roadw ays	07206 (Union County)
LDV	Passenger Car	Local Roadw ays	07208 (Union County)
LDV	Light-Duty Truck	Major Highw ays & Arterials	Study Area
LDV	Light-Duty Truck	Collectors & Off-Ramps	Essex County
LDV	Light-Duty Truck	Collectors & Off-Ramps	Union County
LDV	Light-Duty Truck	Local Roadw ays	Essex County (outside know n zips)
LDV	Light-Duty Truck	Local Roadw ays	Union County (outside know n zips)
LDV	Light-Duty Truck	Local Roadw ays	07102 (Essex County)
LDV	Light-Duty Truck	Local Roadw ays	07105 (Essex County)
LDV	Light-Duty Truck	Local Roadw ays	07114 (Essex County)
LDV	Light-Duty Truck	Local Roadw ays	07202 (Union County)
LDV	Light-Duty Truck	Local Roadw ays	07206 (Union County)
LDV	Light-Duty Truck	Local Roadw ays	07208 (Union County)
Bus	Transit Bus	All Roadw ays	Study Area
Bus	School Bus	All Roadw ays	Study Area
Bus	Intercity Bus	All Roadw ays	Study Area
M/HDV	Single-Unit Truck	Major Highw ays & Arterials	Study Area
M/HDV	Single-Unit Truck	Collectors & Off-Ramps	Essex County
M/HDV	Single-Unit Truck	Collectors & Off-Ramps	Union County
M/HDV	Single-Unit Truck	Local Roadw ays	Essex County (outside know n zips)
M/HDV	Single-Unit Truck	Local Roadw ays	Union County (outside know n zips)
M/HDV	Single-Unit Truck	Local Roadw ays	07102 (Essex County)
M/HDV	Single-Unit Truck	Local Roadw ays	07105 (Essex County)
M/HDV	Single-Unit Truck	Local Roadw ays	07114 (Essex County)
M/HDV	Single-Unit Truck	Local Roadw ays	07202 (Union County)
M/HDV	Single-Unit Truck	Local Roadw ays	07206 (Union County)
M/HDV	Single-Unit Truck	Local Roadw ays	07208 (Union County)
M/HDV	Combination Truck	Major Highw ays & Arterials	Study Area
M/HDV	Combination Truck	Collectors & Off-Ramps	Essex County
M/HDV	Combination Truck	Collectors & Off-Ramps	Union County
M/HDV	Combination Truck	Local Roadw ays	Essex County (outside know n zips)
M/HDV	Combination Truck	Local Roadw ays	Union County (outside know n zips)
M/HDV	Combination Truck	Local Roadw ays	07102 (Essex County)
M/HDV	Combination Truck	Local Roadw ays	07105 (Essex County)
M/HDV	Combination Truck	Local Roadw ays	07114 (Essex County)
M/HDV	Combination Truck	Local Roadw ays	07202 (Union County)
M/HDV	Combination Truck	Local Roadw ays	07206 (Union County)
M/HDV	Combination Truck	Local Roadw ays	07208 (Union County)

Non-Roadway Sources

MJB&A used the most recent PANYNJ emission inventories for most non-roadway emission data and other publicly available data for railyard sources, specifically. Additional data adjustments were made to focus only on emissions that are within the scope of the study area.

MJB&A created detailed geographic boundaries of each non-roadway emission source using satellite imagery. Because the spatial distribution of emissions within these boundaries were not accurately known, all emissions were assumed to be emitted "evenly" throughout the area.

The non-roadway sources included in this analysis are specific to transportation-related emissions and do not provide a comprehensive representation of non-roadway sources within the study area. For instance, emissions associated with electric generating units, construction-related activity, industrial manufacturing, and building energy consumption are not included. In addition, due to the lack of potential emission mitigation options – combined with further complexities of atmospheric dispersion – airplane emissions (landing, taking off, taxiing) are not included.

Ports

MJB&A quantified the NOx, $PM_{2.5}$, and CO_2 emissions associated with select sources located in and around ports. Cargo handling equipment, commercial marine vessels, and on- and off-port idling emissions from heavy-duty diesel vehicles were included in the analysis and were quantified specific to ports within the geographic scope of the study: Port Newark, Port Elizabeth, and Howland Hook (Staten Island).

Cargo Handling Equipment

Emission estimates for cargo handling equipment (CHE) for Port Newark Container Terminal, Port Elizabeth, and Howland Hook Container Terminal were directly obtained from the Port Authority of New York and New Jersey's 2018 Multi-Facility Emissions Inventory.

Commercial Marine Vessels

Idle emissions associated with Commercial Marine Vessels (CMVs) was developed by MJB&A using information and emission factors from the Port Authority of New York and New Jersey's 2018 Multi-Facility Emissions Inventory.

First, MJB&A calculated emissions associated with idling CMVs using PANYNJ's assumptions for total vessel calls, average dwell time by vessel type, as well as average auxiliary engine and boiler load while at dock (kilowatts). The resulting kilowatt-hours (kWh) were then multiplied by engine-specific emissions factors (grams/kWh) to calculate the total grams of each pollutant. This was done for all vessel types in PANYNJ's inventory, shown in Tables 5 & 6.

Table 5. Vessel Counts & Power Load

Vessel Type	Vessel Count	Dwell time (hrs)	Total time (hrs)	Aux Engine Load (kW)	Aux Boiler Load (kW)
Auto Carrier	442	18	7,956	838	314
Bulk Carrier	112	122	13,664	150	125
Container - 1000	195	23	4,485	429	273
Container - 2000	173	17	2,941	1035	361
Container - 3000	71	21	1,491	516	420
Container - 4000	370	23	8,510	1161	477
Container - 5000	167	24	4,008	900	579
Container - 6000	273	26	7,098	990	615
Container - 7000	15	35	525	1372	623
Container - 8000	442	39	17,238	902	668
Container - 9000	76	41	3,116	1037	677
Container - 10000	46	39	1,794	1450	581
Container - 11000	78	38	2,964	1202	790
Container - 13000	114	53	6,042	982	612
Container - 14000	23	50	1,150	1200	287
Cruise Ship	124	11	1,364	8292	1414
General Cargo	39	53	2,067	722	160
RoRo	96	17	1,632	229	259
Tanker - Aframax	4	129	516	724	5030
Tanker - Chemical	79	52	4,108	816	568
Tanker - Panamax	1	1	1	623	3421

Table 6. Emission Factors (g/kWh)

	NOx	PM2.5	CO2
Steam Main and Boiler	2.1	0.7	970
Medium Auxiliary (Tier 0)	14.7	1.2	722
Medium Auxiliary (Tier 1)	13	1.2	722
Medium Auxiliary (Tier 2)	11.2	1.2	722

Because PANYNJ did not disclose the specific emission Tier-level for each CMVs auxiliary engine, MJB&A made the assumption that 5% of CMVs had Tier 0 auxiliary engines, 15% had Tier 1 auxiliary engines and 80% of vessels had Tier 2 auxiliary engines. All CMVs were assumed to have an auxiliary steam boiler onboard.

Next, MJB&A took the total vessel emissions and apportioned them to the specific target area locations. This was performed using PANYNJ's Table 5.6: "Summary of PANYNJ Marine Terminals OGV Emissions by County" from the 2018 Multi Facility Emission Inventory, which provided a breakdown of emissions by New Jersey and New York counties (Table 7).

Table 7. Total Emissions by Vessel Location (short ton)

NJ County	NOx	% NOx	PM	% PM
Bergen	1	*0.0%*	0	*0.0%*
Essex	406	*16.6%*	10	*19.2%*
Hudson	369	*15.1%*	8	*15.4%*
Middlesex	0	*0.0%*	0	*0.0%*
Monmouth	285	*11.7%*	5	*9.6%*
Union	476	*19.5%*	13	*25.0%*

To appropriately split the emissions, it was assumed that all Cruise Ship emissions be assigned to Bayonne, NJ, since this is the only cruise ship terminal in the NY/NJ area. The remaining emissions were then apportioned to the specific locations using Table 7 and the specific percentages of NOx and PM. For pollutant species other than NOx and PM, MJB&A used NOx % as a surrogate.

Heavy-Duty Diesel Vehicles

Emissions for heavy-duty diesel vehicle (HDDV) idling on the various terminals around Newark were obtained from the Port Authority of New York and New Jersey's (PANYNJ's) 2018 Multi-Facility Emissions Inventory. Activity information provided in PANYNJ's report was aggregated to the different terminal types – automobile, container, and warehouses – requiring MJB&A to identify the different terminals at each port location in PANYNJ's territory. PANYNJ's activity data is shown in Table 8.[32]

[32] Table 3.9 in PANYNJ 2018 Multi-Facility Emissions Inventory

Table 8. Port-Related HDDV Activity

Terminal Type	Number Truck Calls (annual)	Distance on Facility (miles)	Average Idle Time Each Visit	Total Distance (miles)	Total Idle Time (hours)	Extended Idling? (>15 mins)
Automobile	43,224	0.25	1.45	10,806	62,675	Yes
Automobile	22,000	0.10	1.56	2,200	34,320	Yes
Automobile	11,000	0.10	1.56	1,100	17,160	Yes
Container	1,870,436	1.50	0.47	2,805,654	869,753	No
Container	1,115,628	1.00	0.54	1,115,628	596,861	No
Container	751,483	1.60	0.39	1,202,373	293,079	No
Container	740,140	1.00	0.33	740,140	244,246	No
Container	239,189	0.10	0.46	23,919	108,831	No
Container	74,368	0.50	0.44	37,184	32,722	No
Warehouse	52,000	0.05	1.75	2,600	31,720	No
Warehouse	40,000	1.50	2.52	60,000	35,200	No
Warehouse	22,500	0.20	0.99	4,500	7,875	No
Warehouse	7,800	1.50	0.23	11,700	624	No
Warehouse	3,120	0.25	0.48	780	530	No
Warehouse	3,120	0.90	1.30	2,808	1,404	No
Warehouse	2,700	0.10	0.98	270	918	No

Using publicly available information, MJB&A mapped the terminal types and their truck calls to their specific locations. Identification of specific terminals used truck calls as an indication of total terminal activity and then researched productivity of terminals in PANYNJ's operational control. Using these factors, MJB&A mapped the locations to the table shown above; results are shown in Table 9.

Table 9. Location of HDDV Calls

Terminal Type	Operator	Location	# of Truck Calls
Auto	BMW	Jersey City	43,224
	Toyota	Newark	22,000
	FAPS	Newark	11,000
Container	APM	Elizabeth	1,870,436
	Maher	Elizabeth	1,115,628
	Global NY	Staten Island	751,483
	Global NJ	Bayonne	740,140
	PNCT	Newark	239,189
	Red Hook	Newark	74,368
Warehouse	East Coast Warehouse	Elizabeth	52,000
	Harbor Freight	Newark	40,000
	TRT Int.	Newark	22,500
	Phoenix Bev	Bayonne	7,800
	Courier	Bayonne	3,120
	ASA Apple	Elizabeth	3,120
	Eastern Warehouse	Newark	2,700

With the terminals mapped to PANYNJ's inventory, idle emissions for on-terminal and off-terminal could be calculated.

For on-terminal, MJB&A relied on PANYNJ's estimate of idle hours by location, as well as gram per hour (g/hr) emission factors for short-term idle and extended idle operation. The resulting emissions by terminal type and location are in Table 10.

Table 10. Estimated HDDV Idling Emissions, On-Terminal

Terminal Type	Operator	Location	Idle Time (hours)			Emissions (MT)		
			Total	Short	Long	NOx	PM2.5	CO2
Auto	BMW	Jersey City	62,675	0	62,675	15.18	0.24	626
	Toyota	New ark	34,320	0	34,320	8.31	0.13	343
	FAPS	New ark	17,160	0	17,160	4.16	0.07	171
Container	APM	Elizabeth	869,753	869,753	0	57.25	4.72	8,260
	Maher	Elizabeth	596,861	596,861	0	39.29	3.24	5,668
	Global NY	Staten Island	293,079	293,079	0	19.29	1.59	2,783
	Global NJ	Bayonne	244,246	244,246	0	16.08	1.33	2,319
	PNCT	New ark	108,831	108,831	0	7.16	0.59	1,034
	Red Hook	New ark	32,722	32,722	0	2.15	0.18	311
Warehouse	East Coast Warehouse	Elizabeth	31,720	31,720	0	2.09	0.17	301
	Harbor Freight	New ark	35,200	35,200	0	2.32	0.19	334
	TRT Int.	New ark	7,875	7,875	0	0.52	0.04	75
	Phoenix Bev	Bayonne	624	624	0	0.04	0.00	6
	Courier	Bayonne	530	530	0	0.03	0.00	5
	ASA Apple	Elizabeth	1,404	1,404	0	0.09	0.01	13
	Eastern Warehouse	New ark	918	918	0	0.06	0.00	9
					Total (in-scope)	**142.7**	**10.9**	**19,301**

Next, MJB&A estimated the off-port idling emissions for HDDVs. Since PANYNJ did not estimate emissions from off-port idling, MJB&A relied on using the total number of truck calls as well as assumptions around local deliveries and average idle time at each location. Table 11 shows the specific assumptions made and the resulting emissions.

Table 11. Estimated HDDV Idling Emissions, Off-Terminal

Terminal Type	Operator	Location	# of Truck Calls	% Local Deliveries	Emissions (MT)		
					NOx	PM2.5	CO2
Auto	BMW	Jersey City	43,224	15%	0.37	0.03	54
	Toyota	New ark	22,000	15%	0.20	0.02	29
	FAPS	New ark	11,000	15%	0.10	0.01	15
Container	APM	Elizabeth	1,870,436	10%	2.03	0.17	292
	Maher	Elizabeth	1,115,628	10%	1.39	0.11	200
	Global NY	Staten Island	751,483	10%	0.68	0.06	97
	Global NJ	Bayonne	740,140	10%	0.56	0.05	81
	PNCT	New ark	239,189	10%	0.25	0.02	37
	Red Hook	New ark	74,368	10%	0.08	0.01	11
Warehouse	East Coast Warehouse	Elizabeth	52,000	50%	1.80	0.15	259
	Harbor Freight	New ark	40,000	50%	1.99	0.16	287
	TRT Int.	New ark	22,500	50%	0.44	0.04	63
	Phoenix Bev	Bayonne	7,800	50%	0.04	0.00	5
	Courier	Bayonne	3,120	50%	0.03	0.00	4
	ASA Apple	Elizabeth	3,120	50%	0.08	0.01	12
	Eastern Warehouse	New ark	2,700	50%	0.05	0.00	8
				Total (in-scope)	**9.1**	**0.7**	**1,310**

As shown, MJB&A assumed specific percentages of total truck calls resulted in local deliveries. Each of those deliveries used PANYNJ's average on-port idle time, but then applied adjustment factors to reflect shorter idle times when off-port.

On-port HDDV idling emissions were aggregated for each port; off-port idling emissions were distributed across idling "hot spots." These hot spots were identified using NJEJA input and satellite imagery (to identify warehouse, commercial activity, and other locations) to determine potential locations for HDDV idling.

Railyards

For the target project area, MJB&A identified the following railyards to include in the project: Oak Island Yard, ExpressRail Elizabeth, ExpressRail Staten Island, South Kearny Yard, Trumbull Yard and Norfolk Southern E-Rail Yard. Since emissions data were not publicly available, MJB&A developed emission estimates for each yard location. It was assumed that yard operation be split into two specific activities – line-hauling and yard switching. Line-hauling is defined as a locomotive pulling a construct of train cars and can take place locally or over long distances. Yard switching operation is when a locomotive is engaged in moving train cars and compiling them into a construct for a line-haul locomotive to pull out of the yard. For locomotive idle emissions, MJB&A assumed that only yard switching locomotives would be idling since line-haul locomotives were assumed to be in operation while in the target project area.

For each yard, it was assumed that both line-haul and yard switchers have a specific load factor, which corresponds to the amount of in-use horsepower used. Below are the average load factors for both line-haul and switch locomotives (Table 12).[33]

Table 12. Average Locomotive Load Factor

Estimated Average Line-Haul Load Factor

Notch	% Full Power	% Operating Time	% Full Power x % Time
DB	2.1%	12.5%	0.003
Idle	0.4%	38.0%	0.002
1	5.0%	6.5%	0.003
2	11.4%	6.5%	0.007
3	23.5%	5.2%	0.012
4	34.3%	4.4%	0.015
5	48.1%	3.8%	0.018
6	64.3%	3.9%	0.025
7	86.6%	3.0%	0.026
8	102.5%	16.2%	0.166
		Avg Load Factor	28%

Estimated Average Switch Load Factor

Notch	% Full Power	% of Operating Time	% Full Power x % Time
DB	2.1%	0.0%	0.000
Idle	0.4%	59.8%	0.002
1	5.0%	12.4%	0.006
2	11.4%	12.3%	0.014
3	23.5%	5.8%	0.014
4	34.3%	3.6%	0.012
5	48.1%	3.6%	0.017
6	64.3%	1.5%	0.010
7	86.6%	0.2%	0.002
8	102.5%	0.8%	0.008
		Avg Load Factor	9%

As shown, line-haul locomotives are assumed to have a load factor of 28%, while switch locomotives have a factor of 9%.

Because an inventory of specific locomotives operating within the target area was not available, MJB&A estimated the distribution of engine emission tier levels for the locomotive population. For line-haul locomotives, the Table 13 was used to apportion locomotive hours.

Table 13. Line-Haul Locomotive % of Inventory

Line-Haul Tier Estimates	
Tier 0	58.1%
Tier 1	9.6%
Tier 2	19.9%
Tier 3	7.3%
Tier 4	5.1%

These apportionment factors were developed based on the U.S. Department of Transportation, Bureau of Transportation Statistics - National Transportation Statistics for Locomotive Tier Levels. Although these represent tier levels at the national level, they were assumed to hold true for the target area.

[33] Taken from EPA's "Locomotive Emission Standards – Regulatory Support Document", April 1998

For switch locomotives, this information was not available since most switch locomotives are old, retired line-haul locomotives not fit for pulling constructs anymore. Therefore, MJB&A assumed that 75% of switch locomotives were unregulated, while 25% had an emissions compliance "Plus" kit added.

As part of the emissions estimation, MJB&A calculated idle emissions for switch locomotives, since a large majority of their time is spent idling. To calculate idle emissions, MJB&A utilized EPA's document "Locomotive Switcher Idling and Idle Control Technology", June 2005 for average idle hours per locomotive as well as the number of gallons burned per hour while idling. Based on the document, MJB&A used an estimate of 4,000 hours of idle operation per locomotive as well as 8.5 gallons of fuel burned per hour of idling. Using gram per gallon emission factors provided by PANYNJ in their 2018 Multi-Facility Emissions Inventory, Table 4.11, as well as locomotive population at each rail yard, MJB&A calculated idle emissions for each location.

Line-haul activity was estimated using 1) the number of constructs leaving the yard per day, 2) the assumption that three locomotives would be needed to pull each construct, 3) each locomotive had 4,000 horsepower, and 4) each construct averaged one hour within the target area. Line-haul constructs per day was obtained from New York Metropolitan Transportation Council (NYMTC).[34] Using this information as well as the average load factor, total annual horsepower-hours were obtained. Horsepower-hours were then multiplied by Tier-specific locomotive emissions factors to obtain total line-haul emissions for each yard.

Switch locomotives located at each railyard were obtained from the Central New Jersey Railfan page.[35] MJB&A estimated the total number of hours each switch locomotive operated, assumed to be 6,000 hours (4,000 hours of idle operation and 2,000 hours of switch operation). Similar to line-haul calculations, the average load factor was used to calculate total annual horsepower-hours, which were then multiplied by Tier-specific locomotive emissions factors to obtain total switch emissions for the yard. Table 14 shows the number of switch locomotives at each railyard.

Table 14. Switch Locomotives Located at Included Railyards

Railyard	Switch Locomotives
Oak Island	5
South Kearny	3
Trumbull	1
NS E-Rail	1
ExpressRail Staten Island[1]	1
ExpressRail Elizabeth[2]	0

[1] No line-haul activity
[2] Yard hostlers and cranes move and place containers for pick-up by line-haul locomotives

Newark International Airport

NOx, $PM_{2.5}$, and CO_2 emission estimates for EWR ground support equipment (GSE) and auxiliary power units (APU) were obtained from the most recent PANYNJ GHG and Criteria Pollutant Emissions Inventory (2017 data).[36]

[34] NYMTC Freight Facilities and System Inventory
[35] http://centralnjfan.railfan.net/njsaa.html
[36] https://www.panynj.gov/content/dam/port-authority/about/environmental-initiatives-/EY2017-Report-Final.pdf

Total Emissions Inventory

This study utilized public resources and data that provided detailed insight into NOx, $PM_{2.5}$, and CO_2 emissions from various roadway and non-roadway sources. However, the quantification of black carbon (BC) – a component of $PM_{2.5}$ resulting from incomplete fuel combustion – has not been externally researched with the same the same level of precision and is largely dependent on engine type, fuel type, and pollution control technologies. Because of the significance of black carbon as a powerful, short-lived climate forcer and dangerous air pollutant, MJB&A performed an additional literature review and subsequent analysis to estimate black carbon emissions associated with each roadway and non-roadway source.

To maintain consistency across emission calculations, MJB&A first utilized assumptions within the U.S. Department of Energy Argonne National Laboratory's Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) 2020 model.[37] GREET 2020 vehicle emission factors and corresponding assumptions are directly informed by U.S. EPA MOVES model and provides a similar breakdown by vehicle type. MJB&A applied black carbon mass fraction assumptions (as a percentage of $PM_{2.5}$, by vehicle type, model year, and fuel type) to modeled $PM_{2.5}$ emissions of roadway vehicles within the analysis scope to create vehicle- and roadway-specific black carbon emission factors consistent with Table 3. Again, NJ Transit bus emissions were calculated using black carbon mass fraction assumptions relevant to its in-use transit bus fleet.

Additional GREET documentation[38] provided black carbon mass fractions associated with select non-roadway sources included in this analysis and were applied directly to $PM_{2.5}$ emissions for commercial marine vessels and cargo handling equipment at ports and auxiliary power units (if applicable) at EWR. Port-related heavy-duty diesel vehicle idling emissions were calculated using heavy-duty truck black carbon factors formed during the analysis of roadway sources. Because heavy-duty vehicle black carbon emission factors have historically been used as a surrogate for locomotive emission factors, MJB&A used characteristics of the switch locomotive inventory and line-haul activity of each included railyard to determine the most applicable black carbon emission factors (based primarily on heavy-duty vehicle emission factors associated with model years of relevant locomotives).

Table 3 provides a summary of the black carbon mass fractions applied to each emission source.

Table 3. Approximate Black Carbon Mass Fractions*

	Source		BC (% of $PM_{2.5}$)
Roadway Sources	Light-duty vehicles		~20%
	Buses		35-60%
	Medium-/heavy-duty vehicles		40-65%
Non-Roadway Sources	Railyard	Switch locomotives	~55%
		Line-Haul locomotives	~20%
	Port	Commercial marine vessels	15%
		Cargo handling equipment	56%
		Heavy-duty diesel vehicles	~56%
	Airport	Ground support equipment	~40%
		Auxiliary power units	31%
	Idling		55-60%

* BC mass fraction ranges correspond with mass fractions applied to different subsets of vehicle types (e.g., transit vs. school bus, state composite M/HDV fleet vs. local fleet, etc.)

37 https://greet.es.anl.gov/greet.models
38 https://greet.es.anl.gov/publication-black-carbon-greet

The calculated and modeled emissions for all roadway and non-roadway sources are shown in Table 15.

Table 15. Roadway and Non-Roadway Emissions in Study Area

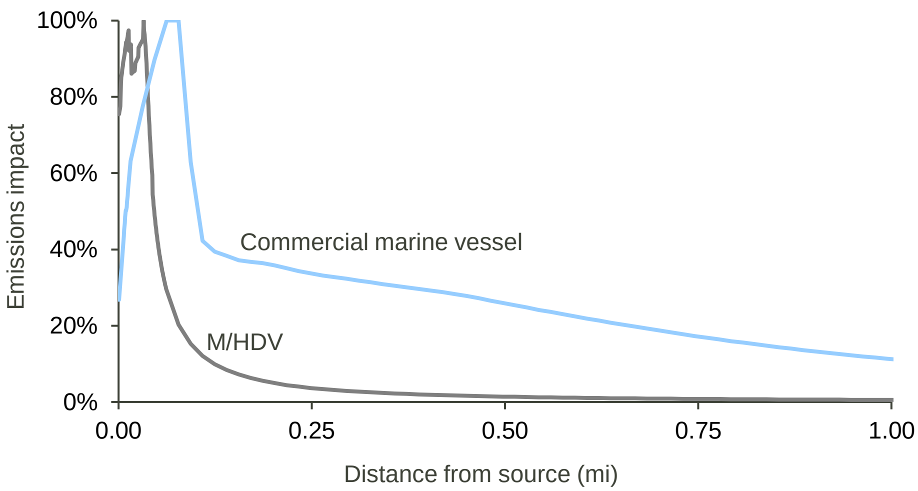
	Type		Emissions (metric ton, MT)				Percent of Total Emissions			
			NOx	$PM_{2.5}$	BC	CO_2	NOx	$PM_{2.5}$	BC	CO_2
Roadway Sources	Light-Duty Vehicle	Motorcycle	5	0.5	0.0	1,313	0.1%	0.3%	0.1%	0.1%
		Passenger cars	524	17.6	3.9	778,962	14.4%	9.9%	5.7%	51.1%
		Light trucks	219	5.1	1.0	234,119	6.0%	2.8%	1.4%	15.4%
		Total LDV	747	23.2	4.9	1,014,394	20.6%	13.0%	7.2%	66.6%
	Bus	Transit buses	27	0.6	0.2	13,769	0.7%	0.4%	0.3%	0.9%
		School buses	46	2.1	0.8	10,553	1.3%	1.2%	1.2%	0.7%
		Intercity buses	19	0.6	0.4	4,012	0.5%	0.4%	0.6%	0.3%
		Total Bus	91	3.4	1.4	28,334	2.5%	1.9%	2.1%	1.9%
	Medium-/Heavy-Duty Vehicle	Medium-duty vehicles	98	4.7	2.0	65,254	2.7%	2.7%	3.0%	4.3%
		Heavy-duty trucks	771	20.9	10.8	173,185	21.2%	11.8%	15.7%	11.4%
		Total M/HDV	869	25.7	12.8	238,439	23.9%	14.4%	18.7%	15.6%
	Total (roadway sources)		**1,707**	**52.2**	**19.1**	**1,281,167**	**47.0%**	**29.4%**	**27.9%**	**84.1%**
Non-Roadway Sources	Railyard	Oak Island	113	4.6	2.3	7,224	3.1%	2.6%	3.4%	0.5%
		ExpressRail Elizabeth	25	0.8	0.2	2,450	0.7%	0.4%	0.2%	0.2%
		ExpressRail Staten Island	10	0.4	0.2	576	0.3%	0.2%	0.3%	0.0%
		South Kearny	83	2.9	1.0	6,979	2.3%	1.7%	1.5%	0.5%
		Trumbull	38	1.3	0.4	526	1.0%	0.7%	0.6%	0.0%
		NS E-Rail	27	0.9	0.3	2,210	0.7%	0.5%	0.5%	0.1%
		Total Railyard	295	11.0	4.4	19,965	8.1%	6.2%	6.5%	1.3%
	Port	Port Newark	142	12.7	3.5	26,056	3.9%	7.1%	5.1%	1.7%
		Port Elizabeth	515	46.0	18.5	97,687	14.2%	25.8%	27.1%	6.4%
		Howland Hook	167	19.0	4.2	20,653	4.6%	10.7%	6.1%	1.4%
		Total Port	824	77.6	26.2	144,396	22.7%	43.7%	38.3%	9.5%
	Airport	Newark Int'l Airport	801	36.3	18.2	77,172	22.0%	20.4%	26.7%	5.1%
	Idling	Off-port, study area	8	0.7	0.4	1,189	0.2%	0.4%	0.6%	0.1%
	Total (non-roadway sources)		**1,928**	**125.6**	**49.3**	**242,722**	**53.0%**	**70.6%**	**72.1%**	**15.9%**
All Sources	**Total Inventory**		**3,636**	**177.8**	**68.4**	**1,523,889**				

Emissions Dispersion and Exposure Analysis

To determine the level of emissions exposure experienced at any given location or area within the study area, MJB&A performed a dispersion analysis that modeled the movement of emissions corresponding with engine type and wind direction. Note that this analysis is NOT equivalent to an atmospheric dispersion model used to develop air quality standards by producing outputs in terms of mass of pollutant per unit of air volume (e.g., micrograms per cubic meter). While the resources and inputs required to perform such an analysis were outside of the scope of this study, this simplified dispersion analysis does account for important factors that affect pollutant dispersion, namely fuel source-specific emission impact curves and wind direction. Ultimately, the output of this analysis ("exposure value") should be interpreted as an indexed value that indicates the relative impact and contribution of emission sources to pollution at a location. These indexed values may be viewed as proportional to full dispersion outputs (micrograms per cubic meter), but should not be compared against each other.

The base emissions inventory provided the magnitude and spatial attributes of these emissions. MJB&A utilized U.S. EPA AERSCREEN modeling to create engine-specific[39] emission dispersion curves to estimate the relative impact of emissions downwind (one-directional) from the source. Figure 3 shows an example of the generic dispersion curves for medium- and heavy-duty vehicles and commercial marine vessels.

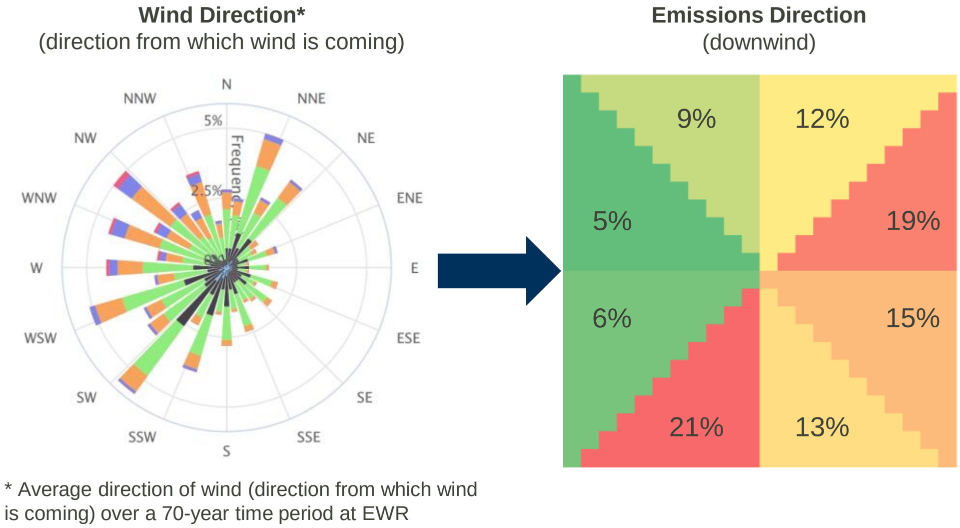
Figure 3. U.S. EPA AERSCREEN Impact Curves



These one-directional impact curves were then converted to account for all horizontal dispersion (e.g., "circular" dispersion from the emission source) and combined with average historic wind data (collected at EWR) to create wind-adjusted, 360-degree impact functions. Figure 4 shows a representation of the applied wind data.

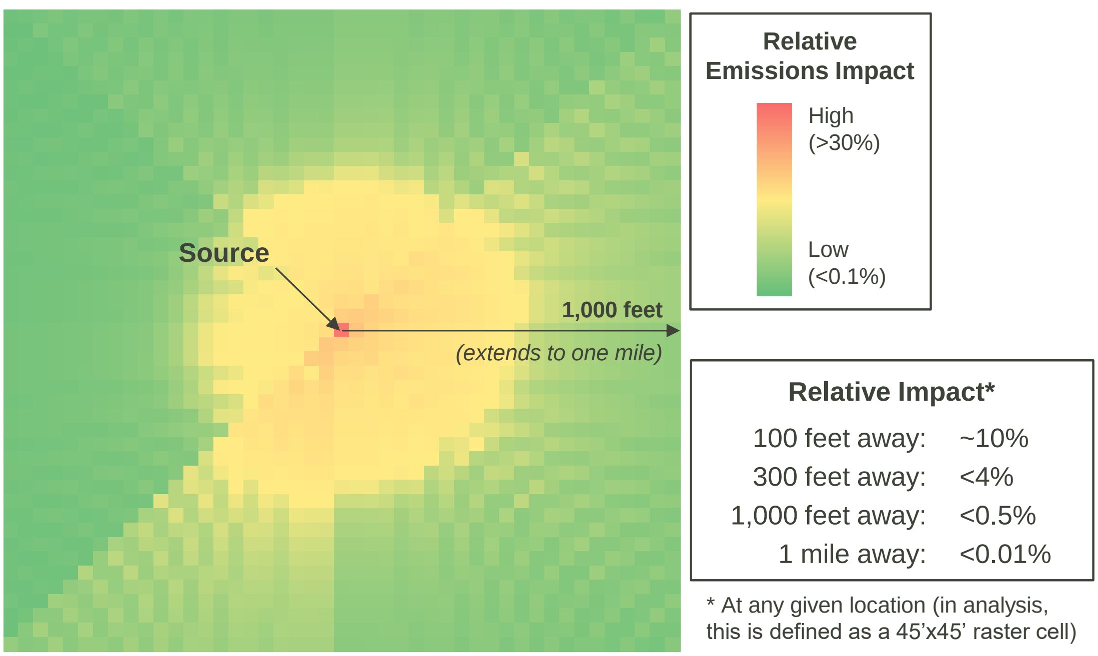
[39] Generic dispersion curves were modeled for light-duty vehicles, medium-/heavy-duty vehicles, commercial marine vessels, port cargo handling equipment, and locomotives

Figure 4. Wind Direction in Newark



MJB&A translated these adjusted impact functions to matrices that were then spatially applied to each individual emission type and location/source (i.e., all raster cells of all 75 emission sources). Similar to the base activity/emissions inventory, this method provides emissions exposure data related to any and all emission source(s) included in the analysis. Figure 5 shows an example of the applied emissions impact curve matrix for commercial marine vessels out to 1,000 feet (note that the analysis uses matrices that extend to one mile from the emissions source).

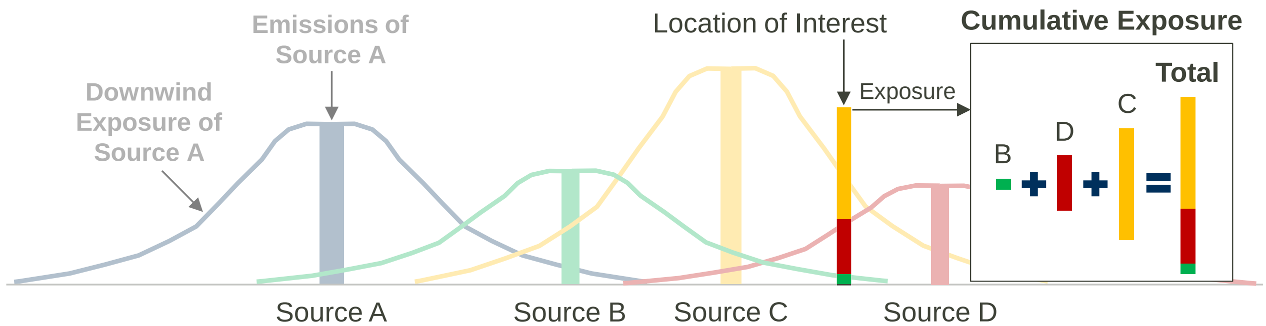
Figure 5. Emissions Impact Dispersion Matrix for Commercial Marine Vessels (out to 1,000 feet)



Result Output and Aggregation

After performing the dispersion analysis on all emission sources, the results were aggregated in a variety of ways to characterize a location's exposure to emissions. To approximate the total cumulative exposure at a specific location (denoted as a raster cell), the exposure value of each emissions source at that location was summed; to approximate the total cumulative exposure in a defined area, the exposure value of all raster cells of each emissions source in that area was summed and normalized by an area metric (e.g., exposure per raster cell or exposure per unit area). Figure 6 shows an illustrative example of how total cumulative exposure values were calculated.

Figure 6. Illustration of Cumulative Exposure Calculation



Appendix B contains summary total cumulative emissions exposure maps for NOx, $PM_{2.5}$, and black carbon.

Evaluating Policy Opportunities and Transportation Electrification

MJB&A developed a spreadsheet tool that models emissions reductions from a 2018 baseline and evaluates the impact of electrification of vehicles operating within study area. Emissions exposure can be compared across specific locations and defined areas, and electrification scenarios can be applied to all emission sources captured by the analysis (roadway and non-roadway sources). Appendix C provides outputs of this tool for the eight receptor sites provided by NJEJA.

<u>Electricity Generation to Meet Demand of Electrified Transportation</u>

To account for the increase in electricity generation required to meet the demand of electrified vehicles and other sources, MJB&A performed a preliminary analysis to estimate the potential net emissions impact of transportation electrification in the region. This analysis did not attempt to model emission dispersion from electricity generating units (EGUs). MJB&A looked at nine natural gas-fired power plants in the area (identified by NJEJA) and PJM East emission rates to create "worst-case" emission scenarios for CO_2, NOx, and $PM_{2.5}$. Projected PJM East 2020 CO_2 and NOx emission rates (emissions per electricity output) were ultimately used along with $PM_{2.5}$ emission rates that were estimated using a combination of nearby EGU data and region-specific emission factors. MJB&A referenced EIA Form-923 (data year 2018)[40] for electricity generation (MWh), fuel type, and combustion technology associated with each nearby EGU; fuel- and technology-specific MWh was then multiplied by emission factors pulled from the GREET 2020 model.[41]

Together with the internal combustion engine emission factors used for different vehicles in this analysis, a comparison could be made between the emissions per mile traveled for an electric vehicle, the average

[40] https://www.eia.gov/electricity/data/eia923/
[41] https://greet.es.anl.gov/files/electricity-13

vehicle on the road, and a new internal combustion engine. Tables 16 and 17 provide summary emissions data used to create Figure 7.

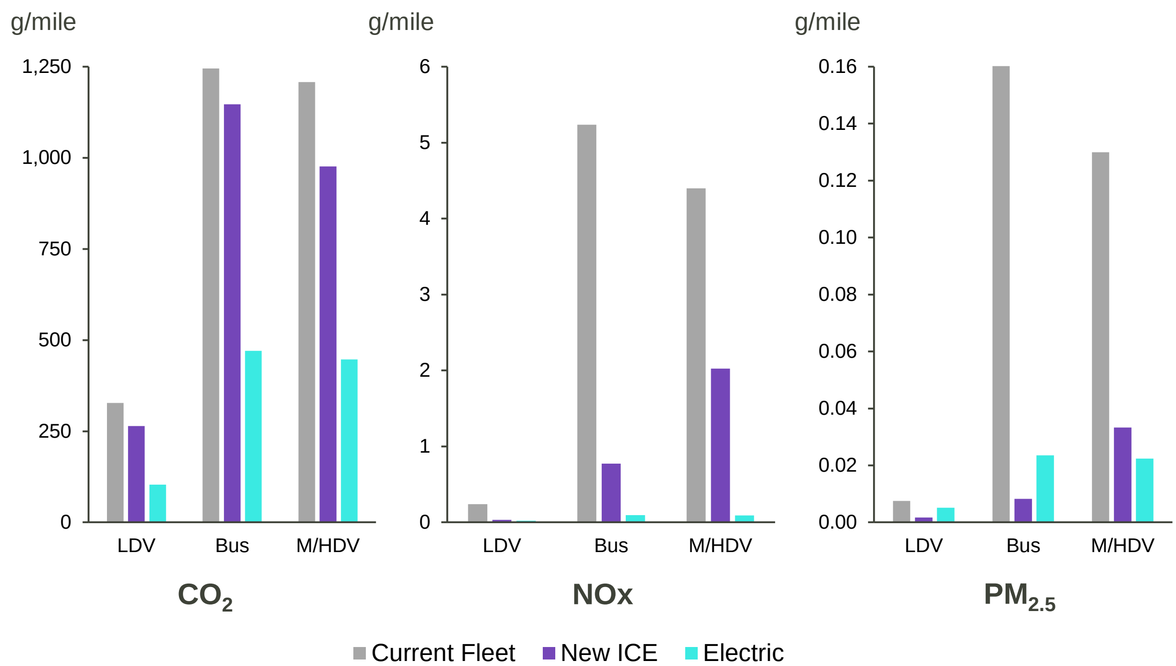
Table 16. Estimated $PM_{2.5}$ Emission, nearby EGU

		PM2.5	
	2018 MWh	MT	g/kWh
Bayonne Energy Center	772,116	30.42	0.0394
Bergen Generating Station	3,949,317	60.20	0.0152
Elmw ood Park Pow er	3,204	0.05	0.0150
Linden Cogen Plant	5,546,963	83.94	0.0151
New ark Bay Cogeneration	31,743	0.48	0.0150
New ark Energy Center	4,512,325	67.68	0.0150
PSEG Essex Generating Station	1,243	0.05	0.0387
PSEG Kearny Generating Station	297,182	11.29	0.0380
PSEG Linden Generating Station	5,265,587	81.18	0.0154
Total	**20,379,680**	**335.29**	**0.0165**

Table 17. Applied Emission Factors

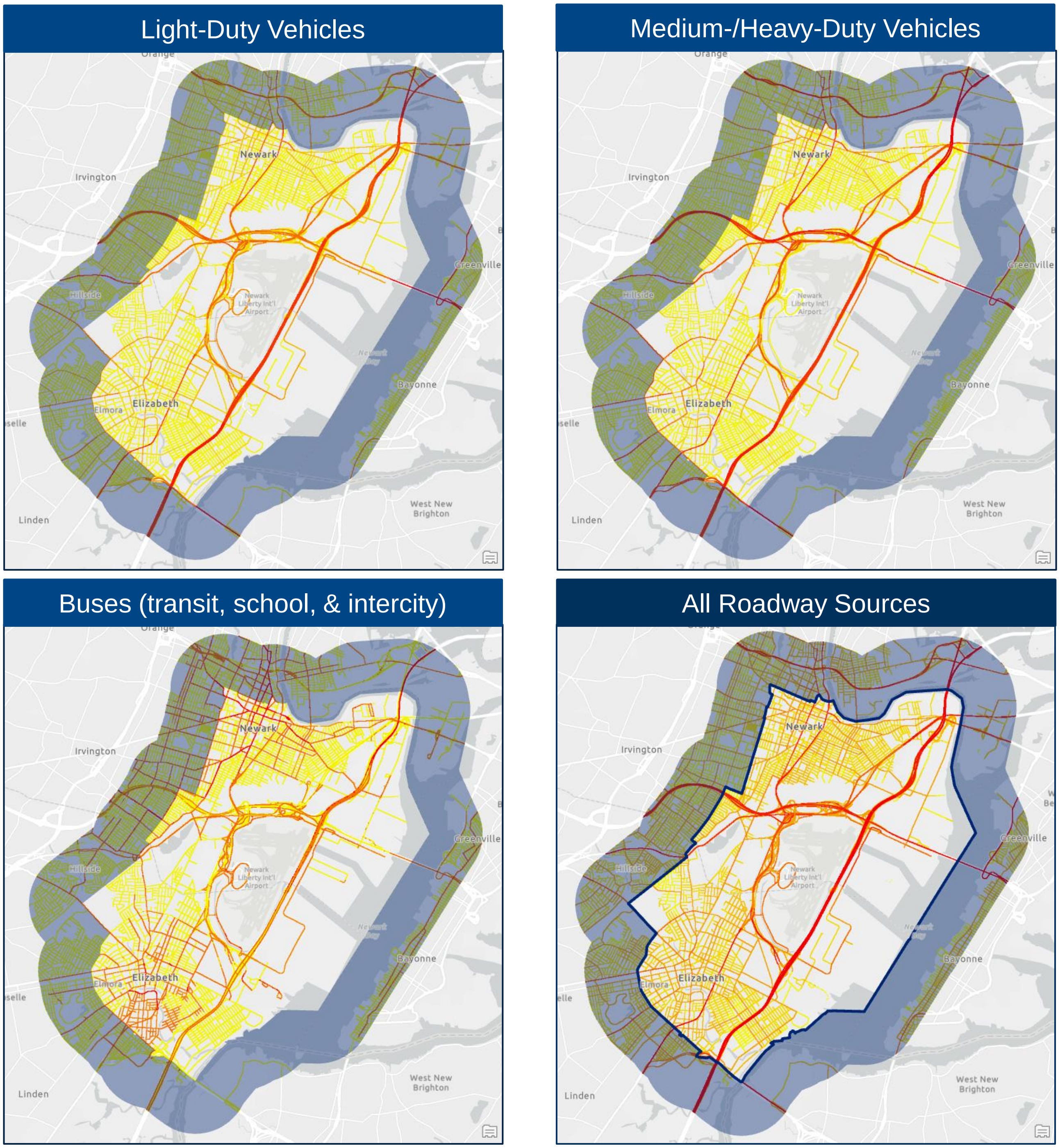
Applied Emission Rate	
	g/kWh
CO2	725
NOx	0.1481
PM2.5	0.0165

Figure 7. Emissions Comparison of Vehicles, by type



Appendix B: Summary NOx, $PM_{2.5}$, and Black Carbon Maps

Roadway Vehicle Traffic (AADT)



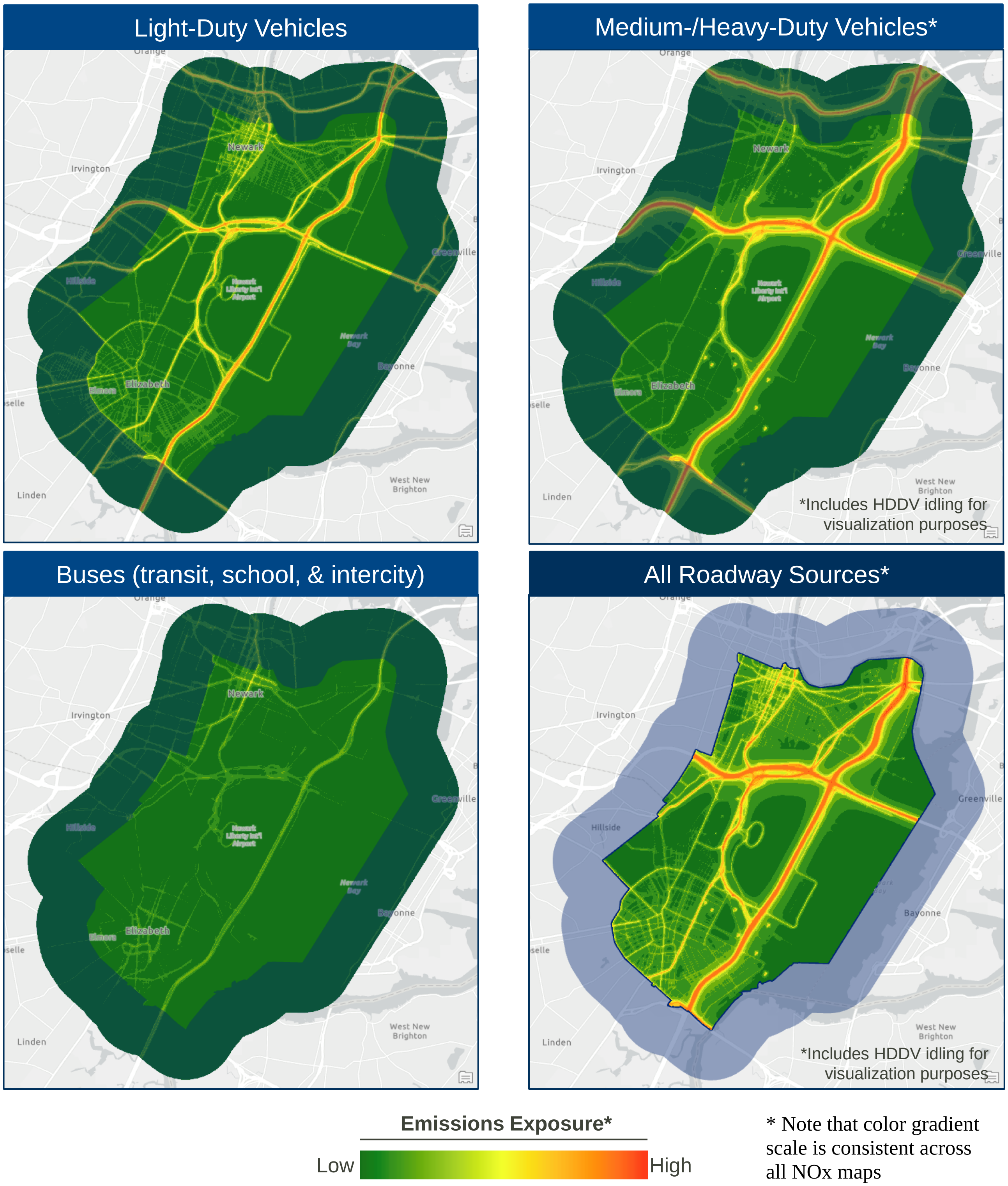
Traffic Volume (AADT)*

Low — High

*Color gradients are specific to vehicle class and should not be compared across maps

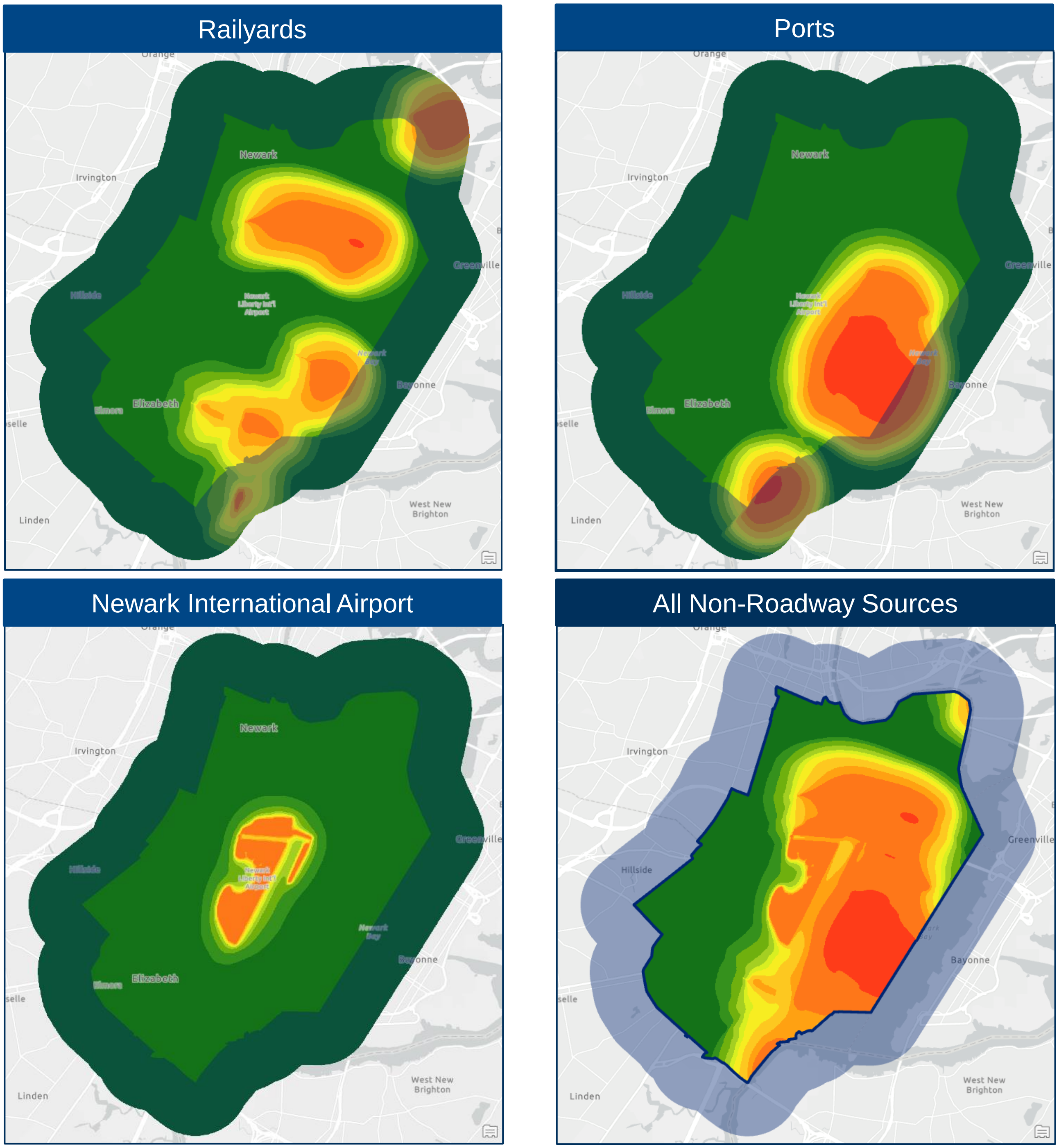
NOx Emissions Exposure

Roadway NOx Emissions Dispersion



* Note that color gradient scale is consistent across all NOx maps

Non-Roadway NOx Emissions Dispersion

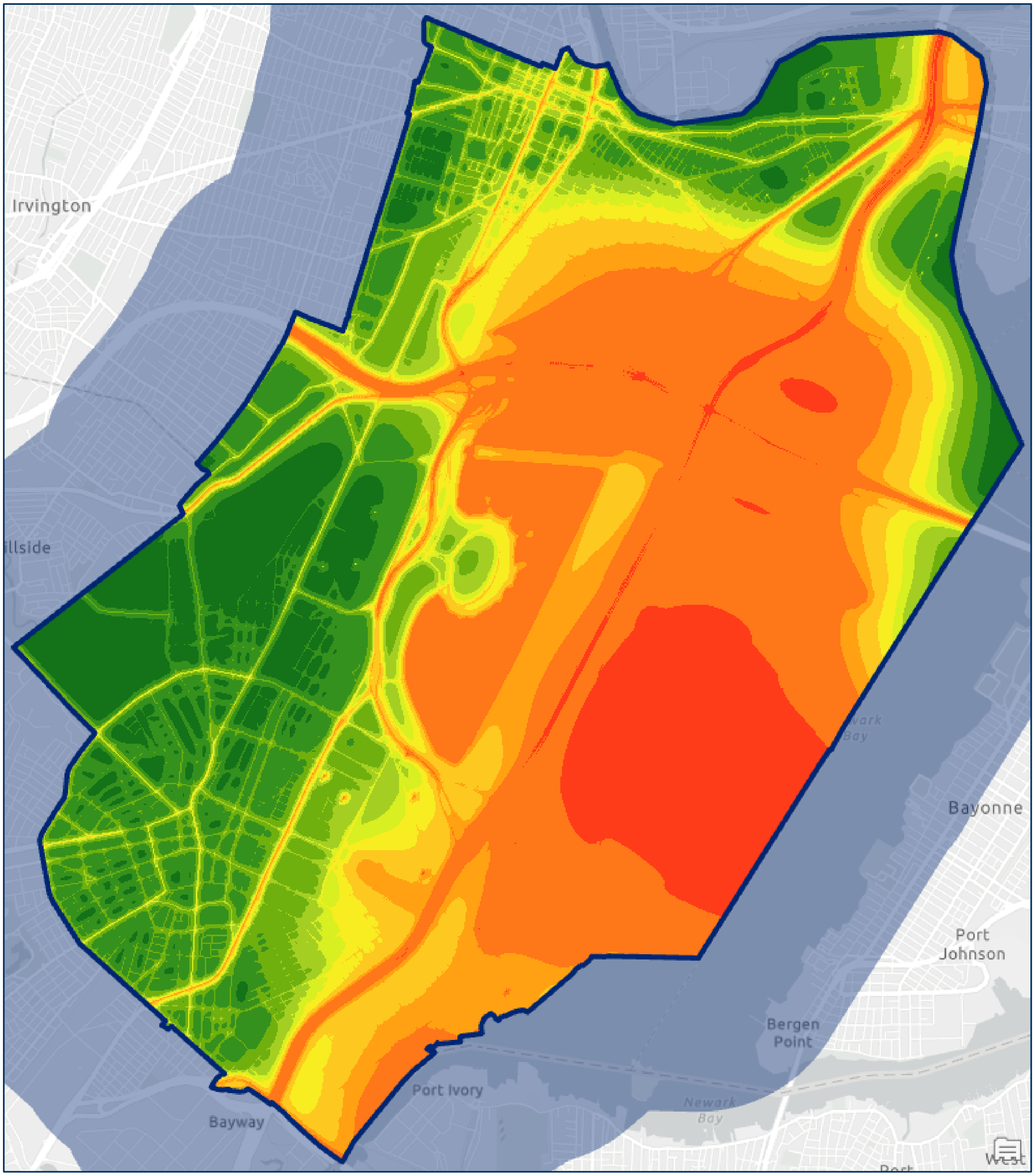


Emissions Exposure*

Low High

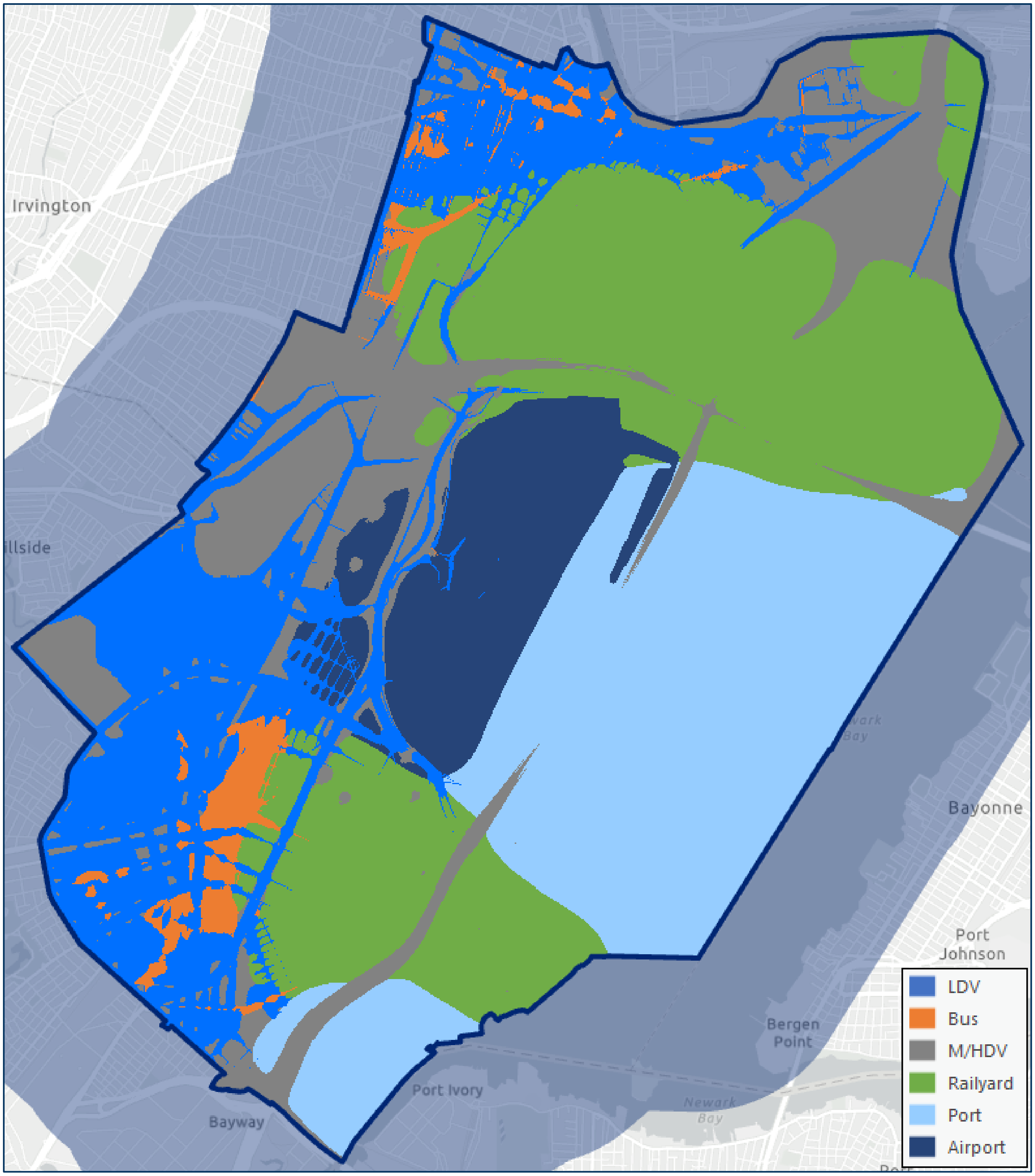
* Note that color gradient scale is consistent across all NOx maps

Total NOx Emissions Exposure (all sources)



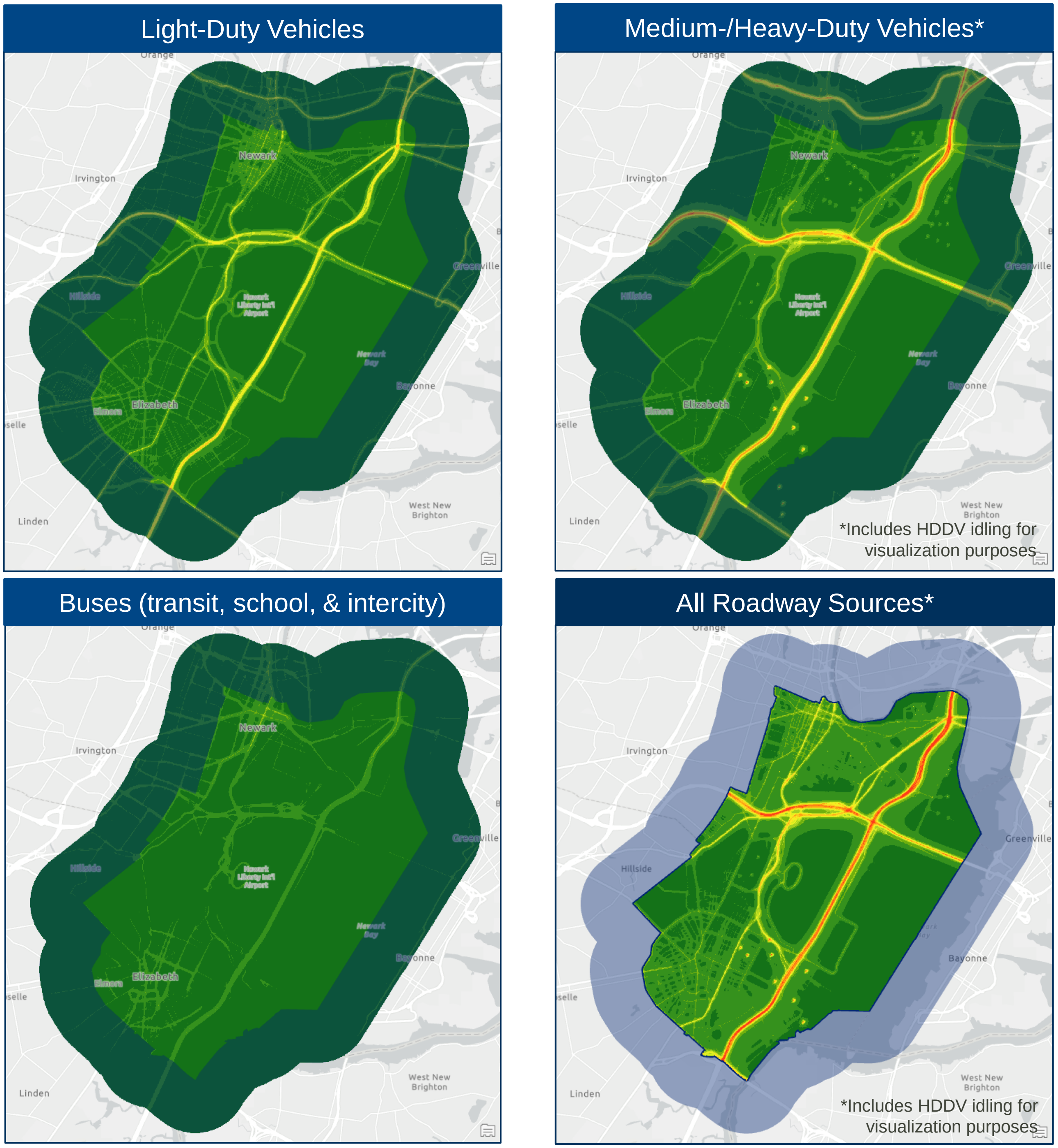
* Note that color gradient scale is consistent across all NOx maps

Largest Source Contributor to NOx Exposure



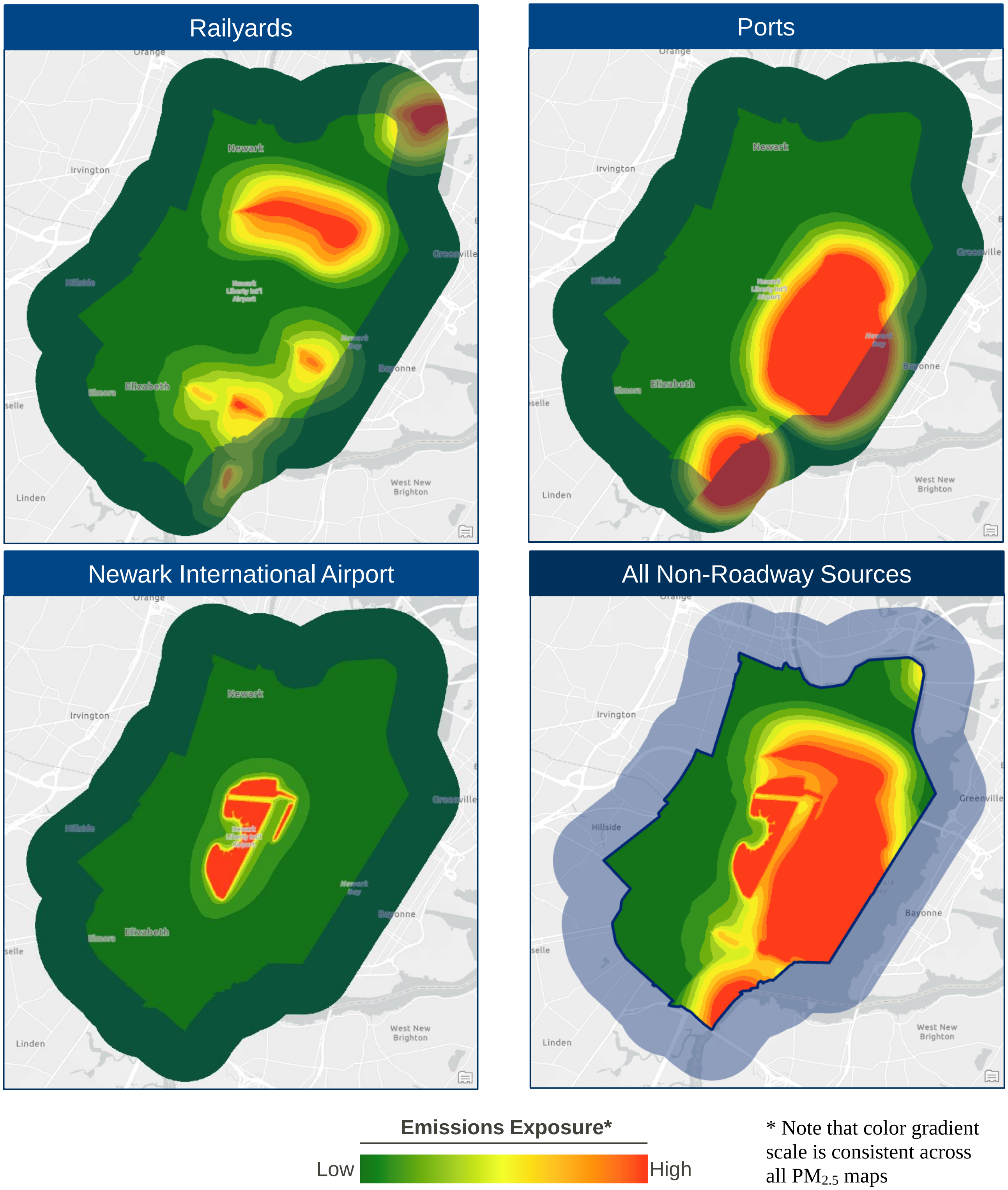
$PM_{2.5}$ Emissions Exposure

Roadway $PM_{2.5}$ Emissions Dispersion



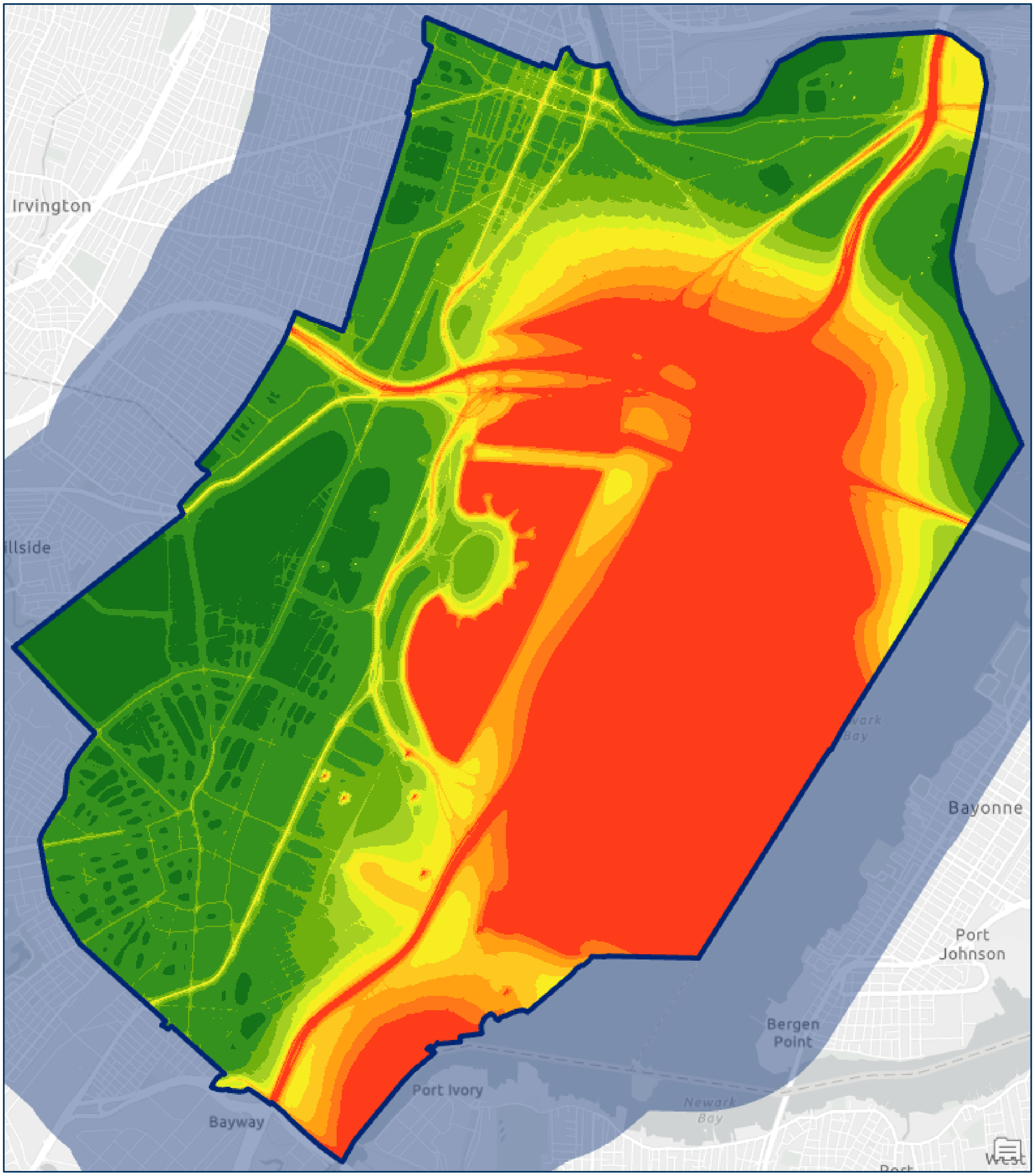
* Note that color gradient scale is consistent across all $PM_{2.5}$ maps

Non-Roadway $PM_{2.5}$ Emissions Dispersion



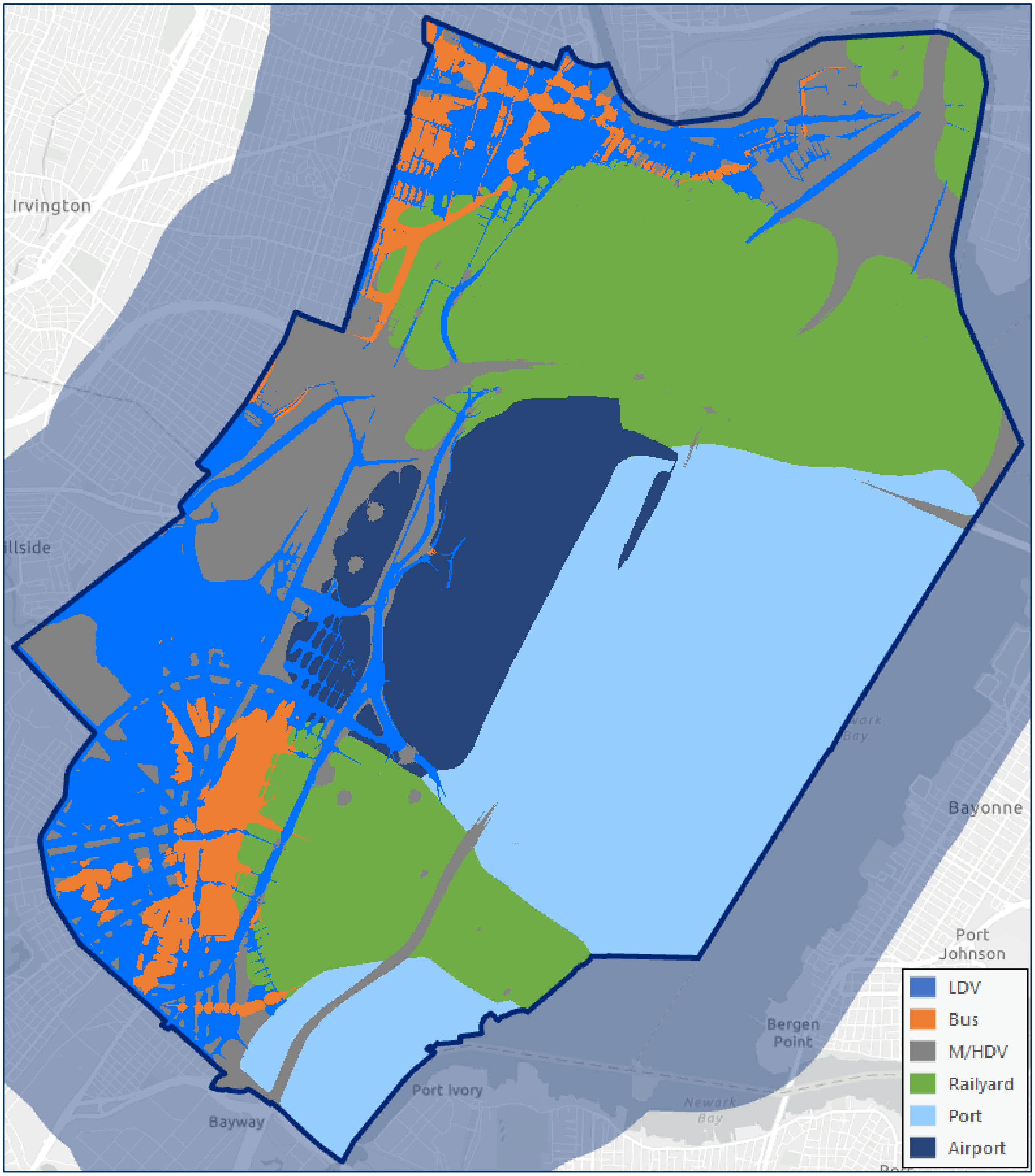
* Note that color gradient scale is consistent across all $PM_{2.5}$ maps

Total $PM_{2.5}$ Emissions Exposure (all sources)



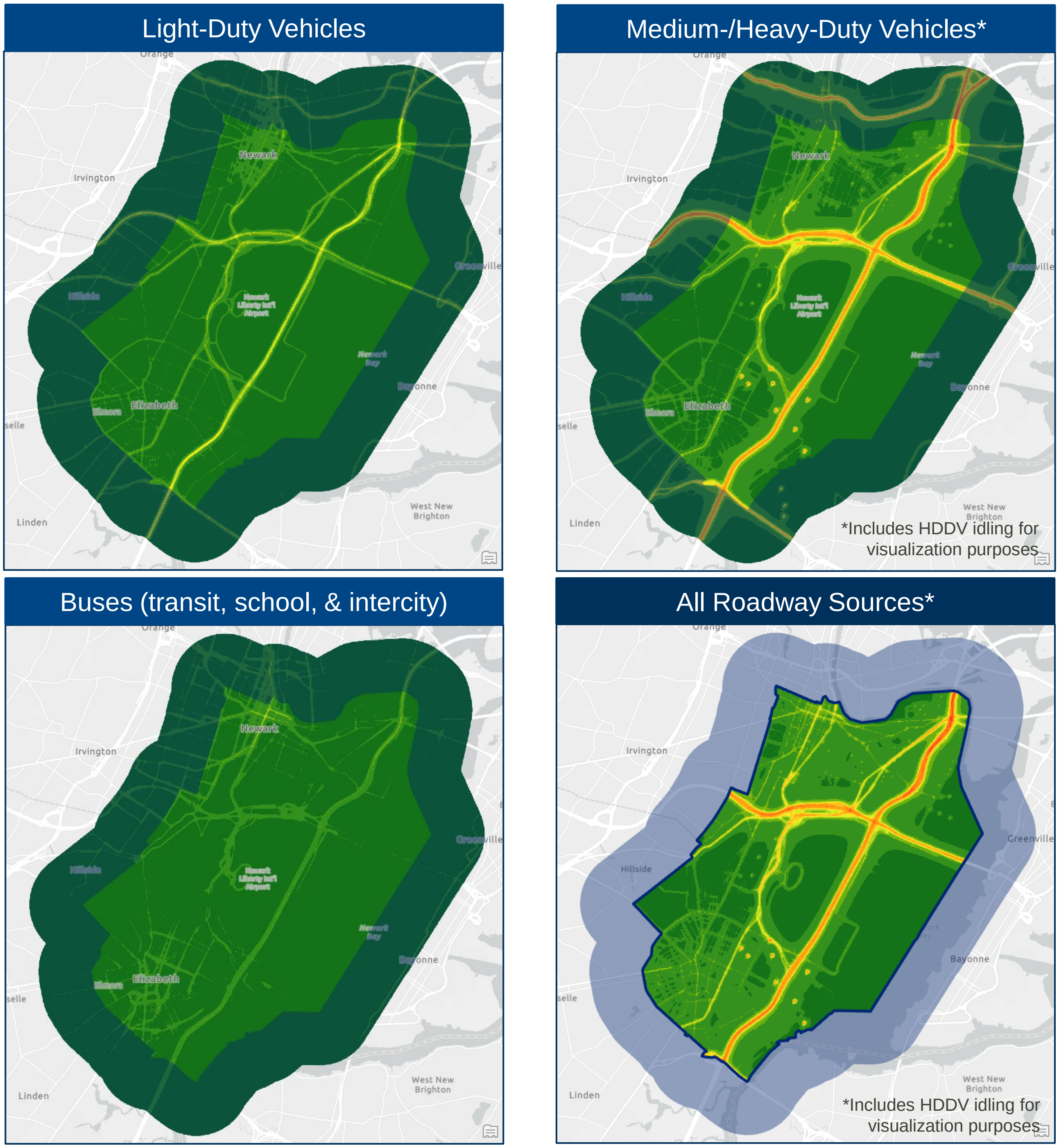
* Note that color gradient scale is consistent across all $PM_{2.5}$ maps

Largest Source Contributor to $PM_{2.5}$ Exposure



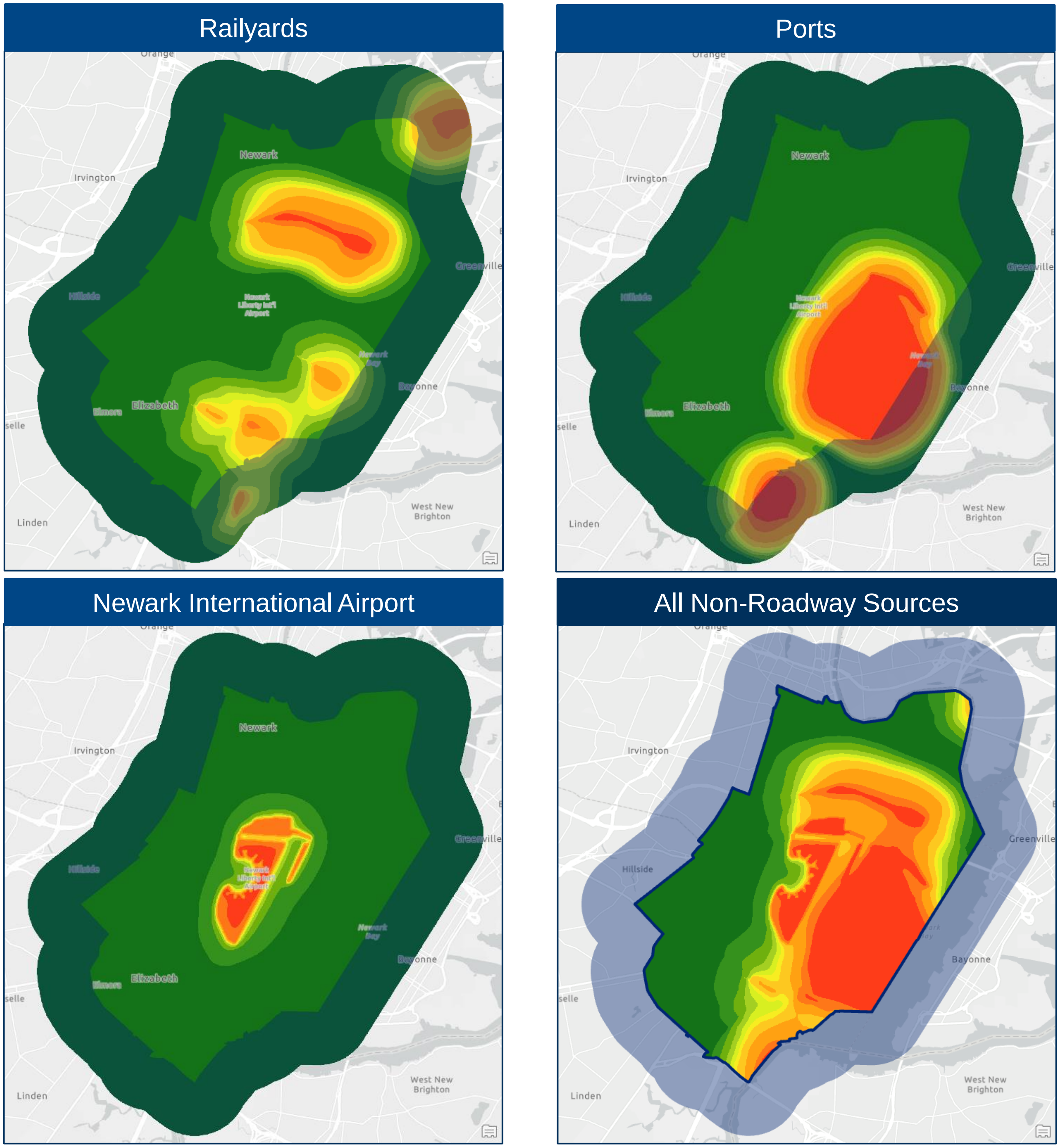
Black Carbon Emissions Exposure

Roadway Black Carbon Emissions Dispersion



* Note that color gradient scale is consistent across all black carbon maps

Non-Roadway Black Carbon Emissions Dispersion

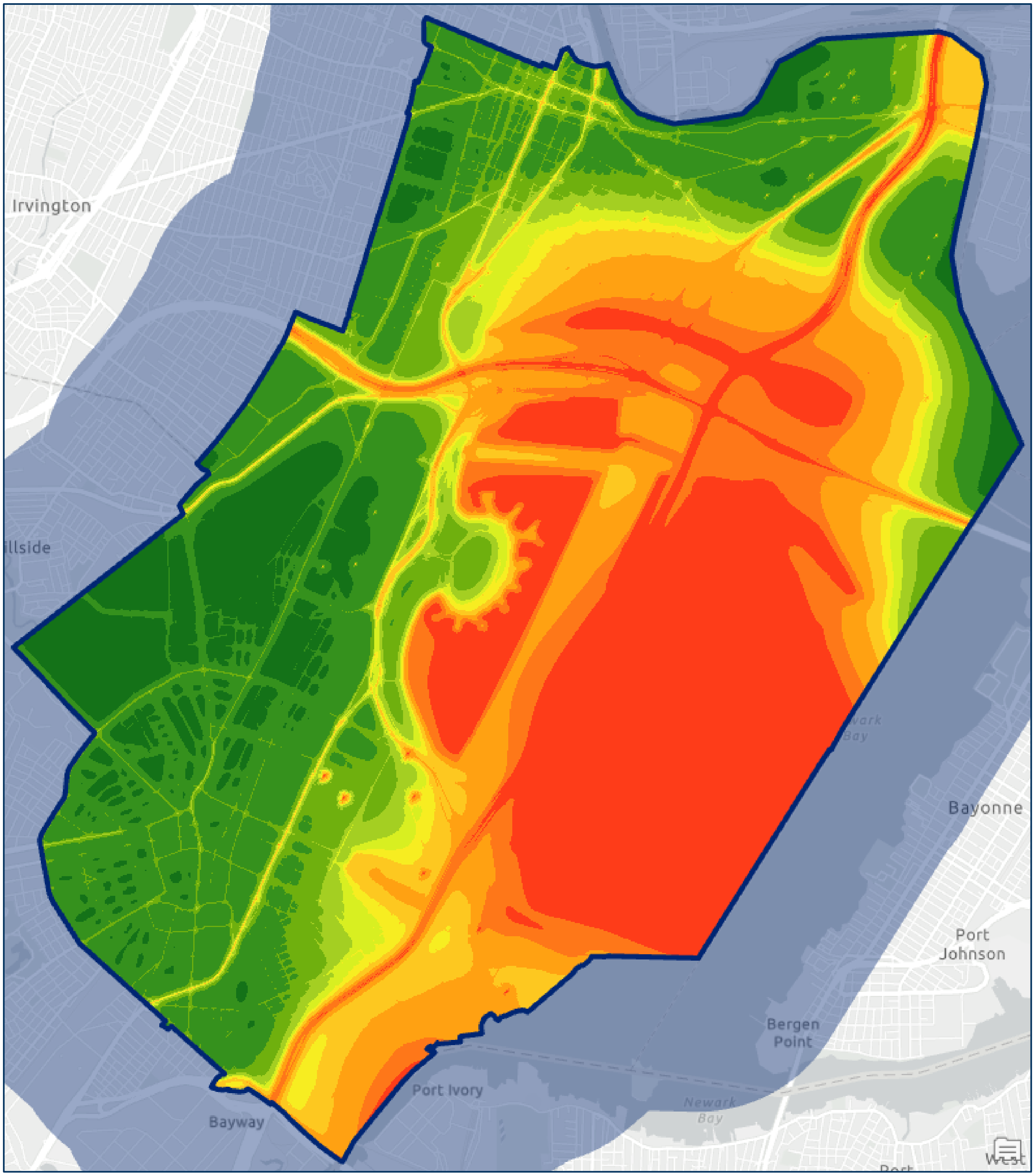


Emissions Exposure*

Low — High

* Note that color gradient scale is consistent across all black carbon maps

Total Black Carbon Emissions Exposure (all sources)

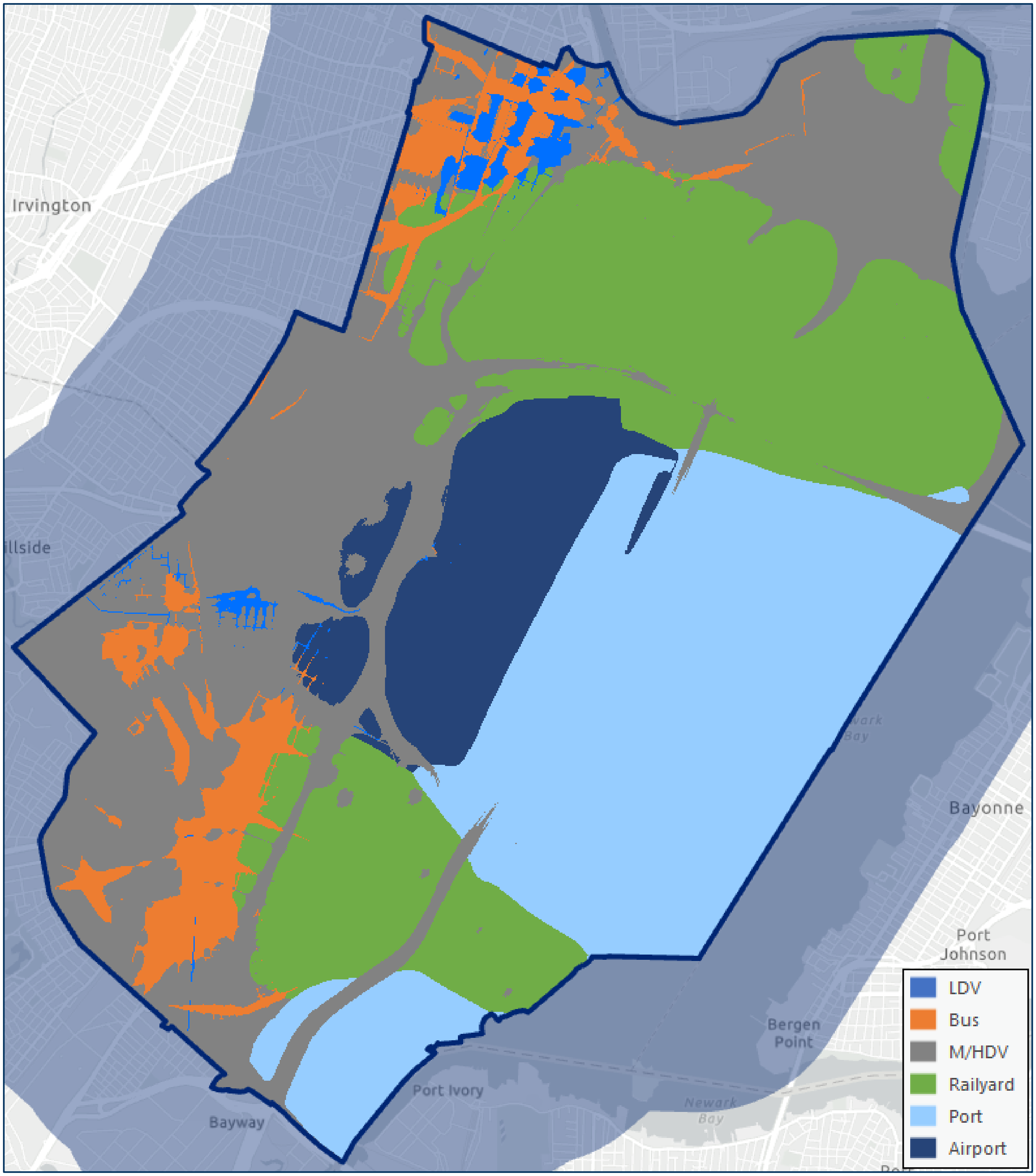


Emissions Exposure*

Low High

* Note that color gradient scale is consistent across all black carbon maps

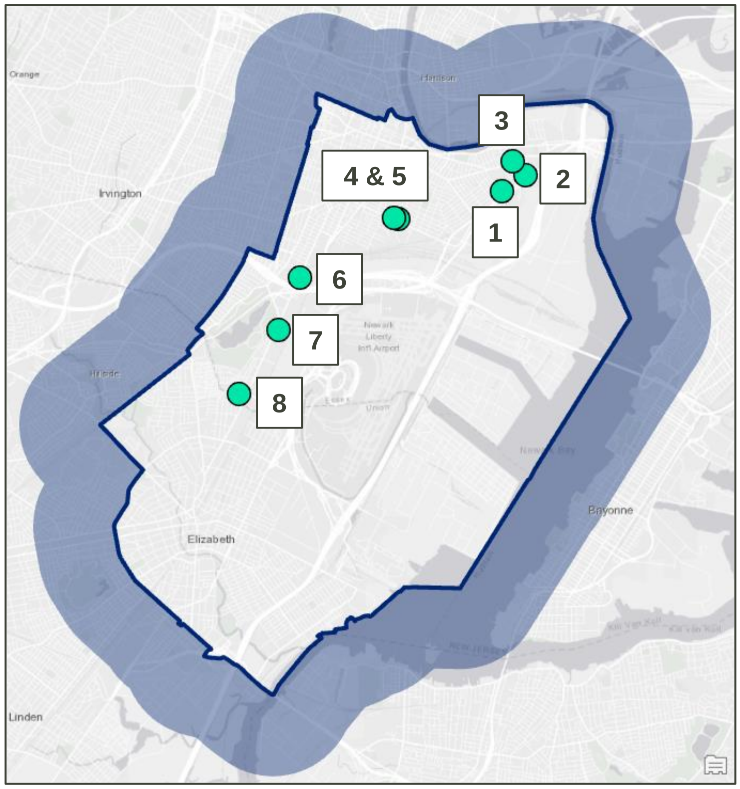
Largest Source Contributor to Black Carbon Exposure



Appendix C: Receptor Site Analysis

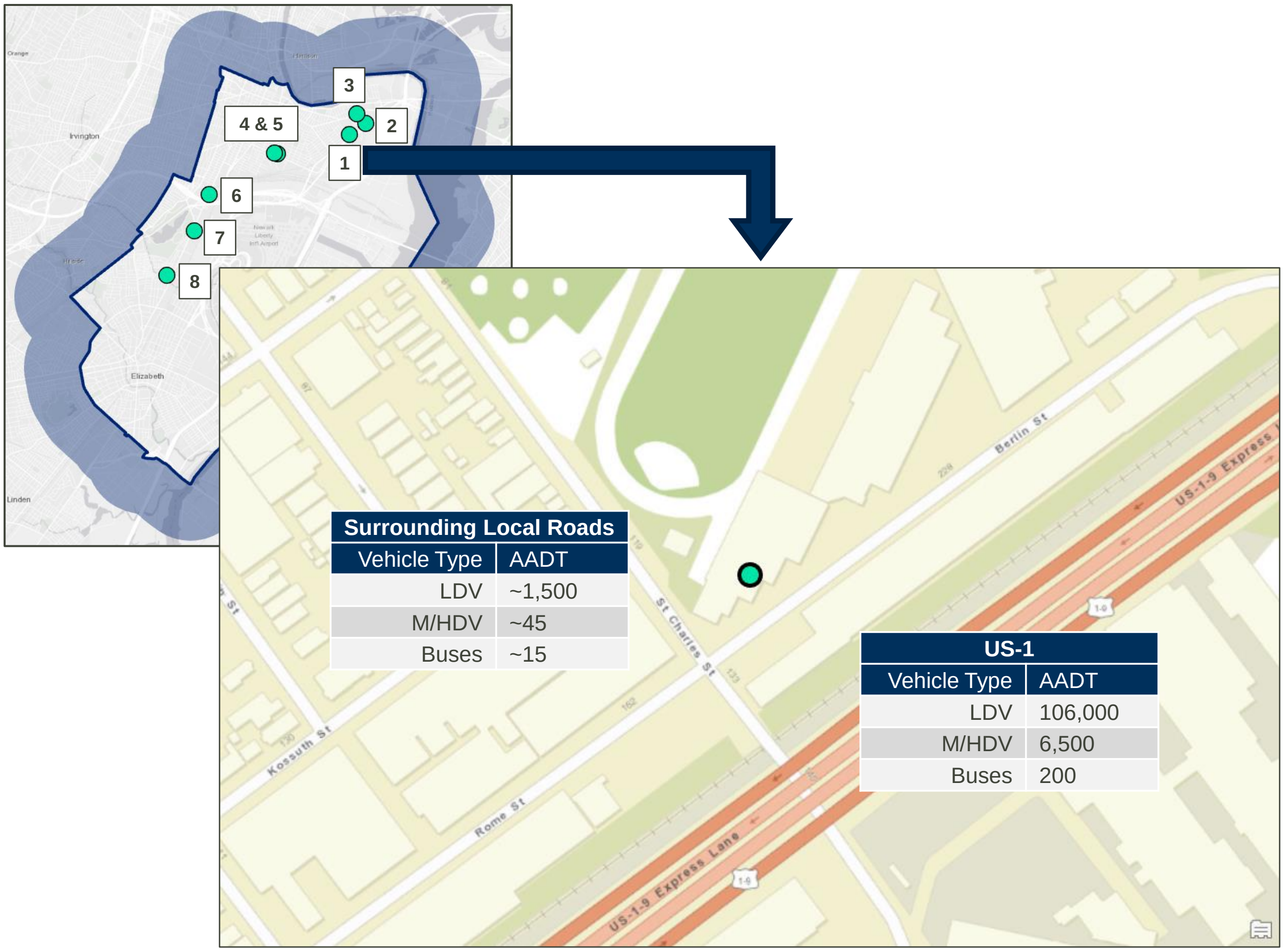
Figure 7 NJEJA Receptor Sites

Receptor Sites



Detailed analysis was performed at each of the eight receptor sites provided by NJEJA. This analysis consisted of determining the emission sources responsible for emission exposure (NOx, $PM_{2.5}$, and black carbon) experienced at each location. In addition, MJB&A applied a potential electrification scenario to view the associated impact on local exposure. This electrification scenario assumed 25 percent of all buses (transit, school, and intercity) and medium- and heavy-duty vehicles (single-unit and combination trucks) were electric. For purposes of this analysis, the emissions exposure for which these electric buses/trucks are responsible (through electricity generation emissions) was assumed to be negligible. The following figures show a close-up map of each location, relevant nearby roadway information, and the emissions exposure experienced in the reference (no electrification) and electrification scenarios.

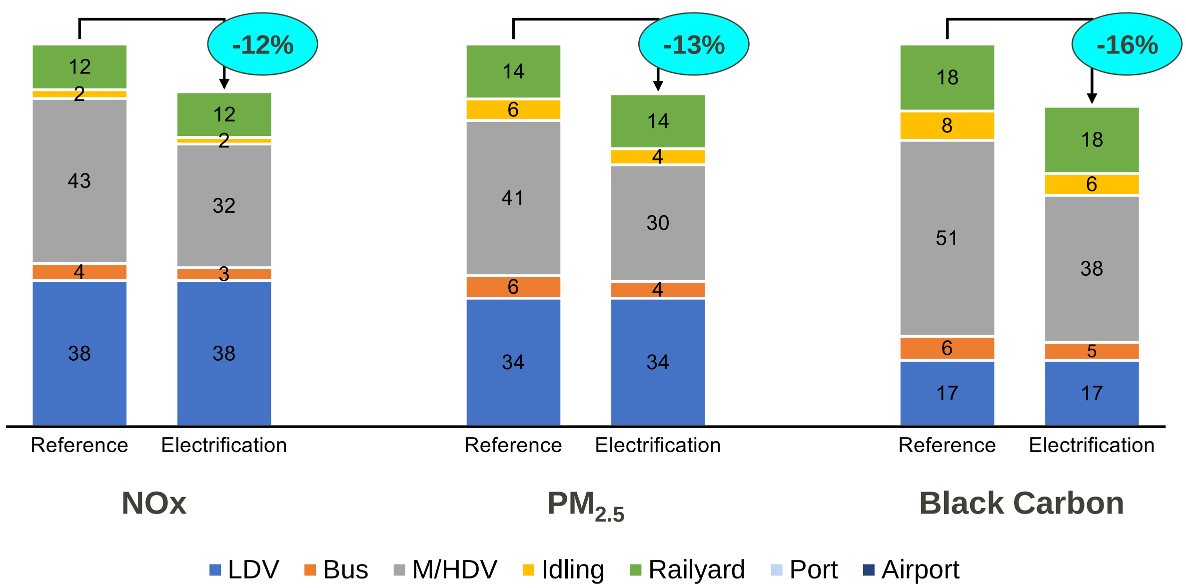
1. **Ironbound Aquatic Center**



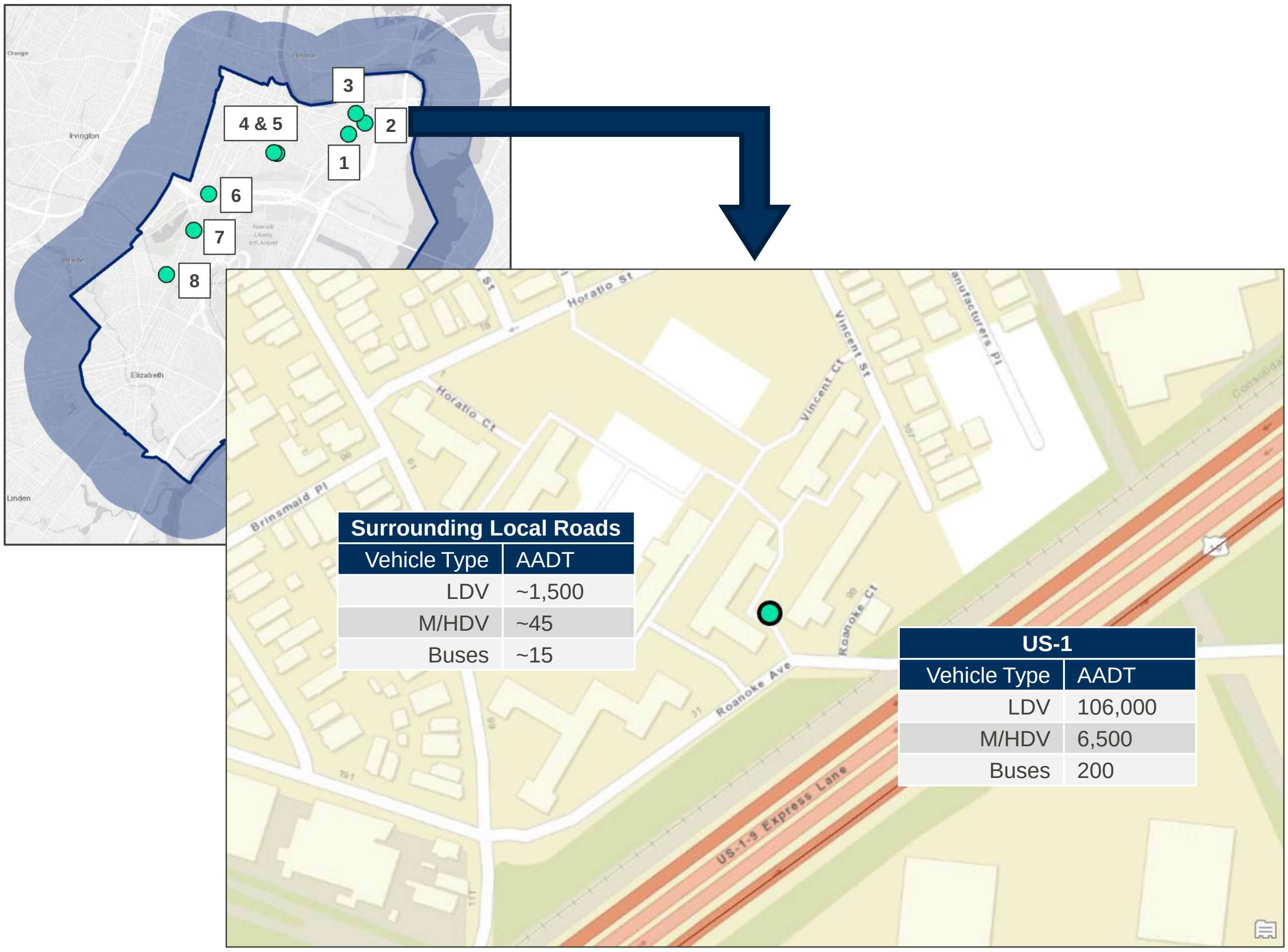
Surrounding Local Roads	
Vehicle Type	AADT
LDV	~1,500
M/HDV	~45
Buses	~15

US-1	
Vehicle Type	AADT
LDV	106,000
M/HDV	6,500
Buses	200

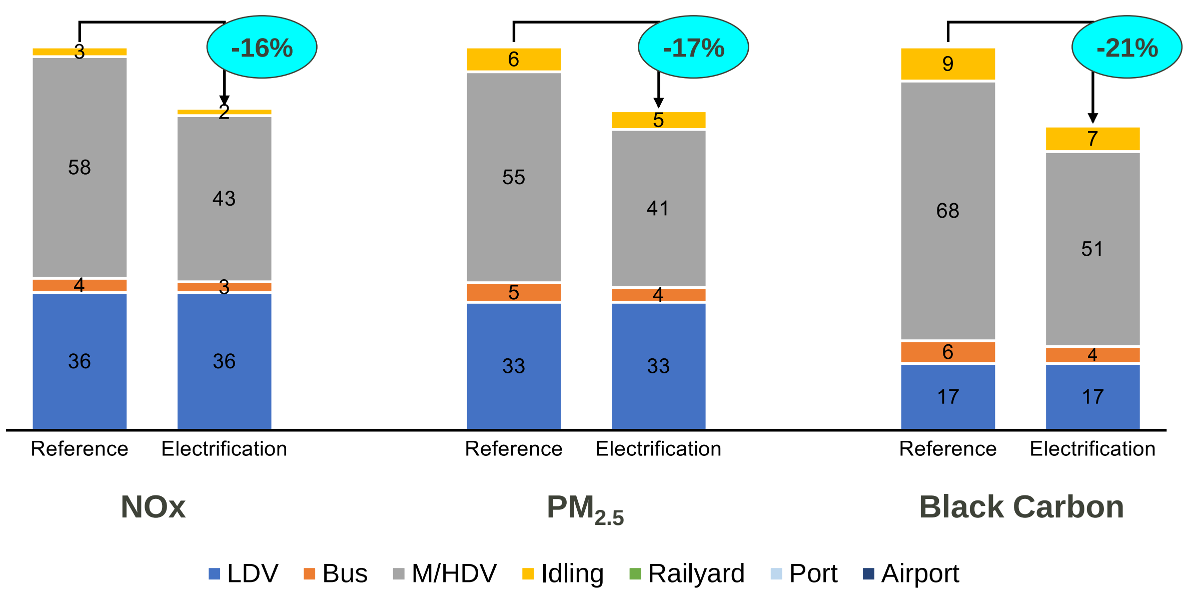
Emissions Exposure and Effect of Electrification



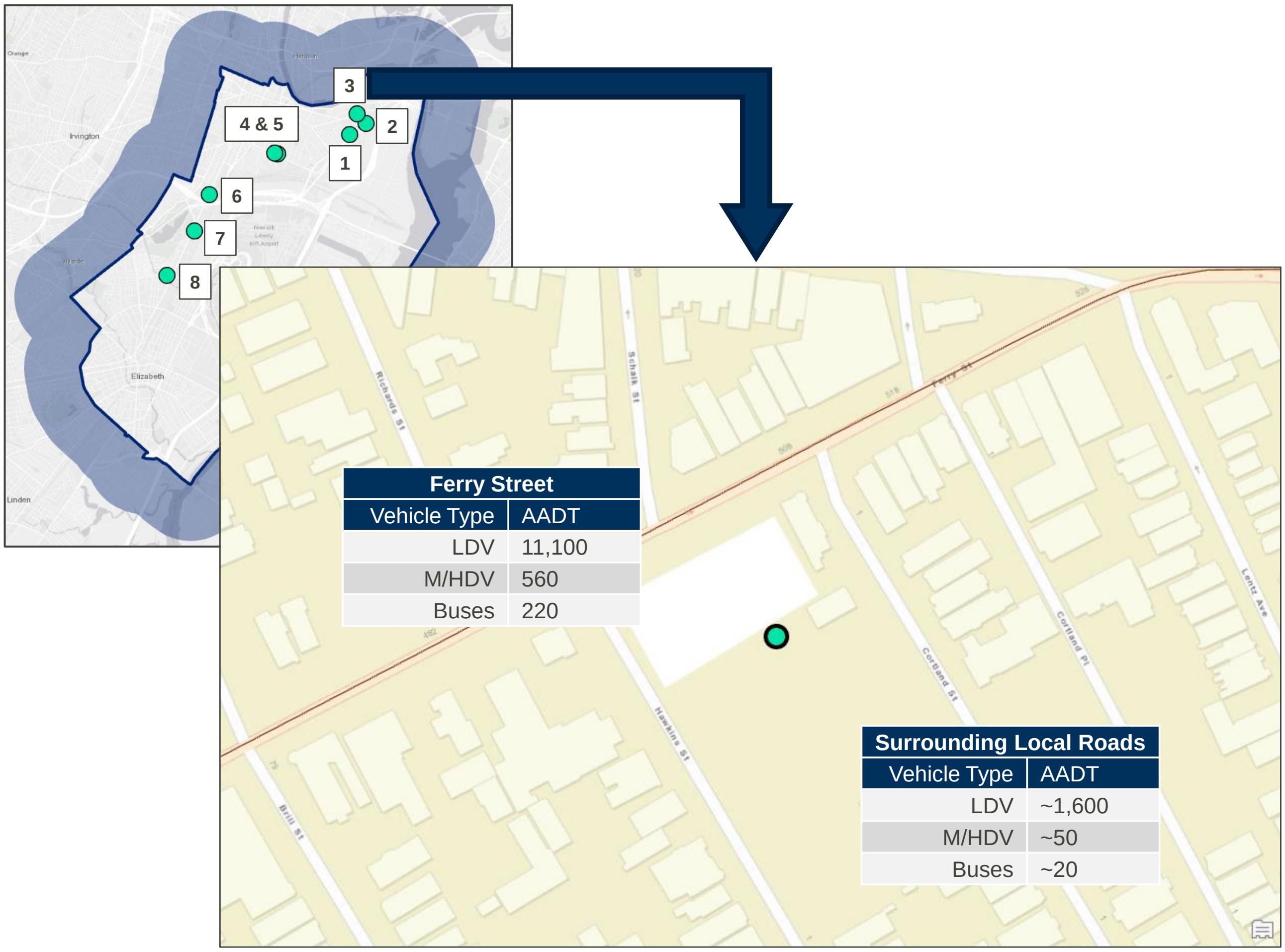
2. Newark Pre-School Council



Emissions Exposure and Effect of Electrification



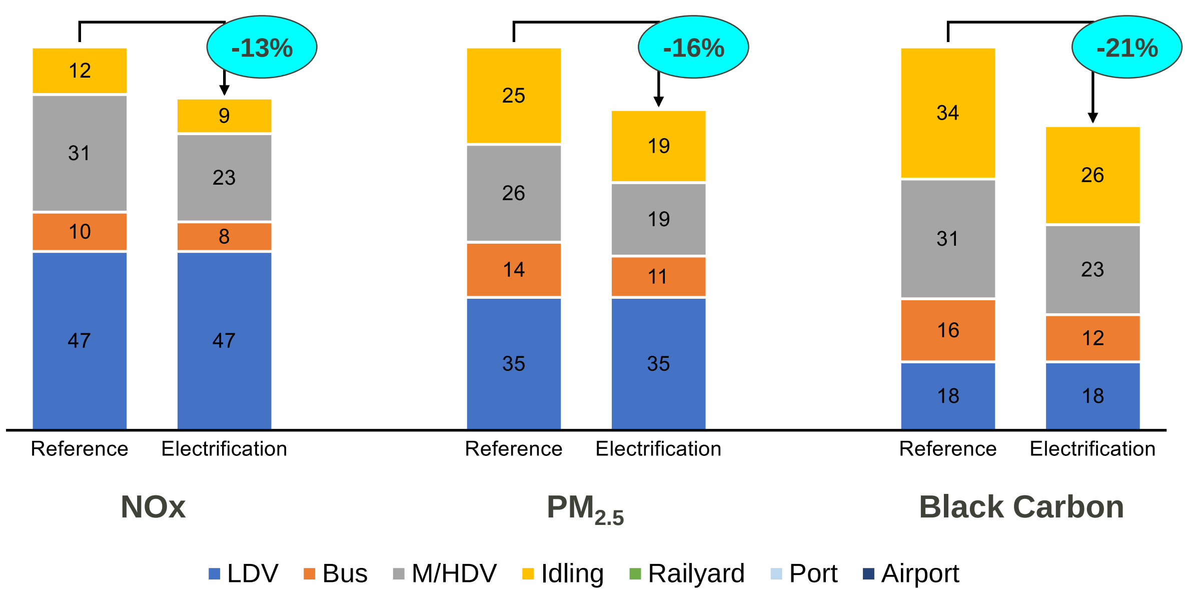
3. Hawkins Street Elementary School



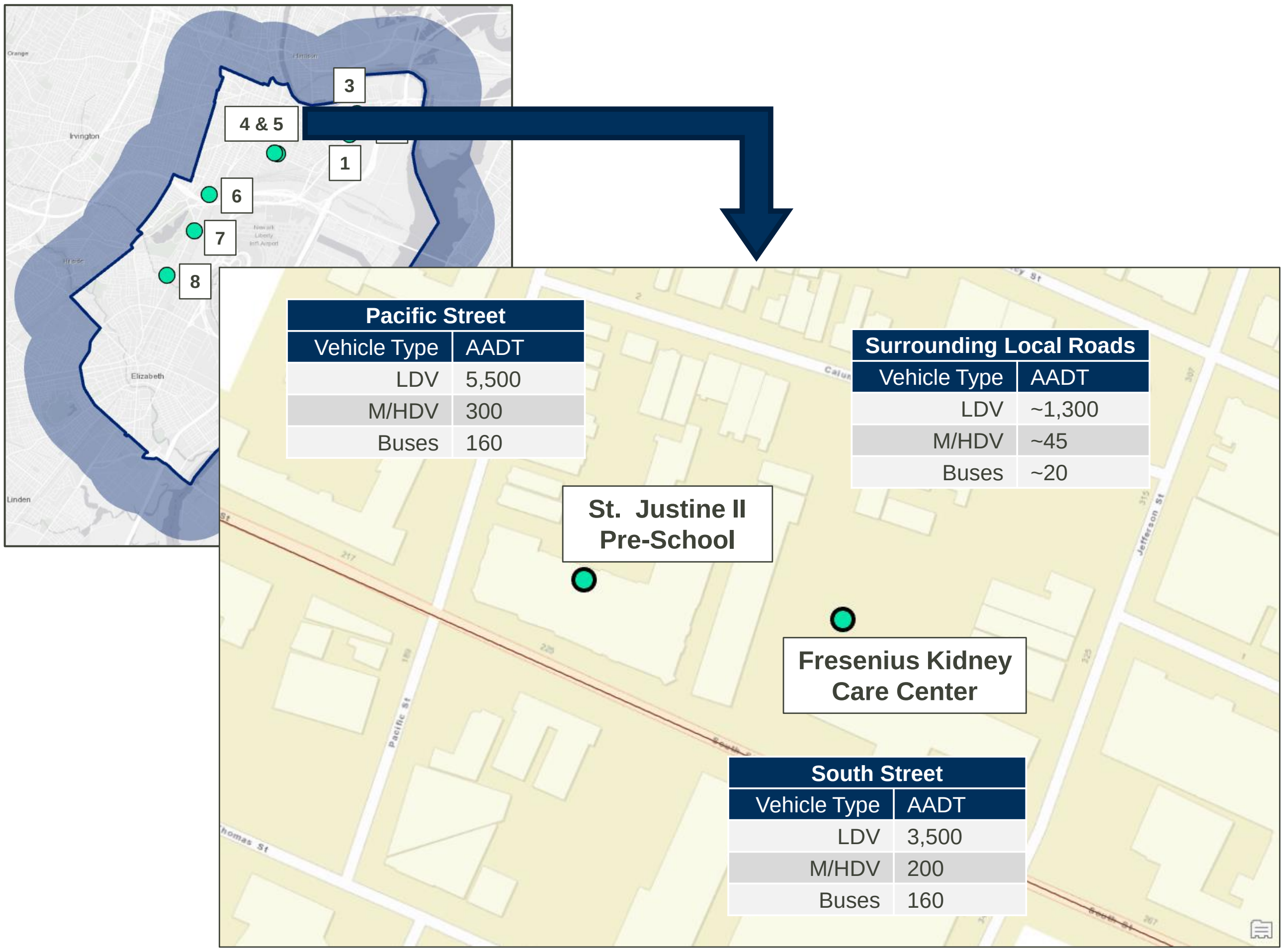
Ferry Street	
Vehicle Type	AADT
LDV	11,100
M/HDV	560
Buses	220

Surrounding Local Roads	
Vehicle Type	AADT
LDV	~1,600
M/HDV	~50
Buses	~20

Emissions Exposure and Effect of Electrification



4 & 5. St. Justine II Pre-School & Fresenius Kidney Care Center

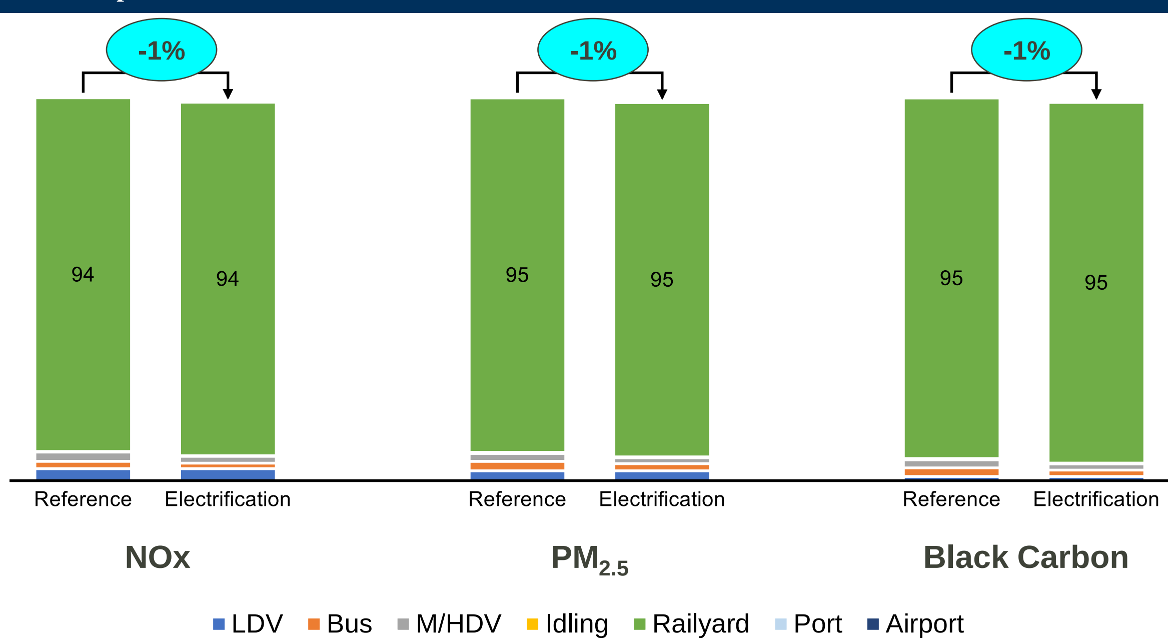


Pacific Street	
Vehicle Type	AADT
LDV	5,500
M/HDV	300
Buses	160

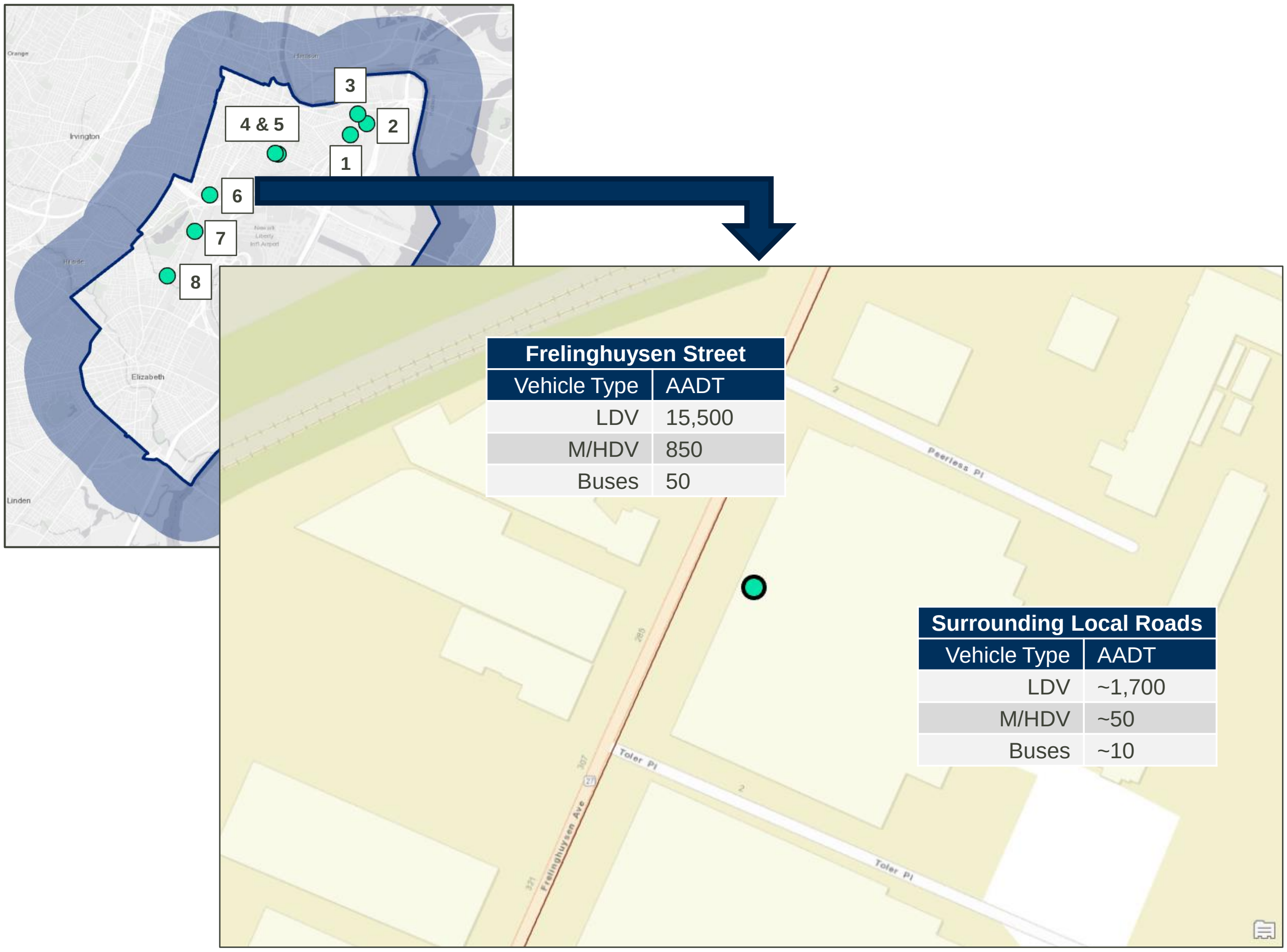
Surrounding Local Roads	
Vehicle Type	AADT
LDV	~1,300
M/HDV	~45
Buses	~20

South Street	
Vehicle Type	AADT
LDV	3,500
M/HDV	200
Buses	160

Emissions Exposure and Effect of Electrification



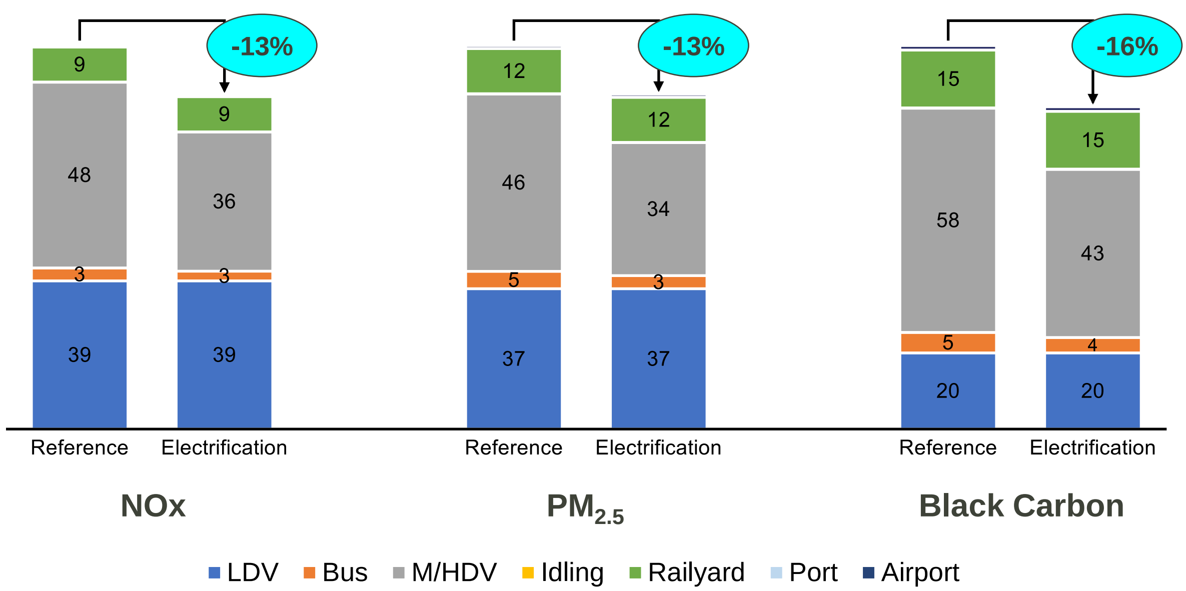
6. The Harbor



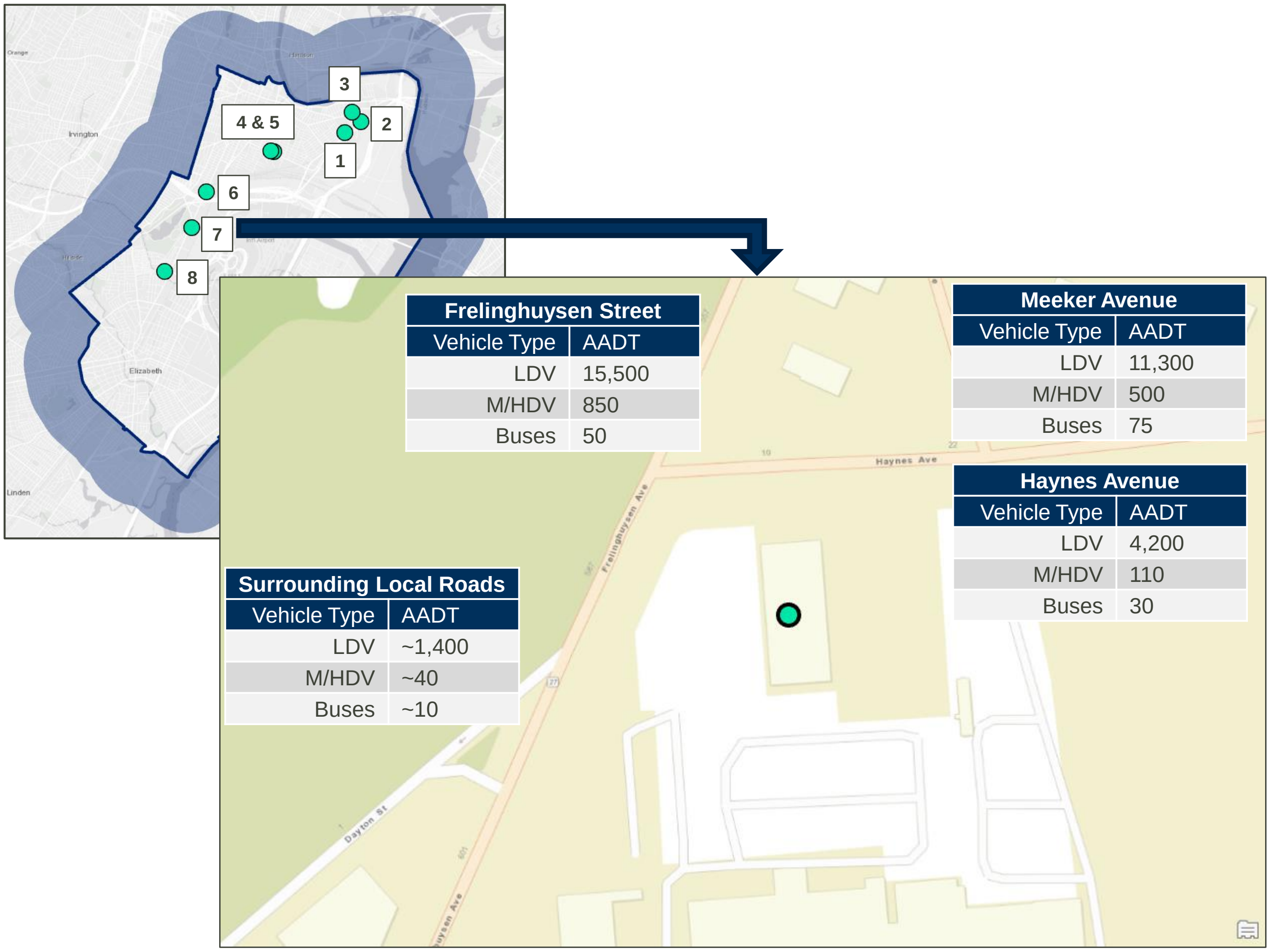
Frelinghuysen Street	
Vehicle Type	AADT
LDV	15,500
M/HDV	850
Buses	50

Surrounding Local Roads	
Vehicle Type	AADT
LDV	~1,700
M/HDV	~50
Buses	~10

Emissions Exposure and Effect of Electrification



7. DaVita Parkside Dialysis Center



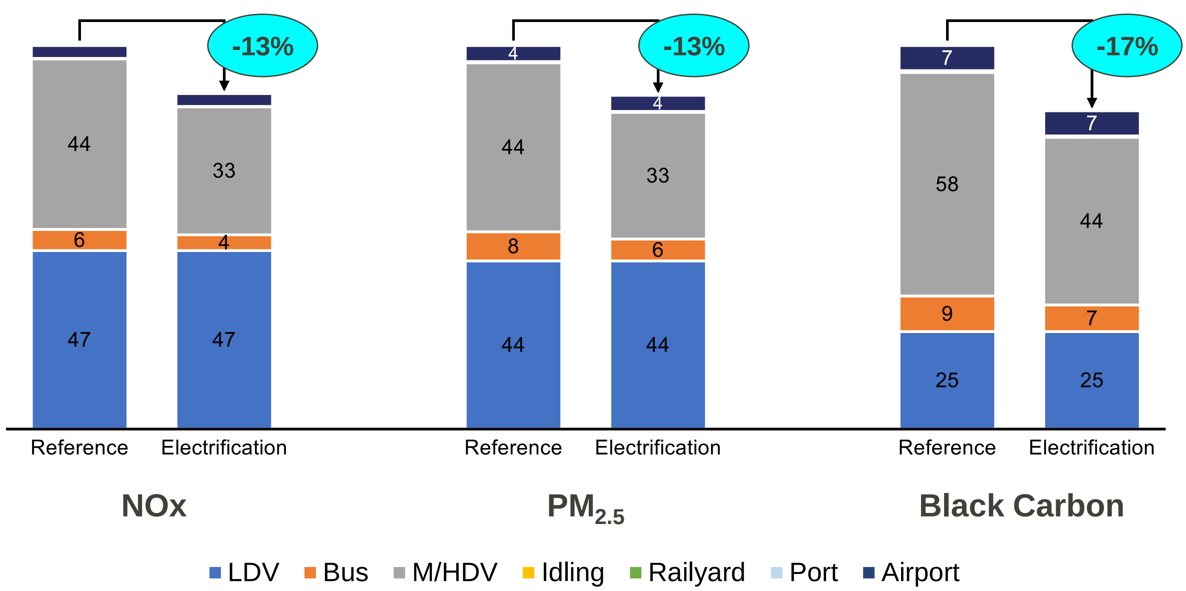
Frelinghuysen Street	
Vehicle Type	AADT
LDV	15,500
M/HDV	850
Buses	50

Meeker Avenue	
Vehicle Type	AADT
LDV	11,300
M/HDV	500
Buses	75

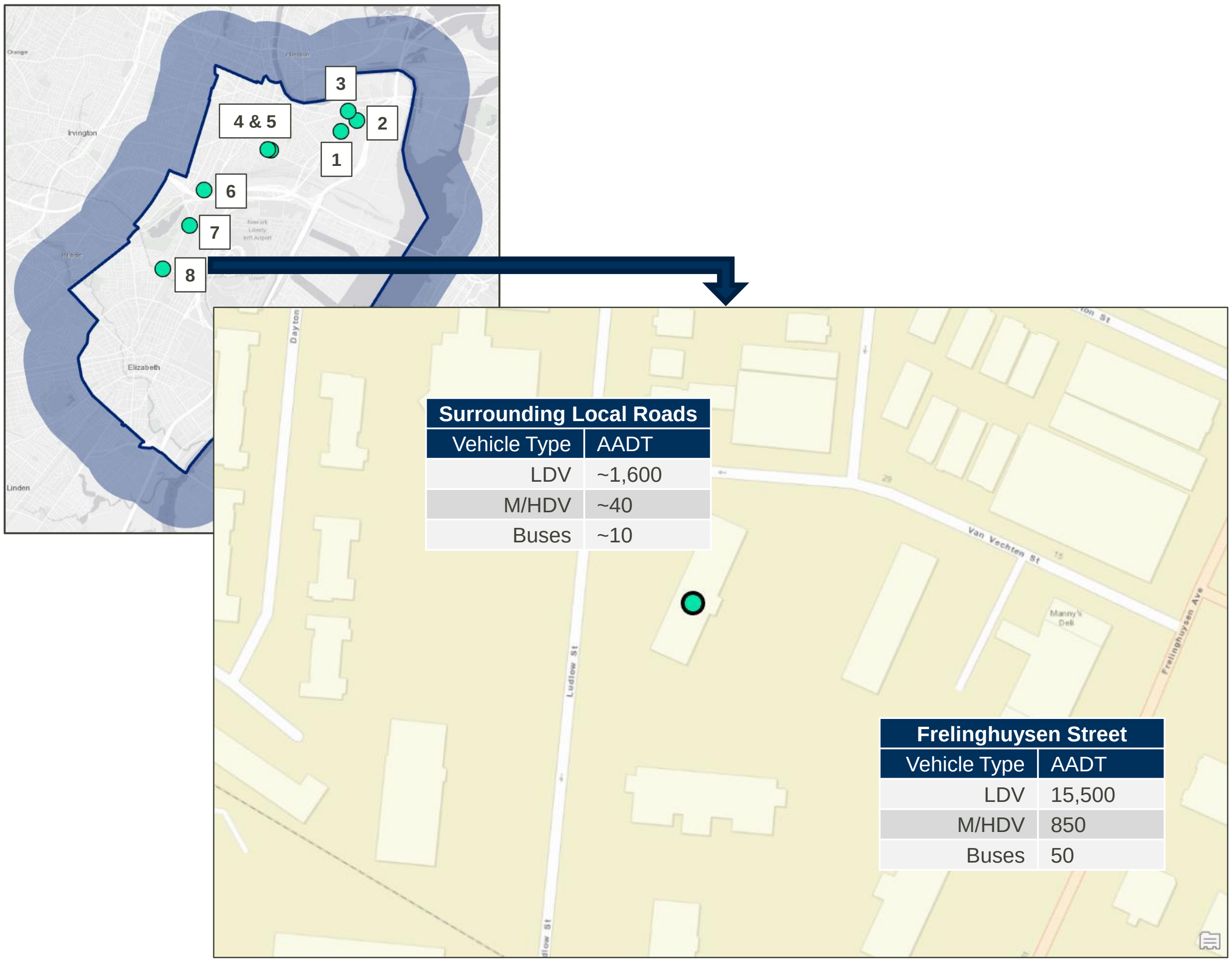
Haynes Avenue	
Vehicle Type	AADT
LDV	4,200
M/HDV	110
Buses	30

Surrounding Local Roads	
Vehicle Type	AADT
LDV	~1,400
M/HDV	~40
Buses	~10

Emissions Exposure and Effect of Electrification



8. Kretchmer Senior Center



Emissions Exposure and Effect of Electrification