WORKING PAPER

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# Nationwide port emissions screening for berthed vessels: Prioritizing U.S. port electrification to improve air quality for near-port communities

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## SUMMARY

Recent federal funding opportunities for emission abatement technologies can help facilitate the maritime industry's transition away from its reliance on diesel fuels. One such technology, shore power, allows at-berth vessels to plug into the local electrical grid and turn off auxiliary engines that would otherwise burn fossil fuel to power essential operations. In addition to reducing greenhouse gas (GHG) emissions near ports, shore power can reduce air pollutant emissions that harm the health of people in communities near ports. This study, the first nationwide port emissions screening for at-berth vessels, helps identify U.S. ports where investments in shore power could meaningfully improve air quality in nearby communities.

Using the International Council on Clean Transportation's Systematic Assessment of Vessel Emissions (SAVE) model, we estimate that at-berth vessels within 5 nautical miles (nm) of the 129 ports considered in this study emitted nearly 26,800 tonnes of air pollutants (nitrogen oxides, sulfur oxides, particulate matter) and almost 1.4 million tonnes of carbon dioxide in 2019 in the absence of shore power. Nearly 21 million people lived in census tracts that were within 5 nm of these ports that also had a median household income below the 2019 national median.

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This screening highlights 43 high-priority ports and port groups that overlapped with lower income census tracts and areas that do not meet U.S. Environmental Protection Agency air quality standards. This study assigns the ports a priority level of 1 through 4 based on at-berth vessel air pollutant emissions estimates and the population near each port. We found potential at priority 1 (New York City port group and Los Angeles port group) and priority 2 (New Orleans, Seattle, Galveston port group, Houston, and Oakland port group) ports to reduce emissions from at-berth vessel activity by installing shore power compatible with the highest emitting ship types at the port, which include tanker, container, cargo, cruise, and tug vessels.

While many of the priority 1 and 2 ports have shore power currently installed or planned for these high-emitting ships, U.S. ports can use available federal funding to install or update zero-emission port equipment, develop air quality monitoring plans, or conduct emission inventories for more tailored emission estimates than this nationwide screening provides. As more ports complete emission inventories and further data is available on emission sources, it may be easier to identify additional areas to decarbonize that could yield meaningful air quality improvements.

# INTRODUCTION

Recent federal funding opportunities, including the Bipartisan Infrastructure Law (BIL) of 2021 and the Inflation Reduction Act (IRA) of 2022, can help the maritime industry transition away from diesel-powered technology by adopting sustainable fuels and investing in emission abatement technologies at ports. Shore power technology allows vessels at berth to plug into local electrical grids and turn off auxiliary engines that would otherwise burn fossil fuel to power essential vessel operations. In addition to reducing greenhouse gas (GHG) emissions near ports, shore power can reduce air pollutant emissions that harm the health of surrounding populations.

This nationwide port emissions screening highlights U.S. ports where investments in shore power could meaningfully impact air quality in nearby communities. This study assesses 129 U.S. ports and port groups, identified by considering at-berth vessel air pollutant emissions estimates, historical air quality, and proximity to communities below the median household income. We assign ports a priority level 1 through 4 based on at-berth vessel air pollutant emissions estimates and the population surrounding each port. We further assess the status of shore power at priority 1 and 2 ports and determine which ship types could benefit from the installation of shore power at each port.

# BACKGROUND

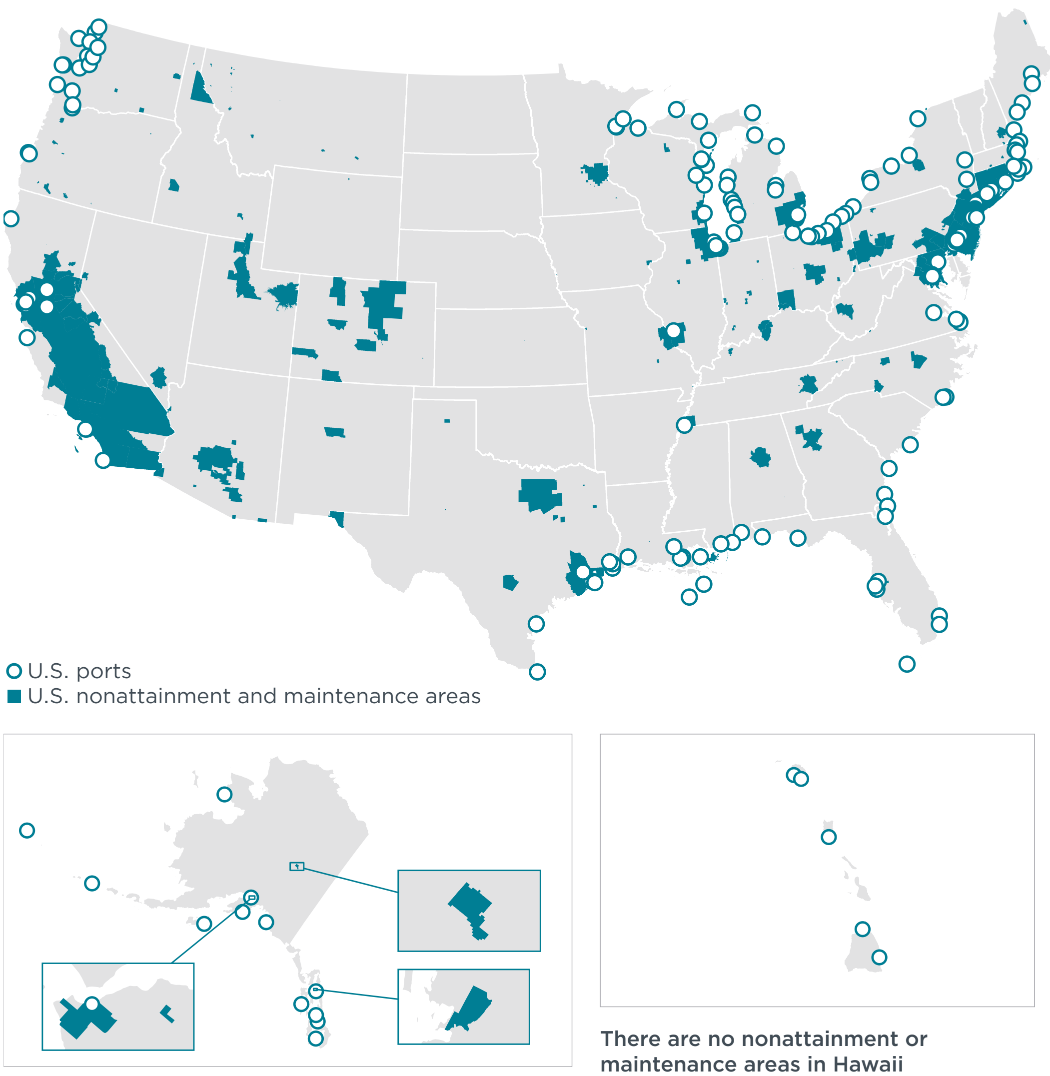
## AIR QUALITY ISSUES IN PORTS

Nearly all oceangoing vessels (OGVs) are equipped with combustion engines which burn fossil fuels. While main engines can be turned off while vessels berth at port, auxiliary engines are typically used to provide electricity onboard and allow essential activities like lighting, communication, and refrigeration to continue (Wang et al., 2015). Both main and auxiliary engines emit GHGs and air pollutants such as nitrogen oxides ($NO_X$), sulfur oxides ($SO_X$), particulate matter ($PM_{2.5}$ and $PM_{10}$), and ground-level ozone ($O_3$), depending on which fuel they burn (Li & Du, 2020). High concentrations of and prolonged exposure to these pollutants can threaten the health of people in port communities and damage local ecosystems (U.S. Environmental Protection Agency [EPA], 2017).

The National Ambient Air Quality Standards (NAAQS), established by EPA, set limits on six criteria air pollutants that are especially harmful to public health.[1] Areas that do not meet the NAAQS limits are designated as nonattainment areas (NAAs) and are monitored as efforts are made to meet the limits. Once an NAA improves air quality and adheres to criteria pollutant limits, it is designated as a maintenance area and subject to continued monitoring (U.S. EPA, 2014). Figure 1 highlights the locations in the United States designated as nonattainment or maintenance areas for any criteria air pollutant as of the end of 2023 and shows the locations of the ports included in this study (U.S. EPA, 2023c).

**Figure 1**

**Areas designated as nonattainment or maintenance by the U.S. EPA**




*Note:* Alaska and Hawaii are not to scale.
*Data source:* U.S. EPA (2023c)

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1 The six air pollutants are carbon monoxide (CO), lead, $NO_2$, $SO_2$, $PM_{2.5}$ and $PM_{10}$, and $O_3$ (U.S. EPA, 2014).

Emissions from ships anchoring and berthing near highly trafficked ports worsen air quality in nearby communities. EPA reported that almost 39 million people in the United States live within three miles of a port (U.S. EPA, 2017). Many members of these communities are people of color who live near or below the national median household income (U.S. EPA, 2022). These communities can be disproportionately affected by vessel emissions, raising environmental justice concerns. Extended exposure to high levels of criteria air pollutants can lead to premature mortality and health problems such as heart and lung disease, respiratory diseases, and cancer (U.S. EPA, 2017). Children, older adults, and people with underlying health conditions are at an increased risk of developing these issues. Existing state and federal emission limits and fuel requirements protect these vulnerable communities, but additional steps can be taken to address shipping emissions that are projected to increase.

## SHORE POWER AS AN EMISSIONS ABATEMENT TECHNOLOGY

Shore power, also known as cold ironing or alternative maritime power, allows ships at berth to turn off fossil fuel-burning auxiliary engines by plugging into local electrical grids, nearly eliminating their in-port emissions (Wang et al., 2015). Overall emission reductions vary depending on how local grid electricity is produced; cleaner grids result in higher life-cycle emission reductions, but grids that produce electricity with less sustainable methods yield less substantial reductions compared with the use of auxiliary engines. Nonetheless, shore power generally reduces local emissions near port communities since grid energy is often produced outside port boundaries.

Previous research on shore power's effects at the ports of Savannah and Charleston in 2017 and 2018 reported significant potential to reduce air pollutants and GHG emissions. The projects found that shore power at the port of Savannah's Garden Terminal could reduce containership $NO_X$ emissions by 98%, $SO_2$ by 55%, $PM_{2.5}$ by 53%, and $CO_2$ by 32% (Billings & Perez, 2019). At the port of Charleston, shore power could reduce containership $NO_X$ emissions by 98%, $SO_2$ by 69%, $PM_{2.5}$ by 77%, and $CO_2$ by 49% compared with emissions from the use of marine diesel fuel (Billings & Perez, 2020). Real-world emission reductions vary based on the port and the ships at berth, but the installation of shore power can improve air quality in most cases.

Ports in the United States with high voltage shore power infrastructure installed, under construction, or planned are shown in Table 1. The table also provides the number of shore power berths, which vessel types they are equipped to accommodate, and their year of installation.

**Table 1**
**Current and planned U.S. high-voltage shore power infrastructure**

| Port | Number of shore power berths | Vessel type | First year of installation |
|---|---|---|---|
| **Existing shore power** | | | |
| **Brooklyn** | 1 | Cruise | 2015 |
| **Hueneme** | 3 | Refrigerated cargo | 2014 |
| **Juneau** | 2 | Cruise | 2001 |
| **Long Beach** | 1<br>15<br>1 | Tanker<br>Container<br>Cruise | 2000<br>2009<br>2011 |
| **Los Angeles** | 2<br>79 | Cruise<br>Container | 2004<br>2004 |
| **Oakland** | 19 | Container | 2012–2013 |
| **Port Miami** | 5 | Cruise | 2024 |
| **San Diego** | 2<br>— | Cruise<br>Refrigerated cargo | 2010<br>2010 |
| **San Francisco** | 1 | Cruise | 2010 |
| **Seattle** | 2<br>1<br>— | Cruise<br>Cruise<br>Ferries | 2004<br>2024 (planned)<br>2025 (planned) |
| **Tacoma** | 3<br>— | Container<br>RORO | 2009, 2022<br>2009 |
| **Planned shore power** | | | |
| **Galveston** | — | Cruise | Planned |
| **Philadelphia** | — | Container | Planned |

*Note:* Complete information on the number of shore power berths or their dates of installation was not available for all ports.
*Data sources*: U.S. EPA, (2022), Florida Ports Council, (2024)

## GOVERNMENT FUNDING FOR SHORE POWER

Recent legislation provides funding for the implementation of port electrification technologies at ports. The BIL of 2021 provides $450 million per year in grant money from 2022 to 2026 for the U.S. Maritime Administration's (MARAD) Port Infrastructure Development Program (PIDP). The PIDP funds projects aimed at improving the loading, unloading, and movement of goods at ports, strengthening climate resilience, and developing emissions reduction strategies (U.S. Department of Transportation, 2024). A quarter of available PIDP funds are designated for projects at small ports.

The IRA of 2022 provided $2.25 billion to the Clean Ports Program (CPP) to reduce pollution at ports and develop climate change mitigation plans (U.S. EPA, 2023b) and $750 million to the CPP for ports located in NAAs, bringing the total to $3 billion. The CPP included two separate, non-exclusive funding programs for ports working to decarbonize, the Zero-Emission Technology Deployment Competition and the Climate and Air Quality Planning Competition.

## CURRENT DATA GAPS

A 2023 report released by the U.S. EPA Office of Inspector General identified major gaps in EPA air quality monitoring at U.S. ports (U.S. EPA, 2023a). The report found that most U.S. ports have no air quality monitoring programs or emission inventories, making it difficult to assess the national scale of port emissions. Emission inventories can help a port identify specific terminals or equipment where decarbonization efforts could be focused. Repeated inventories at a port can also be useful to track emission changes over time and evaluate the impacts of port electrification technology. As more ports conduct recurring emission inventories, it will become more evident where investments in port electrification could positively impact air quality and human health.

## METHODOLOGY

This screening used the International Council on Clean Transportation's (ICCT) Systematic Assessment of Vessel Emissions (SAVE) model accompanied by Automatic Identification System (AIS) data to estimate 2019 emissions from at-berth vessels within 5 nautical miles (nm) of 129 U.S. ports.[2] We combined $NO_X$, $SO_X$, and $PM_{10}$ estimates into one air pollutant estimate for each port to create a ranking system. We only considered air pollutants in our ranking system due to their known impact on human health, but estimated $CO_2$ emissions to provide a GHG baseline for ports. All emissions estimates are provided in supplemental material published with this study.[3] We used the ArcGIS mapping tool to include NAAs, 2019 census tract boundaries, 2019 median household income, and 2019 census tract population estimates.

We identified 43 ports of interest – those with census tracts where the median household income was below the 2019 national median that overlapped with EPA-designated NAAs. Ports of interest were assigned a priority level 1 through 4 based on absolute air pollutant estimates and the population in the affected tracts. Population estimates in this screening only include people living in census tracts where the median household income was below the 2019 national median, referred to as BNM tracts. We also noted ports with shore power infrastructure currently installed or planned according to EPA (2022).

### IDENTIFYING U.S. PORTS

The World Port Index (WPI) lists the latitude and longitude coordinates, as well as general characteristics, of thousands of ports around the world. For this analysis, we used the WPI to select every U.S. port categorized as having a harbor size of Small (132), Medium (38), or Large (21) (National Geospatial-Intelligence Agency, 2019). We omitted ports with a harbor size of Very Small (475) to limit recreational marinas that often already have low voltage shore power installed. This resulted in a sample size of 191 ports.[4] We used ArcGIS to add a buffer of 5 nm around each port to capture as many berthing vessels in each port as possible. The buffers were used to estimate the emissions from at-berth ships (Faber et al., 2020). In instances where the 5 nm buffers from multiple ports overlapped, we combined the buffers and considered the ports a single port group; the emissions from berthing vessels in all ports in a group were summed and attributed to the group. Most notably, we combined the

2 We used 2019 data to avoid disruptions caused by the COVID-19 pandemic. The 2019 data is recent enough to provide an adequate understanding of at-berth vessel emissions at ports. Our $PM_{10}$ estimates include $PM_{2.5}$. The portion of our $PM_{10}$ estimates that come from $PM_{2.5}$ is reported separately in the supplemental material published with this study.

3 The supplemental material is a spreadsheet that lists all 129 ports; the composition of each port group; the $NO_X$, $SO_X$, PM, and $CO_2$ estimates for each port; the BNM population they overlap; whether they overlap an NAA; and if they have shore power installed or planned. It can be found at: https://theicct.org/publication/us-port-emissions-screening-berthed-vessels-sept24.

4 We found that Frankfort (MI), Michigan City (IN), Port St. Joe (FL), Port Washington (WI), Racine (WI), Raymond (WA), Sheboygan (WI), South Bend (WA), and Waukegan (IL) had no emissions data, so we removed them from the final port count. This left 182 individual ports before combining overlaps and 129 after.

ports of Los Angeles and Long Beach (Los Angeles port group), combined many overlapping ports in the Port Authority of New York and New Jersey (New York City port group), and combined the ports of Oakland, San Francisco, Alameda, and Point Richmond (Oakland port group). Table A1 in the appendix lists all port groups and their constituent ports. There are 129 ports or port groups in this screening (104 individual ports plus the 25 port groups consisting of 78 ports total), from which we estimated at-berth vessel emissions. Unless otherwise specified, "ports" collectively refers to the 129 individual ports and port groups.

## ESTIMATING EMISSIONS AT PORTS

Emissions data were estimated from at-berth vessels within the 5 nm buffers using the ICCT's SAVE model.[5] As detailed in Olmer et al. (2017), the SAVE model estimates emissions using AIS data to determine which ships berthed within the buffer areas in 2019 and referencing their S&P Global ship characteristics. Real-time global maritime vessel tracking data including ship location, speed over ground (SOG), and draught were obtained from exactEarth (now called Spire). Ship characteristics such as engine type, fuel burned, capacity, and build year were obtained from S&P Global. During processing, the fuel type for any ships marked as residual was changed to distillate to account for emissions regulations within the North American Emission Control Areas (ECAs).

Since shore power can only reduce emissions from ships close enough to shore to plug in, we only included ships at berth in this analysis. Ships at berth were defined in the Fourth IMO GHG Study as SOG ≤1 knots and Port Distance ≤1 nm for all vessels, and 1–5 nm for chemical tankers, liquefied gas tankers, oil tankers, and other liquid tankers only (Faber et al., 2020). We then estimated the emissions of three air pollutants ($NO_X$, $SO_X$, $PM_{10}$) as well as $CO_2$ from every berthing ship in a U.S. port in 2019.[6] Emissions were estimated in grams (g) and later converted to metric tonnes (t). Shore power plug-ins do not eliminate emissions from boilers; therefore, we omitted boiler emissions from our study (U.S. EPA, 2022). This allowed us to specifically estimate the at-berth vessel emissions from the auxiliary engines which could potentially be reduced by shore power.

The results for $NO_X$, $SO_X$, and $PM_{10}$ emissions were combined to identify ports where berthing vessel emissions pose a high risk to the health of near-port communities. We separated air pollutant and $CO_2$ estimates, because they have different effects on air quality and human health. Given that a focus of this study is the air quality impacts from port activity, we highlighted air pollutant emissions in our ranking system. While we do not incorporate $CO_2$ emissions into our ranking system, all emissions estimates are listed in the supplemental material published with this analysis to provide a baseline for ports that do not have air quality monitoring programs or emission inventories.

This nationwide methodology did not account for emissions reductions at ports with current shore power installed.[7] Our estimates represent the emissions from at-berth vessels in the absence of shore power or state-specific emissions reduction regulations. Considering existing shore power and state regulations would reduce our emissions estimates at ports where they are present, but this was outside of the scope of this study. The impacts of current shore power on our estimates are discussed below.

5 Emissions data is approximate based on our methodology.

6 The $NO_X$ emissions factors used in this study are from the Fourth IMO GHG Study (Faber et al., 2020).

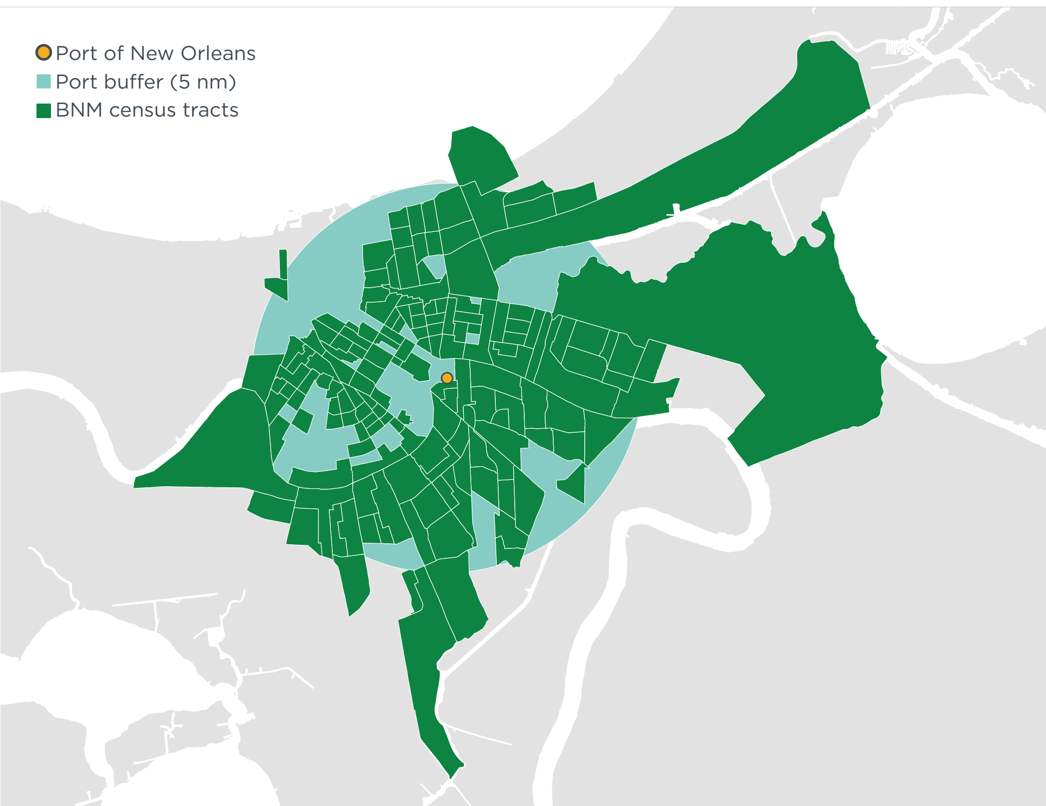
7 The SAVE model does not account for known real-world shore power installation or state-specific emissions reduction regulations. The scope of this analysis does not incorporate real-world emissions reductions from those methods because of the uncertainty of shore power usage by ships at each port in this study.

## ADDITIONAL MAPPING SOURCES

2019 census tract shapefiles and 2019 census data were obtained from the U.S. Census Bureau (U.S. Census Bureau, 2024a; 2024c). We identified ports with 5 nm buffers that overlapped with census tracts with a median household income below the 2019 national median of $68,703 (U.S. Census Bureau, 2020). We then calculated the total population of these BNM tracts to estimate which ports overlapped with the highest populations. Only BNM tracts were included in the population estimate; census tracts that overlapped with the 5 nm buffers but had a median household income higher than the 2019 national median were not included. Figure 2 illustrates this methodological concept by showing the BNM tracts that overlap the Port of New Orleans 5 nm buffer.

EPA provides open access GIS data on all U.S. counties designated nonattainment and maintenance (U.S. EPA, 2023c). We combined the GIS layers of nonattainment and maintenance areas of all available criteria air pollutants in ArcGIS to create one comprehensive layer of every area with hazardous air quality in the United States. This layer used the most recent EPA data as of 2023.

**Figure 2**
**BNM tracts overlapping the Port of New Orleans 5 nm buffer**

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## IDENTIFYING PORTS OF INTEREST

Any ports overlapping both with BNM tracts and EPA-designated NAAs were identified as "ports of interest" and were ranked based on two values: the absolute air pollutant sum from berthing vessels in the port as estimated by our SAVE model and the total population living in BNM tracts overlapping port buffers. Our criteria highlighted ports in areas with substandard air quality with high at-berth vessel emission estimates near a large population below the median household income.

Out of the 129 ports in this screening, 119 overlapped with BNM tracts. The BNM tracts overlapping these 119 ports had nearly 21 million people living in them, more than the combined population of New York City, Los Angeles, Chicago, Houston, Phoenix, and Philadelphia (the six most populous U.S. cities) in 2022 (U.S. Census Bureau, 2024b). BNM tract population estimates from each port are included in the supplemental materials.

Out of all 129 ports, 43 overlapped with both EPA-designated NAAs and BNM tracts. These 43 ports are a mix of individual ports (29) and port groups (14 groups consisting of 55 ports total).

### PORT AREA CAVEAT

The use of the 5 nm buffers is a broad method to incorporate many terminals at a port but may over- or underestimate emissions under different circumstances. It may overestimate emissions at ports that overlapped and were combined into one group. For example, emissions estimates from all 21 ports in the New York City port group were combined. The Port of New York and New Jersey does not include some of these ports, so emissions estimates from this screening appear high when compared with other emissions inventories. In ports where the terminals are spread over a distance larger than 5 nm, we may underestimate the emissions. The 5 nm buffer at the Port of Houston did not include the container terminals at the port, so emissions estimates differ from other inventories. Future work conducted with official port boundaries may yield different results. Port-specific shapefiles could give a more tailored analysis on a case-by-case basis, but this methodology was appropriate for the scale of this national screening.

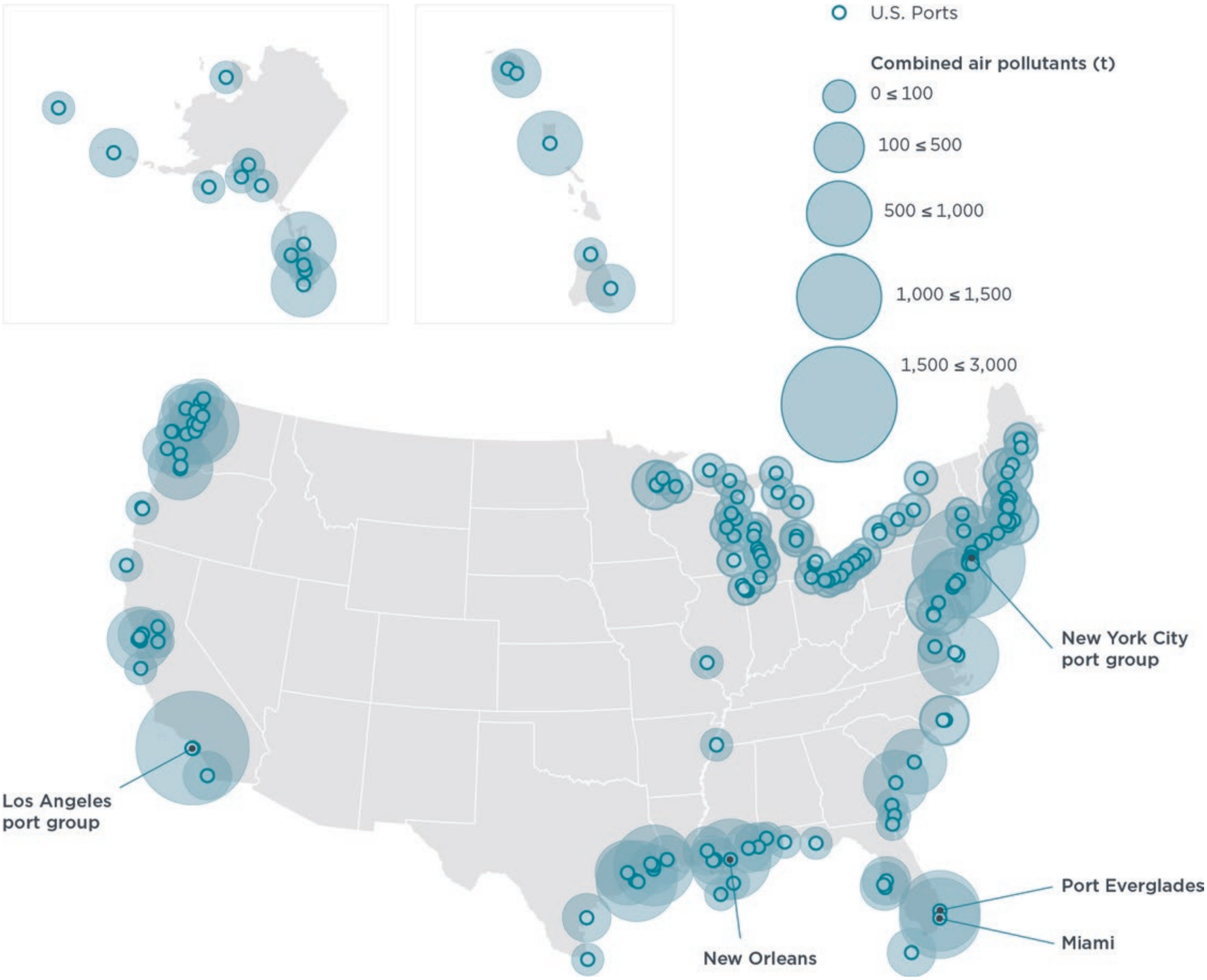
## RESULTS

### EMISSIONS FROM ALL U.S. PORTS

The combined air pollutant estimate ($NO_X$, $SO_X$, and $PM_{10}$) from at-berth vessels in all 129 U.S. ports in 2019 was nearly 26,800 tonnes. That is roughly equivalent to the combined $NO_X$, $SO_2$, and $PM_{10}$ emissions estimates from all school buses in the United States in 2020 (U.S. EPA, 2024). The five ports with the highest combined air pollutant estimates from at-berth vessels in 2019 were the New York City port group, the Los Angeles port group, Port Everglades, New Orleans, and Miami. Air pollutant emissions from these five ports combined were an estimated 8,040 t, or just over 30% of the 26,800 t national total. Figure 3 illustrates the combined air pollutant estimates from berthing vessels in all 129 U.S. ports.

**Figure 3**

**Combined $NO_x$, $SO_x$, and $PM_{10}$ emission estimates from at-berth vessels in U.S. ports, 2019**

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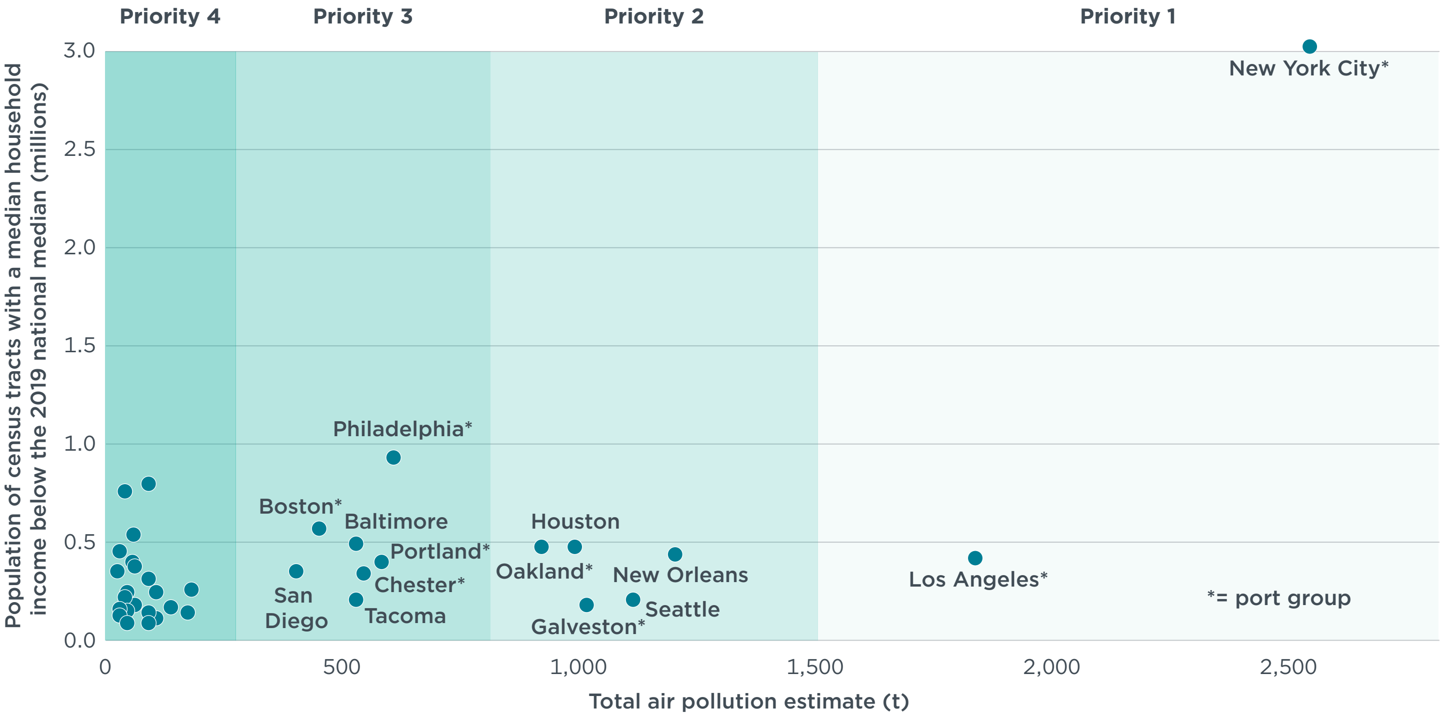
The combined $CO_2$ estimate from at-berth vessels in all 129 U.S. ports was almost 1.4 million tonnes, nearly as much as the 1.6 million tonnes emitted from all vessels operating in the Great Lakes-St. Lawrence Seaway in 2019 (Meng & Comer, 2022).

## PORTS OF INTEREST

There are 43 ports of interest highlighted in this screening. These ports overlapped both with BNM tracts and EPA-designated NAAs. Air pollutant estimates and populations in BNM tracts at each of these ports of interest are represented in Figure 4. We visually separated the ports of interest into four different priority levels based on natural groupings that emerged. Priority 1 ports had the highest combination of air pollutant and population estimates; priority 4 ports had the lowest combination.

**Figure 4**

**Priority categorization of 43 ports of interest based on at-berth vessel air pollutant estimates and populations in BNM tracts**




*Note:* There are 29 priority 4 ports. It was not possible to label them legibly in the figure. They are, alphabetically: Anchorage, Bridgeport, Chicago, Cleveland, Detroit, Duluth, Everett, Fairport, Fernandina Beach, Grand Haven, Holland, Lorain, Manitowoc, Mare Island, Milwaukee, Muskegon, New Haven, New London, Olympia, Port of Memphis, Sacramento, St. Joseph, Stockton, Sturgeon Bay, Tampa, Toledo, Tri-City Port, Washington, DC, and Yonkers.

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The New York City and Los Angeles port groups are categorized as priority 1 due to their high at-berth vessel air pollutant emission estimates and the large population living in BNM tracts. Combined, at-berth vessels in the priority 1 port groups accounted for an estimated 4,400 t of air pollutants, 16% of this screening's national estimate of 26,800 t. We estimate that at-berth vessels emitted nearly 2,600 t in the New York City port group and more than 1,800 t in the Los Angeles port group in 2019. More than 3.5 million people lived in BNM tracts that overlapped with the priority 1 port groups, 17% of the total 21 million people in BNM tracts in the entire screening. The New York City port group had almost 3.2 million people living in BNM tracts, the most of any port in the screening. The Los Angeles port group had more than 372,000 people living in BNM tracts.

Five ports are categorized as priority 2: New Orleans, Seattle, the Galveston port group, Houston, and the Oakland port group. Berthing vessels in these five ports emitted more than 5,200 t of air pollutants (19% of the national air pollutant estimate) and 1.5 million people (7% of the BNM total) lived in BNM tracts. Of the five priority 2 ports, New Orleans had the largest at-berth vessel air pollutant emissions estimate (1,200 t), and the Oakland port group had the largest BNM population (442,000 people).

Seven ports are categorized as priority 3: the Philadelphia port group, the Portland (OR) port group, the Chester port group, Tacoma, Baltimore, the Boston port group, and San Diego. At-berth vessels in the priority 3 ports emitted more than 3,500 t of air pollutants (13% of the national air pollutant estimate) and more than 3.1 million people (15% of the BNM total) lived in BNM tracts. At-berth vessels in the Philadelphia port group emitted an estimated 600 t of air pollutants, the largest estimate of all priority 3 ports. The estimated emissions of the Philadelphia port group also affected nearly 980,000 people, the second largest BNM population in this screening after the New York City port group.

At-berth vessels in the 29 priority 4 ports accounted for 1,150 t of air pollutants (4% of the national air pollutant estimate) and 5.8 million people (28% of the BNM total) lived in BNM tracts. Every priority 4 port had an at-berth vessel air pollutant estimate below 160 t. The Chicago port group and Yonkers overlapped with the third and fourth-highest populations living in BNM tracts in the screening: 830,000 and 806,000 people, respectively.

The following sections focus on priority 1 and 2 ports due to their combination of high emissions estimates and high population in BNM tracts.

## HIGHEST EMITTING SHIP TYPES AND EXISTING SHORE POWER AT PRIORITY 1 AND PRIORITY 2 PORTS

Figure 5 shows air pollutant estimates by ship class at the seven priority 1 and priority 2 ports in 2019. Ship classes are aggregated based on methodology from Faber et al. (2020), except for tug and offshore, which are reported separately to give a more port-specific representation of the highest emitting ship classes. Information on shore power installed or planned at the seven ports in this section is from U.S. EPA (2022).

Container vessels accounted for the highest air pollutant estimate from a single ship type in the New York City port group in 2019. Tug and tanker vessels had the second and third-highest air pollutant estimates. The Port of Brooklyn is the only port in the New York City port group with shore power currently installed, with one berth that can serve cruise vessels. Starcrest Consulting Group (2020c) estimated that at the Brooklyn Cruise Terminal in 2019, 12 of 42 cruise vessel calls used shore power. Real-world 2019 at-berth cruise vessel air pollutant emissions in the New York City port group were likely lower than the estimates in this screening due to the available shore power connection. There are no shore power terminals for container, tug, or tanker vessels in the New York City port group.

Container vessels also accounted for the highest air pollutant estimate from a single ship type in the Los Angeles port group in 2019, closely followed by tankers. The Port of Los Angeles and the Port of Long Beach (combined in this screening as the Los Angeles port group) both have shore power installed for cruise and container vessels. The Port of Long Beach also has shore power available for tankers. Both ports in the group also have low-voltage shore power installed for tugs. Real-world emissions from at-berth container, cruise, and tanker vessels in the Los Angeles port group in 2019 were likely lower than our estimates due to the presence of shore power at the ports. Starcrest Consulting Group estimated that in 2019, 42% of OGVs calling the Port of Los Angeles (2020b) and 49% of OGVs calling the Port of Long Beach (2020a) connected to shore power.

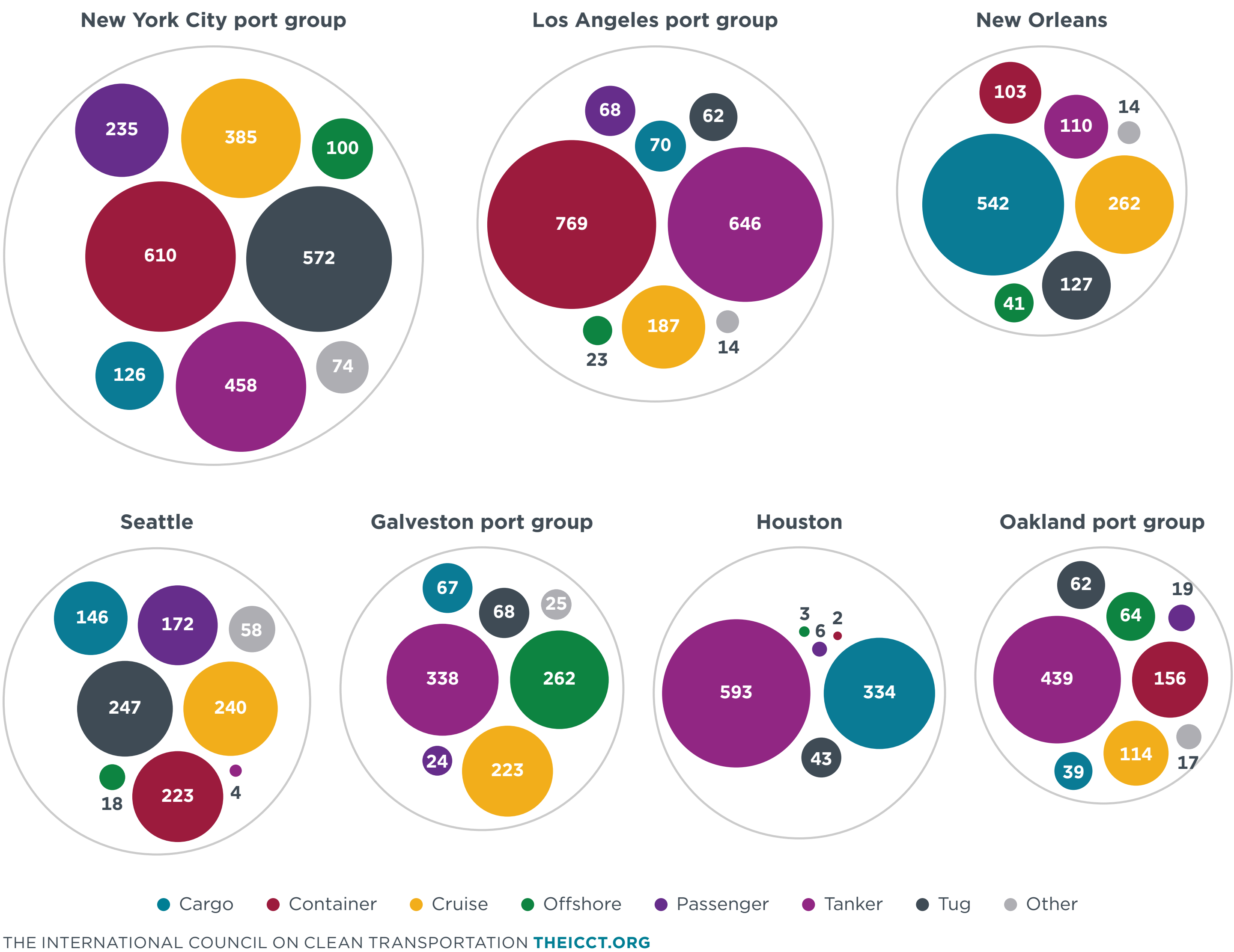
The Port of New Orleans was the only priority 1 or 2 port where cargo vessels accounted for the highest portion of the at-berth air pollutant estimate in 2019. There is no shore power installed at the Port of New Orleans.

The Port of Seattle had similar 2019 at-berth air pollutant estimates from tug, cruise, and container vessels. The Port of Seattle has existing shore power terminals for cruise ships and plans to install more for cruise ships and ferries. It also has low-voltage shore power for tugs. The 2019 real-world air pollutant emissions from at-berth cruise and tug vessels in the Port of Seattle were likely lower than our estimates in this study.

Tanker vessels accounted for the highest portion of the at-berth air pollutant estimate in the Galveston port group, the Port of Houston, and the Oakland port group in 2019. Within the Galveston port group, only the Port of Galveston plans to install shore power for cruise ships. The Port of Houston has no shore power installed or planned. The Port of Oakland and the Port of San Francisco (combined in this screening as part of the Oakland port group) have 19 shore power berths for container vessels and 1 for cruise ships, respectively. The availability of shore power in the Oakland port group likely resulted in lower real-world at-berth container and cruise vessel air pollutant emissions in 2019 than our screening estimated. None of these three ports have current or planned shore power capacity for tankers.

**Figure 5**

**Combined at-berth air pollutant estimates, in tonnes, by ship class in priority 1 and 2 ports**



## DECARBONIZATION PLANS AND SHORE POWER POTENTIAL AT PRIORITY 1 AND PRIORITY 2 PORTS

The New York City and Los Angeles port groups performed recent emissions inventories and have decarbonization plans that include additional implementation or consideration of shore power. Some priority 2 ports also have emissions inventories and decarbonization plans.

The Port Authority of New York and New Jersey has a decarbonization plan to reach net-zero GHG emissions by 2050, with an intermediate target of 50% direct emissions reduction by 2030 (Port Authority of New York and New Jersey, 2021). The plan lists actions that would help meet these targets, including identifying the most effective zero-emission port technologies for investment. The Port Authority plans to install zero-emission technology and promote policies that incentivize the use of the equipment to yield the biggest emission reductions. The results of this study indicate that the New York City port group could first consider installing shore power for container or tanker vessels, as they make up a large share of emissions from visiting ships. Electrification of tugs could also yield emissions reductions in the port group.

The Port of Los Angeles and the Port of Long Beach have both committed to reducing GHG emissions from port sources by 40% by 2030 and 80% by 2050 (compared with 1990 levels), as described in the San Pedro Bay Ports 2017 Clean Air Action Plan Update (San Pedro Bay Ports, 2023). Decarbonization commitments at California ports are heavily influenced by the California Air Resources Board (CARB), which oversees air pollution reduction programs in the state. Due to the unique circumstances in California, the Clean Air Act allows CARB to request emission standards that are more stringent than federal limits.[8]

California's Ocean-Going Vessels At-Berth Regulation aims to reduce $NO_x$ and PM emissions from auxiliary engines of at-berth OGVs in California ports (California Air Resources Board, 2020). The regulation requires vessels to either plug into shore power or use another CARB-approved emissions reduction method when berthing in a California port. Currently, container, cruise, and refrigerated cargo vessels must adhere to the regulation. Roll-on/roll-off vessels must adhere to the regulation by 2025, and tankers must adhere by 2025 when berthing within the Los Angeles port group and by 2027 when berthing in all other California ports. If implementation continues as planned, the regulation will considerably reduce future emissions from at-berth roll-on/roll-off vessels and tankers.

The Port of New Orleans developed a 2018 Master Plan that commits to develop sustainably but does not include specific decarbonization targets or dates (Port of New Orleans, 2018). The Port of New Orleans has no shore power berths. Our screening identified installing shore power for cargo vessels, which we estimated make up the largest share of emissions from OGVs at the port, as an option that could reduce air pollutants and improve the air quality for nearby communities.

In a collaborative effort as part of the Northwest Ports Clean Air Strategy, the Port of Seattle set the goals of installing shore power at all major cruise and container berths by 2030 and phasing out port-related emissions by 2050 (Port of Seattle, 2020). This

8 If EPA approves CARB requests, the California-specific regulations are implemented, and other states can adopt the same measures.

screening identified that the Port of Seattle could benefit from installing shore power berths for container vessels, which the port already aims to do, and electrifying tugs.

While the Port of Galveston Strategic Master Plan contains neither specific decarbonization targets nor dates, it mentions involvement in programs relating to GHG and air pollutant reductions, community engagement, and environmental leadership (Port of Galveston, 2019). This screening identified that providing shore power for tankers could substantially reduce air pollutant emissions in the Galveston port group.

The Port of Houston set a goal to achieve a net-zero GHG footprint by 2050 with an interim checkpoint in 2040 (Port Houston, 2022). The port mentions shipping decarbonization as a key component of this goal. Our findings indicate that the Port of Houston could begin to reduce emissions by exploring shore power options for tankers.

The ports in the Oakland port group have individual goals to reach zero emissions in their official air quality plans, but the group is also heavily influenced by CARB.

# DISCUSSION

## COMPARISON WITH EXISTING PORT EMISSION INVENTORIES

A recent ICCT study by Meng and Comer (2023) estimated the emission reductions associated with electrification at the Port of New York and New Jersey using the ICCT's global online Port Emissions Inventory Tool (goPEIT) combined with the SAVE model.[9] The study estimated 2019 OGV, harbor craft, and drayage truck emissions from each of the port's jurisdictions, which are substantially smaller areas than those in this screening. Starcrest Consulting Group also conducted 2019 emissions inventories at the Port of New York and New Jersey, the Port of Los Angeles, the Port of Long Beach, and the Port of Houston (Starcrest Consulting Group,2020a; 2020b; 2020c; 2021). The study areas and methodology of the Starcrest inventories differ from those in this screening. Table 2 compares the at-berth emissions estimates at the New York City port group, the Los Angeles port group, and the Port of Houston in this screening to estimates in the ICCT and Starcrest studies.[10]

We combined the OGV hoteling at-berth estimates from the Starcrest 2019 Port of Los Angeles and Long Beach emission inventories, because our screening methodology combined the two ports as the Los Angeles port group. At the Port of Houston, our 5 nm buffer method did not capture every terminal, so we compared our estimates with the entire Starcrest emission inventory and then only the terminals our buffer included.

9 goPEIT is a free online tool that takes inputs such as engine use hours, distance traveled, and fuel used to estimate GHG and pollutant emissions.

10 We reported Starcrest OGV Hoteling-at berth Auxiliary Engine estimates. Harbor Craft estimates are not included in the Starcrest estimates in this table. Starcrest estimated $CO_2e$ rather than $CO_2$.

**Table 2**
**2019 emission estimates from this study compared with previous ICCT work and Starcrest Consulting Group estimates**

| | Study | $NO_x$ (t) | $SO_x$ (t) | $PM_{10}$ (t) | $CO_2$ (t) |
|---|---|---|---|---|---|
| **Port of NY and NJ** | Starcrest | 1,100 | 50 | 30 | 110,000 |
| | Meng & Comer | 900 | 30 | 20 | 56,000 |
| | ICCT Screening | 2,400 | 60 | 80 | 140,000 |
| **Ports of Los Angeles and Long Beach** | Starcrest | 1,200 | 50 | 30 | 78,000 |
| | ICCT Screening | 1,700 | 40 | 80 | 104,000 |
| **Port of Houston** | Starcrest (entire emission inventory) | 1,600 | 100 | 40 | 166,000 |
| | Starcrest (terminals our methodology included) | 600 | 30 | 10 | 55,000 |
| | ICCT Screening | 950 | 30 | 10 | 60,000 |

Emissions estimate differences are primarily due to study area differences. Our study's broader methodology allowed us to estimate emissions from ports across the nation, whereas our comparison studies used official port boundaries. Additionally, Starcrest's Los Angeles and Long Beach inventories both considered emissions reductions from using shore power, which this screening did not.

## LIMITATIONS OF SHORE POWER

Cost and the uncertainty of use are issues of concern related to the installation of shore power. A 2015 ICCT study estimated that in addition to shore-side infrastructure, ship-side costs to install shore power capability can range from $300,000–$2 million (Wang et al., 2015). There is additional uncertainty about whether ships could or would use plugs if they were installed based on system compatibility and the existence of incentive programs. On a larger scale, shore power requires an electrical grid capable of handling the power demand. Evaluating a grid's cleanliness and capability at ports is crucial to understanding where port electrification could feasibly be integrated to reduce emissions without overburdening near-port communities.

The public health benefits of reducing emissions near ports through shore power should also be considered when discussing the costs. The monetary benefits of avoided mortality and morbidity from reduced air pollution can be compared with the high initial costs of installing shore power at ports to assess costs and benefits (U.S. EPA, 2022). Long-term costs of shore power also depend on the future prices of marine fuel versus electricity, which vary from port to port.

Federal funding can help offset the initial investment and maintenance costs associated with shore power. There is potential for priority 1–4 ports to achieve meaningful emissions reductions with funding from federal legislation like the BIL or IRA. Port-specific federal funding could place more focus on shore power and port electrification to improve air quality around near-port communities.

## ENVIRONMENTAL JUSTICE INDICATORS

Due to the broad scope of this nationwide screening, our methodology is not the only way to assess potential environmental justice impacts from ship pollution, and further studies using different methods may yield different results. We consider median household income and air quality nonattainment status as high-level environmental justice indicators, but this is by no means the only method to use. Other tools, such as the EPA EJScreen, which combines environmental and socioeconomic data, could be used to provide a more complete picture of environmental justice indications at individual ports.

The population data in this screening come from the 2019 Census and represent the number of people living in BNM tracts that overlapped with our 5 nm port buffers. They do not include people living in census tracts above the national median household income, who are also affected by port-related emissions. Additionally, due to the nature of air pollutants, people in port-adjacent communities can also be affected by vessel emissions even if they are not within 5 nm of the port or do not live in an NAA. Port workers who do not live near ports are also affected by port-related emissions while at work. Consideration of these caveats could be included in future work.

### FUTURE RESEARCH

This is the first at-berth vessel emissions screening of its kind and uses novel methods to categorize the ports in the study. Our nationwide emissions screening gives a comprehensive review of regions and port areas where emissions are high and many people are affected, but additional information could be obtained with more detailed boundaries. Future emissions inventories could benefit from a more targeted approach, estimating emissions from individual ports using official port boundaries, or accounting for existing shore power and state-specific emissions regulations.

## CONCLUSION

This study aimed to identify U.S. ports where investment in shore power infrastructure could reduce emissions and improve air quality at local port communities. We used the SAVE model accompanied by AIS data to estimate $NO_X$, $SO_X$, $PM_{10}$, and $CO_2$ emissions from ships berthing in 129 U.S. ports in 2019. In the absence of shore power, we estimated that ships at-berth in these ports emitted approximately 27,000 tonnes of combined air pollutants ($NO_X$, $SO_X$, and $PM_{10}$) and nearly 1.4 million tonnes of $CO_2$.

Of the 129 ports considered in our analysis, 43 had nearby communities with average incomes below the national median and were also within EPA-designated NAAs. We categorized these 43 ports into four priority levels based on the total air pollutant estimates from ships and the total population in nearby BNM tracts. At-berth vessels emitted a combined 4,400 tonnes of air pollutants at two priority 1 ports, the New York City and Los Angeles port groups, which had more than 3.5 million people living in nearby BNM tracts. At-berth vessels in the five priority 2 ports (New Orleans, Seattle, the Galveston port group, Houston, and the Oakland port group) emitted more than 5,200 tonnes of air pollutants, and 1.5 million people lived in nearby BNM tracts. At-berth vessels in the seven priority 3 ports (the Philadelphia port group, the Portland (OR) port group, the Chester port group, Tacoma, Baltimore, the Boston port group, and San Diego) emitted more than 3,500 tonnes of air pollutants, with more than 3.1 million people in BNM tracts near them. At-berth vessels in the 29 priority 4 ports emitted an estimated 1,150 tonnes of air pollutants, with 5.8 million people living in nearby BNM tracts.

Any of the seven priority 1 and 2 ports could consider investing in port electrification, such as shore power, that specifically targets the highest emitting ship types. The New York City port group has shore power available for cruise ships, but container ships and tugs emitted the most pollution in the port group in 2019. In the Los Angeles port group, shore power and emissions regulations exist for container ships and tankers, which emitted the most air pollutants in 2019, followed by cruise ships. Many priority 1 and 2 ports have existing port decarbonization plans that mention reducing emissions from port-related activity; some of these plans include implementing shore power or other port electrification technology to reduce port-related emissions and improve air quality for near-port communities.

Federal funding available through legislation like the BIL or the IRA can help ports make investments to meet their decarbonization goals and assist the transition to port electrification. This funding could support the installation of shore power, the establishment of air quality monitoring programs, or the preparation of emissions inventories to better assess where shore power could meaningfully reduce emissions and improve air quality for surrounding populations.

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# APPENDIX A: PORT GROUPS

**Table A1**

**Port group names and associated ports**

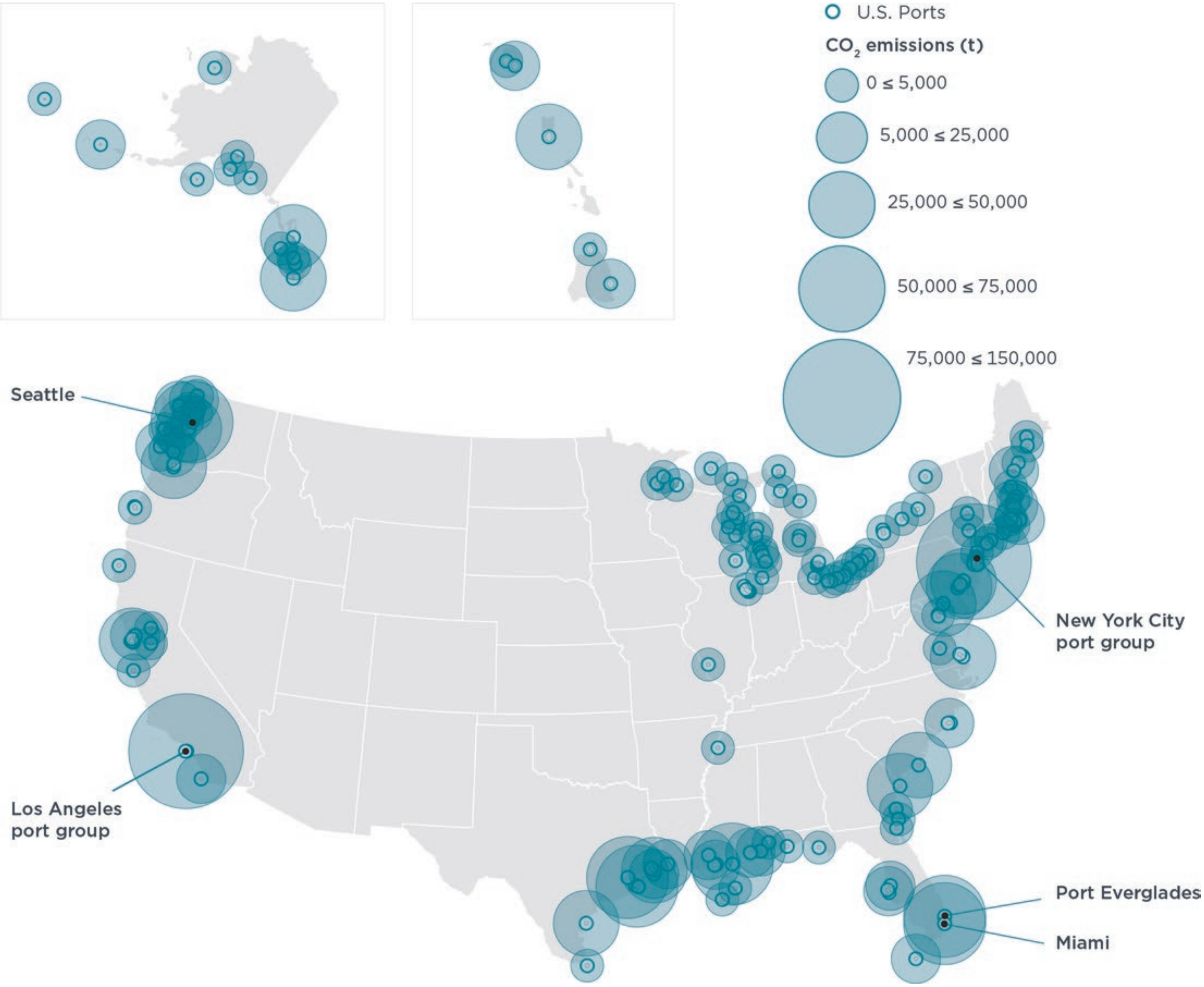
| Port group | Ports included in the group | Number of ports in the group |
|---|---|---|
| **Aberdeen (WA)** | Aberdeen, Hoquiam | 2 |
| **Beaumont (TX)** | Beaumont, Port Neches | 2 |
| **Boston (MA)** | Boston, Quincy | 2 |
| **Buffalo (NY)** | Buffalo, Tonawanda | 2 |
| **Chester (PA)** | Chester, Marcus Hook, Wilmington (DE) | 3 |
| **Chicago (IL)** | Buffington, Calumet Harbor, Chicago, Gary, Indiana Harbor | 5 |
| **Convent (LA)** | Convent, St. James | 2 |
| **Detroit (MI)** | Detroit, Rouge River, Wyandotte | 3 |
| **Duluth (MN)** | Duluth, Superior | 2 |
| **Empire (OR)** | Coos Bay, Empire | 2 |
| **Galveston (TX)** | Galveston, Texas City | 2 |
| **Huron (OH)** | Huron, Sandusky | 2 |
| **Los Angeles (CA)** | Long Beach, Los Angeles | 2 |
| **Mare Island (CA)** | Mare Island, Port Vallejo | 2 |
| **Marinette (WI)** | Marinette, Menominee | 2 |
| **Muskegon (MI)** | Muskegon, White Lake | 2 |
| **New York City (NY)** | Bayonne, Brooklyn, Carteret, Chrome, Elizabethport, Grasselli, Gulfport, Hoboken, Jersey City, Leonardo, Mariners Harbor SI, Newark, New York City, Perth Amboy, Port Reading, Port Richmond, Port Socony, South Amboy, Stapleton, Tompkinsville, Weehawken | 21 |
| **Newport (RI)** | Newport, Tiverton | 2 |
| **Norfolk (VA)** | Newport News, Norfolk, Portsmouth (VA) | 3 |
| **Oakland (CA)** | Alameda, Oakland, Point Richmond, San Francisco | 4 |
| **Philadelphia (PA)** | Camden, Gloucester (NJ), Philadelphia | 3 |
| **Portland (OR)** | Portland (OR), Vancouver | 2 |
| **St. Petersburg (FL)** | Port Manatee, St. Petersburg | 2 |
| **Washington, DC** | Alexandria (VA), Washington, DC | 2 |
| **Wilmington (NC)** | Wilmington (NC), Wrightsville | 2 |

*Note:* Ports that were not grouped with others are not on this list but can be found in the supplemental materials.

## APPENDIX B: $CO_2$ ESTIMATES

**Figure B1**

**$CO_2$ emission estimates from at-berth vessels in U.S. ports, 2019**

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