United States Environmental Protection Agency

EPA AND PORT EVERGLADES PARTNERSHIP:
Emission Inventories and Reduction Strategies

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NOTE

Eastern Research Group provided technical support to the U.S. Environmental Protection Agency in the development of the methodologies, emission inventories, emission reduction strategy analyses, and other tasks.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

AAPA	American Association of Port Authorities
AIS	automatic identification system
ARB	Air Resources Board (California)
BAU	Business as Usual (scenario)
BC	black carbon
BEV	battery electric vehicle
CH_4	methane
CHE	cargo handling equipment
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
DOC	diesel oxidation catalyst
DPF	diesel particulate filter
DPM	diesel particulate matter
DPM_{10}	diesel particulate matter less than or equal to 10 microns in diameter
$DPM_{2.5}$	diesel particulate matter less than or equal to 2.5 microns in diameter
ECA	Emission Control Area
eGRID	Emissions & Generation Resource Integrated Database
EPA	U.S. Environmental Protection Agency
FECR	Florida East Coast Railway
FRCC	Florida Reliability Coordinating Council
g/bhp-hr	grams per brake horsepower-hour
g/hp-hr	grams per horsepower-hour
g/kW-hr	grams per kilowatt-hour
GHG	greenhouse gas
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
hp	horsepower
hr	hour
ICTF	Intermodal Container Transfer Facility
IHS	Information Handling Services
kW	kilowatt
kW-hr	kilowatt-hour
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MARPOL	International Convention for the Prevention of Pollution from Ships

MOVES	MOtor Vehicle Emissions Simulator
MY	model year
N_2O	nitrous oxide
NERC	North American Electric Reliability Corporation
NPSA	National Port Strategy Assessment
NOx	nitrogen oxides
OGV	ocean going vessel
PM	particulate matter
PM_{10}	particulate matter less than or equal to 10 microns in diameter
$PM_{2.5}$	particulate matter less than or equal to 2.5 microns in diameter
ppm	parts per million
RORO	roll-on roll-off (vessel)
RTG	rubber tired gantry
SCC	source classification code
SCR	selective catalytic reduction
SO_2	sulfur dioxide
TEU	twenty-foot equivalent unit
tons	short tons
U.S.	United States
ULSD	ultra-low sulfur diesel
VOC	volatile organic compound

1. EXECUTIVE SUMMARY

1.1 Introduction

Ports are key to the United States economy and serve as gateways to transport cargo, fuel, and passengers around the globe. Seaport cargo activity alone accounts for over a quarter of the U.S. Gross Domestic Product and supports the employment of over 23 million Americans.[1] As part of its Ports Initiative, the U.S. Environmental Protection Agency (EPA) recognizes the importance of working closely with ports to understand the on-the-ground, day-to-day operations and examine the methods available to estimate associated air pollution emissions.[2]

In 2016, EPA's Office of Transportation and Air Quality and Broward County's Port Everglades announced a voluntary partnership to study mobile source emissions.[3] Port Everglades is the first port to partner with EPA in this way. Port Everglades is one of the nation's leading container ports, South Florida's main seaport for receiving petroleum products, and one of the busiest cruise ports in the world.[4] Port Everglades is located in an area that currently meets EPA's national ambient air quality standards, and the Port is committed to environmental stewardship now and in the future.

Port Everglades Passenger Terminal
(Source: Port Everglades)

[1] American Association of Port Authorities (AAPA), http://www.aapa-ports.org/advocating/content.aspx?ItemNumber=21150.
[2] For more information on EPA's Ports Initiative, see https://www.epa.gov/ports-initiative.
[3] For further information on the EPA-Port Everglades Partnership, see https://www.epa.gov/ports-initiative/epa-partnership-agreement-broward-countys-port-everglades.
[4] For further information on Port Everglades, see http://www.porteverglades.net.

Through this partnership, Port Everglades developed the *2015 Baseline Air Emissions Inventory*,[5] which presents port-related emissions based on 2015 activity levels at Port Everglades that can be used as a benchmark to measure the impact of future port changes. The baseline inventory was also used in EPA's development of future hypothetical emission inventories and scenarios to evaluate potential new strategies to reduce diesel emissions at Port Everglades. Diesel engines are important components of the American economy, and although they can be reliable and efficient, older diesel engines can emit significant amounts of air pollution, including particulate matter (PM) and nitrogen oxides (NOx). Emission sources that were considered in this partnership included ocean going vessels, harbor craft, cargo handling equipment, trucks, and locomotives. EPA also evaluated the current and future emissions and potential strategies for three "off-port" transportation corridors—a marine corridor, truck corridor, and rail corridor—for port-related traffic outside the Port.

This partnership will help EPA provide future methods, lessons learned, and practical examples that can be shared with other ports, related agencies, and stakeholders. The findings from this partnership will inform EPA's update to the Port Emissions Inventory Guidance, so that other U.S. ports, port-related industry, state and local governments, tribes, and surrounding communities have clear technical guidance to estimate and understand emission inventories and potential reductions from port-related strategies. This future guidance update was included in stakeholder recommendations from the Mobile Sources Technical Review Subcommittee of the Clean Air Act Advisory Committee.[6]

This report provides valuable information for Port Everglades and its stakeholders to consider and can inform other ports of the full range of strategies available for reducing port emissions. However, it is not a policy document and does not include policy recommendations for Port Everglades. The emission reduction scenarios are hypothetical, and although EPA considered several general factors in its analysis, the scenario results do not consider the logistics and costs for implementation. Additionally, some strategies that were considered are beyond the port's jurisdictional authority to implement.

Key findings of the Port Everglades Partnership are explored in further detail below.

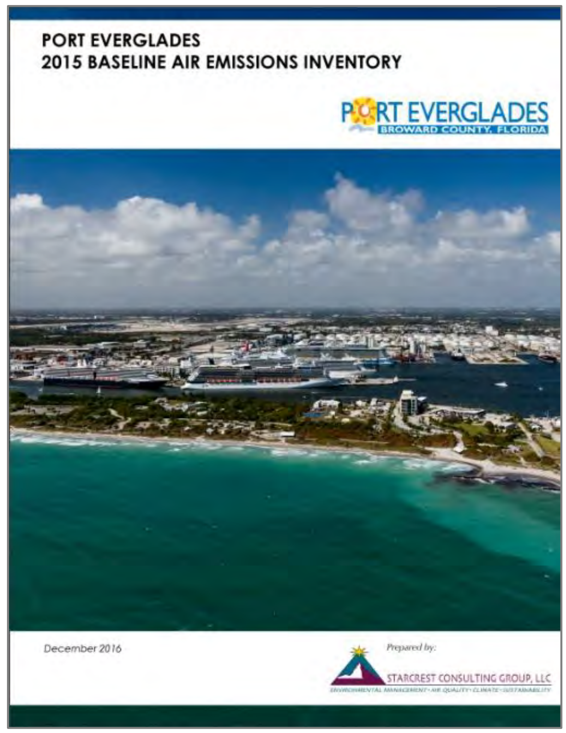
[5] Starcrest Consulting Group, LLC, *Port Everglades 2015 Baseline Air Emissions Inventory*, December 2016 http://www.porteverglades.net/environment/air-quality/air-emissions-inventory.

[6] For further information on the "Final Ports Initiative Workgroup Report: Recommendations for the U.S. EPA," see: https://www.epa.gov/caaac/final-ports-initiative-workgroup-report-recommendations-us-epa.

1.2 Partnering with Port Everglades was key to developing methods and lessons learned that can be applied at other ports

Through the partnership, EPA and Port Everglades worked together on common environmental objectives and shared their perspectives. Port Everglades' leadership helped EPA better understand port operations and allowed EPA to use the Port as a technical training ground.[7] The partnership also supported the Port's overall environmental mission and commitment to environmental stewardship.[8] The Port has invested significantly in cleaner equipment (such as electric cranes), and has also supported other improvements to enhance operations (such as reducing on-port truck bottlenecks).

Port Everglades developed the *2015 Baseline Air Emissions Inventory* that identifies and quantifies pollutants emitted from port-related mobile vehicles and equipment operating within the Port. This work guided EPA's development of future year emission reduction scenarios. Additionally, Port Everglades leveraged existing relationships with partners, regional and state agencies, and others to access non-confidential data not readily accessible to EPA,[9] which allowed EPA to refine its analysis. This general experience will inform future EPA guidance.



Port Everglades 2015 Baseline Air Emissions Inventory (Source: Starcrest Consulting Group)

Through its collaboration with Port Everglades, EPA can cite practical examples, methods, and lessons learned with respect to the development of port-specific inventories and evaluation of emission reduction strategies that can be shared with other ports, related agencies, and stakeholders across the United States. This ultimately provides Port Everglades with a strong technical foundation to make informed decisions with more accurate data, allowing the Port to continue to support clean air, and meet the needs of its customers, stakeholders, and community. The lessons learned through EPA's analysis can be applied to other interested ports.

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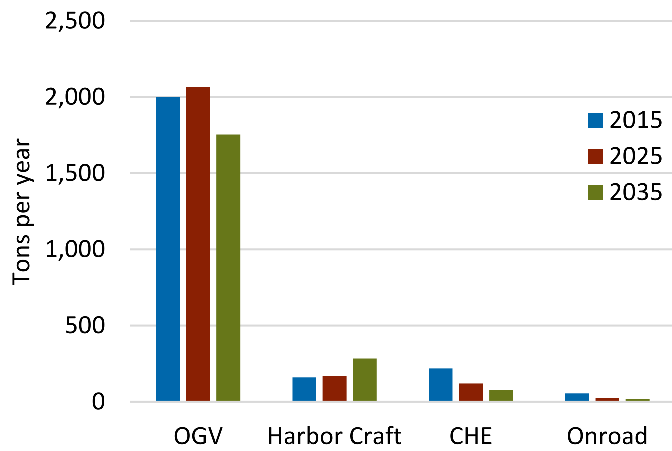
7 Neugaard, E. and Buchan, P., "Port Everglades: A Framework for Cooperation with the EPA," *Journal of Ports and Terminals*, Ed. 75, Autumn 2017.

8 Port Everglades, "About Us—Mission Statement," http://www.porteverglades.net/about-us.

9 EPA did not receive any confidential business or terminal-specific information through the partnership.

1.3 Inventories can help benchmark port and port industry progress

An emissions inventory is an important benchmark against which to measure progress and enables informed decision making. The *Port Everglades 2015 Baseline Air Emissions Inventory* was developed from detailed local mobile source activity and fleet information, including ocean going vessels (OGVs), harbor craft, cargo handling equipment (CHE), onroad vehicles, and rail operations. EPA used growth projections from Port Everglades' *2014 Master/Vision Plan*[10] and fleet turnover rates to produce hypothetical Business as Usual (BAU) emission inventories for multiple pollutants for the years 2025 and 2035, with a limited analysis for 2050.[11] Figure 1-1 depicts the baseline and projected BAU inventories for on-port NOx emissions. OGVs are the biggest source of emissions and are expected to remain so in future years, despite the Emission Control Area emission requirements, while projected increases in activity will drive increases in harbor craft emissions.



Note: NOx on-port rail emissions are <2 tons per year.

Figure 1-1. Port Everglades Baseline and Projected BAU On-port NOx Emissions

With these inventories, Port Everglades can now examine emission trends by source, identify potential opportunities for emission reductions, and prioritize future investment or operational changes to reduce emissions. For example, the equipment inventory revealed that harbor craft are aging (Figure 1-2), presenting an opportunity to reduce emissions significantly through incentives to encourage vessel or engine replacement. The Port anticipates conducting additional inventories in the future to benchmark air emissions and track progress.[12]

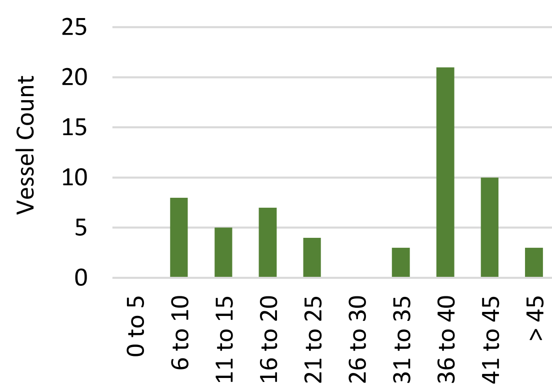


Figure 1-2. Harbor Craft Age Distribution (Years Old)

[10] Port Everglades, 2014 *Master/Vision Plan* reports, June 24, 2014, http://www.porteverglades.net/construction/master-vision-plan/master-plan-reports.

[11] EPA's analysis included criteria pollutants and precursors (e.g., PM and NOx), greenhouse gases, and air toxics (i.e., diesel PM). All pollutants were analyzed for the years 2025 and 2035, and for 2050, carbon dioxide equivalents (CO_2e) were analyzed. For the full set of assumptions used to generate emission inventories and projections, see the individual sections later in this report.

[12] Neugaard, E. and P. Buchan, "Port Everglades: A Framework for Cooperation with the EPA," *Journal of Ports and Terminals*, Ed. 75, Autumn 2017.

1.4 Emissions are being reduced, but more can be done with available strategies

The BAU inventories show that EPA's engine and fuel regulations, as well as emerging commercially available technologies, are expected to reduce port-related emissions. For example, new vehicle and equipment emission standards are already reducing NOx and PM emission rates as older equipment is replaced at ports across the country. However, voluntarily implementing operational strategies or accelerating equipment replacement rates, for example, could further reduce emissions, or reduce emissions sooner. In consultation with Port Everglades, EPA identified voluntary strategies, listed in Table 1-1, to analyze for additional reductions beyond the BAU case.

Table 1-1. On-port Strategies Considered at Port Everglades

Sector	Strategy Descriptions
Ocean Going Vessels	• Reduced hotelling time • At-berth alternative control technology (capture and treat) • Lower sulfur fuels and alternative fuels such as liquefied natural gas (LNG) • Shore power
Harbor Craft	• Engine replacement (to Tier 3) and vessel replacement (to Tier 4)
Cargo Handling Equipment	• Equipment replacement (to Tier 4) and equipment electrification • Diesel particulate filters and oxidation catalysts
Onroad	• Truck replacement to MY2010+ and battery electric vehicles (BEVs) • Truck idle reduction
Rail[13]	• Increase modal shift of cargo from truck to rail

Many of these strategies are applicable to any port, but the emission-reducing potential of a given strategy highly depends on a port's individual characteristics. Attributes such as the port's primary activity type and level; types of vessels, equipment, and fuels used; and the technologies and operations utilized onsite impact the emissions reduction potential of a given strategy. In addition to supporting environmental goals, some strategies have potential co-benefits, such as reducing fuel usage and improving operational efficiencies that may enhance a port's competitiveness.

[13] Replacing older diesel locomotives, such as switchers, is an effective emission reduction strategy to consider. However, at Port Everglades, the Florida East Coast Railway has already updated its line-haul locomotive fleet to cleaner technology and has constructed the Intermodal Container Transfer Facility, which does not use switcher locomotives, at the Port. For further general information about other rail strategies, see EPA's *National Port Strategy Assessment* at: https://www.epa.gov/ports-initiative/national-port-strategy-assessment-reducing-air-pollution-and-greenhouse-gases-us.

1.5 Strategies and scenarios are effective to reduce on-port emissions

To evaluate the effectiveness of various strategies, EPA's analysis explored the potential of hypothetical scenarios, applied at different levels of implementation, to reduce future year emissions.

Figure 1-3 highlights potential NOx reductions for a selection of on-port strategies, including:

- **OGVs**: Use LNG in 5–10 percent of containerships
- **Harbor Craft**: Replace 20 percent of Tier 0 vessels with Tier 4 vessels
- **CHE**: Replace Tier 0 through Tier 3 equipment with Tier 4 or electric equipment
- **Trucks**: Limit on-port truck idling to 5 minutes per truck per visit

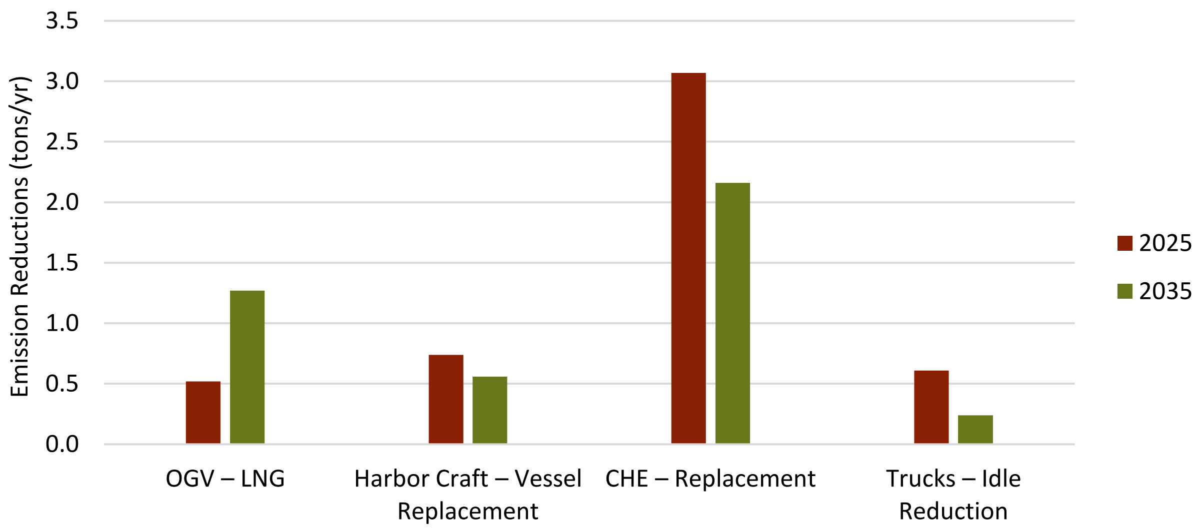


Figure 1-3. Projected Annual NOx Emission Reductions for Selected On-port Strategies

This chart illustrates that significant reductions are possible from these strategies, which are just a subset of the strategies examined in EPA's analysis for on-port emissions. A variety of strategies are available and ports can assess which make the most sense for their specific conditions. Note that the hypothetical scenarios[14] evaluated in this study do not include specific implementation details but assume coordination and collaboration by the various maritime industry stakeholders.

[14] In selecting scenarios, EPA qualitatively considered several factors, such as capital costs, market barriers, and potential for market penetration by analysis year. However, a detailed cost-benefit analysis was not conducted for this analysis and cost per ton of pollutant reduced was not calculated.

1.6 Potential actions can have benefits beyond a port's boundary

Ports are a nexus between transportation modes and activities that generate emissions at sea and on land, both on the port property and on nearby transportation corridors. As part of its analysis, EPA examined three transportation corridors to estimate emissions from port-related vessel and vehicle activity occurring outside Port Everglades. The off-port corridors included a marine corridor, a truck corridor, and a rail corridor.

For each corridor, EPA developed a 2015 off-port baseline inventory and projected future BAU emissions for the same years and pollutants as the on-port analysis. Hypothetical scenarios were also developed to examine potential strategies to reduce off-port emissions along transportation corridors. Figure 1-4 shows potential NOx reductions in 2025 and 2035 for a selection of off-port reduction strategies, including:

- **OGVs**: Have 50 percent of vessels participate in voluntary vessel speed reduction to 12 knots or less
- **OGVs**: Use LNG in 5–10 percent of containerships
- **Trucks**: Accelerate replacement of pre-2007 and pre-2010 trucks with model year 2010 or later trucks and some BEVs

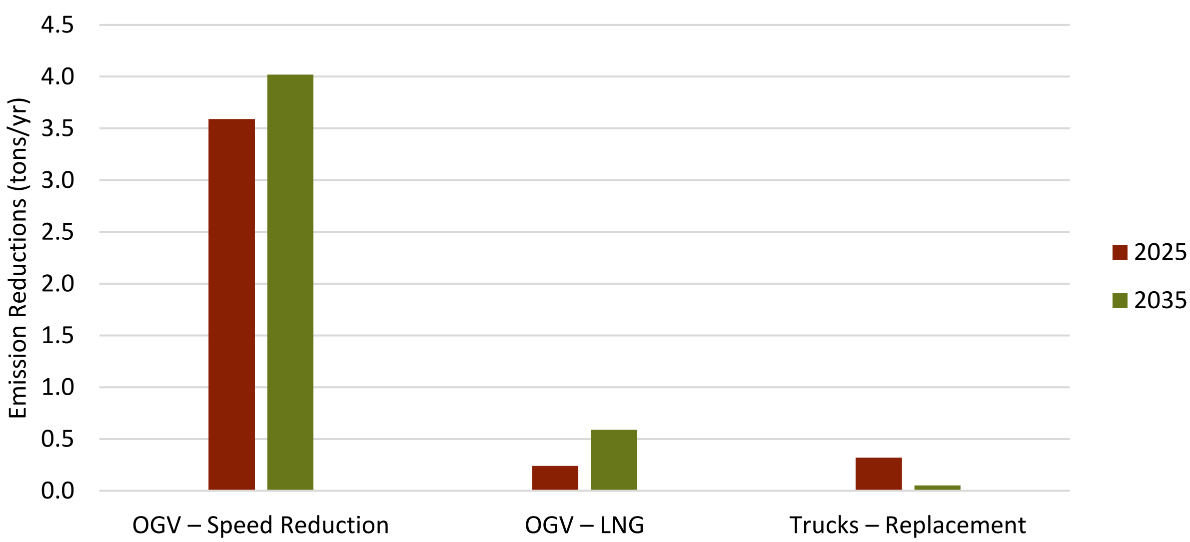


Figure 1-4. Projected Annual $PM_{2.5}$ Emission Reductions for Selected Off-port Strategies

Quantifying mobile source emissions using local data along these types of corridors can help stakeholders identify impacts and opportunities to reduce emissions.

1.7 Data and methods are available for developing port inventories and analyses

This partnership provided an opportunity to consider data and methods currently available for developing the emission inventories for port-related vehicle and equipment sectors. For each sector, inventories relied upon data describing the emission sources, such as vessel, equipment or vehicle type; engine type; horsepower; age; and other parameters. Activity and operational data, describing the amount of time and the circumstances in which the sources operate, were also used. These and other data are discussed throughout the report.

Emissions inventory resources

Emission estimation methods are currently available for all land and marine emission sources at ports. For OGVs, automatic identification system data from the U.S. Coast Guard were used to identify vessel movements in conjunction with Port Everglades' vessel call records. For harbor craft, information was collected about the type of craft and activity operating at the port. For locomotives, the Florida East Coast Railway, in consultation with Port Everglades, provided information on its locomotive fleet and operating characteristics. Additionally, EPA's MOtor Vehicle Emissions Simulator (i.e., MOVES2014a)[15] was used to model emissions from both onroad vehicles and nonroad CHE.

Partnering with Port Everglades allowed EPA to refine inventory development methods and will inform EPA's next update of the Port Emissions Inventory Guidance. Since the release of EPA's existing guidance in 2009,[16] additional information and methods have become available. For example, the MOVES model was not yet available when the existing guidance was issued, and its predecessor did not have the same capabilities. Lessons learned and methods developed from the EPA-Port Everglades partnership will be incorporated into EPA's updated guidance and will inform future inventory development and strategy analyses across the U.S.

[15] More information on EPA's MOVES model can be found at: https://www.epa.gov/moves.

[16] U.S. EPA, *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories Final Report*, April 2009, https://www.epa.gov/moves/current-methodologies-preparing-mobile-source-port-related-emission-inventories-final-report.

2. INTRODUCTION

2.1 Overview of Analysis

EPA conducted this analysis to develop baseline and future year emission inventories at Broward County's Port Everglades and to evaluate available technology and operational strategies for emission reductions. While this report provides valuable information for Port Everglades and port stakeholders to consider, it is not a policy document and does not include policy recommendations for Port Everglades. This work will inform EPA's future update of its Port Emissions Inventory Guidance.

Background. Ports are key to the United States economy and serve as gateways to transport cargo, fuel, and passengers around the globe. Seaport cargo activity alone accounts for over a quarter of the U.S. Gross Domestic Product and supports the employment of over 23 million Americans.[17] Diesel engines are important components of the American economy, and although they can be reliable and efficient, older diesel engines can emit significant amounts of air pollution. There are a wide range of technological and operational strategies that can reduce port-related emissions.

This analysis is part of EPA's broader Ports Initiative that works in collaboration with port industry, communities, and all levels of government to improve environmental performance and increase economic prosperity.[18] In 2016, EPA released the *National Port Strategy Assessment: Reducing Air Pollution and Greenhouse Gases at U.S. Ports* (NPSA). The NPSA provides a national picture of port-related emission trends and the potential for emission reduction strategies based on estimated emissions from a sample of 19 seaports that represent a variety of activities and locations around the country.[19]

Partnership. In 2016, EPA and Broward County's Port Everglades (hereafter also referred to as "the Port") announced a voluntary partnership to develop baseline and future year emission inventories, and to evaluate technological and operational strategy scenarios to reduce air pollution emissions at ports.[20] Port Everglades is Florida's largest container port and one of the busiest cruise ports in the world. The Port also receives, stores, and distributes refined petroleum products for South Florida. While Port Everglades is located in an area that currently meets EPA's national ambient air quality standards, the port is committed to environmental stewardship now and in the future. Port Everglades is the first port in the U.S. to partner with EPA in this way.

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[17] American Association of Port Authorities (AAPA), http://www.aapa-ports.org/advocating/content.aspx?ItemNumber=21150.

[18] For more information, see https://www.epa.gov/ports-initiative.

[19] For further information on the *National Port Strategy Assessment*, see https://www.epa.gov/ports-initiative/national-port-strategy-assessment-reducing-air-pollution-and-greenhouse-gases-us.

[20] For further information on the *EPA-Port Everglades Partnership Agreement*, see https://www.epa.gov/sites/production/files/2016-06/documents/epa-Port Everglades-partnership-agreement-executed.pdf.

As part of the partnership, Port Everglades developed the *Port Everglades 2015 Baseline Air Emissions Inventory*[21] (hereafter referred to as the “2015 On-port Baseline Inventory”), which presents port-related emissions based on 2015 activity levels at Port Everglades.

Using that information, as part of the partnership, EPA developed:

- Hypothetical emission inventories and reduction scenarios for Port Everglades for future analysis years.
- Emission inventories for certain off-port mobile source corridors outside Port Everglades.
- Documentation of methods, lessons learned, and practical examples that may be shared with other ports, related agencies, and stakeholders.

Throughout the partnership, EPA and Port Everglades worked together on all deliverables in addition to consulting with each other and providing technical assistance throughout the development of the 2015 On-port Baseline Inventory and EPA’s analyses.

Geographical Scope. In this report, “on-port” refers to the geographical area covered by the 2015 On-port Baseline Inventory. The on-port landside geographical scope used for the 2015 On-Port Baseline Inventory and EPA’s on-port analysis is shown in Figure 2-1. “Off-port” refers to the port-related corridors included in this analysis that extend beyond Port Everglades. These include a marine corridor, a truck corridor, and a rail corridor. The off-port corridors are described further in Section 9.

[21] Starcrest Consulting Group, LLC, *Port Everglades 2015 Baseline Air Emissions Inventory*, December 2016, http://www.porteverglades.net/environment/air-quality/air-emissions-inventory.

Figure 2-1. On-port Landside Geographical Domain[22]

[22] Ibid.

Mobile Source Sectors Analyzed. This analysis focused on the potential of strategies to reduce emissions from diesel-powered vehicles and equipment.[23] The five mobile source sectors analyzed were:

- Ocean going vessels (OGVs): OGVs are ships with engines of 30 liters[24] displacement per cylinder or more (i.e., Category 3 engines).[25] There are many kinds of OGVs; the ship types that were considered in this analysis are described in Section 4.

- Harbor craft: Harbor craft assist in moving OGVs around the harbor, move cargo and people around the port harbor area, and provide fuel to OGVs; they also transport crew and supplies to offshore facilities. Harbor craft are vessels with engine displacements of less than 30 liters per cylinder and are classified as Category 1 and 2 vessels. There are many kinds of harbor craft; however, this analysis focused specifically on tugs and towboats.

- Cargo handling equipment (CHE): CHE are located on-port to move cargo on and off OGVs and harbor craft. Additionally, CHE move cargo around the port so that it can be loaded onto trucks and rail cars. A wide selection of CHE was accounted for by this analysis, including yard tractors, container handlers, and cranes.

- Onroad vehicles: The primary contributors to the onroad emissions inventory are heavy-duty diesel trucks that transport cargo into and out of the port. The most common type is the combination truck, usually configured to haul cargo containers, liquids, or standard box trailers.

- Rail: The rail emission sources included in this analysis are line-haul locomotives, which move cargo into and out of the Port. Rail yard, or switcher, locomotives are not used at Port Everglades' Intermodal Container Transfer Facility (ICTF), and therefore, these types of locomotives were not included in the 2015 On-port Baseline Inventory or EPA's analysis.

Pollutants. Port-related emissions and reductions were estimated for several different criteria pollutants and precursors, climate related pollutants, and air toxics. Even though Port Everglades is located in an area that currently meets EPA's national ambient air quality standards, this analysis evaluates all of these pollutants so that it can serve as a practical example for ports across the U.S. that have different air quality circumstances. Criteria pollutants include common air pollutants that are identified by the Clean Air Act, such as particulate matter (PM) and ground-level ozone. Precursors are air pollutants that form criteria pollutants, such as nitrogen oxides (NOx) and volatile organic compounds (VOCs), which

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[23] Even though the 2015 On-port Baseline Inventory includes stationary sources, such as administrative building electrical power consumption, this analysis focuses on only mobile source emission estimates and reductions.

[24] 30 liters is approximately 8 gallons.

[25] Note that some OGVs can have smaller Category 2 engines; however, for simplicity in this analysis, all OGVs were assumed to have Category 3 engines.

combine to form ground-level ozone. Climate related pollutants include greenhouse gases (GHGs), while air toxics are hazardous air pollutants that are known or suspected to cause serious health effects.

The following list includes the specific pollutants characterized in this analysis:

- Criteria pollutants and precursors:
  - NOx
  - Particulate matter less than or equal to 10 microns (PM_{10})
  - Particulate matter less than or equal to 2.5 microns ($PM_{2.5}$)
  - Sulfur dioxide (SO_2)
  - VOCs
- Climate related pollutants:
  - Carbon dioxide equivalents (CO_2e)
  - Black carbon (BC)
- Air toxics:
  - Diesel particulate matter less than or equal to 10 microns (DPM_{10})
  - Diesel particulate matter less than or equal to 2.5 microns ($DPM_{2.5}$)

Consistent with the 2015 On-port Baseline Inventory, CO_2e are calculated by weighting three GHGs by the following global warming potentials:[26]

- Carbon dioxide (CO_2): 1
- Methane (CH_4): 25
- Nitrous oxide (N_2O): 298

SO_2 was not analyzed for the non-OGV mobile source sectors since these sectors in the United States currently use ultra-low sulfur diesel (ULSD), which is a cleaner-burning diesel fuel that has significantly reduced the SO_2 emitted by these sources. SO_2 emissions from OGVs were estimated because, although these vessels are required to use low sulfur distillate fuels (up to 1000 ppm sulfur content) while operating in the North American Emission Control Area, including operations at ports, there is a potential for additional reductions through the use of even lower sulfur fuels.

2.2 Overview of Methodology

EPA's analysis builds on the methodology established in the 2015 On-port Baseline Inventory. First, future year emission inventories were developed based on anticipated operational growth

[26] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013*, April 2015, https://www.epa.gov/sites/production/files/2016-03/documents/us-ghg-inventory-2015-main-text.pdf.

at Port Everglades and the expected normal replacement of older, higher-emitting equipment with newer, lower-emitting equipment over time. Then, hypothetical emission reduction strategy scenarios were developed in consultation with the Port and analyzed to quantify their potential for reducing emissions. Additionally, baseline and future emission inventories as well as the potential for additional emission reductions were explored for three off-port corridors: a marine corridor, truck corridor, and a rail corridor.

2015 Baseline Emissions Inventory. This analysis builds on the results of the 2015 On-Port Baseline Inventory, which includes inventories for each of the mobile source sectors described above in Section 2.1. Because this inventory is primarily based on local activity data collected with the support of Port Everglades, it is a strong foundation for EPA's analysis. The baseline inventory relied on local activity data collected for the 2015 calendar year from a variety of public and proprietary sources, including U.S. Coast Guard automatic identification system (AIS) data, Information Handling Services' (IHS) Register of Ships, Starcrest's Vessel Boarding Program, vessel call logs shared by the Port, and confidential surveys of terminal and facility operational managers. Note that EPA and Port Everglades respected the privacy and confidentiality of the terminal operators at Port Everglades, and EPA did not receive confidential business or terminal-specific information through this partnership. For details on the data collection and inventory development methodology, please see the 2015 On-port Baseline Inventory.

The 2015 On-port Baseline Inventory included the same pollutants as this analysis (listed in Section 2.1), except for BC and $DPM_{2.5}$, which were added in EPA's analysis. Additionally, carbon monoxide (CO) was included in the 2015 baseline analysis but was not included here. In EPA's analysis, BC and $DPM_{2.5}$ were calculated from the particulate matter emissions that were included in the 2015 On-port Baseline Inventory.

Future Emission Projections. To project future emissions, Business as Usual (BAU) emission scenarios were developed based on the most recent local information available at the time of EPA's analysis for anticipated growth and changes at Port Everglades, as identified in the *2014 Master/Vision Plan*.[27] Hypothetical future emission inventories were estimated for 2025, 2035, and 2050,[28] based on the Port's anticipated growth in throughput and past fleet turnover rates. Although these hypothetical future emission inventories are based on local information, they are presented to illustrate EPA's analysis and are not intended to form the basis for policy recommendations.

Reduction Strategies and Scenarios. The hypothetical emission reduction scenarios were developed in consultation between EPA and Port Everglades, and include strategies to use cleaner technologies and operational improvements. Table 2-1 lists the emission reduction strategies analyzed for each mobile source sector. It should be noted that EPA's analysis included hypothetical scenarios of potential strategies for which Port Everglades has no direct

[27] Port Everglades, *2014 Master/Vision Plan* reports, June 24, 2014, http://www.porteverglades.net/construction/master-vision-plan/master-plan-reports

[28] Note that for 2050, only CO_2e inventories and reductions were quantified.

control. The analysis methodology did not make assumptions regarding the details, logistics, costs and/or other implications of how to apply or implement the reduction strategies nor did it assume which entity or entities would implement each strategy. The scenarios do not consider jurisdiction or geographical boundaries, except when determining if the emission reductions would occur on-port or off-port. Some of the strategies considered only apply to the on-port or off-port analysis, and some apply to both.

Table 2-1. Summary of Emission Reduction Strategies

Sector	Strategy Descriptions
OGV	• Vessel speed reduction • Reduced hotelling time • At-berth alternative control technology (capture and treat) • Lower sulfur fuels and alternative fuels such as liquefied natural gas (LNG) • Shore power
Harbor Craft	• Engine replacement (to Tier 3) • Vessel replacement (to Tier 4)
CHE	• Equipment replacement (to Tier 4) and equipment electrification • Diesel particulate filters and oxidation catalysts
Onroad	• Truck replacement to MY2010+ and battery electric vehicles (BEVs) • Truck idle reduction
Rail	• Increase modal shift of cargo from truck to rail

In most cases, high and low implementation scenarios were developed for each strategy. For strategies involving new technologies, both the high and low scenarios would involve substantial investments in new vehicles, equipment, vessels, and/or fuels, with the high scenario assuming a larger investment than the low scenario. For the operational strategies that go above and beyond the improvements continuously being sought at Port Everglades, the high scenario represents a greater achievement in operational improvements than the low scenario. In selecting scenarios, EPA qualitatively considered several factors, such as capital costs, market barriers, and potential for market penetration. However, a detailed cost-benefit analysis was not conducted for this analysis and cost per ton of pollutant reduced was not calculated. Please note that totals in tables contained in this report may not equal the aggregated displayed totals due to rounding.

2.3 Organization of Report

The remainder of the report is organized as follows:

Section 3—Summary Results provides an overview of the baseline emissions, projected BAU emissions, and potential emission reductions for the mobile source categories operating on-port and in off-port corridors.

Sections 4 through 8 present on-port results for the five source categories examined. Each section summarizes the on-port baseline emissions for 2015; presents the methodology and results for projecting BAU emissions for 2025, 2035, and 2050; and evaluates the potential for various emission reduction strategies. The considered source categories are presented in the following order:

- OGVs (Section 4)
- Harbor craft (Section 5)
- CHE (Section 6)
- Onroad vehicles (Section 7)
- Rail (Section 8)

Section 9—Off-port Corridor Analysis provides off-port results for the source categories that operate in off-port marine, truck, and rail corridors. This section includes a description of how the off-port corridors were selected, the methodology and results for the baseline and projected off-port emission inventories, and the potential for various emission reduction strategies. Please note that CHE do not operate in the off-port corridors, and thus are not relevant for the off-port analysis.

3. SUMMARY RESULTS

3.1 On-port Results Summary

This section summarizes the results of the components of EPA's analysis of mobile source emissions at Port Everglades. The on-port mobile source sectors analyzed include ocean going vessels (OGVs), harbor craft, cargo handling equipment (CHE), onroad vehicles, and rail.

On-port 2015 baseline emissions and Business as Usual (BAU) emission projections for the years 2025, 2035, and 2050 for NOx, $PM_{2.5}$, and CO_2e emissions are summarized in Figure 3-1, Figure 3-2, and Figure 3-3, respectively. As seen in the figures, OGVs are the biggest source of emissions and are expected to remain so in future years despite the Emission Control Area (ECA) emission requirements.[29] Rail emissions are not visible in the figures as they are orders of magnitude smaller than emissions for the other sectors.

Baseline emissions and BAU projections are presented in Table 3-1 for all pollutants considered in EPA's analysis. Note that SO_2 was only evaluated for OGVs. Additionally, for the 2050 analysis, only CO_2e inventories and reductions were quantified. Baseline and projected inventories like these are useful to examine emission trends by source, which may help ports identify potential emission reduction opportunities and prioritize future investment or operational changes to reduce emissions.

Selected on-port NOx, $PM_{2.5}$, and CO_2e emission reduction strategies are highlighted in Figure 3-4, Figure 3-5, and Figure 3-6, respectively. These figures show that a variety of strategies are available and ports can assess which make the most sense for their specific conditions. However, note that cost per ton of pollutant reduced was not calculated as part of this analysis, which is an important part of cost-benefit analysis that would inform strategy selection.

A summary of results of all analyzed on-port strategies and scenarios for each source category is presented in Table 3-2. This summary only includes NOx, $PM_{2.5}$, and CO_2e; however, on-port results for all pollutants are included along with methodology details in Sections 4 through 8. Increased use of natural gas-powered OGVs is projected to decrease NOx and $PM_{2.5}$ emissions through 2035 and CO_2e emissions through 2050. Accelerated replacement of harbor craft and CHE has the potential to reduce emissions above what is projected in the BAU case. Idle reduction may also facilitate significant reductions in truck emissions.

As described in later sections, some strategies and scenarios were not evaluated for all three future years of 2025, 2035, and 2050, and some were not evaluated for all pollutants (i.e., some strategies only targeted a subset of the pollutants). EPA's analysis also includes percent reductions from the BAU for each strategy scenario. See subsequent sections for details on all emission inventories, strategy scenarios, and results.

[29] U.S. Environmental Protection Agency, *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Category 3 Marine Diesel Engines*, EPA-420-R-09-019, December 2009, https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1005ZGH.txt.

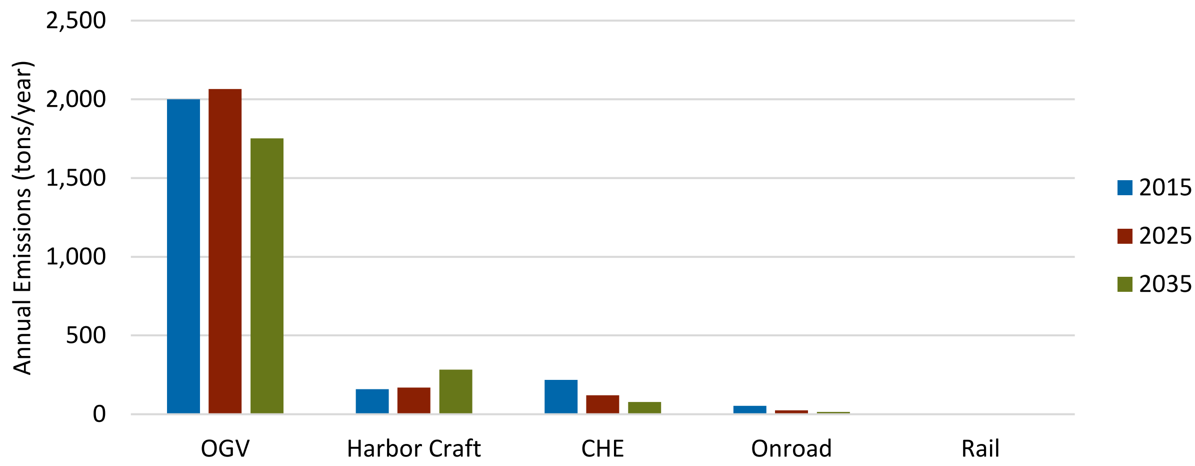

Figure 3-1. On-port Baseline and BAU NOx Emissions

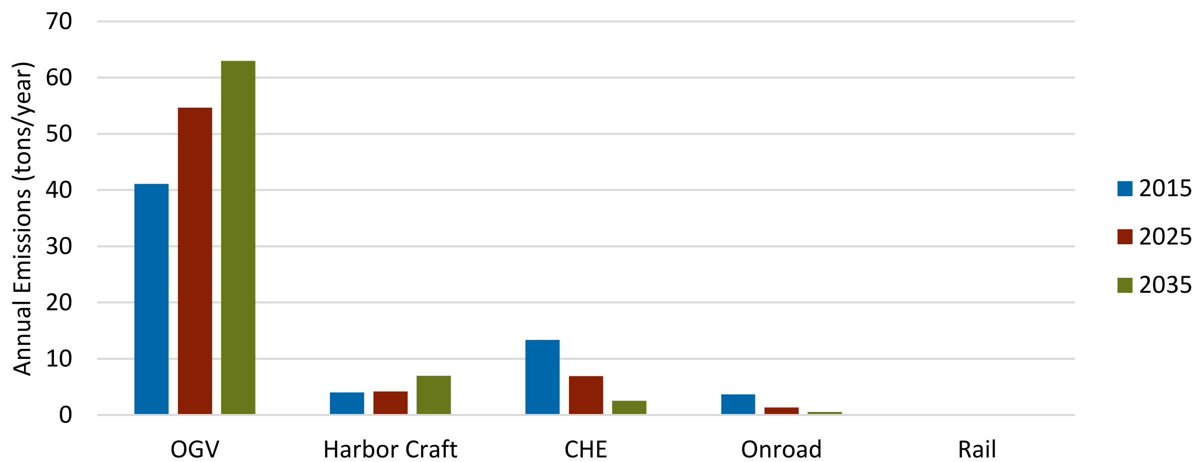

Figure 3-2. On-port Baseline and BAU $PM_{2.5}$ Emissions

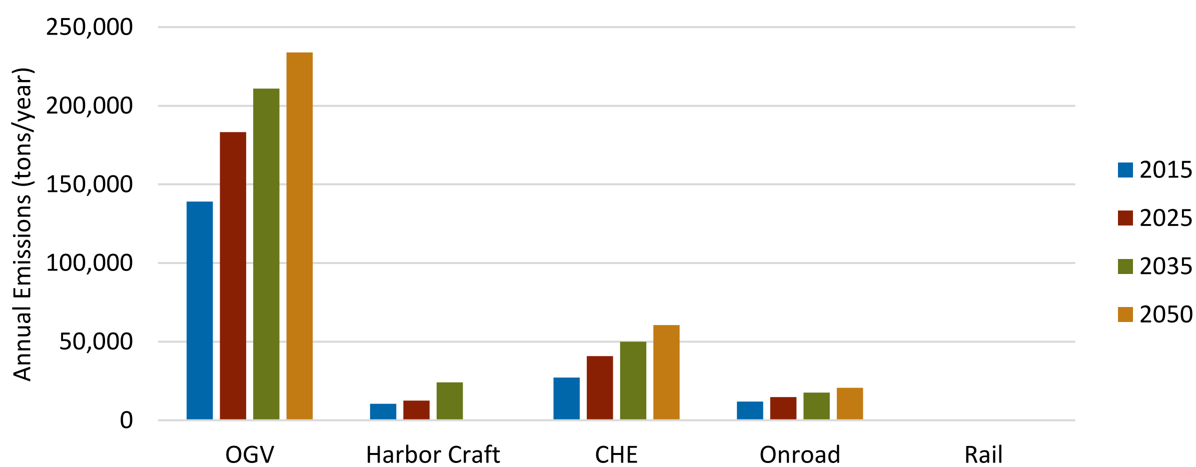

Figure 3-3. On-port Baseline and BAU CO_2e Emissions

Table 3-1. Summary of On-port Baseline and BAU Emissions

Year	Mode	Annual Emissions (tons/year)								
		NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	SO_2	VOC	CO_2e[a]
2015[30]	OGV	2,000.82	43.73	41.07	37.95	35.66	31.64	88.45	73.44	139,046.22
	Harbor Craft	159	4.36	4.01	4.36	4.01	3.09	--[a]	6.09	10,457.61
	CHE	218.16	13.82	13.38	13.82	13.38	4.66	--	24.81	27,259.02
	Onroad	54.04	3.96	3.65	3.94	3.64	1.69	--	5.99	11,887.31
	Rail	1.41	0.02	0.02	0.02	0.02	0.01	--	0.04	142.54
	Total	**2,433.43**	**65.89**	**62.13**	**60.09**	**56.71**	**41.09**	**--**	**110.37**	**188,792.70**
2025	OGV	2,065.47	58.18	54.67	51.07	47.99	42.08	116.56	98.24	183,165.83
	Harbor Craft	168.66	4.57	4.20	4.57	4.20	3.23	--	6.69	12,496.85
	CHE	120.61	7.14	6.93	7.14	6.93	2.42	--	13.83	40,704.41
	Onroad	24.32	1.42	1.31	1.41	1.30	0.61	--	2.25	14,777.72
	Rail	1.57	0.03	0.03	0.03	0.03	0.02	--	0.36	180.17
	Total	**2,380.63**	**71.34**	**67.14**	**64.22**	**60.45**	**48.36**	**--**	**121.37**	**251,324.98**
2035	OGV	1,753.08	67.02	62.98	58.75	55.16	48.47	134.23	113.7	210,972.08
	Harbor Craft	284.29	7.59	6.98	7.59	6.98	5.37	--	11.78	24,115.26
	CHE	78.42	2.60	2.52	2.60	2.52	0.88	--	13.73	49,929.53
	Onroad	15.54	0.56	0.52	0.55	0.51	0.07	--	1.16	17,558.34
	Rail	1.51	0.04	0.04	0.04	0.04	0.03	--	0.82	205.91
	Total	**2,132.84**	**77.81**	**73.04**	**69.53**	**65.21**	**54.82**	**--**	**141.19**	**302,781.12**
2050	OGV	--	--	--	--	--	--	--	--	233,860.74
	Harbor Craft	--	--	--	--	--	--	--	--	--
	CHE	--	--	--	--	--	--	--	--	60,521.19
	Onroad	--	--	--	--	--	--	--	--	20,753.28
	Rail	--	--	--	--	--	--	--	--	212.72
	Total	--	--	--	--	--	--	--	--	--

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

[30] Starcrest Consulting Group, LLC, *Port Everglades 2015 Baseline Air Emissions Inventory*, December 2016.

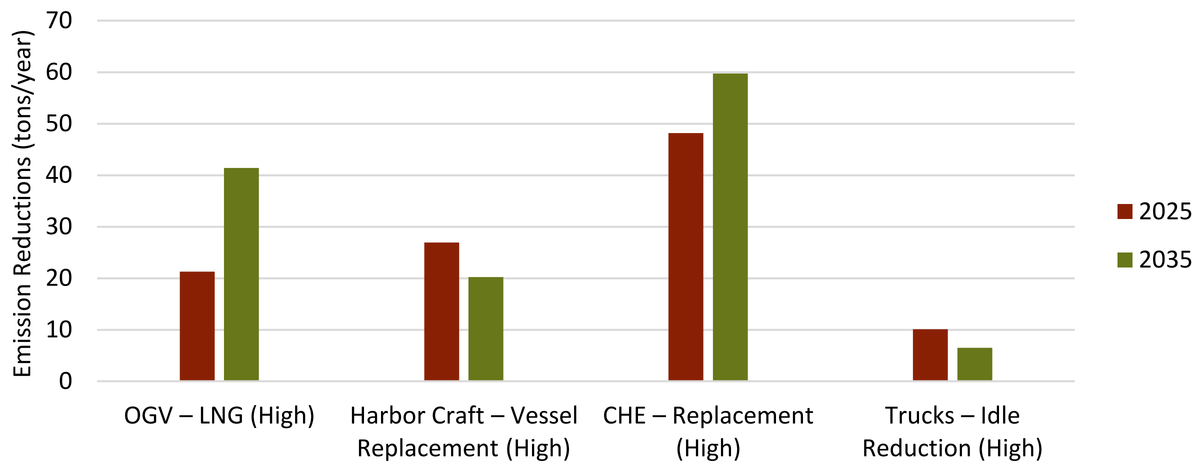

Figure 3-4. Selected On-port NOx Reduction Strategies

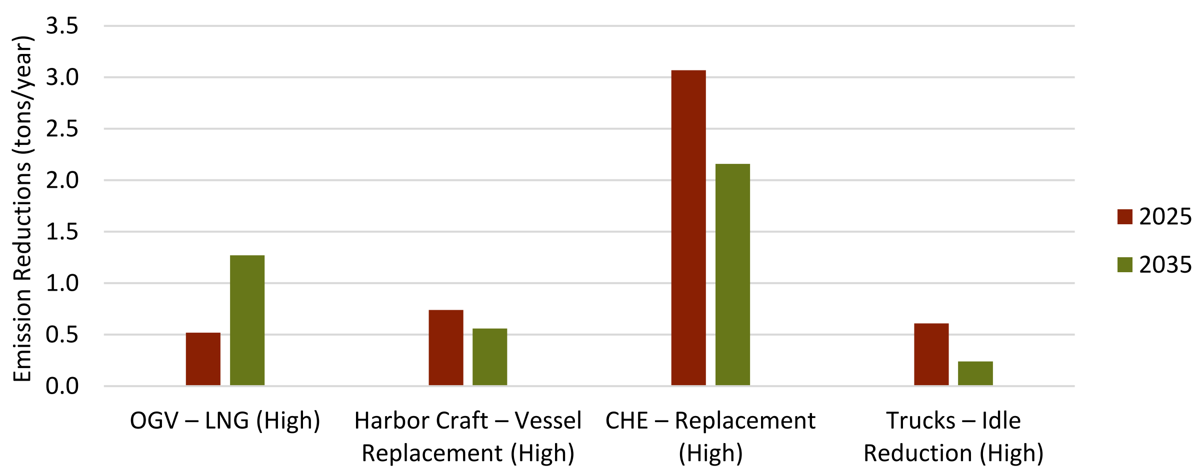

Figure 3-5. Selected On-port $PM_{2.5}$ Reduction Strategies

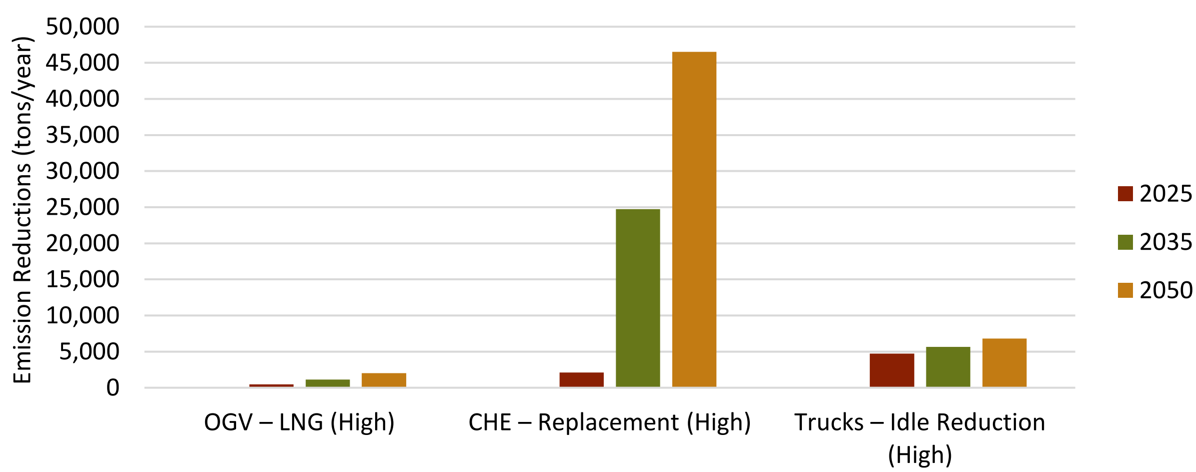

Figure 3-6. Selected On-port CO_2e Reduction Strategies

Table 3-2. Summary of On-port Emission Reductions

Strategy	Scenario	Emission Reductions (tons/year)						
		NOx		$PM_{2.5}$		CO_2e		
		2025	2035	2025	2035	2025	2035	2050
Ocean Going Vessels								
Reduced Hotelling Time	Low	13.60	13.48	0.31	0.38	847.75	1,039.97	2,520.72
	High	27.20	26.97	0.63	0.77	1,695.51	2,079.94	5,041.44
At-Berth Alternative Control Technology	Low	0.97	3.77	0.07	0.24	−118.80	−668.04	--[a]
	High	4.83	7.54	0.37	0.48	−593.98	−1,336.09	--
Lower Sulfur Fuels	Low	--	--	0.32	1.86	--	--	--
	High	--	--	0.81	3.71	--	--	--
Liquefied Natural Gas (LNG)	Low	4.26	8.28	0.10	0.25	91.07	223.44	676.96
	High	21.28	41.42	0.52	1.27	455.35	1,117.18	2,030.89
Shore Power	High	--	182.18	--	4.33	--	2,940.91	8,099.06
Harbor Craft								
Engine Replacement	Low	13.93	10.45	0.63	0.48	--	--	--
	High	22.63	13.93	1.03	0.63	--	--	--
Vessel Replacement	Low	13.46	10.10	0.37	0.28	--	--	--
	High	26.92	20.19	0.74	0.56	--	--	--
Cargo Handling Equipment								
Diesel Particulate Filters	Low	--	--	2.00	0.72	--	--	--
	High	--	--	3.37	0.82	--	--	--
Diesel Oxidation Catalysts	Low	--	--	0.44	0.16	--	--	--
	High	--	--	0.78	0.18	--	--	--
Equipment Replacement	Low	25.37	54.12	1.37	1.88	0.00	13,041.27	42,848.10
	High	48.19	59.74	3.07	2.16	2,091.53	24,751.53	46,535.95
Alternative Fuels	Low	16.36	7.68	0.79	0.50	--	--	--
	High	21.51	9.39	1.20	0.69	--	--	--
Reefer Electrification	High	1.48	1.82	0.04	0.06	3,136.57	3,848.32	4,663.77

Table 3-2. Summary of On-port Emission Reductions

Strategy	Scenario	Emission Reductions (tons/year)						
		NOx		$PM_{2.5}$		CO_2e		
		2025	2035	2025	2035	2025	2035	2050
Onroad Vehicles								
Idle Reduction	Low	3.36	2.17	0.20	0.08	1,571.73	1,881.45	2,271.77
	High	10.08	6.50	0.61	0.24	4,715.20	5,644.36	6,815.30
Operational Improvements	Low	0.67	0.43	0.04	0.02	314.35	376.29	454.35
	High	1.34	0.87	0.08	0.03	628.69	752.58	908.71
Truck Replacement	Low	5.87	2.92	0.89	0.11	0.00	2,505.10	5,923.40
	High	7.26	4.66	0.90	0.15	0.00	4,921.36	9,872.34
Rail								
Truck-to-Rail Intermodal Shift	High	0.30	−0.06	0.05	0.02	613.06	1,275.06	2,390.23

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

3.2 Off-port Results Summary

This section summarizes the results of the off-port components of EPA's analysis of emissions. The off-port mobile source sectors analyzed include OGVs, harbor craft, onroad vehicles, and rail in the following corridors:

1. Marine corridor: The marine corridor accounted for OGV and harbor craft activity occurring from the state/federal waters boundary located 3 nautical miles offshore to the international border with the Bahamas (i.e., the continental shelf boundary), which is approximately 20 to 25 nautical miles from shore.

2. Truck corridor: The onroad freight corridor focused on truck activity on the I-595 spur from I-95 into the Port boundary.

3. Rail corridor: The off-port rail corridor covered the 10 kilometers of a railway line operated by Florida East Coast Railway extending north of the Intermodal Container Transfer Facility spur.

Off-port 2015 baseline emissions and BAU emission projections for NOx, $PM_{2.5}$, and CO_2e emissions are summarized for the years 2025, 2035, and 2050 in Figure 3-7, Figure 3-8, and Figure 3-9, respectively. As seen in the figures, OGVs are the biggest source of emissions and are expected to remain so in future years. Rail emissions are not visible in the figures as they are orders of magnitude smaller than emissions for the other sectors. Note that the absolute magnitude of the emissions for each sector is highly dependent on the size of the corridor and how much activity occurs in the corridor. For example, the marine corridor is much larger than both landside corridors; however, harbor craft have very little activity in the marine corridor.

Baseline emissions and BAU projections are presented in Table 3-3 for all pollutants considered in EPA's analysis. Note that SO_2 was only evaluated for OGVs. Additionally, for the 2050 analysis, only CO_2e inventories and reductions were quantified.

Selected off-port NOx, $PM_{2.5}$, and CO_2e emission reduction strategies are highlighted in Figure 3-10, Figure 3-11, and Figure 3-12, respectively. These figures show that potential actions taken to reduce emissions can have benefits beyond a port's boundary. Given the assumed implementation conditions, the voluntary vessel speed reduction strategy is effective at reducing OGV emissions in off-port corridors. Accelerating fleet turnover to cleaner technology through truck replacements has the potential to reduce NOx and $PM_{2.5}$ emissions significantly through 2035, despite the projected growth in truck activity. Since replacement of trucks with battery electric vehicles is not assumed to occur before 2035, CO_2e emission reductions from this strategy are not projected in 2025.

A summary of results of all analyzed off-port strategies and scenarios for each source category is presented in Table 3-4. This summary only includes NOx, $PM_{2.5}$, and CO_2e; however, off-port results for all pollutants are included along with methodology details in Section 9. This section also includes results by percent reduction from the BAU for each strategy scenario.

As described in Section 9, some strategies and scenarios were not evaluated for all three future years of 2025, 2035, and 2050, and some were not evaluated for all pollutants (i.e., some strategies only targeted a subset of the pollutants). Additionally, not all emissions for the considered pollutants occurring in the Port's off-port corridors are captured by EPA's analysis.

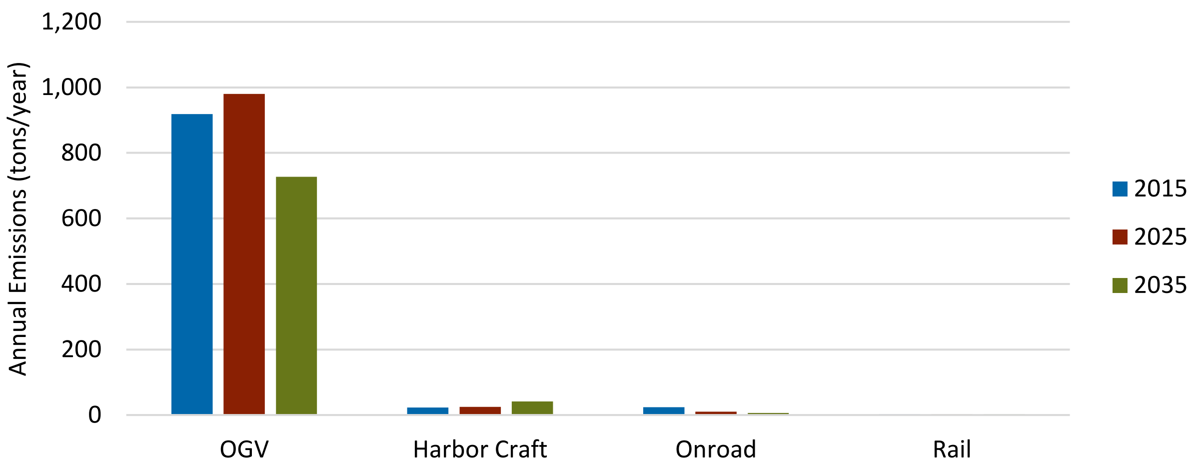

Figure 3-7. Off-port Baseline and BAU NOx Emissions

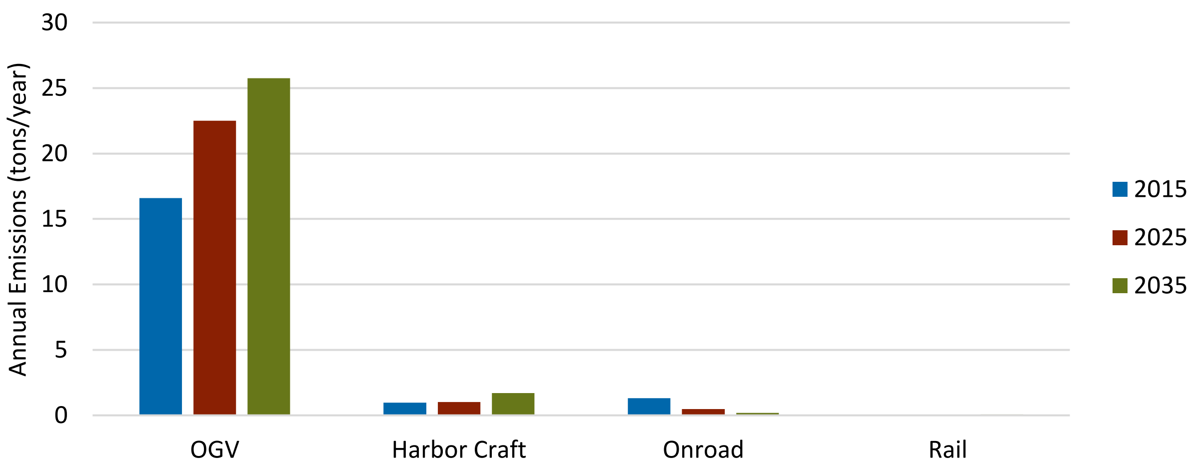

Figure 3-8. Off-port Baseline and BAU $PM_{2.5}$ Emissions

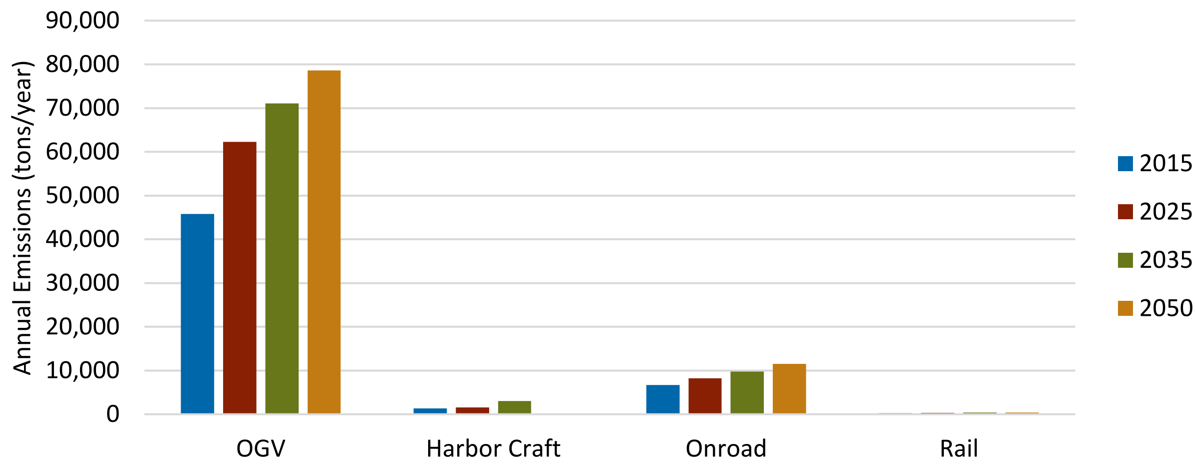

Figure 3-9. Off-port Baseline and BAU CO_2e Emissions

Table 3-3. Summary of Off-port Baseline and BAU Emissions

Year	Source	Annual Emissions (tons/year)								
		NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	SO_2	VOC	CO_2e
2015	OGV	918.91	17.28	16.59	17.08	16.40	12.76	29.14	41.56	45,779.34
	Harbor Craft	23.40	0.99	0.97	0.99	0.97	0.75	--[a]	1.02	1,324.75
	Onroad	23.69	1.43	1.31	1.42	1.30	0.61	--	1.64	6,657.57
	Rail	2.59	0.04	0.04	0.04	0.04	0.03	--	0.07	261.04
	Total	**968.59**	**19.74**	**18.91**	**19.53**	**18.71**	**14.15**	--	**44.29**	**54,022.70**
2025	OGV	979.99	23.53	22.50	23.25	22.28	17.36	39.63	56.37	62,298.97
	Harbor Craft	24.82	1.04	1.02	1.04	1.02	0.79	--	1.13	1,583.07
	Onroad	10.66	0.51	0.47	0.50	0.46	0.22	--	0.63	8,251.94
	Rail	2.88	0.06	0.05	0.06	0.05	0.03	--	0.66	329.95
	Total	**1,018.35**	**25.14**	**24.04**	**24.85**	**23.81**	**18.40**	--	**58.79**	**72,463.93**
2035	OGV	727.51	26.87	25.74	25.65	25.43	19.80	45.19	64.63	71,044.82
	Harbor Craft	41.84	1.73	1.69	1.73	1.69	1.30	--	1.98	3,054.86
	Onroad	6.76	0.20	0.19	0.20	0.18	0.03	--	0.31	9,774.84
	Rail	2.76	0.07	0.07	0.07	0.07	0.05	--	1.49	377.09
	Total	**778.87**	**28.87**	**27.69**	**27.65**	**27.37**	**21.18**	--	**68.41**	**84,251.61**
2050	OGV	--	--	--	--	--	--	--	--	78,603.92
	Harbor Craft	--	--	--	--	--	--	--	--	--
	Onroad	--	--	--	--	--	--	--	--	11,530.98
	Rail	--	--	--	--	--	--	--	--	389.56
	Total	--	--	--	--	--	--	--	--	**--**

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

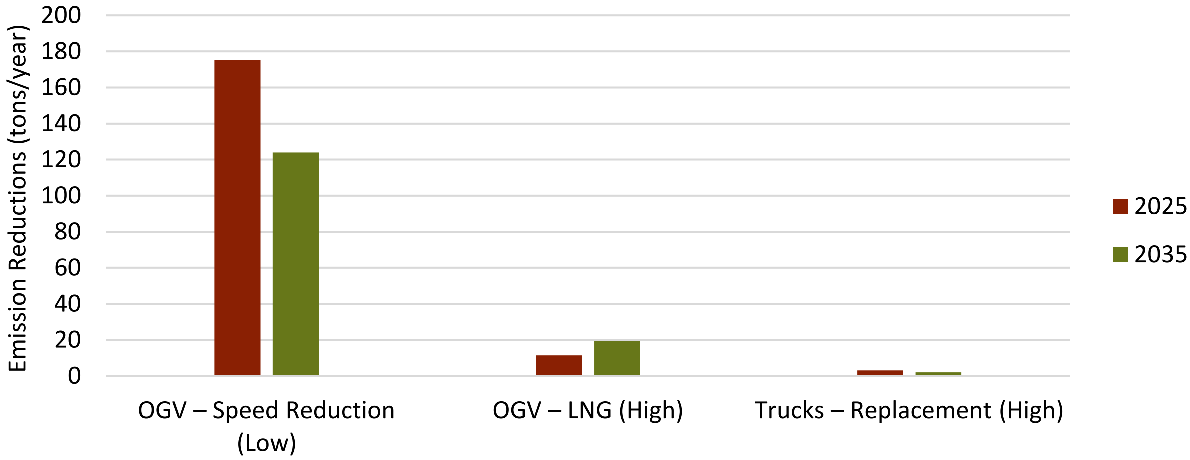

Figure 3-10. Selected Off-port NOx Reduction Strategies

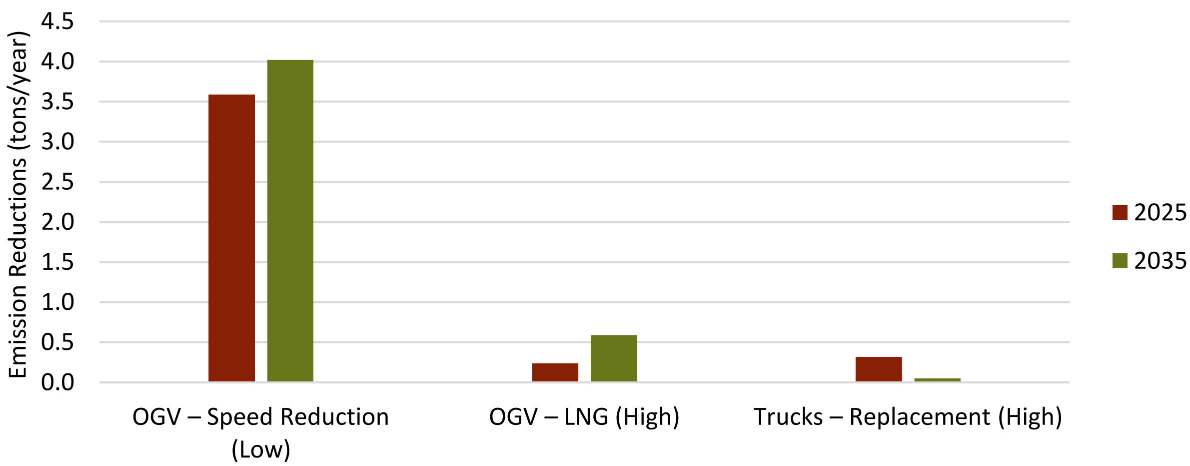

Figure 3-11. Selected Off-port $PM_{2.5}$ Reduction Strategies

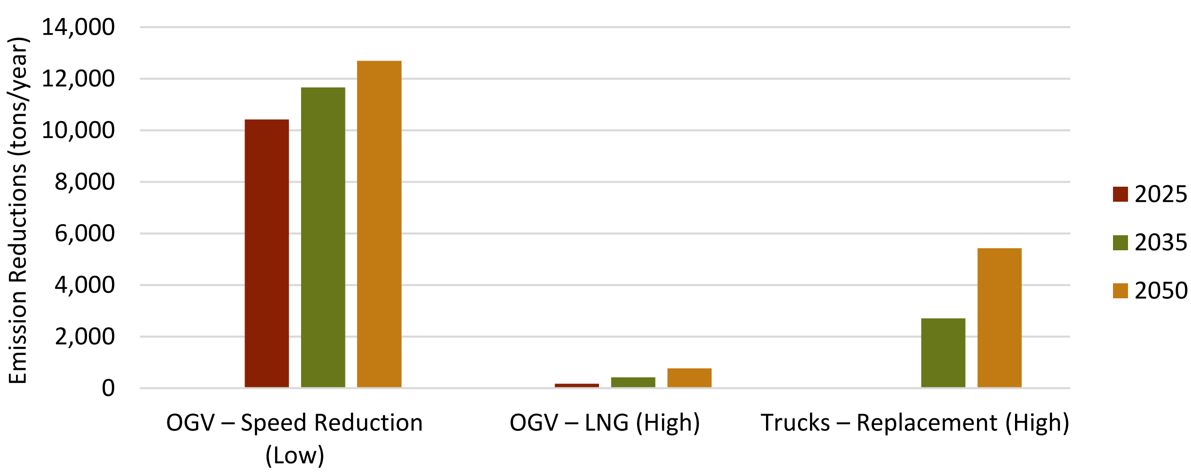

Figure 3-12. Selected Off-port CO_2e Reduction Strategies

Table 3-4. Summary of Off-port Emission Reductions

Strategy	Scenario	Emission Reductions (tons/year)						
		NO_x		$PM_{2.5}$		CO_2e		
		2025	2035	2025	2035	2025	2035	2050
Ocean Going Vessels								
Vessel Speed Reduction During Transit	Low	175.19	124.05	3.59	4.02	10,417.25	11,661.24	12,689.28
	High	315.34	223.29	6.46	7.24	18,751.04	20,990.23	22,840.70
Lower Sulfur Fuels	Low	--[a]	--	0.13	0.76	--	--	--
	High	--	--	0.33	1.52	--	--	--
LNG	Low	2.30	3.89	0.05	0.12	34.48	84.60	256.31
	High	11.51	19.45	0.24	0.59	172.40	422.98	768.94
Harbor Craft								
Engine Replacement	Low	1.37	1.03	0.10	0.07	--	--	--
	High	2.23	1.37	0.16	0.10	--	--	--
Vessel Replacement	Low	1.33	0.99	0.06	0.04	--	--	--
	High	2.65	1.99	0.11	0.09	--	--	--
Onroad Vehicles								
Truck Replacement	Low	2.52	1.25	0.32	0.04	0.00	1,376.60	3,255.01
	High	3.12	2.00	0.32	0.05	0.00	2,704.37	5,425.02

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

4. OCEAN GOING VESSELS

For the purpose of this analysis, ocean going vessels (OGVs) are considered to be ships with engines of 30 liters displacement per cylinder or more (i.e., Category 3 engines). While some OGVs can have smaller Category 2 engines, it was assumed for simplicity in this analysis that all OGVs had Category 3 engines. These vessels may be used to transport cargo or people; some engage in trans-oceanic voyages while others may stay in the region or even in coastal waters. Table 4-1 lists the vessel types that were included in this analysis.

Table 4-1. OGV Types

Ship Type	Description
Auto Carrier	Dry-cargo vessel that carries containerized automobiles
Bulk Carrier	Dry-cargo vessel that carries loose cargo
Containership	Dry-cargo vessel that carries containerized cargo
Cruise Ship	Passenger vessel used for pleasure voyages
General Cargo Ship	Cargo vessel that carries a variety of dry cargo
Roll-on/Roll-off (RORO)	Vessel that handles cargo that is rolled on and off the ship
Tankers	Liquid-cargo vessel including chemical tankers, petroleum product tankers, liquid food product tankers, etc.
Miscellaneous	Vessel that transports cargo that is not otherwise designated above

This section presents the on-port baseline emissions inventory and projected Business as Usual (BAU) emissions for OGVs (Section 4.1), the considered strategies and scenarios to reduce OGV emissions (Section 4.2), and a summary of the primary results and lessons learned (Section 4.3). Note that OGV emissions occurring in off-port corridors are presented in Section 9.1.

4.1 Baseline and Projected Business as Usual Inventories

The 2015 On-port Baseline Inventory[31] contains on-port emission estimates for OGV activity based on U.S. Coast Guard automatic identification system (AIS) data, Information Handling Services' (IHS) Register of Ships, Starcrest's Vessel Boarding Program, and wharfinger vessel call data supplied by Port Everglades. The geographical scope of the inventory includes all waterways and berths within the Port and state waters associated with Broward County, which extend three nautical miles from the shoreline. The baseline inventory includes emissions from main propulsion engines, auxiliary engines, and boilers, and are provided by vessel type as well as by the following operating modes:[32]

- Maneuvering: When a vessel is moving inside the geographical domain.
- Hotelling: When a vessel is stationary at the dock/berth.

[31] Starcrest Consulting Group, LLC, *Port Everglades 2015 Baseline Air Emissions Inventory*, December 2016.
[32] Note that there is no transit (or "at-sea") mode of operation in the on-port geographical domain.

- At-Anchorage: When a vessel is stationary within the anchorage area (i.e., in the coastal zone).

For details on the data collection and inventory development methodology, please see the 2015 On-port Baseline Inventory. The OGV baseline emission inventories presented here include pollutants from the 2015 On-port Baseline Inventory as well as $DPM_{2.5}$ and BC, which EPA added for its analysis.[33] [34] Additionally, the CO_2e results, which were presented in metric tons in the baseline inventory, were converted to short tons here for consistency with the other pollutants.

A hypothetical BAU scenario was developed based on anticipated growth and changes at Port Everglades as identified in the *2014 Master/Vision Plan*.[35] Growth factors by vessel/cargo type were developed from projected throughput at the Port, as summarized in Table 4-2.[36]

Table 4-2. Projected Growth Factors Used for Future OGV Activity

Vessel/Cargo Type (units)	Projected Throughput				Growth Factor (unitless)			
	2015	2025	2035	2050	2015	2025	2035	2050
Bulk (tons)[a]	1,565,000	1,870,000	3,609,000	3,906,000	1.000	1.195	2.306	2.496
Container (TEUs)[a]	1,060,000	1,435,000	1,761,000	2,134,000	1.000	1.354	1.661	2.013
Cruise (passengers)[b]	3,773,000	5,306,000	5,730,000	6,065,000	1.000	1.406	1.519	1.607
Liquid Bulk (barrels/day)[c]	305,000	357,000	381,000	416,000	1.000	1.170	1.249	1.364
				Average	**1.000**	**1.281**	**1.684**	**1.870**

[a] Projections derived from the "Baseline-Plus Estimate" given in the *2014 Master/Vision Plan* for these sectors
[b] Projections derived from the "Medium Estimate" given in the *2014 Master/Vision Plan* for this sector
[c] Projections derived from the only estimate given in the *2014 Master/Vision Plan* for this sector

Additionally, it was assumed that the future age distribution of the vessel fleet would be similar to the current fleet, such that the fraction of vessels less than ten years old would be identical in each of the projected years. Table 4-3 provides the fraction of vessels under ten years old by vessel type based on wharfinger vessel call data supplied by Port Everglades. Please note that this assumption implies that the current OGV fleet will be completely replaced prior to 2050 in the BAU scenario.

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33 $DPM_{2.5}$ was calculated as a fraction of DPM_{10} by applying the ratio of $PM_{2.5}$ to PM_{10} emissions from diesel-powered main and auxiliary engines. BC was calculated as 77% of $PM_{2.5}$ based on the EPA's *Report to Congress on Black Carbon*.

34 U.S. Environmental Protection Agency, *Report to Congress on Black Carbon*, EPA-450/R-12-001, p. 87, March 2012, https://www3.epa.gov/airquality/blackcarbon/2012report/fullreport.pdf.

35 Port Everglades, *2014 Master/Vision Plan* reports, June 24, 2014.

36 Growth factors for 2035 and 2050 are not included in the range of projections provided in the *2014 Master/Vision Plan* cited in this report. Therefore, the factors were extrapolated from expected growth between 2028 and 2033, the last five years presented in the *2014 Master/Vision Plan*.

Table 4-3. Replacement Rate Assumed for Future OGV Fleet

Vessel Type	% Under 10 Years Old
Containerships	33%
Cruise ships	42%
Liquid bulk carriers	66%
Bulk carriers	61%
Fleet Average	**35%**

The assumed future vessel replacement rates are important because new vessels will need to comply with international Tier III standards, which have lower NOx emissions. For slow speed engines—the most common engine type found on OGVs calling at Port Everglades—this standard is 3.4 grams of NOx per kW-hr.[37] For comparison, the average emission factor for vessels calling at Port Everglades in 2015 was 14.65 grams of NOx per kW-hr. Note that the simplifying assumption that the age distribution of OGVs calling at Port Everglades will remain the same in the future results in a more aggressive fleet turnover to the Tier III standards than what is predicted at other ports.[38] [39]

Hypothetical future emission inventories were then estimated for 2025, 2035, and 2050[40] by first applying the growth factors by vessel or cargo type to the 2015 baseline emissions to reflect increased trade, and then applying adjustment factors based on expected changes in the fleet emission factors subject to the assumptions described above.

The subsequent tables in this section show the on-port OGV baseline and hypothetical BAU emissions, presented by vessel type and modal operation. Table 4-4 shows the 2015 baseline emissions for on-port OGVs by vessel type. Table 4-5 presents the 2025 BAU emissions, Table 4-6 presents the 2035 BAU emissions, and Table 4-7 presents the 2050 BAU emissions. Table 4-8 summarizes the inventories for 2015, 2025, 2035, and 2050 by the following modes: anchorage, hotelling, and maneuvering. Note that a containership classified as "Container—1000" vessel is assumed to accommodate up to 1,999 twenty-foot equivalent units (TEUs) in this analysis.

As shown in the tables, BAU inventories for almost all pollutants are projected to increase in the future due to the anticipated growth in marine freight and cruise traffic. The exception is

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[37] U.S. Environmental Protection Agency, *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Category 3 Marine Diesel Engines*, EPA-420-R-09-019, December 2009, https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1005ZGH.txt.

[38] Starcrest Consulting Group, LLC, *Bay Wide Ocean-Going Vessel International Maritime Organization Tier Forecast 2015-2050*, June 2017, https://www.portoflosangeles.org/pdf/CAAP_Vessel_Tier_Forecasts_2015-2050-Final.pdf.

[39] This simplifying assumption regarding future OGV tier distributions was appropriate based on the purpose and on data available for this analysis.

[40] Note that for 2050, only CO_2e inventories and reductions were quantified.

for NOx emissions, which are projected to decrease in 2035 due to the compliance with the Emission Control Area (ECA) NOx standards. However, these results are highly dependent on the assumptions described above regarding OGV fleet turnover, and actual future emissions will depend largely on actual vessel turnover to the cleaner emission standards.

Table 4-4. 2015 Baseline Emissions for On-port OGVs by Vessel Type

Vessel Type	Annual Emissions (tons/year)[41]								
	NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	SO_2	VOC	CO_2e
Auto Carrier	2.69	0.06	0.06	0.05	0.05	0.04	0.11	0.15	165.91
Bulk	33.48	0.81	0.76	0.61	0.58	0.59	1.82	1.28	2,866.65
Bulk—Heavy Load	2.50	0.05	0.05	0.04	0.04	0.04	0.12	0.08	183.48
Container—1000	288.18	6.25	5.87	5.33	5.01	4.52	12.87	10.22	20,229.01
Container—2000	38.77	0.84	0.79	0.73	0.69	0.61	1.52	1.96	2,387.71
Container—3000	23.67	0.55	0.52	0.46	0.43	0.40	0.95	1.60	1,502.33
Container—4000	40.54	0.91	0.85	0.79	0.75	0.66	1.45	2.83	2,290.38
Container—5000	27.97	0.66	0.62	0.56	0.52	0.48	1.12	1.92	1,758.09
Container—6000	29.13	0.65	0.61	0.55	0.51	0.47	1.06	2.10	1,667.33
Container—9000	1.30	0.03	0.03	0.03	0.02	0.02	0.07	0.08	107.58
Cruise	995.61	19.67	18.48	19.66	18.47	14.23	35.69	32.36	55,940.55
General Cargo	138.93	2.86	2.68	2.51	2.36	2.06	5.83	4.41	9,158.84
Miscellaneous	6.68	0.14	0.13	0.12	0.11	0.10	0.29	0.21	451.19
RORO	81.47	1.75	1.64	1.58	1.48	1.27	3.49	2.73	5,486.49
Tanker—Chemical	207.13	5.34	5.01	3.78	3.55	3.86	12.51	7.90	19,705.17
Tanker—Handysize	42.52	1.56	1.46	0.62	0.58	1.12	4.61	1.81	7,283.55
Tanker—Panamax	38.14	1.55	1.45	0.51	0.48	1.12	4.77	1.75	7,541.21
Tanker—Suezmax	2.11	0.07	0.07	0.03	0.03	0.05	0.20	0.08	320.75
Total	**2,000.82**	**43.73**	**41.07**	**37.95**	**35.66**	**31.64**	**88.45**	**73.44**	**139,046.22**

[41] Starcrest Consulting Group, LLC, *Port Everglades 2015 Baseline Air Emissions Inventory*, December 2016.

Table 4-5. 2025 BAU Emissions for On-port OGVs by Vessel Type

Vessel Type	Annual Emissions (tons/year)								
	NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	SO_2	VOC	CO_2e
Auto Carrier	3.07	0.08	0.07	0.07	0.06	0.06	0.14	0.19	212.53
Bulk	33.36	0.97	0.91	0.73	0.69	0.70	2.18	1.53	3,425.64
Bulk—Heavy Load	2.49	0.06	0.06	0.05	0.05	0.05	0.14	0.09	219.26
Container—1000	320.26	8.47	7.95	7.22	6.78	6.12	17.42	13.84	27,390.08
Container—2000	34.00	1.13	1.06	0.99	0.93	0.82	2.05	2.65	3,232.96
Container—3000	24.70	0.75	0.70	0.62	0.58	0.54	1.29	2.17	2,034.15
Container—4000	44.20	1.23	1.16	1.07	1.01	0.89	1.97	3.84	3,101.18
Container—5000	35.71	0.89	0.84	0.75	0.71	0.64	1.51	2.60	2,380.45
Container—6000	24.65	0.88	0.83	0.74	0.70	0.64	1.43	2.84	2,257.56
Container—9000	1.75	0.05	0.04	0.04	0.03	0.03	0.09	0.10	145.66
Cruise	1,232.24	27.65	25.98	27.65	25.97	20.00	50.18	45.50	78,652.42
General Cargo	70.80	3.66	3.44	3.21	3.02	2.64	7.47	5.65	11,732.48
Miscellaneous	6.39	0.17	0.17	0.15	0.14	0.13	0.37	0.26	577.97
RORO	43.89	2.24	2.11	2.02	1.90	1.62	4.48	3.50	7,028.20
Tanker—Chemical	126.82	6.24	5.86	4.42	4.15	4.51	14.63	9.24	23,055.05
Tanker—Handysize	30.71	1.82	1.71	0.72	0.68	1.32	5.39	2.11	8,521.75
Tanker—Panamax	28.94	1.81	1.70	0.59	0.56	1.31	5.58	2.04	8,823.21
Tanker—Suezmax	1.49	0.08	0.08	0.03	0.03	0.06	0.24	0.09	375.28
Total	**2,065.47**	**58.18**	**54.67**	**51.07**	**47.99**	**42.08**	**116.56**	**98.24**	**183,165.83**

Table 4-6. 2035 BAU Emissions for On-port OGVs by Vessel Type

Vessel Type	Annual Emissions (tons/year)								
	NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	SO_2	VOC	CO_2e
Auto Carrier	3.48	0.10	0.10	0.09	0.08	0.07	0.18	0.25	279.39
Bulk	28.21	1.88	1.76	1.42	1.33	1.36	4.20	2.95	6,610.49
Bulk—Heavy Load	2.02	0.12	0.12	0.10	0.09	0.09	0.27	0.18	423.10
Container—1000	351.15	10.38	9.75	8.86	8.32	7.51	21.37	16.97	33,600.38
Container—2000	21.92	1.39	1.31	1.22	1.15	1.00	2.52	3.25	3,965.99
Container—3000	14.57	0.91	0.86	0.76	0.71	0.66	1.58	2.66	2,495.36
Container—4000	38.78	1.51	1.42	1.32	1.24	1.09	2.41	4.71	3,804.33
Container—5000	27.16	1.09	1.03	0.92	0.87	0.79	1.85	3.19	2,920.18
Container—6000	16.59	1.08	1.02	0.91	0.85	0.78	1.76	3.48	2,769.43
Container—9000	2.15	0.06	0.05	0.04	0.04	0.04	0.11	0.13	178.69
Cruise	967.02	29.87	28.07	29.87	28.06	21.61	54.21	49.15	84,973.70
General Cargo	82.16	4.81	4.52	4.22	3.97	3.48	9.82	7.43	15,423.49
Miscellaneous	3.93	0.23	0.22	0.20	0.18	0.17	0.48	0.35	759.80
RORO	55.74	2.95	2.77	2.66	2.50	2.13	5.88	4.60	9,239.25
Tanker—Chemical	87.50	6.67	6.26	4.72	4.43	4.82	15.62	9.87	24,611.76
Tanker—Handysize	24.97	1.95	1.83	0.77	0.72	1.41	5.76	2.26	9,097.15
Tanker—Panamax	24.55	1.93	1.81	0.63	0.59	1.40	5.96	2.18	9,418.97
Tanker—Suezmax	1.18	0.09	0.08	0.04	0.03	0.06	0.25	0.09	400.62
Total	**1,753.08**	**67.02**	**62.98**	**58.75**	**55.16**	**48.47**	**134.23**	**113.70**	**210,972.08**

Table 4-7. 2050 BAU Emissions for On-port OGVs by Vessel Type

Vessel Type	Annual CO_2e Emissions (tons/year)
Auto Carrier	310.25
Bulk	7,155.15
Bulk—Heavy Load	457.97
Container—1000	40,720.99
Container—2000	4,806.46
Container—3000	3,024.18
Container—4000	4,610.54
Container—5000	3,539.03
Container—6000	3,356.34
Container—9000	216.55
Cruise	89,896.47
General Cargo	17,127.03
Miscellaneous	843.72
RORO	10,259.74
Tanker—Chemical	26,877.86
Tanker—Handysize	9,934.76
Tanker—Panamax	10,286.21
Tanker—Suezmax	437.50
Total	**233,860.74**

Table 4-8. Baseline and Projected BAU Emissions for On-port OGVs by Mode

Year	Mode	Annual Emissions (tons/year)								
		NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	SO_2	VOC	CO_2e
2015[42]	At-Anchorage	94.22	2.21	2.07	1.73	1.62	1.59	4.93	3.13	7,756.29
	Hotelling	1,525.74	33.86	31.79	28.76	27.01	24.48	71.29	50.22	112,075.96
	Maneuvering	380.84	7.67	7.21	7.46	7.01	5.55	12.23	20.09	19,213.96
	Total	**2,000.82**	**43.73**	**41.07**	**37.95**	**35.66**	**31.64**	**88.45**	**73.44**	**139,046.22**
2025	Anchorage	74.34	2.75	2.58	2.16	2.03	1.99	6.13	3.90	9,639.89
	Hotelling	1,598.22	45.09	42.34	38.84	36.47	32.60	93.86	67.42	147,529.53
	Maneuvering	392.90	10.34	9.73	10.07	9.47	7.49	16.55	26.92	25,996.40
	Total	**2,065.47**	**58.18**	**54.67**	**51.07**	**47.99**	**42.08**	**116.56**	**98.24**	**183,165.83**
2035	Anchorage	69.41	3.32	3.11	2.62	2.46	2.39	7.37	4.72	11,605.03
	Hotelling	1,357.09	51.59	48.45	44.34	41.64	37.31	107.62	77.04	169,154.56
	Maneuvering	326.59	12.10	11.38	11.77	11.07	8.76	19.23	31.94	30,212.48
	Total	**1,753.08**	**67.02**	**62.98**	**58.75**	**55.16**	**48.47**	**134.23**	**113.70**	**210,972.08**
2050	Anchorage	--[a]	--	--	--	--	--	--	--	13,161.01
	Hotelling	--	--	--	--	--	--	--	--	186,845.38
	Maneuvering	--	--	--	--	--	--	--	--	33,854.35
	Total	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**233,860.74**

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

42 Starcrest Consulting Group, LLC, *Port Everglades 2015 Baseline Air Emissions Inventory*, December 2016.

4.2 Emission Reduction Strategies and Scenarios

The following on-port emission reduction strategies were selected in consultation with Port Everglades:

- Reduced hotelling time (5 or 10 percent reduction)[43]
- At-berth alternative control technology (capture and treat)
- Use of lower sulfur fuels (500 ppm or 200 ppm sulfur content)
- Use of liquefied natural gas (LNG)
- Application of shore power to reduce auxiliary engine operations while dockside[44]

Because Port Everglades does not have direct control over implementing these strategies, the hypothetical scenarios for each are predicated on the assumption of the coordination and collaboration between various maritime industry stakeholders for implementation. Table 4-9 summarizes applicability and implementation assumptions for each strategy and scenario.

Several factors were considered when developing the emission reduction strategies, including the specific vessel types best targeted by each strategy as well as the feasibility of implementing the fuel and technology strategies. As part of this consultation, the Port shared its non-confidential vessel call log with EPA, which allowed for incorporation of more detailed vessel characteristics into this portion of the analysis. Emission reductions for some strategies, such as shore power, were applied only to OGVs that visited Port Everglades multiple times a year (i.e., "frequent callers") due to high per-vessel capital costs, while other strategies, such as at-berth alternative control technology, were applied only to non-frequent callers. In addition, some strategies were applied to either propulsion or auxiliary OGV engines and their respective types of emissions (e.g., targeting auxiliary engines would reduce OGV hotelling emissions).

Hypothetical emission reductions were calculated for every emission reduction strategy and low/high scenario in Table 4-9 using the emission reduction factors presented in Table 4-10. Some strategies (e.g., reduced hotelling time) impact all pollutants proportionally, while the impacts of others vary by pollutant. For example, use of lower sulfur fuels would only reduce SO_2 and PM emissions. Reductions were calculated independently for all scenarios relative to the applicable portion of the BAU inventories. For example, strategies that address hotelling emissions were applied to the portion of hotelling emissions in the BAU inventories. Additional details on the selected emission reduction strategies and scenarios are presented in Sections 4.2.1 through 4.2.5.

43 The reduced hotelling time strategy is hypothetical and would go above and beyond the dockside improvements continuously being sought at Port Everglades. This analysis does not attempt to predict or dictate the exact nature of how the reduced hotelling would be achieved, but assumes it would comply with all safety regulations and guidelines.

44 Note that Port Everglades has previously evaluated the potential of using shore power and concluded that it is not economically feasible to implement at present. This strategy is included in this hypothetical analysis because, as technologies advance, various stakeholders in the maritime industry may continue to evaluate the feasibility of shore power at Port Everglades and other ports.

Table 4-9. Summary of On-port Emission Reduction Scenarios for OGVs

Strategy	Affected Vessel Types	Scenario	Implementation Rates			Notes
			2025	2035	2050	
Reduced Hotelling Time	Containerships	Low	100%	100%	100%	Assumed 5% reduction in hotelling
		High	100%	100%	100%	Assumed 10% reduction in hotelling
At-Berth Alternative Control Technology	Containerships & tankers	Low	1%	5%	N/A	Applied to non-frequent callers only
		High	5%	10%	N/A	
Lower Sulfur Fuels	All OGVs	Low	10% use of 500 ppm	25% use of 200 ppm	N/A	
		High	25% use of 500 ppm	50% use of 200 ppm	N/A	
LNG	Containerships	Low	1%	2%	5%	
		High	5%	10%	15%	
Shore Power	Passenger & containerships	High	0%	25% passenger 10% container	60% passenger 35% container	Assumed 2 hours for connecting and disconnecting

Table 4-10. On-port OGV Emission Reduction Factors by Scenario

Strategy	Scenario	Notes	NOx	PM_{10}	$PM_{2.5}$	DPM	VOC	SO_2	CO_2	CH_4	N_2O
Reduced Hotelling Time	Low	5% reduction in dockside duration	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
	High	10% reduction in dockside duration	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
At-Berth Alternative Control Technology	Low/High	Containerships	73.0%	78.0%	78.0%	78.0%	78.0%	78.0%	-9.0%	--[a]	--
		Tankers	75.0%	80.0%	80.0%	80.0%	80.0%	80.0%	-7.0%	--	--
Lower Sulfur Fuels	Low/High	500 ppm	--	5.9%	5.9%	5.9%	--	50.0%	--	--	--
		200 ppm	--	11.8%	11.8%	11.8%	--	80.0%	--	--	--
LNG	High		87.7%	82.4%	82.4%	82.4%	16.7%	99.0%	22.4%	--	26.7%
Shore Power	High	Reduction in emissions relative to local eGRID and GREET emission factors	97.3%	80.8%	80.0%	80.8%	98.0%	12.7%	20.1%	−365.8%	82.4%

[a] A double dash (“--”) represents a value that was not calculated as part of this analysis.

4.2.1 Reduced Hotelling Time

Because the emissions of dockside auxiliary engines while hotelling are generally significant, any reduction in time spent hotelling is likely to reduce emissions. For this strategy, this analysis focused on containership hotelling. The reduced hotelling times presented in Table 4-11, in hours and by vessel capacity, were respectively calculated by assuming 5 and 10 percent reductions in hotelling above and beyond the dockside improvements continuously being sought at Port Everglades.

Table 4-11. Containership Hotelling Time by Vessel Capacity

Container Capacity (TEUs)	Average Hotelling Time (hrs)[45]	Hotelling Time with 5% Reduction (hrs)	Hotelling Time with 10% Reduction (hrs)
1000	20	19.0	18.0
2000	17	16.2	15.3
3000	11	10.5	9.9
4000	10	9.5	9.0
5000	17	16.2	15.3
6000	19	18.1	17.1
9000	63	59.9	56.7

Please note that this analysis does not attempt to predict or dictate the exact nature of how the reduced hotelling would be achieved, but assumes it would comply with all safety regulations and guidelines.[46] The reduced hotelling times presented above were used in conjunction with the on-port containership auxiliary hotelling emissions to estimate the associated emission reductions.

4.2.2 At-berth Alternative Control Technology (Capture and Treat)

At-berth alternative control systems, also known as "capture and treat systems," reduce dockside marine vessel emissions by capturing a vessel's stack emissions and routing them to an after-treatment based emission control device located alongside the vessel. These systems typically are based on selective catalytic reduction (SCR) technology. There are two variants of these systems: 1) a mobile version that operates from a barge adjacent to the vessel; and 2) a stationary version located on the dock. In either case, the system captures the emissions and routes them through an SCR reactor. This analysis assumes the system is barge mounted and takes 2 hours per call to connect to and disconnect from the vessel's exhaust stack. When the

[45] Starcrest Consulting Group, LLC, *Port Everglades 2015 Baseline Air Emissions Inventory*, December 2016.

[46] The opportunities and challenges for reducing hotelling time vary substantially, not only from port to port, but also between business lines. For example, the activities that occur while a ship is dockside are very different for cruise ships and cargo ships. Examining the opportunities for reducing hotelling time for each business line at Port Everglades was outside the scope for this analysis; however, ports are encouraged to look for opportunities where possible.

system is being connected or disconnected, the vessel's emissions are not being captured and treated. While the efficiency of this technology can vary by case, it was assumed in this analysis that it was 90–95 percent effective at reducing auxiliary engine hotelling emissions while it is operating. In addition, it was assumed that an auxiliary generator on the barge produces emissions while the system is in place.

For the scenario analysis, at-berth alternative control technology reductions were only applied to containerships and tankers that visited the port less than five times per year (i.e., non-frequent callers). This is because the strategy does not require high per-ship investments, so it should be feasible to apply it to non-frequent callers. Table 4-12 summarizes the percentage of non-frequent containerships and tankers calling at Port Everglades based on the Port's vessel call log.

Table 4-12. Summary of Non-Frequent Containership and Tanker Port Calls

Vessel Type	Total Vessel Count	Non-Frequent Caller Count	Percent Non-Frequent Caller
Containership	146	39	27%
Tanker	225	171	76%

It was assumed that the frequency of port calls will remain the same for the projected future years. To calculate the emission impacts of this strategy for each scenario, the non-frequent caller proportion of the projected BAU auxiliary hotelling emissions in Table 4-12 was reduced based on the rate of implementation in Table 4-9 and the anticipated emission reductions noted in Table 4-10.

4.2.3 Use of Lower Sulfur Fuels

Since the designation and entry into force of the ECA through amendment to Annex VI to the International Convention for the Prevention of Pollution from Ships (MARPOL) in 2012, ships operating in the boundaries of that area are required to use lower sulfur fuel. The original sulfur limit, 10,000 ppm, was reduced to 1,000 ppm beginning on January 1, 2015. This sulfur limit is much lower than the global marine fuel sulfur limit of 35,000 ppm that applies outside designated ECAs.[47]

For additional emission reductions, this strategy assumes a proportion of ships would use fuel with a sulfur concentration of 500 ppm in 2025 and 200 ppm in 2035. The assumed implementation rates for the low and high scenarios are listed in Table 4-9 and the emission reductions associated with use of lower sulfur fuels are listed in Table 4-10.

[47] More information about the North American ECA can be found in U.S. Environmental Protection Agency, *Designation of North American Emission Control Area to Reduce Emissions from Ships*, EPA-420-F-10-015, March 2010, https://nepis.epa.gov/Exe/ZyPDF.cgi/P100AU0I.PDF?Dockey=P100AU0I.pdf.

4.2.4 Use of LNG

Increased use of natural gas-powered vessels can reduce emissions from NOx, CO_2, PM, and SO_2. This analysis does not account for fugitive methane emissions from natural gas use, such as from equipment leakage. In addition, assumptions were not made regarding implementation details, such as whether LNG use would be increased through retrofits or new vessels only, or the nature of LNG refueling infrastructure.

The LNG implementation rates for containerships from Table 4-9 and the emission reductions noted in Table 4-10 were applied to the projected BAU containership emissions in Table 4-8 to evaluate the anticipated changes in emissions from this strategy.

4.2.5 Shore Power

Another way to reduce emissions at ports is by using shore power technology, also known as "cold ironing." Shore power allows ships to plug into electrical power sources on shore and turn off their auxiliary diesel engines while at dock. Because the cost of the shore power infrastructure for both vessels and port terminals can be substantial,[48] this strategy was only applied to passenger vessels and containerships that frequently called at the Port (defined in this analysis as vessels that called at Port Everglades 5 or more times per year).

The potential emission reductions depend on the fuel and electricity generation technology mix of the power source. For this analysis, emission factors were derived from EPA's Emissions & Generation Resource Integrated Database (eGRID),[49] using data for the Florida Reliability Coordinating Council (FRCC) North American Electric Reliability Corporation (NERC) region. The eGRID data were supplemented with complementary Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET)[50] data from Argonne National Laboratories to gap-fill missing pollutants (i.e., VOCs and particulate matter). The emission reduction estimates presented in Table 4-10 were calculated by comparing these emission factors to those of Tier 2 medium speed auxiliary Category 2 engines.

To estimate the emission impacts of this strategy, the frequent caller proportion of the projected BAU auxiliary hotelling emissions from containerships and passenger vessels were reduced based on the implementation rates in Table 4-9 and the anticipated emission reductions noted in Table 4-10.[51]

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48 For an example of the required port-side infrastructure, when Port Everglades previously evaluated shore power, they found that they would need a 40 MW substation to accommodate two cruise terminals, in addition to infrastructure to bring the power from the substation to the vessel berth.

49 U.S. Environmental Protection Agency, Emissions & Generation Resource Integrated Database (eGRID2014), 2017, https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid.

50 Argonne National Laboratory, U.S. Department of Energy, GREET2016 Model, 2016, https://greet.es.anl.gov/index.php.

51 It was assumed that connecting and disconnecting the ship from shore power would take 2 hours per call.

4.3 Emission Reduction Scenario Results and Lessons Learned

The modeled emission reductions by strategy and scenario are summarized in Figure 4-1, Figure 4-2, Figure 4-3, and Table 4-13 for on-port operations, while Table 4-14 shows the emission reductions as a percentage of wider OGV emissions for each pollutant. The percent reductions for reduced hotelling time, at-berth alternative control technology, and shore power are shown relative to total on-port OGV hotelling emissions, as these strategies only address emissions from hotelling for certain vessel types. Percent reductions for increased use of low sulfur fuels are shown relative to total OGV emissions, as they reduce emissions from all considered OGV modes of operation. Similarly, the percent reductions for increased use of LNG in containerships are shown relative to total OGV emissions.

The analysis shows that on-port OGV emissions are dominated by hotelling operations; therefore, emission reduction strategies that focus on hotelling operations such as shore power are projected to have the greatest overall impact. The fuel use strategies that impact all OGV operations also show notable reductions.

This analysis benefited from access to highly detailed baseline inventories based on AIS data and the Port's non-confidential vessel call records. However, a more nuanced approach to future OGV tier distributions based on studies done for other U.S. ports would improve the projected BAU inventories.

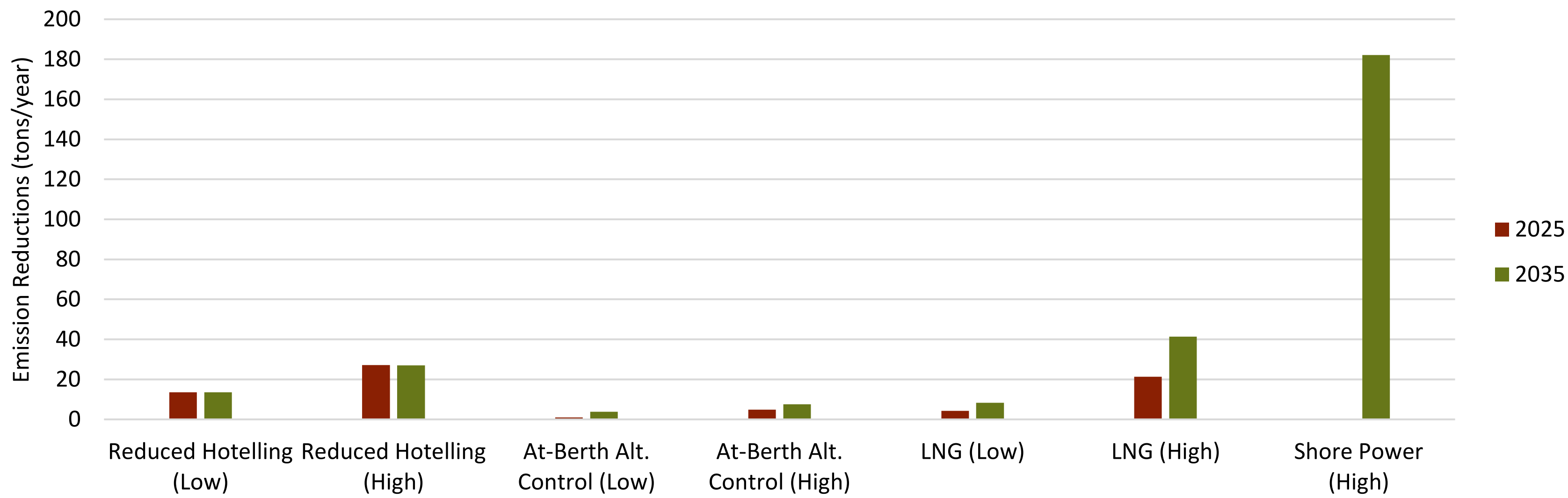

Figure 4-1. On-port OGV NOx Reduction Strategies

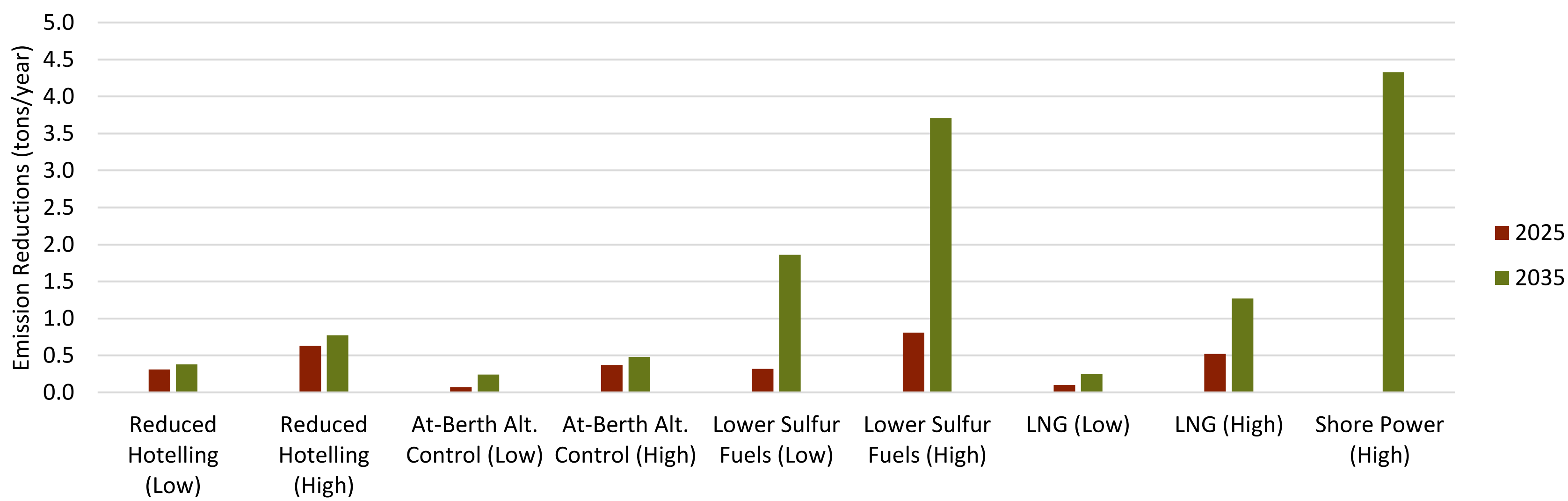

Figure 4-2. On-port OGV $PM_{2.5}$ Reduction Strategies

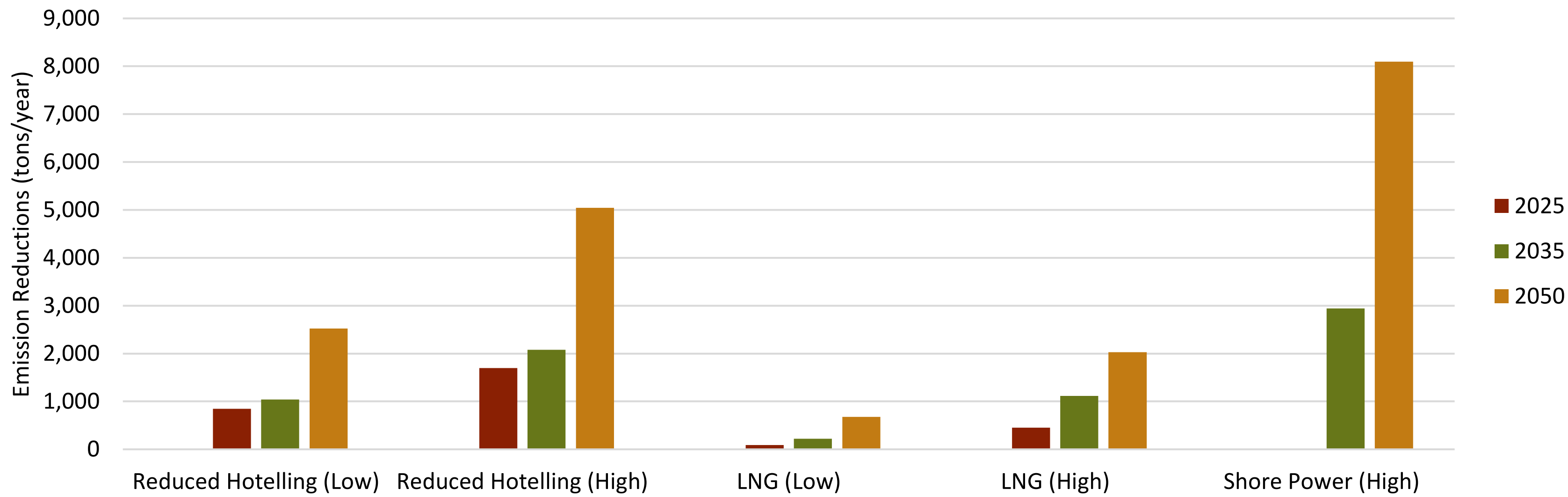

Figure 4-3. On-port OGV CO_2e Reduction Strategies

Table 4-13. Total Reductions from BAU On-port OGV Emissions by Scenario

Year	Strategy	Scenario	Emission Reductions (tons/year)								
			NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	SO_2	VOC	CO_2e[a]
2025	Reduced Hotelling Time	Low	13.60	0.33	0.31	0.33	0.31	0.24	0.60	0.54	847.75
		High	27.20	0.67	0.63	0.67	0.63	0.49	1.21	1.09	1,695.51
	At-Berth Alternative Control Technology	Low	0.97	0.08	0.07	0.08	0.08	0.05	0.05	0.30	−118.80
		High	4.83	0.38	0.37	0.42	0.42	0.28	0.27	1.48	−593.98
	Lower Sulfur Fuels	Low	--[a]	0.34	0.32	0.30	0.28	0.25	5.83	--	--
		High	--	0.86	0.81	0.75	0.71	0.62	14.57	--	--
	LNG	Low	4.26	0.11	0.10	0.09	0.09	0.08	0.26	0.05	91.07
		High	21.28	0.55	0.52	0.47	0.44	0.40	1.28	0.23	455.35
2035	Reduced Hotelling Time	Low	13.48	0.41	0.38	0.41	0.38	0.29	0.74	0.67	1,039.97
		High	26.97	0.82	0.77	0.82	0.77	0.59	1.48	1.34	2,079.94
	At-Berth Alternative Control Technology	Low	3.77	0.25	0.24	0.25	0.24	0.18	0.41	0.37	−668.04
		High	7.54	0.50	0.48	0.50	0.48	0.37	0.82	0.75	−1,336.09
	Lower Sulfur Fuels	Low	--	1.98	1.86	1.73	1.63	1.43	26.84	--	--
		High	--	3.95	3.71	3.46	3.25	2.86	53.69	--	--
	LNG	Low	8.28	0.27	0.25	0.23	0.22	0.19	0.63	0.11	223.44
		High	41.42	1.35	1.27	1.15	1.09	0.98	3.13	0.57	1,117.18
	Shore Power	High	182.18	4.65	4.33	1.49	1.39	3.33	1.32	9.22	2,940.91
2050	Reduced Hotelling Time	Low	--	--	--	--	--	--	--	--	2,520.72
		High	--	--	--	--	--	--	--	--	5,041.44
	LNG	Low	--	--	--	--	--	--	--	--	676.96
		High	--	--	--	--	--	--	--	--	2,030.89
	Shore Power	High	--	--	--	--	--	--	--	--	8,099.06

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

Table 4-14. Percent Reductions from BAU On-port OGV Emissions by Scenario

Year	Strategy	Scenario	Percent Reductions from BAU Emissions								
			NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	SO_2	VOC	CO_2e[a]
2025	Reduced Hotelling Time	Low	0.85%	0.73%	0.73%	0.85%	0.85%	0.74%	0.64%	0.80%	0.57%
		High	1.70%	1.49%	1.49%	1.73%	1.73%	1.50%	1.29%	1.62%	1.15%
	At-Berth Alternative Control Technology	Low	0.06%	0.18%	0.17%	0.21%	0.22%	0.15%	0.05%	0.44%	−0.08%
		High	0.30%	0.84%	0.87%	1.08%	1.15%	0.86%	0.29%	2.20%	−0.40%
	Lower Sulfur Fuels	Low	--[a]	0.58%	0.59%	0.59%	0.59%	0.59%	5.00%	0.00%	--
		High	--	1.48%	1.48%	1.47%	1.47%	1.47%	12.50%	0.00%	--
	LNG	Low	0.21%	0.19%	0.18%	0.18%	0.19%	0.19%	0.22%	0.05%	0.05%
		High	1.03%	0.95%	0.95%	0.92%	0.92%	0.95%	1.10%	0.23%	0.25%
2035	Reduced Hotelling Time	Low	0.99%	0.79%	0.78%	0.92%	0.91%	0.78%	0.69%	0.87%	0.61%
		High	1.99%	1.59%	1.59%	1.85%	1.85%	1.58%	1.38%	1.74%	1.23%
	At-Berth Alternative Control Technology	Low	0.28%	0.48%	0.50%	0.56%	0.58%	0.48%	0.38%	0.48%	−0.39%
		High	0.56%	0.97%	0.99%	1.13%	1.15%	0.99%	0.76%	0.97%	−0.79%
	Lower Sulfur Fuels	Low	--	2.95%	2.95%	2.94%	2.96%	2.95%	20.00%	--	--
		High	--	5.89%	5.89%	5.89%	5.89%	5.90%	40.00%	--	--
	LNG	Low	0.47%	0.40%	0.40%	0.39%	0.40%	0.39%	0.47%	0.10%	0.11%
		High	2.36%	2.01%	2.02%	1.96%	1.98%	2.02%	2.33%	0.50%	0.53%
	Shore Power	High	13.42%	9.01%	8.94%	3.36%	3.34%	8.93%	1.23%	11.97%	1.74%
2050	Reduced Hotelling Time	Low	--	--	--	--	--	--	--	--	1.35%
		High	--	--	--	--	--	--	--	--	2.70%
	LNG	Low	--	--	--	--	--	--	--	--	0.29%
		High	--	--	--	--	--	--	--	--	0.87%
	Shore Power	High	--	--	--	--	--	--	--	--	4.33%

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

5. HARBOR CRAFT

In the context of port operations, harbor craft include marine watercraft that assist in moving ocean going vessels (OGVs) around the harbor, move cargo and people around the port harbor area, and provide fuel to OGVs. Harbor craft are assumed to have main engines with displacements less than 30 liters per cylinder (i.e., Category 1 and 2 engines). While many kinds of harbor craft operate at ports across the country, only articulated tugs, assist tugs, and towboats (collectively referred to as tugs and towboats hereafter) are presented and included in this analysis, as described in Table 5-1. Pilot boats and recreational vessels, which were included in the 2015 On-port Baseline Inventory,[52] are not considered here, since they would not be affected by the hypothetical emission reduction strategies and scenarios modeled, as discussed later in this section.

Table 5-1. Harbor Craft Vessel Types

Vessel Type	Description
Articulated Tug Barges	Tugs specifically designed to work with tank barges
Assist Tugs	Tugs that assist and escort OGVs calling at the port
Towboats	A broad category of ocean tugs, pushboats, and towboats that tow/push barges

This section presents the on-port baseline emissions inventory and projected Business as Usual (BAU) emissions for harbor craft (Section 5.1), the hypothetical strategies and scenarios to reduce harbor craft emissions (Section 5.2), and a summary of the results and lessons learned (Section 5.3). For harbor craft emissions occurring in off-port corridors, see Section 9.2.

5.1 Baseline and Projected Business as Usual Inventories

The 2015 On-port Baseline Inventory, contains emission estimates for harbor craft activity based on U.S. Coast Guard automatic identification system (AIS) data, Information Handling Services' (IHS) Register of Ships, Starcrest's Vessel Boarding Program, and wharfinger vessel call data. The geographical scope of the inventory includes all waterways and berths within the Port and state waters associated with Broward County, which extend three nautical miles from the shoreline. Emissions are presented by vessel type from both propulsion and auxiliary engines.

For details on the data collection and inventory development methodology, please see the 2015 On-port Baseline Inventory. The harbor craft baseline emission inventories presented here include emissions[53] from only the harbor craft types listed in Table 5-1 from the 2015 On-

[52] Starcrest Consulting Group, LLC, *Port Everglades 2015 Baseline Air Emissions Inventory*, December 2016.

[53] Note that unlike the OGV inventories, the harbor craft inventories are presented by vessel type only, not by operating mode.

port Baseline Inventory as well as $DPM_{2.5}$ and BC, which EPA added for its analysis.[54] [55] Additionally, the CO_2e results, which were presented in metric tons in the baseline inventory, were converted to short tons in this analysis for consistency with the other pollutants.

A hypothetical BAU scenario was developed based on anticipated growth and changes at Port Everglades as identified in the *2014 Master/Vision Plan*.[56] Table 5-2 summarizes the projected growth rates for bulk cargo movements, which were used as surrogates for growth of tug and towboat operations.[57] Note that growth factors for 2050 were not necessary for the harbor craft analysis, as only greenhouse gases were included for that year in EPA's analysis, and the selected emission reduction strategies (discussed in Section 5.2) do not address greenhouse gases.

Table 5-2. Projected Growth Factors Used for Future Harbor Craft Activity

Vessel/Cargo Type	Projected Throughput (tons)			Growth Factor (unitless)		
	2015	2025	2035	2015	2025	2035
Bulk[a]	1,565,000	1,870,000	3,609,000	1.000	1.195	2.306

[a] Projections derived from the "Baseline-Plus Estimate" given in the *2014 Master/Vision Plan* for this sector

Additionally, it was assumed that the future age distribution of the vessel fleet would be like that of the current fleet, such that the fraction of vessels less than ten years old would remain the same in each of the projection years. The assumed ten-year vessel replacement rate is given in Table 5-3 as the fraction of vessels in the age 0 to 10 category. Please note that this assumption implies that there will still be Tier 0 vessels in the fleet in 2035 in the BAU scenario. The actual future emissions will depend largely on actual vessel turnover.

Table 5-3. Baseline Age Distribution of Tugs and Towboats

Vessel Age (years)	Vessel Count	Age Distribution
0 to 10	8	13%
11 to 20	12	20%
21 to 30	4	7%
31 to 40	24	39%
Greater than 40	13	21%
Total	**61**	**100%**

[54] $DPM_{2.5}$ was calculated as a fraction of DPM_{10} by applying the ratio of $PM_{2.5}$ to PM_{10} emissions from diesel-powered main and auxiliary engines. BC was calculated as 77% of $PM_{2.5}$ based on the EPA's *Report to Congress on Black Carbon*.

[55] U.S. Environmental Protection Agency, *Report to Congress on Black Carbon*, EPA-450/R-12-001, p. 87, March 2012.

[56] Port Everglades, *2014 Master/Vision Plan* reports, June 24, 2014.

[57] Growth factors for 2035 were not included in the range of projections provided in the *2014 Master/Vision Plan* cited in this report. Therefore, the factors were extrapolated from expected growth between 2028 and 2033, the last five years presented in the *2014 Master/Vision Plan*.

The assumed future vessel replacement rates are important because new vessels will need to comply with Tier 4 emission standards.[58] [59] Based on the 2015 tug and towboat fleet age distribution shown in Table 5-3, it was assumed that all vessels retired and replaced in future years due to normal attrition would be Tier 0 replaced with Tier 4. Table 5-4 compares these emission standards and presents the expected percent reductions when Tier 0 vessels are replaced with Tier 4 vessels. For simplicity, this reduction was calculated assuming that all tugs and towboats at Port Everglades have Category 2 engines.

Table 5-4. Emission Standards for Category 2 Vessels by Tier Level (g/kW-hr)

Tier	NOx	PM_{10}	$PM_{2.5}$	DPM	BC	VOC	CO_2	CH_4	N_2O
Emission Standard[60]									
Tier 0	13.20	0.72	0.72	0.72	0.72	0.50	690.00	0.01	0.03
Tier 4	1.80	0.04	0.04	0.04	0.04	0.19	690.00	0.01	0.03
Percent Emission Reduction									
Tier 0 to 4	86.4%	94.4%	94.4%	94.4%	94.4%	62.0%	0.0%	0.0%	0.0%

Hypothetical future emission inventories were then estimated for 2025 and 2035 by starting with the 2015 baseline emissions, applying the growth factors, and then applying adjustment factors based on expected changes in the fleet emission factors due to the turnover to new standards. Emission inventories were not calculated for 2050 because the selected emission reduction strategies (discussed below) do not address greenhouse gases.

A summary of baseline and BAU projected emissions is presented in Table 5-5. Based on the assumptions in this analysis, emissions are projected to increase for all pollutants due to the anticipated increase in marine freight traffic, and emissions from assist tugs are the largest share of this category.

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[58] For the purposes of this analysis, it was assumed that all harbor craft at Port Everglades are U.S. flagged vessels that comply with EPA's emission standards. Note that for simplicity, this analysis did not consider the impact of EPA's Marine Remanufacture Program, which reduces PM emissions from legacy fleet vessels. For more information on this program, see U.S. Environmental Protection Agency, *Frequently Asked Questions from Marine Engine Owners and Rebuilders about EPA's Marine Remanufacture Program*, EPA-420-F-09-003, February 2009, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1002UMW.PDF.

[59] U.S. Environmental Protection Agency, *Control of Emissions of Air Pollution From Locomotive Engines and Marine Compression-Ignition Engines Less Than 30 Liters per Cylinder*, Federal Register, Vol. 73, No. 126, June 2008, https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-emissions-air-pollution-locomotive.

[60] Ibid.

Table 5-5. 2015 Baseline and 2025 and 2035 BAU Emissions for On-port Harbor Craft

Year	Vessel Type	Annual Emissions (tons/year)							
		NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e
2015[61]	Articulated Tug Barge	17.00	0.44	0.41	0.44	0.41	0.32	0.51	1,297.41
	Assist Tug	131.00	3.60	3.31	3.60	3.31	2.55	5.25	8,502.12
	Towboat	11.00	0.32	0.29	0.32	0.29	0.22	0.33	658.08
	Total	**159.00**	**4.36**	**4.01**	**4.36**	**4.01**	**3.09**	**6.09**	**10,457.61**
2025	Articulated Tug Barge	18.03	0.46	0.43	0.46	0.43	0.33	0.56	1,550.42
	Assist Tug	138.96	3.77	3.47	3.77	3.47	2.67	5.77	10,160.03
	Towboat	11.67	0.34	0.30	0.34	0.30	0.23	0.36	786.40
	Total	**168.66**	**4.57**	**4.20**	**4.57**	**4.20**	**3.23**	**6.69**	**12,496.85**
2035	Articulated Tug Barge	30.40	0.77	0.71	0.77	0.71	0.55	0.99	2,991.85
	Assist Tug	234.23	6.26	5.76	6.26	5.76	4.44	10.15	19,605.88
	Towboat	19.67	0.56	0.50	0.56	0.50	0.39	0.64	1,517.53
	Total	**284.29**	**7.59**	**6.98**	**7.59**	**6.98**	**5.37**	**11.78**	**24,115.26**

61 Starcrest Consulting Group, LLC, *Port Everglades 2015 Baseline Air Emissions Inventory*, December 2016.

5.2 Emission Reduction Strategies and Scenarios

The following emission reduction strategies were selected in consultation between EPA and Port Everglades:

- Engine replacement (to Tier 3)
- Vessel replacement (to Tier 4)

Because Port Everglades does not have direct control over implementing these strategies, the hypothetical scenarios for each are predicated on the assumption of the coordination and collaboration of various maritime industry stakeholders for implementation. Several factors were considered when developing these strategies, including the specific vessel types best targeted by each strategy as well as the feasibility of implementation. As part of EPA's consultation with Port Everglades, the Port shared its non-confidential vessel call log with EPA, which allowed for more detail in this portion of the analysis.

Based on the age distribution of the tug and towboat fleet and the expected remaining life for most vessels at Port Everglades, it was determined that there are many Tier 0 vessels that could be candidates for engine or vessel replacement with cleaner diesel technologies; therefore, only these types of technologies were included in this analysis.[62] Since engine replacement on older vessels to Tier 4 engines may not always be possible due to engine room and other vessel-based limitations, the engine replacement strategy assumes that Tier 0 engines will be replaced with Tier 3 engines. Since new vessels do not have this structural limitation, the vessel replacement strategy assumes that the replacement vessels will be equipped with Tier 4 engines.

Table 5-6. On-port Harbor Craft Emission Reduction Factors by Strategy

Strategy	Notes	NOx	PM_{10}	$PM_{2.5}$	DPM	BC	VOC
Engine Replacement	Per vessel reductions from replacing Tier 0 with Tier 3	44.7%	80.6%	80.6%	80.6%	80.6%	--[a]
Vessel Replacement	Per vessel reductions from replacing Tier 0 with Tier 4	86.4%	94.4%	94.4%	94.4%	94.4%	62.0%

[a] VOC emission reductions from engine replacement were not calculated as part of this analysis.

Table 5-6 shows the percent emission reductions assumed for these two strategies by pollutant. As Tier 3 and 4 emission standards for marine engines do not address greenhouse gas emissions, these pollutants are not included in Table 5-6. Additionally, since the 2050 analysis only included greenhouse gas pollutants, emission reductions for 2050 were not calculated for

[62] Harbor craft shore power was not evaluated in this analysis because the 2015 On-port Baseline Inventory did not present harbor craft at-berth emissions separately from the total harbor craft emissions; consequently, there was not enough detail available to include this strategy.

harbor craft.[63] The emission reduction values presented in Table 5-6 were applied to the 2025 and 2035 BAU inventories for the number of vessels affected by each scenario, as summarized in Table 5-7.

Table 5-7. Summary of On-port Emission Reduction Scenarios for Harbor Craft

Strategy	Scenario	Implementation Rates		Notes
		2025	2035	
Engine Replacement	Low	20% (8 vessels)	20% (6 vessels)	Replacing Tier 0 engines with Tier 3 engines
	High	30% (13 vessels)	30% (8 vessels)	
Vessel Replacement	Low	10% (4 vessels)	10% (3 vessels)	Replacing Tier 0 vessels with Tier 4 vessels
	High	20% (8 vessels)	20% (6 vessels)	

5.3 Emission Reduction Scenario Results and Lessons Learned

The projected emission reductions by scenario are summarized in Figure 5-1, Figure 5-2, and Table 5-8 for on-port harbor craft operations. Table 5-9 shows the percent emission reductions for each scenario relative to total on-port harbor craft emissions for tugs and towboats. This analysis shows that due to the longevity of tugs and towboats, significant emission reductions may be possible through voluntary programs that support the replacement of older engines and vessels. While normal fleet turnover to newer emission standards can reduce the BAU growth in emissions, accelerated engine and vessel replacement have the potential to reduce total harbor craft emissions above what is projected in the BAU case. The reductions possible in 2025 are greater than those in 2035 because there are more vessels available for replacement (i.e., older vessels) in earlier years.

This analysis benefited from knowing the age distribution of the tug and towboat fleet operating at Port Everglades. A more detailed baseline inventory, such as separating hotelling emissions from other operating modes, could have enabled the analysis of additional strategies, such as anti-idling measures or the application of shore power for harbor craft.

[63] Note that there are technologies involving electrification that do address greenhouse gases in addition to shore power that were not included here. For more information, see EPA's *National Port Strategy Assessment*, https://www.epa.gov/ports-initiative/national-port-strategy-assessment-reducing-air-pollution-and-greenhouse-gases-us.

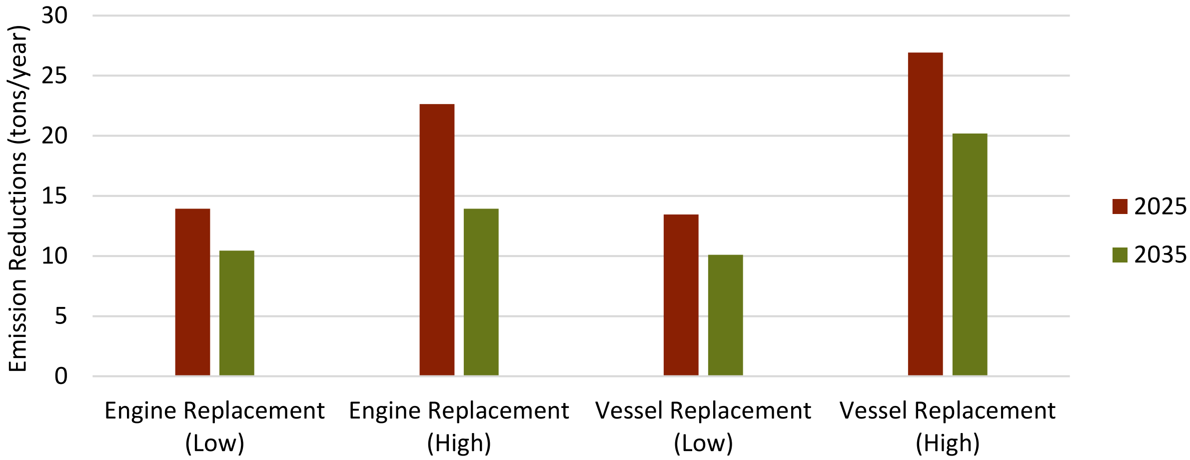

Figure 5-1. On-port Harbor Craft NOx Reduction Strategies

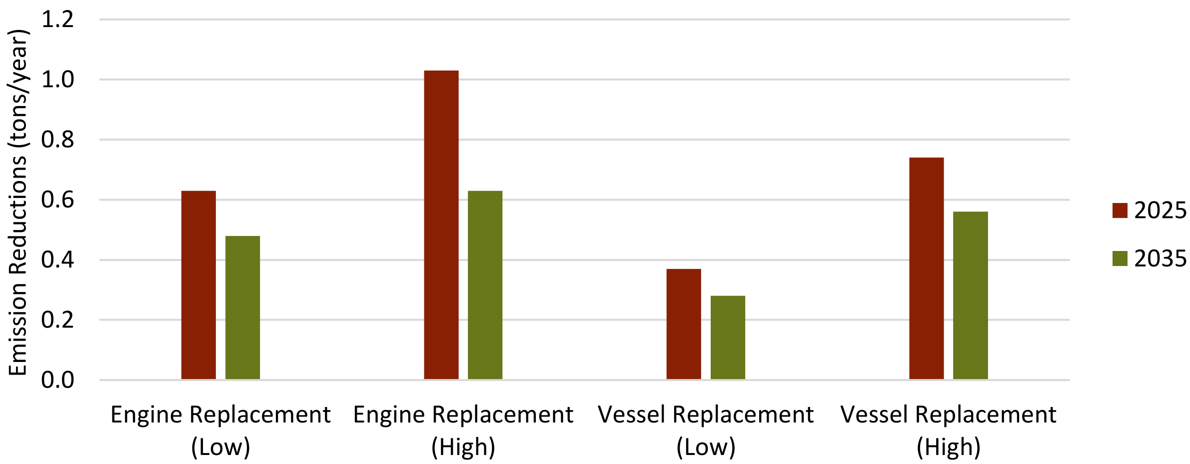

Figure 5-2. On-port Harbor Craft $PM_{2.5}$ Reduction Strategies

Table 5-8. Total Reductions from BAU On-port Harbor Craft Emissions by Scenario

Year	Strategy	Scenario	Emission Reductions (tons/year)						
			NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC
2025	Engine Replacement	Low	13.93	0.69	0.63	0.69	0.63	0.49	--[a]
		High	22.63	1.12	1.03	1.12	1.03	0.79	--
	Vessel Replacement	Low	13.46	0.40	0.37	0.40	0.37	0.28	0.37
		High	26.92	0.81	0.74	0.81	0.74	0.57	0.75
2035	Engine Replacement	Low	10.45	0.52	0.48	0.52	0.48	0.37	--
		High	13.93	0.69	0.63	0.69	0.63	0.49	--
	Vessel Replacement	Low	10.10	0.30	0.28	0.30	0.28	0.22	0.28
		High	20.19	0.61	0.56	0.61	0.56	0.43	0.56

Table 5-9. Percent Reductions from BAU On-port Harbor Craft Emissions by Scenario

Year	Strategy	Scenario	Percent Reductions from BAU Emissions						
			NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC
2025	Engine Replacement	Low	8.26%	15.10%	15.00%	15.10%	15.00%	15.17%	--
		High	13.42%	24.51%	24.52%	24.51%	24.52%	24.46%	--
	Vessel Replacement	Low	7.98%	8.75%	8.81%	8.75%	8.81%	8.67%	5.53%
		High	15.96%	17.72%	17.62%	17.72%	17.62%	17.65%	11.21%
2035	Engine Replacement	Low	3.68%	6.85%	6.88%	6.85%	6.88%	6.89%	--
		High	4.90%	9.09%	9.03%	9.09%	9.03%	9.12%	--
	Vessel Replacement	Low	3.55%	3.95%	4.01%	3.95%	4.01%	4.10%	2.38%
		High	7.10%	8.04%	8.02%	8.04%	8.02%	8.01%	4.75%

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

6. CARGO HANDLING EQUIPMENT

Cargo handling equipment (CHE) includes nonroad equipment that are critical for moving cargo, passenger luggage, products, and supplies on and off vessels and around the port. The following CHE types in operation at Port Everglades were included in EPA's analysis:

- Aerial lifts
- Cranes
- Empty container handlers
- Excavators
- Forklifts
- Loaders
- Manlifts
- Off-highway trucks
- Power packs
- Reach stackers
- Rubber tired gantry (RTG) cranes
- Scissor lifts
- Skid steer loaders
- Sweepers
- Top loaders
- Yard tractors

This section begins with an overview of the baseline emissions inventory and projected Business as Usual (BAU) emissions for CHE (Section 6.1), which is followed by a presentation of the hypothetical CHE emission reduction strategies and scenarios (Section 6.2) and a discussion of the key results and lessons learned (Section 6.3).

6.1 Baseline and Projected Business as Usual Inventories

The 2015 On-port Baseline Inventory[64] includes emissions for each piece of CHE operating at Port Everglades using data on equipment counts, engine characteristics, and activity. Existing relationships between Port Everglades and its tenants were critical for obtaining this supporting information through confidential surveys of terminal and facility operational managers.[65]

Only emissions from diesel CHE are considered in EPA's analysis, since emissions from the few gasoline and propane CHE at Port Everglades (6 and 10 units, respectively) are not impacted by the strategies and scenarios presented in Section 6.3. The presented emission inventories include pollutants from the 2015 On-port Baseline Inventory, in addition to $DPM_{2.5}$ and BC.[66] [67] CO_2e results were converted from metric tons in that report to short tons here for consistency with the other pollutants. Given the sole focus on diesel CHE, the baseline PM and DPM inventories are identical. Note that the CHE baseline inventory only covers equipment operating on the port; no off-port CHE was considered in this analysis. For additional details on the data collection and baseline inventory development methodology, please refer to the 2015 On-port Baseline Inventory.

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64 Starcrest Consulting Group, LLC, *Port Everglades 2015 Baseline Air Emissions Inventory*, December 2016.

65 Note that EPA did not receive any confidential business or terminal-specific information through the partnership.

66 $DPM_{2.5}$ emissions were calculated to be equal to $PM_{2.5}$ emissions, and BC emissions were calculated to be 34.9% of $PM_{2.5}$ emissions. The BC fraction is based on EPA's SPECIATE 4.3 repository.

67 U.S. Environmental Protection Agency, SPECIATE 4.3, September 2011, https://www.epa.gov/air-emissions-modeling/speciate-version-45-through-40.

In line with the *2014 Master/Vision Plan*,[68] a hypothetical Business as Usual scenario was developed based on anticipated growth and changes at Port Everglades. The growth factors in Table 6-1 are based on projected throughput of container freight at the Port, which was used as a surrogate for growth of CHE operations, and were applied directly to the unit-specific baseline data to estimate future emissions.[69]

Table 6-1. Projected Growth Factors Used for Future CHE Activity

Vessel/Cargo Type	Projected Throughput (TEUs[a])				Growth Factor (unitless)			
	2015	2025	2035	2050	2015	2025	2035	2050
Container	1,060,000	1,435,000	1,761,000	2,134,000	1.000	1.354	1.661	2.013

[a] Twenty-foot equivalent units

In addition to accounting for anticipated growth in port traffic in emission estimates, the hypothetical estimates were adjusted to reflect the incorporation of newer equipment that complies with the latest emission standards[70] based on past fleet turnover rates. The methodology used to estimate engine tier level distributions for 2025, 2035, and 2050 ensures that the in-use model year distributions for future analysis years are consistent with the 2015 baseline distribution. The resulting CHE counts by tier level in each analysis year are presented in Table 6-2, while Table 6-3 summarizes the projected population and average tier level of each CHE type by analysis year.

Table 6-2. Baseline and Projected CHE Count by Tier Level

Tier	2015	2025	2035	2050
Tier 0	45	26	7	4
Tier 1	38	30	20	8
Tier 2	196	142	56	2
Tier 3	108	125	30	8
Tier 4	36	250	590	829
Total	**423**	**573**	**703**	**851**

68 Port Everglades, 2014 *Master/Vision Plan* reports, June 24, 2014.

69 Growth factors for 2035 and 2050 are not included in the range of projections provided in the *2014 Master/Vision Plan* cited in this report. Therefore, the factors were extrapolated from expected growth between 2028 and 2033, the last five years presented in the *2014 Master/Vision Plan*.

70 U.S. Environmental Protection Agency, *Nonroad Compression-Ignition Engines: Exhaust Emission Standards*, March 2016, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OA05.pdf.

Table 6-3. CHE Count and Average Tier Level by BAU Year

Equipment Type	2025		2035		2050	
	Count	Average Tier Level	Count	Average Tier Level	Count	Average Tier Level
Aerial Lifts	4	2	5	2	6	2
Cranes	5	3	6	4	8	4
Empty Container Handlers	3	4	3	4	4	4
Excavators	1	3	2	3	2	4
Forklifts	241	3	294	4	356	4
Loaders	1	3	2	3	2	3
Manlifts	1	1	2	1	2	1
Off-highway Trucks	5	3	7	3	8	4
Power Packs	7	4	8	4	10	4
Reach Stackers	5	4	6	4	8	4
RTG Cranes	4	4	5	4	6	4
Scissor Lifts	5	2	7	2	8	4
Skid Steer Loaders	1	0	2	0	2	0
Sweepers	4	3	5	3	6	4
Top Loaders	74	3	90	4	109	4
Yard Tractors	212	3	259	4	314	4
Total	**573**	**--**[a]	**703**	**--**	**851**	**--**

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

For most pollutants, per-unit projected BAU emissions were calculated[71] by multiplying the equipment type-specific emission factor—extracted from MOVES2014a-NONROAD[72] outputs—by the product of annual operating hours, rated horsepower, and load factor. Because the MOVES model does not produce N_2O or BC estimates, fuel-based emission factors for N_2O and the elemental carbon fraction of $PM_{2.5}$ were used to estimate these emissions.

Table 6-4 presents the CHE 2015 baseline inventory results. A summary of projected CHE BAU emissions are presented in Table 6-5, Table 6-6, and Table 6-7 for the analysis years 2025, 2035, and 2050, respectively.

Even though freight traffic activities are projected to increase during the 2015–2035 period, aggregate emissions for most considered pollutants do not increase in the BAU scenario due to expected fleet turnover of older, high-emitting equipment with newer diesel equipment that meets EPA's latest emission standards. However, emissions could be further reduced by

71 For average rated horsepower, average annual operating hours, assumed load factor, and MOVES2014a-NONROAD source classification code (SCC) by CHE type, see Tables 5.1 and 5.2 of the 2015 On-port Baseline Inventory.

72 EPA's MOtor Vehicle Emission Simulator (MOVES) is a state-of-the-science emission modeling system that estimates emissions for mobile sources at the national, county, and project level for criteria air pollutants, greenhouse gases, and air toxics. For more information, see https://www.epa.gov/moves.

voluntarily implementing the hypothetical emission reduction strategies presented in the following section.

Table 6-4. 2015 Baseline Emissions for On-port CHE

Equipment Type	Annual Emissions (tons/year)[73]							
	NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e
Aerial Lifts	0.16	0.02	0.02	0.02	0.02	0.01	0.03	18.74
Cranes	13.72	0.70	0.68	0.70	0.68	0.24	1.07	2,925.53
Empty Container Handlers	1.24	0.06	0.06	0.06	0.06	0.02	0.11	155.43
Excavators	0.19	0.02	0.02	0.02	0.02	0.01	0.01	38.58
Forklifts	28.06	2.83	2.74	2.83	2.74	0.96	4.86	3,571.48
Loaders	0.07	0.01	0.01	0.01	0.01	0.00	0.01	13.23
Manlifts	0.03	0.00	0.00	0.00	0.00	0.00	0.01	3.31
Off-highway Trucks	0.26	0.04	0.03	0.04	0.03	0.01	0.02	60.63
Power Packs	22.90	1.08	1.04	1.08	1.04	0.36	1.92	2,087.78
Reach Stackers	1.28	0.04	0.04	0.04	0.04	0.01	0.19	610.68
RTG Cranes	0.12	0.00	0.00	0.00	0.00	0.00	0.06	263.45
Scissor Lifts	0.05	0.01	0.01	0.01	0.01	0.00	0.01	5.51
Skid Steer Loaders	0.04	0.01	0.01	0.01	0.01	0.00	0.01	3.31
Sweepers	0.14	0.01	0.01	0.01	0.01	0.00	0.01	34.17
Top Loaders	74.01	2.67	2.59	2.67	2.59	0.90	4.30	8,935.32
Yard Tractors	75.89	6.32	6.12	6.32	6.12	2.14	12.19	8,531.88
Total	**218.16**	**13.82**	**13.38**	**13.82**	**13.38**	**4.66**	**24.81**	**27,259.02**

[73] Starcrest Consulting Group, LLC, *Port Everglades 2015 Baseline Air Emissions Inventory*, December 2016.

Table 6-5. 2025 BAU Emissions for On-port CHE

Equipment Type	Annual Emissions (tons/year)							
	NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e
Aerial Lifts	0.22	0.03	0.03	0.03	0.03	0.01	0.04	28.98
Cranes	30.48	0.77	0.75	0.77	0.75	0.26	1.42	4,387.19
Empty Container Handlers	0.11	0.00	0.00	0.00	0.00	0.00	0.06	232.09
Excavators	0.26	0.03	0.03	0.03	0.03	0.01	0.02	57.96
Forklifts	23.23	2.18	2.11	2.18	2.11	0.74	2.16	5,207.63
Loaders	0.09	0.01	0.01	0.01	0.01	0.00	0.01	19.98
Manlifts	0.05	0.01	0.01	0.01	0.01	0.00	0.01	5.00
Off-highway Trucks	0.35	0.05	0.05	0.05	0.05	0.02	0.03	89.94
Power Packs	1.48	0.04	0.04	0.04	0.04	0.01	0.81	3,136.57
Reach Stackers	1.73	0.07	0.07	0.07	0.07	0.02	0.25	915.86
RTG Cranes	0.16	0.00	0.00	0.00	0.00	0.00	0.09	394.97
Scissor Lifts	0.06	0.01	0.01	0.01	0.01	0.00	0.02	8.00
Skid Steer Loaders	0.05	0.01	0.01	0.01	0.01	0.00	0.02	4.00
Sweepers	0.16	0.01	0.01	0.01	0.01	0.00	0.01	27.98
Top Loaders	26.16	0.99	0.96	0.99	0.96	0.34	3.91	13,405.91
Yard Tractors	36.02	2.93	2.84	2.93	2.84	0.99	4.97	12,779.35
Total	**120.61**	**7.14**	**6.93**	**7.14**	**6.93**	**2.42**	**13.83**	**40,704.41**

Table 6-6. 2035 BAU Emissions for On-port CHE

Equipment Type	Annual Emissions (tons/year)							
	NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e
Aerial Lifts	0.27	0.04	0.03	0.04	0.03	0.01	0.05	34.98
Cranes	37.39	0.95	0.92	0.95	0.92	0.32	1.74	5,380.01
Empty Container Handlers	0.14	0.01	0.01	0.01	0.01	0.00	0.08	285.05
Excavators	0.32	0.03	0.03	0.03	0.03	0.01	0.02	69.96
Forklifts	13.73	0.57	0.56	0.57	0.56	0.19	1.77	6,390.31
Loaders	0.11	0.02	0.02	0.02	0.02	0.01	0.02	23.98
Manlifts	0.06	0.01	0.01	0.01	0.01	0.00	0.01	6.00
Off-highway Trucks	0.43	0.06	0.06	0.06	0.06	0.02	0.04	111.92
Power Packs	1.82	0.06	0.06	0.06	0.06	0.02	1.00	3,848.32
Reach Stackers	1.22	0.02	0.02	0.02	0.02	0.01	0.30	1,122.72
RTG Cranes	0.19	0.01	0.01	0.01	0.01	0.00	0.11	483.91
Scissor Lifts	0.08	0.01	0.01	0.01	0.01	0.00	0.02	10.00
Skid Steer Loaders	0.06	0.02	0.02	0.02	0.02	0.01	0.02	5.00
Sweepers	0.19	0.01	0.01	0.01	0.01	0.00	0.01	33.98
Top Loaders	12.77	0.38	0.37	0.38	0.37	0.13	4.35	16,443.56
Yard Tractors	9.64	0.42	0.40	0.42	0.40	0.14	4.20	15,679.83
Total	**78.42**	**2.60**	**2.52**	**2.60**	**2.52**	**0.88**	**13.73**	**49,929.53**

Table 6-7. 2050 BAU Emissions for On-port CHE

Equipment Type	Annual CO_2e Emissions (tons/year)
Aerial Lifts	43.11
Cranes	6,521.54
Empty Container Handlers	345.53
Excavators	87.04
Forklifts	7,746.66
Loaders	28.32
Manlifts	8.43
Off-highway Trucks	135.26
Power Packs	4,663.77
Reach Stackers	1,361.42
RTG Cranes	586.24
Scissor Lifts	13.02
Skid Steer Loaders	7.31
Sweepers	41.86
Top Loaders	19,929.85
Yard Tractors	19,001.83
Total	**60,521.19**

6.2 Emission Reduction Strategies and Scenarios

The following CHE emission reduction strategies were modeled for diesel-powered CHE:

- Retrofit with diesel particulate filters (DPFs)
- Retrofit with diesel oxidation catalysts (DOCs)
- Replace older equipment with cleaner diesel and/or electric technologies
- Replace with new alternative fuel units (i.e., liquefied petroleum gas [LPG] or compressed natural gas [CNG])
- Reefer power pack electrification

These strategies were developed in consultation with Port Everglades based on the characteristics of the port. The associated emission reduction scenarios are summarized in Table 6-8, which provides the number of units affected by each scenario in years 2025, 2035, and 2050, assuming low and high implementation rates.

CHE units with the greatest potential for future emission reductions, i.e., younger units that do not meet the latest emission standards, were specifically targeted by the retrofit and replacement scenarios. As a result, adoption rates of most of the considered CHE strategies were highly dependent on tier level and engine age distribution in each of the analysis years.

The number of units targeted for retrofit or replacement in the first projection year, 2025, was calculated by multiplying the projected number of units in each tier level in Table 6-2 by the technology penetration percentages in Table 6-8.

Note that by targeting CHE with the longest remaining useful life, some older units are not included in this strategy. However, it is assumed that these older units will be retired and replaced through natural attrition in higher proportions than average. This "accelerated retirement" effect was considered when defining the "high" retrofit scenarios in 2035; the underlying assumption is that all potential targets for these scenarios have been removed from the fleet through attrition by this year and, thus, the number of targeted units is 0. Additionally, note that only strategies that had a quantifiable impact on greenhouse gas emissions were included for 2050.

The hypothetical CHE emission reduction strategies are described in more detail in Sections 6.2.1 through 6.2.4.

Table 6-8. Summary of Emission Reduction Scenarios for On-port CHE

Strategy	Affected Equipment Types	Scenario	Units Targeted			Percent Implementation by Engine Tier and Analysis Year[a]
			2025	2035	2050	
Retrofit with DPFs	All pre-Tier 4 diesel	Low	95*	30**	N/A	* 50% Tier 0 and 1, 25% Tier 2 and 3 ** 100% Tier 0 and 1, 50% Tier 2 and 3
		High	190*	0**	N/A	* 100% Tier 0 and 1, 50% Tier 2 and 3 ** 100% Tier 0 and 1, 75% Tier 2 and 3
Retrofit with DOCs	All pre-Tier 4 diesel	Low	95*	30**	N/A	* 50% Tier 0 and 1, 25% Tier 2 and 3 ** 100% Tier 0 and 1, 50% Tier 2 and 3
		High	190*	0**	N/A	* 100% Tier 0 and 1, 50% Tier 2 and 3 ** 100% Tier 0 and 1, 75% Tier 2 and 3
Replace older equipment with cleaner diesel and/or electric technologies	All diesel	Low	112*	123**	366***	* 100% Tier 0 and 50% of Tier 1 and 2 replaced with 50% Tier 3 and 50% Tier 4 ** 100% Tier 0–3 replaced with 50% Tier 4 and 50% electric; 10% Tier 4 replaced with electric *** 100% Tier 0–3 replaced with electric; 50% Tier 4 replaced with electric
		High	198*	236**	382***	* 100% Tier 0–2 replaced with 75% Tier 4 and 25% electric ** 100% Tier 0–3 replaced with 50% Tier 4 and 50% electric; 25% Tier 4 replaced with electric *** 100% Tier 0–3 replaced with electric; 75% Tier 4 replaced with electric
Replace with new alternative fuel units	All pre-Tier 4 diesel	Low	49*	43**	N/A	* 25% Tier 0–2 replaced with alt. fuel meeting Tier 4 ** 50% Tier 0–3 replaced with alt. fuel meeting Tier 4
		High	100*	32**	N/A	* 50% Tier 0–2 replaced with alt. fuel meeting Tier 4 ** 75% Tier 0–3 replaced with alt. fuel meeting Tier 4
Reefer electrification	Power packs	High	7*	1*	2*	* 100% of units replaced with electric

[a] Percentages reflect the proportion of equipment being retrofitted/replaced, relative to the scenario populations by engine tier and analysis year.

6.2.1 Retrofit with Diesel Particulate Filters or Diesel Oxidation Catalysts

Of the considered retrofit strategies, DPFs are effective at reducing PM and VOC emissions, while DOCs facilitate a reaction between PM, VOCs, and CO in the exhaust steam of an engine to produce CO_2 and water.

The anticipated emission reductions from retrofitting CHE with DPFs and DOCs are based on data from the California Air Resources Board (ARB) and EPA's list of verified retrofit systems for nonroad mobile equipment.[74] [75] Approximately 20 DPF retrofit technologies are currently verified by EPA and each is associated with PM and VOC reductions of 90 percent. Two DOC retrofit products are verified, with documented reductions for PM and VOCs of 20 percent and 80 percent, respectively. These emission reduction factors were applied to the target fraction of the Tier 0−3 equipment emissions from the BAU case, as specified by the assumed implementation rates listed in Table 6-8.

6.2.2 Replace Older Equipment

Replacing older diesel equipment with equipment meeting Tier 4 standards can reduce emissions because Tier 4 engines emit significantly less pollution than earlier models.[76] This strategy also includes engine replacements to Tier 4 engines as well as upgrades to hybrid or full-battery electric systems.

The emission reductions associated with this scenario were modeled by assuming that new diesel and hybrid engines have the same emission rates as corresponding new Tier 3 and Tier 4 units, while fully electric units were assumed to have zero tailpipe emissions.[77] Tier 3 units were assigned a model year of 2008, while Tier 4 units were assumed to be new in each analysis year.

6.2.3 Use of Alternative Fuels

Shifting from diesel to alternative fuel systems is an effective way to reduce NOx and PM emissions. The emission reductions associated with this shift were derived from LPG and CNG emission rates extracted from MOVES2014a-NONROAD output. Since LPG and CNG emission factors were not available for all considered CHE types, several cross-type substitutions were made, as documented in Table 6-9. Deviations in horsepower across matches were not expected to significantly impact results, as MOVES g/bhp-hr emission factors are similar across horsepower bins for a given source classification code (SCC).

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74 List of ARB-verified retrofits available at: https://www.arb.ca.gov/diesel/verdev/vt/cvt.htm.

75 List of EPA-verified retrofits available at: https://www.epa.gov/verified-diesel-tech/verified-technologies-list-clean-diesel.

76 U.S. Environmental Protection Agency, *Nonroad Compression-Ignition Engines: Exhaust Emission Standards*, March 2016, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OA05.pdf.

77 Upstream emissions for replacing equipment with electric models were not included in this analysis.

Table 6-9. Matching Diesel CHE to Alternative Fuel Equipment

Diesel CHE			Alternative Fuel CHE	
Equipment Type	SCC	HP Bin	Equipment Type	HP Bin
Diesel Excavators	2270002036	600	N/A[a]	
Diesel Cranes	2270002045	3000	LPG Cranes	175
Diesel Off-highway Trucks	2270002051	175	LPG Forklifts	175
Diesel Skid Steer Loaders	2270002072	75	LPG Skid Steer Loaders	75
Diesel Skid Steer Loaders	2270002072	300	LPG Skid Steer Loaders	100
Diesel Aerial Lifts	2270003010	40	LPG Aerial Lifts	40
Diesel Aerial Lifts	2270003010	100	LPG Aerial Lifts	75
Diesel Aerial Lifts	2270003010	175	LPG Aerial Lifts	175
Diesel Forklifts	2270003020	75	CNG Forklifts	50
Diesel Forklifts	2270003020	100	CNG Forklifts	50
Diesel Forklifts	2270003020	175	CNG Forklifts	50
Diesel Sweepers	2270003030	75	CNG Sweepers	300
Diesel Other General Industrial Equipment	2270003040	600	CNG Other General Industrial Equipment	100
Diesel Yard Tractors	2270003070	175	CNG Yard Tractors	175

[a] The CHE inventory included only one excavator, and there was no suitable equipment-horsepower surrogate available from the MOVES2014a-NONROAD model. Therefore, the excavator was excluded from the low and high alternative fuel scenarios (i.e., the excavator remains diesel-fueled).

To estimate BC reductions, the ratio of elemental carbon to exhaust $PM_{2.5}$ (0.0955), derived from MOVES2014a onroad output, was applied. The impact of the alternative fuel strategies on CO_2e and VOC emissions were not included due to uncertainty in accurately quantifying the impact of methane slippage.

6.2.4 Reefer Electrification

Emission reductions are possible by electrifying the power packs used to power refrigerated containers while dockside. The associated emission reductions were estimated by assuming that a proportion of power packs, given the number of units targeted, produces zero emissions in each analysis year. Note that upstream emissions associated with this strategy were not included in this analysis.

6.3 Emission Reduction Scenario Results and Lessons Learned

The emission reductions from the hypothetical CHE strategies and scenarios are summarized in Figure 6-1, Figure 6-2, Figure 6-3, and Table 6-10 for each analysis year. Table 6-11 displays these emission reductions as a percentage of total CHE emissions for each pollutant. Since just CO_2e emission reductions are presented for 2050, only the strategies that impact greenhouse gas emissions (i.e., replace with cleaner diesel and/or electric technologies and reefer electrification) are presented for that year.

Given high implementation assumptions, retrofitting diesel CHE with DPFs is projected to reduce PM and DPM emissions by 49 percent in 2025 and 33 percent in 2035, while retrofitting diesel CHE with DOCs is associated with PM and DPM emission reductions of 11 and 7 percent in 2025 and 2035, respectively. Replacing older CHE with advanced technology engines or alternative fuel units was determined to be feasible for reducing emissions over a broad range of pollutants and engine sizes. Specifically, the equipment replacement strategy is associated with NOx emission reductions of 21 percent in 2025 and 69 percent in 2035 under low implementation and 40 percent in 2025 and 76 percent in 2035 under high implementation.

The effectiveness of the considered emission control strategies was found to be sensitive to expected hours of use and remaining engine life of targeted units, highlighting the importance of accurate inputs for the development of realistic emission projections. This analysis benefited from the availability of highly detailed fleet characterization data (e.g., engine-specific model year, horsepower, and annual hours of operation data), which facilitated a detailed emissions inventory and allowed for precise evaluations of emission reduction scenarios.

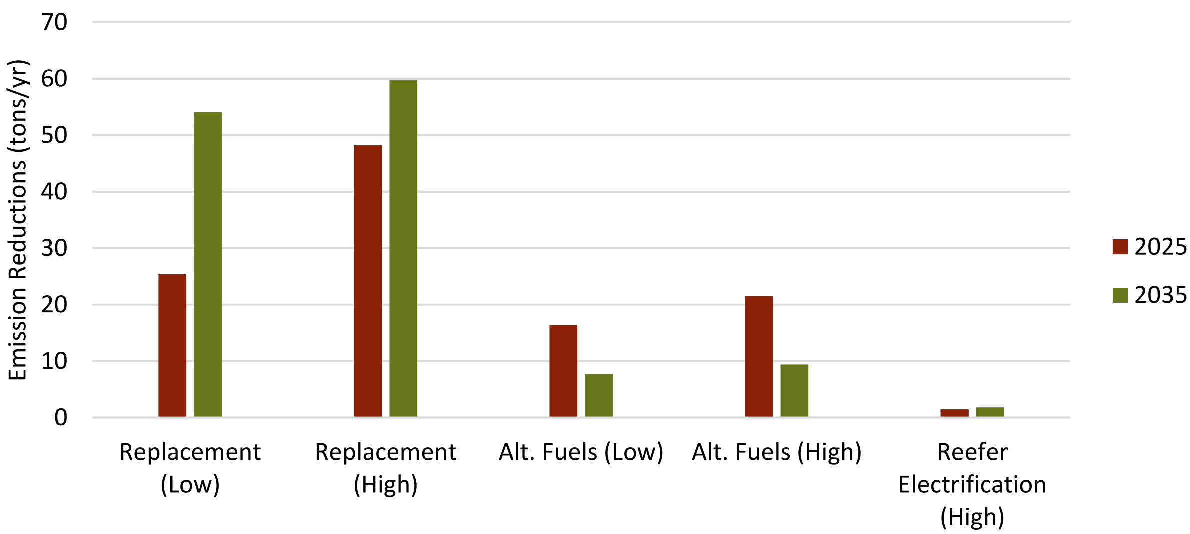

Figure 6-1. On-port CHE NOx Reduction Strategies

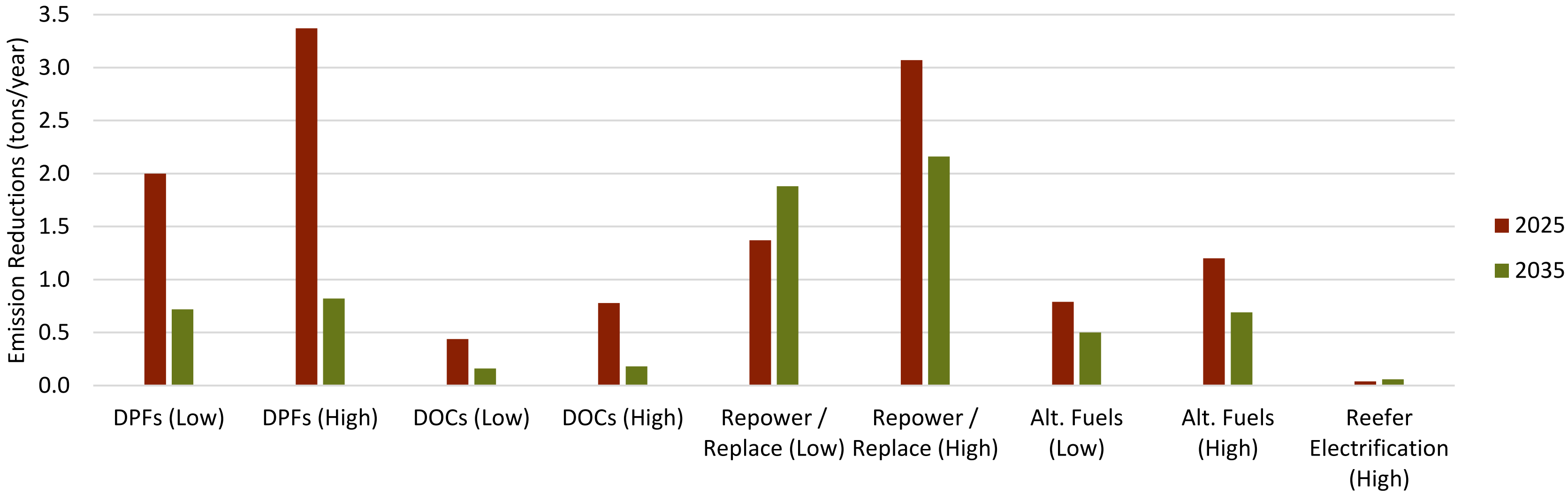

Figure 6-2. On-port CHE $PM_{2.5}$ Reduction Strategies

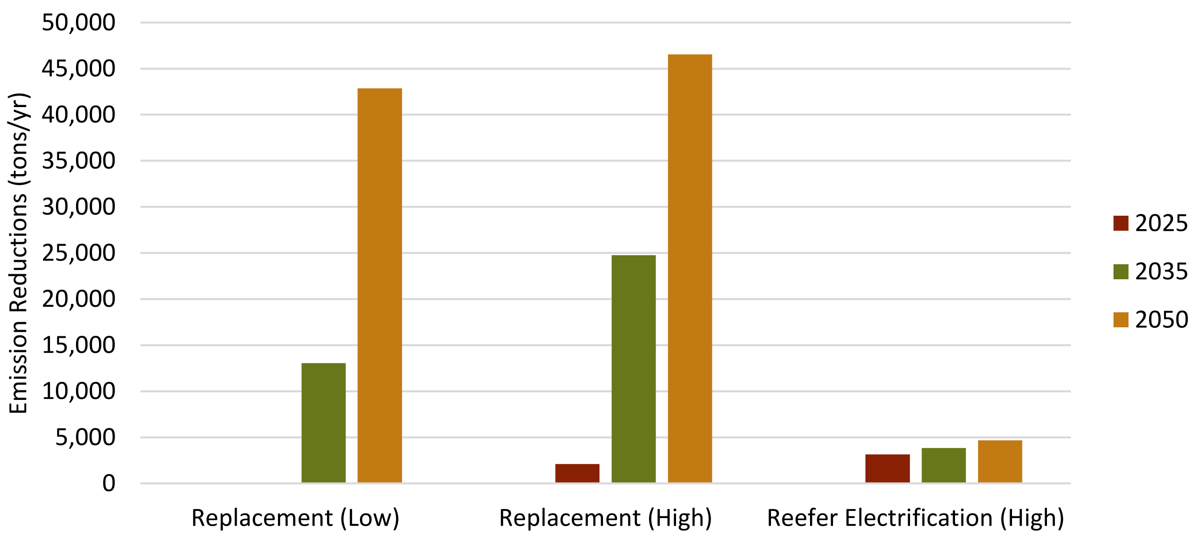

Figure 6-3. On-port CHE CO_2e Reduction Strategies

Table 6-10. Total Reductions from BAU On-port CHE Emissions by Scenario

Year	Strategy	Scenario	Emission Reductions (tons/year)							
			NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e
2025	DPFs	Low	--[a]	2.06	2.00	2.06	2.00	0.70	2.95	--
		High	--	3.47	3.37	3.47	3.37	1.18	4.08	--
	DOCs	Low	--	0.46	0.44	0.46	0.44	0.16	2.63	--
		High	--	0.80	0.78	0.80	0.78	0.27	3.82	--
	Equipment Replacement	Low	25.37	1.42	1.37	1.42	1.37	0.48	1.11	0.00
		High	48.19	3.17	3.07	3.17	3.07	1.07	3.02	2,091.53
	Alternative Fuels	Low	16.36	0.82	0.79	0.82	0.79	0.34	--	--
		High	21.51	1.25	1.20	1.25	1.20	0.50	--	--
	Reefer Electrification	High	1.48	0.04	0.04	0.04	0.04	0.01	0.81	3,136.57
2035	DPFs	Low	--	0.74	0.72	0.74	0.72	0.25	0.79	--
		High	--	0.85	0.82	0.85	0.82	0.29	0.90	--
	DOCs	Low	--	0.17	0.16	0.17	0.16	0.06	0.71	--
		High	--	0.19	0.18	0.19	0.18	0.06	0.80	--
	Equipment Replacement	Low	54.12	1.94	1.88	1.94	1.88	0.66	4.71	13,041.27
		High	59.74	2.23	2.16	2.23	2.16	0.75	7.42	24,751.53
	Alternative Fuels	Low	7.68	0.52	0.50	0.52	0.50	0.21	--	--
		High	9.39	0.72	0.69	0.72	0.69	0.28	--	--
	Reefer Electrification	High	1.82	0.06	0.06	0.06	0.06	0.02	1.00	3,848.32
2050	Equipment Replacement	Low	--	--	--	--	--	--	--	42,848.10
		High	--	--	--	--	--	--	--	46,535.95
	Reefer Electrification	High	--	--	--	--	--	--	--	4,663.77

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

Table 6-11. Percent Reductions from BAU On-port CHE Emissions by Scenario

Year	Strategy	Scenario	Percent Reductions from BAU Emissions							
			NO_x	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e
2025	DPFs	Low	--[a]	28.85%	28.86%	28.85%	28.86%	28.93%	21.33%	--
		High	--	48.60%	48.63%	48.60%	48.63%	48.76%	29.50%	--
	DOCs	Low	--	6.44%	6.35%	6.44%	6.35%	6.61%	19.02%	--
		High	--	11.20%	11.26%	11.20%	11.26%	11.16%	27.62%	--
	Equipment Replacement	Low	21.03%	19.89%	19.77%	19.89%	19.77%	19.83%	8.03%	0.00%
		High	39.96%	44.40%	44.30%	44.40%	44.30%	44.21%	21.84%	5.14%
	Alternative Fuels	Low	13.56%	11.48%	11.40%	11.48%	11.40%	14.05%	--	--
		High	17.83%	17.51%	17.32%	17.51%	17.32%	20.66%	--	--
	Reefer Electrification	High	1.23%	0.56%	0.58%	0.56%	0.58%	0.41%	5.86%	7.71%
2035	DPFs	Low	--	28.46%	28.57%	28.46%	28.57%	28.41%	5.75%	--
		High	--	32.69%	32.54%	32.69%	32.54%	32.95%	6.55%	--
	DOCs	Low	--	6.54%	6.35%	6.54%	6.35%	6.82%	5.17%	--
		High	--	7.31%	7.14%	7.31%	7.14%	6.82%	5.83%	--
	Equipment Replacement	Low	69.01%	74.62%	74.60%	74.62%	74.60%	75.00%	34.30%	26.12%
		High	76.18%	85.77%	85.71%	85.77%	85.71%	85.23%	54.04%	49.57%
	Alternative Fuels	Low	9.79%	20.00%	19.84%	20.00%	19.84%	23.86%	--	--
		High	11.97%	27.69%	27.38%	27.69%	27.38%	31.82%	--	--
	Reefer Electrification	High	2.32%	2.31%	2.38%	2.31%	2.38%	2.27%	7.28%	7.71%
2050	Equipment Replacement	Low	--	--	--	--	--	--	--	70.80%
		High	--	--	--	--	--	--	--	76.89%
	Reefer Electrification	High	--	--	--	--	--	--	--	7.71%

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

7. ONROAD VEHICLES

Onroad vehicles at Port Everglades include heavy-duty diesel trucks that are used to move cargo in and out of the port, light-duty and medium-duty vehicles that transport passengers to and from the cruise ship terminals, and vehicles owned and operated by the Port. Specifically, emissions from passenger cars, transit buses, light trucks/vans, and heavy-duty trucks are considered in EPA's analysis, although the strategy scenarios target only heavy-duty diesel trucks. This section of the report includes the on-port emissions from onroad vehicles. The associated off-port emissions are discussed in Section 9.3.

This section begins with a presentation of the baseline emissions inventory and projected Business as Usual (BAU) emissions for onroad vehicles (Section 7.1). This is followed by a discussion of the considered emission reduction strategies and scenarios to reduce onroad emissions (Section 7.2) and the primary results and lessons learned (Section 7.3).

7.1 Baseline and Projected Business as Usual Inventories

The 2015 On-port Baseline Inventory[78] contains onroad emission estimates from trucks, passenger vehicles, and Port-owned vehicles based on gate counts and confidential surveys of terminal and facility operational managers. EPA did not receive any confidential business or terminal-specific information through the partnership. For details on the data collection and inventory development methodology, please see the 2015 On-port Baseline Inventory.

The onroad baseline inventory presented here includes the information from the 2015 On-port Baseline Inventory as well as $DPM_{2.5}$ and BC, which EPA added for its analysis.[79] [80] Additionally, the CO_2e results, which were presented in metric tons in the baseline inventory, were converted to short tons for consistency with the other pollutants.

A hypothetical BAU scenario was developed based on anticipated growth and changes at Port Everglades as identified in the *2014 Master/Vision Plan*.[81] Expected growth in containerized throughput was used to project future heavy-duty truck activity, and growth in the number of cruise passengers was used to project future light-duty and bus activity. These growth factors are summarized in Table 7-1.[82]

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78 Starcrest Consulting Group, LLC, *Port Everglades 2015 Baseline Air Emissions Inventory*, December 2016.

79 $DPM_{2.5}$ emissions were calculated relative to the $PM_{2.5}$ emissions based on the ratio of diesel to gasoline vehicles. All passenger cars were assumed to be gasoline and 6.5% of light-duty trucks and all heavy-duty vehicles were assumed to be diesel. BC emissions were calculated to be 34.9% of $PM_{2.5}$ emissions. The BC fraction is based on EPA's SPECIATE 4.3 repository.

80 U.S. Environmental Protection Agency, SPECIATE 4.3, September 2011.

81 Port Everglades, *2014 Master/Vision Plan* reports, June 24, 2014.

82 Growth factors for 2035 and 2050 are not included in the range of projections provided in the *2014 Master/Vision Plan* cited in this report. Therefore, they were extrapolated from expected growth between 2028 and 2033, the last five years presented in the *2014 Master/Vision Plan*.

Table 7-1. Projected Growth Factors Used for Future Onroad Vehicle Activity

Vessel/Cargo Type (units)	Projected Throughput				Growth Factor (unitless)			
	2015	2025	2035	2050	2015	2025	2035	2050
Cruise (passengers)	3,773,000	5,306,000	5,730,000	6,065,000	1.000	1.406	1.519	1.607
Container (TEUs[a])	1,060,000	1,435,000	1,761,000	2,134,000	1.000	1.354	1.661	2.013

[a] Twenty-foot equivalent units

Hypothetical BAU emission inventories were then estimated for 2025, 2035, and 2050[83] by starting with the 2015 baseline emissions, applying the growth factors by vessel or cargo type, and then applying adjustment factors based on expected changes in the fleet emission factors. The fleet emission factors change over time because as vehicles age out of the fleet, they are replaced with newer vehicles that meet newer, cleaner emission standards. EPA's MOVES model incorporates the effects of fleet turnover in its emission factors for future years.[84] Table 7-2 presents the combined effect of the growth factors and changes in fleet emission factors, which were derived from running MOVES2014a.

Table 7-2. BAU Emission Projection Factors for Onroad Vehicles

Year	Vehicle Type	Factors Relative to 2015 Emissions						
		NO_X	PM_{10}	$PM_{2.5}$	DPM	BC	VOC	CO_2e
2025	Passenger Car	0.14	0.95	0.84	0.00	0.84	0.10	0.92
	Light Truck/Van	0.27	0.64	0.63	0.27	0.63	0.18	1.05
	Transit Bus	0.46	0.39	0.39	0.39	0.39	0.46	1.36
	Heavy Truck	0.46	0.36	0.36	0.36	0.36	0.41	1.26
2035	Passenger Car	0.06	0.69	0.61	0.00	0.61	0.07	0.84
	Light Truck/Van	0.10	0.48	0.46	0.14	0.31	0.11	1.20
	Transit Bus	0.20	0.14	0.14	0.14	0.05	0.12	1.61
	Heavy Truck	0.29	0.14	0.14	0.14	0.04	0.21	1.51
2050	Passenger Car	--[a]	--	--	--	--	--	0.78
	Light Truck/Van	--	--	--	--	--	--	0.93
	Transit Bus	--	--	--	--	--	--	1.52
	Heavy Truck	--	--	--	--	--	--	1.83

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

The emission projection factors were then applied to each element of the on-port onroad vehicle inventory. Note that for most of the criteria pollutants and precursors, the effect of

[83] Note that for 2050, only CO_2e inventories and reductions were quantified.

[84] EPA's MOtor Vehicle Emission Simulator (MOVES) is a state-of-the-science emission modeling system that estimates emissions for mobile sources at the national, county, and project level for criteria air pollutants, greenhouse gases, and air toxics. For more information, see https://www.epa.gov/moves.

fleet turnover outweighs the increase in activity in future years (as the factors are generally less than 1).

Emission results for the 2015 baseline and 2025, 2035, and 2050 BAU onroad vehicle inventories are presented in Table 7-3. Results in this table are expressed as short tons per year. This analysis does not account for EPA's Heavy-Duty GHG Phase 2 rule[85] because it is currently not included in MOVES2014a.

Table 7-3. Baseline and Projected BAU Emissions for On-port Onroad Vehicles

Year	Annual Emissions (tons/year)							
	NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e[a]
2015[86]	54.04	3.96	3.65	3.94	3.64	1.69	5.99	11,887.31
2025	24.32	1.42	1.31	1.41	1.30	0.61	2.25	14,777.72
2035	15.54	0.56	0.52	0.55	0.51	0.07	1.16	17,558.34
2050	--[b]	--	--	--	--	--	--	20,753.28

[a] CO_2e values were calculated based on a factor of 101.17 gallons per metric ton CO_2e and weighted by the 2015 on-port onroad baseline inventory mix of 85/15 diesel/gas consumption.
[b] A double dash ("--") represents a value that was not calculated as part of this analysis.

Even though onroad vehicle activity is assumed to increase in the future, criteria pollutant emissions are projected to decrease due to the introduction of newer vehicles that meet cleaner emission standards. However, for CO_2e, the increase in activity results in CO_2e increases in the future.

7.2 Emission Reduction Strategies and Scenarios

The following on-port emission reduction strategies were selected in consultation between EPA and Port Everglades:

- On-port truck idle reduction
- Additional operational improvements
- Truck replacement with cleaner diesel and electric technologies (e.g., 2007/2010 compliant trucks and battery electric vehicles [BEVs])

Because Port Everglades does not have direct control over implementing these strategies, the hypothetical scenarios for each are predicated on the assumption of the coordination and collaboration of various maritime industry stakeholders for implementation. The implementation rates for all considered scenarios are provided in Table 7-4. Details on the modeling approaches for these strategy scenarios are presented in Sections 7.2.1–7.2.3 below.

85 U.S. Environmental Protection Agency, *Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles—Phase 2*, Federal Register, Vol. 81, No. 206, October 25, 2016, https://www.gpo.gov/fdsys/pkg/FR-2016-10-25/pdf/2016-21203.pdf.

86 Starcrest Consulting Group, LLC, *Port Everglades 2015 Baseline Air Emissions Inventory*, December 2016.

Note that an additional strategy for reducing onroad emissions was also considered in this analysis, a truck-to-rail intermodal shift, which is discussed in Section 8.

Table 7-4. Summary of On-port Emission Reduction Scenarios for Heavy-Duty Trucks

Strategy	Scenario	Implementation Rate		
		2025	2035	2050
Idle Reduction	Low	25% idle reduction	25% idle reduction	25% idle reduction
	High	75% idle reduction	75% idle reduction	75% idle reduction
Operational Improvements	Low	5% idle reduction	5% idle reduction	5% idle reduction
	High	10% idle reduction	10% idle reduction	10% idle reduction
Truck Replacement	Low	Replace 100% pre-2007 trucks with 50% 2007, 50% 2010+	Replace 100% pre-2010 trucks with 2010+ Replace 15% of 2010+ with BEV	Replace 30% 2010+ with BEV
	High	Replace 100% pre-2007 trucks with 40% 2007–2009, 40% 2010+, 20% BEV	Replace 100% pre-2010 trucks with BEV Replace 30% of 2010+ with BEV	Replace 50% 2010+ with BEV

7.2.1 On-port Truck Idle Reduction

This strategy would apply to heavy-duty diesel trucks that idle on-port while waiting to pick up or drop off cargo.

- The "high" idle reduction scenario adopts a five-minute limit on idling within port for drayage trucks. As the 2015 On-port Baseline Inventory assumes 30 minutes of on-port idle per truck, a five-minute limit would amount to an 83 percent reduction in idle. For implementing the scenario, a 75 percent reduction was chosen to account for exceptions to the five-minute limit for work-related idle[87] and driver safety.

- For the "low" idle reduction scenario, a 25 percent reduction in idle was chosen, which, for example, could represent idle restrictions only in certain locations.

Note that it may be difficult to achieve these levels of idling reductions at Port Everglades due to truck drivers' air conditioning needs in Broward County's subtropical climate. While this issue could be partially alleviated by using alternatives to idling, this level of detail was not considered in this analysis. Instead, these scenarios were modeled as a straightforward post-processing step, where truck idle emissions were reduced proportionally. This was possible because idle emissions were broken out separately in the 2015 On-port Baseline Inventory. Other operational methods to reduce truck idle are discussed in the following strategy. The

[87] Work-related idle occurs when the truck is idling while loading or unloading cargo (e.g., to power accessories).

percent reductions in idle for each scenario were applied to the BAU idle emissions in each of the projection years.

7.2.2 Operational Improvements

This strategy would reduce vehicle idling and queue time and improve traffic flow; it is assumed that the improvements would proportionally reduce the amount of time trucks spend in the Port. This analysis does not attempt to predict or dictate the exact nature of the operational improvements, but assumes they would comply with all safety regulations and guidelines.[88] For each projection year, the percent reductions for each operational scenario were applied to the BAU idle emissions for heavy-duty diesel trucks.

Note that this strategy is hypothetical, supplementing the operational improvements continuously being sought at Port Everglades. For example, in 2014, the Port rebuilt McIntosh Road, the main on-port truck cargo route, as a multi-lane loop road to reduce truck congestion and idling.[89] In addition, some terminals at Port Everglades have implemented truck appointment systems, which reduce the amount of time trucks spend on-port.

7.2.3 Truck Replacement with Cleaner Diesel Trucks and Electric Vehicles

Significant emission reductions are also possible through programs that accelerate adoption of current engine technologies by truck operators using older vehicles. This strategy assumed that older diesel trucks would be replaced by 2007/2010 model year diesel trucks or BEVs.

MOVES2014a was used to estimate the emission reductions from truck replacements by using different inputs to reflect newer age distributions of trucks and the transition to battery electric vehicles. This was done for both the low and high scenarios in each year as shown in Table 7-4 above.

7.3 Emission Reduction Scenario Results and Lessons Learned

Emission reductions for the onroad scenarios are presented in Figure 7-1, Figure 7-2, Figure 7-3, and Table 7-5. Table 7-6 shows the percentage emission reductions associated with each scenario in each year, based on the total onroad on-port emissions in that year.

In general, except for emissions of CO_2e, accelerating fleet turnover to cleaner technology through truck replacements has the potential to reduce emissions significantly through 2035, despite the projected growth in truck activity. Truck replacement is especially effective in the year 2025, reducing NOx by about 30 percent and PM by about 70 percent compared to the

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88 Some examples of operational improvements include increasing the physical capacity of the gate complex, automated truck registration and container identification systems, and extending the operational hours of the gate system.

89 Port Everglades, *Port Everglades Realigns Southport Roadway for Efficient, Safer Truck Movement*, March 2014, http://www.porteverglades.net/articles/post/port-everglades-realigns-southport-roadway-for-efficient-safer-truck-movement.

BAU case. Note that this strategy would not reduce emissions of CO_2e in 2025, as it assumes that trucks would be replaced with newer model year conventional trucks; not until 2035 are BEV replacements assumed. In 2035, truck replacement still shows benefits, as it would reduce emissions of NOx by about 30 percent and PM by about 30 percent compared to the BAU case. Idle reduction also has the potential to reduce truck emissions significantly, and the high implementation scenario would reduce NOx by about 40 percent in both 2025 and 2035, and PM by more than 45 percent in both years.

This analysis benefited from having details in the baseline inventory such as hours of on-port idling and truck counts. However, having additional detail, such as the local truck age distribution, could have strengthened this analysis further.

Note that the onroad inventories for 2015 and the BAU years include all vehicles visiting the port, both light-duty and heavy-duty. In contrast, the strategies examined would apply only to heavy-duty trucks, which are the largest part of the onroad vehicle inventory. Had the onroad inventories included only the heavy-duty trucks, the emission reductions from the strategies considered would have been an even larger percentage of the total.

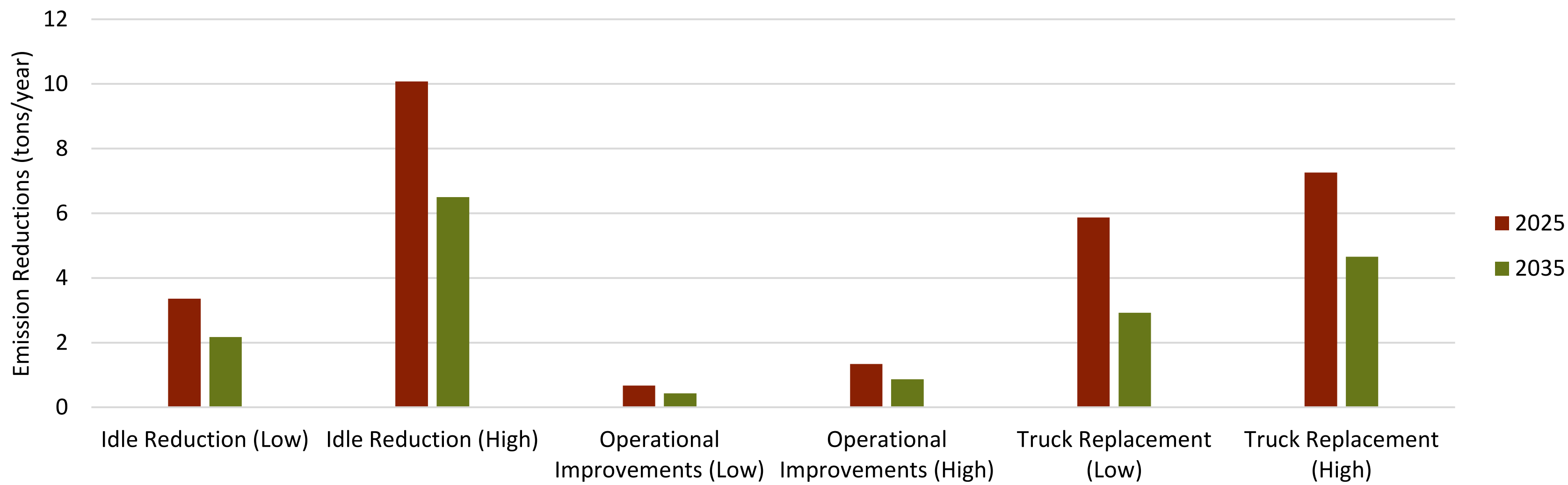

Figure 7-1. On-port Truck NOx Reduction Strategies

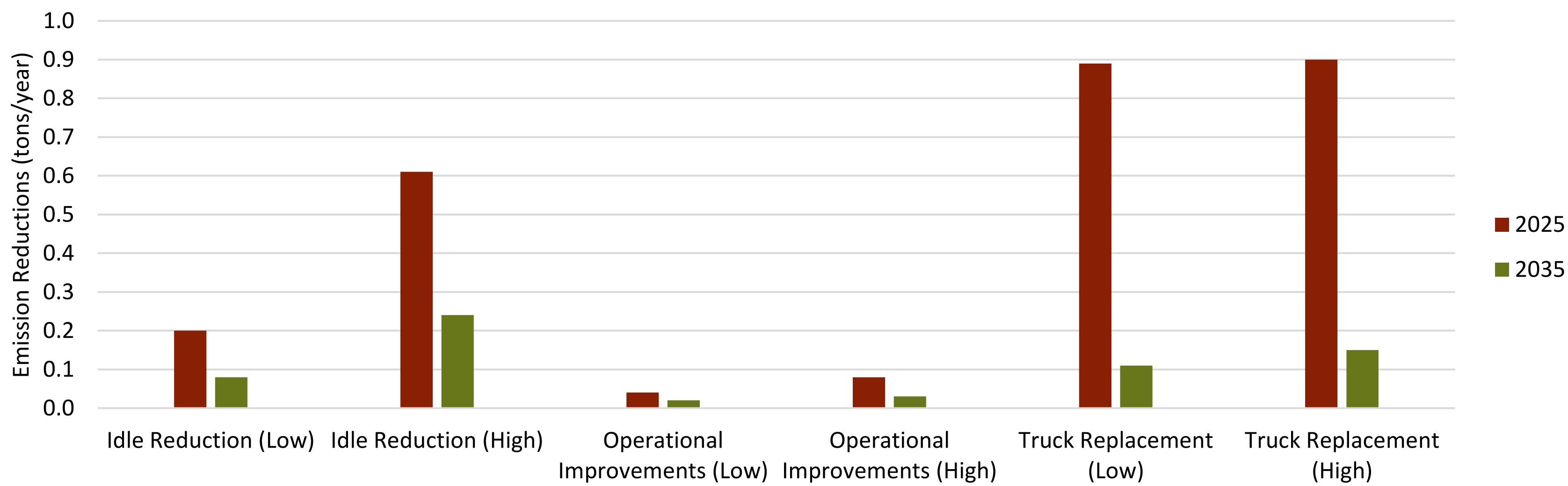

Figure 7-2. On-port Truck $PM_{2.5}$ Reduction Strategies

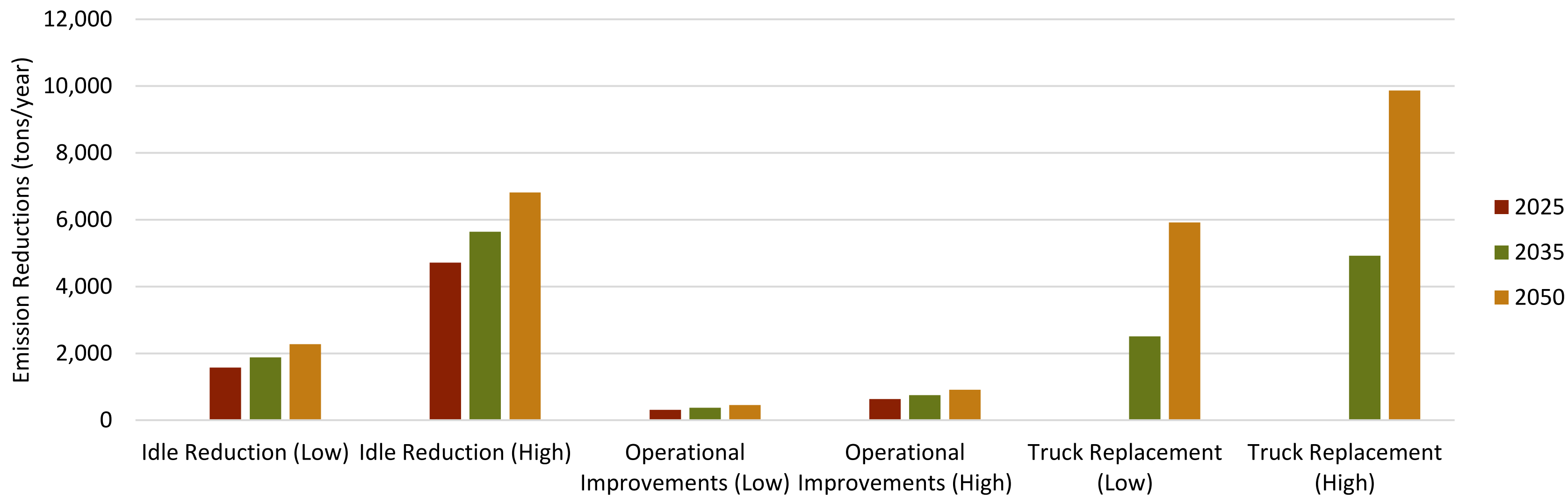

Figure 7-3. On-port Truck CO_2e Reduction Strategies

Table 7-5. Total Reductions from BAU On-port Onroad Vehicle Emissions by Scenario

Year	Strategy	Scenario	Emission Reductions (tons/year)							
			NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e
2025	Idle Reduction	Low	3.36	0.22	0.20	0.22	0.20	0.10	0.38	1,571.73
		High	10.08	0.67	0.61	0.67	0.61	0.29	1.13	4,715.20
	Operational Improvements	Low	0.67	0.04	0.04	0.04	0.04	0.02	0.08	314.35
		High	1.34	0.09	0.08	0.09	0.08	0.04	0.15	628.69
	Truck Replacement	Low	5.87	0.96	0.89	0.96	0.89	0.41	1.23	0.00
		High	7.26	0.97	0.90	0.97	0.90	0.42	1.26	0.00
2035	Idle Reduction	Low	2.17	0.09	0.08	0.09	0.08	0.01	0.19	1,881.45
		High	6.50	0.26	0.24	0.26	0.24	0.03	0.58	5,644.36
	Operational Improvements	Low	0.43	0.02	0.02	0.02	0.02	0.00	0.04	376.29
		High	0.87	0.03	0.03	0.03	0.03	0.00	0.08	752.58
	Truck Replacement	Low	2.92	0.12	0.11	0.12	0.11	0.02	0.22	2,505.10
		High	4.66	0.17	0.15	0.17	0.15	0.02	0.33	4,921.36
2050	Idle Reduction	Low	--[a]	--	--	--	--	--	--	2,271.77
		High	--	--	--	--	--	--	--	6,815.30
	Operational Improvements	Low	--	--	--	--	--	--	--	454.35
		High	--	--	--	--	--	--	--	908.71
	Truck Replacement	Low	--	--	--	--	--	--	--	5,923.40
		High	--	--	--	--	--	--	--	9,872.34

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

Table 7-6. Percent Reductions from BAU On-port Onroad Vehicle Emissions by Scenario

Year	Strategy	Scenario	Percent Reductions from BAU Emissions							
			NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e
2025	Idle Reduction	Low	13.82%	15.49%	15.27%	15.60%	15.38%	16.39%	16.89%	10.64%
		High	41.45%	47.18%	46.56%	47.52%	46.92%	47.54%	50.22%	31.91%
	Operational Improvements	Low	2.75%	2.82%	3.05%	2.84%	3.08%	3.28%	3.56%	2.13%
		High	5.51%	6.34%	6.11%	6.38%	6.15%	6.56%	6.67%	4.25%
	Truck Replacement	Low	24.14%	67.61%	67.94%	68.09%	68.46%	67.21%	54.67%	0.00%
		High	29.85%	68.31%	68.70%	68.79%	69.23%	68.85%	56.00%	0.00%
2035	Idle Reduction	Low	13.96%	16.07%	15.38%	16.36%	15.69%	14.29%	16.38%	10.72%
		High	41.83%	46.43%	46.15%	47.27%	47.06%	42.86%	50.00%	32.15%
	Operational Improvements	Low	2.77%	3.57%	3.85%	3.64%	3.92%	0.00%	3.45%	2.14%
		High	5.60%	5.36%	5.77%	5.45%	5.88%	0.00%	6.90%	4.29%
	Truck Replacement	Low	18.79%	21.43%	21.15%	21.82%	21.57%	28.57%	18.97%	14.27%
		High	29.99%	30.36%	28.85%	30.91%	29.41%	28.57%	28.45%	28.03%
2050	Idle Reduction	Low	--[a]	--	--	--	--	--	--	10.95%
		High	--	--	--	--	--	--	--	32.84%
	Operational Improvements	Low	--	--	--	--	--	--	--	2.19%
		High	--	--	--	--	--	--	--	4.38%
	Truck Replacement	Low	--	--	--	--	--	--	--	28.54%
		High	--	--	--	--	--	--	--	47.57%

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

8. RAIL

Two types of locomotives typically support port-related cargo operations: yard engines and line-haul engines. Yard engines, also referred to as "switchers," disassemble and assemble trains for shipment. The on-port Intermodal Container Transfer Facility (ICTF) at Port Everglades, provided by the Florida East Coast Railway (FECR), is designed to move only intermodal containers, which are transferred to and from rail cars using cargo handling equipment.[90] Because rail cars are not decoupled in this process, the ICTF does not require switcher locomotives. Thus, only emissions from line-haul engines are considered in EPA's analysis. In addition, this analysis reflects the significant investment by FECR in cleaner locomotive technology, as described in more detail below.

The emission inventories derived from rail activity for the baseline year and in future years under BAU conditions are described in Section 8.1. This is followed by a discussion of the emission reductions that could result from the implementation of a truck-to-rail intermodal shift strategy in Section 8.2 and a summary of results and lessons learned in Section 8.3.

A rail strategy, such as the truck-to-rail intermodal shift strategy considered, may be effective at reducing emissions both on-port and off-port when it impacts locomotive operations within the port boundary and in the off-port rail corridor servicing the port. However, this section addresses rail emissions occurring on-port only; see Section 9.4 for more information on the off-port rail corridor analysis.

8.1 Baseline and Projected Business as Usual Inventories

The 2015 On-port Baseline Inventory[91] contains emission estimates for rail activity based on information provided by FECR. For details on the data collection and inventory development methodology, please see the 2015 On-port Baseline Inventory.

The rail baseline emission inventories presented here include pollutants from the 2015 On-port Baseline Inventory as well as $DPM_{2.5}$ and BC, which EPA added for its analysis.[92] [93] Additionally, the CO_2e results, which were presented in metric tons in the baseline inventory, were converted to short tons here for consistency with the other pollutants. Emissions are separately presented for two modes: locomotive idling and transit. The 2015 locomotive emissions are based on the use of Tier 3 locomotives.

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[90] For more information, see https://www.fecrwy.com/news/fec-unveils-new-rail-facility-adjacent-port-everglades.

[91] Starcrest Consulting Group, LLC, *Port Everglades 2015 Baseline Air Emissions Inventory*, December 2016.

[92] $DPM_{2.5}$ was calculated as a fraction of DPM_{10} by applying the ratio of $PM_{2.5}$ to PM_{10} emissions from diesel-powered main and auxiliary engines. BC was calculated as 77% of $PM_{2.5}$ based on the EPA's *Report to Congress on Black Carbon*.

[93] U.S. Environmental Protection Agency, *Report to Congress on Black Carbon*, EPA-450/R-12-001, p. 87, March 2012.

A hypothetical BAU scenario was developed based on anticipated growth and changes at Port Everglades as identified in the *2014 Master/Vision Plan*.[94] Table 8-1 summarizes projected growth rates for containerized throughput relative to the 2015 baseline, which are used as surrogates for growth in rail activity.[95] The BAU scenario assumes the current fraction of total container cargo at Port Everglades diverted to rail remains constant at 8.59 percent in future analysis years (e.g., 91,070 ICTF twenty-foot equivalent units [TEUs]/1,060,000 port TEUs = 0.0859).

Table 8-1. Baseline and BAU Projections of Container Handling at Port Everglades ICTF

Year	TEU Growth Factor[a]	BAU Port TEUs	BAU TEUs Handled by ICTF
2015	1.000	1,060,000	91,070
2025	1.354	1,435,000	123,267
2035	1.661	1,761,000	151,270
2050	2.013	2,134,000	183,311

[a] Relative to 2015 base year

The baseline rail emission inventories developed in 2015 assumed all port rail activity was diesel-powered. At the time of EPA's analysis, the FECR was in the process of converting its fleet to dual fuel diesel/liquefied natural gas (LNG) locomotives. Therefore, the BAU inventory projections developed for this analysis reflect the turnover to LNG fuel. The following implementation rates were assumed to account for anticipated future use of diesel/LNG fueled locomotives under BAU conditions: 25 percent of the fleet by 2025, 50 percent by 2035, and 100 percent by 2050. After this analysis was completed, FECR announced that all locomotives operating at Port Everglades were dual fuel diesel/LNG capable by the end of 2017.[96] Therefore, while the BAU inventories presented here overestimate expected future rail emissions due to the accelerated turnover of FECR's entire fleet to clean technology, the LNG conversion program doesn't affect the emission reductions analysis since LNG conversion was not included as a reduction strategy for this sector.

[94] Port Everglades, *2014 Master/Vision Plan* reports, June 24, 2014.

[95] Growth factors for 2035 and 2050 are not included in the range of projections provided in the *2014 Master/Vision Plan* cited in this report. Therefore, the factors were extrapolated from expected growth between 2028 and 2033, the last five years presented in the *2014 Master/Vision Plan*.

[96] For more information, see https://www.fecrwy.com/node/618.

Table 8-2 lists Tier 3 locomotive emission factors[97] [98] and dual fuel diesel/LNG emission factors,[99] [100] along with composite, weighted emission factors for each projection year that account for the rate of adoption of dual fuel locomotives in the future. It also lists the corresponding emission adjustment factors, relative to the baseline emissions. This analysis does not account for fugitive methane emissions from natural gas use, such as from equipment leakage.

Table 8-2. Tier 3 and Dual Fuel Diesel/LNG Locomotive Emission Factors

Engine	Emission Factors (g/hp-hr)									
	NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2	CH_4	N_2O[a]
Tier 3 (g/hp-hr)	4.95	0.08	0.07	0.08	0.07	0.05	0.14	494	0.04	0.013
Diesel/LNG (g/hp-hr)	1.40	0.09	0.08	0.09	0.08	0.06	3.30	370	--[b]	0.013
Year	**Weighted Emission Factors (g/hp-hr)**									
2025	4.063	0.083	0.073	0.083	0.073	0.049	0.930	462.0	--	0.013
2035	3.175	0.085	0.075	0.085	0.075	0.050	1.720	430.0	--	0.013
2050	1.400	0.090	0.080	0.090	0.080	0.005	3.300	366.0	--	0.013
Year	**Emission Adjustment Factors Relative to 2015 (unitless)**									
2025	0.821	1.031	1.036	1.031	1.036	0.701	6.643	0.935	--	1.000
2035	0.641	1.063	1.071	1.063	1.071	0.725	12.286	0.870	--	1.000
2050	0.283	1.125	1.143	1.125	1.143	0.773	23.571	0.741	--	1.000

[a] It was assumed N_2O emissions are the same for Tier 3 and dual fuel locomotives in this analysis.
[b] A double dash ("--") represents a value that was not calculated as part of this analysis.

Hypothetical future emission inventories were then estimated for 2025, 2035, and 2050[101] by starting with the 2015 baseline emissions, applying the appropriate growth factors, and then applying adjustment factors based on expected changes in the fleet emission factors. A summary of baseline and BAU projected emissions is presented in Table 8-3.

Locomotives are a small emission source at Port Everglades due to the relatively small volume of rail throughput compared to other sectors. Because the assumptions regarding FECR's

97 U.S. Environmental Protection Agency, *Control of Emissions of Air Pollution From Locomotive Engines and Marine Compression-Ignition Engines Less Than 30 Liters per Cylinder*, Federal Register, Vol. 73, No. 126, June 2008, https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-emissions-air-pollution-locomotive.

98 U.S. Environmental Protection Agency, *Emission Factors for Locomotives,* EPA-420-F-09-025, April 2009, https://nepis.epa.gov/Exe/ZyPDF.cgi/P100500B.PDF?Dockey=P100500B.pdf.

99 BNSF Railway Company/Union Pacific Railroad Company/Association of American Railroads/California Environmental Associates, *An Evaluation of Natural Gas-Fueled Locomotives*, November 2007, https://www.arb.ca.gov/railyard/ryagreement/112807lngqa.pdf.

100 Energy Conversions, Inc., Emissions and Natural Gas Locomotives, https://www.energyconversions.com/locoemis.htm.

101 Note that for 2050, only CO_2e inventories and reductions were quantified.

planned increase in the use of dual fuel diesel/LNG powered engines assumed a much longer phase in period, these projections likely overestimate expected future rail emissions.

Table 8-3. Baseline and Projected BAU Emissions for On-port Rail by Mode

Year	Mode	Annual Emissions (tons/year)							
		NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e
2015[102]	Idling	0.79	0.01	0.01	0.01	0.01	0.01	0.02	79.49
	Transit	0.63	0.01	0.01	0.01	0.01	0.01	0.02	63.05
	Total	**1.41**	**0.02**	**0.02**	**0.02**	**0.02**	**0.01**	**0.04**	**142.54**
2025	Idling	0.88	0.02	0.02	0.02	0.02	0.01	0.20	100.47
	Transit	0.70	0.01	0.01	0.01	0.01	0.01	0.16	79.70
	Total	**1.57**	**0.03**	**0.03**	**0.03**	**0.03**	**0.02**	**0.36**	**180.17**
2035	Idling	0.84	0.02	0.02	0.02	0.02	0.01	0.46	114.82
	Transit	0.67	0.02	0.02	0.02	0.02	0.01	0.36	91.09
	Total	**1.51**	**0.04**	**0.04**	**0.04**	**0.04**	**0.03**	**0.82**	**205.91**
2050	Idling	--[a]	--	--	--	--	--	--	118.62
	Transit	--	--	--	--	--	--	--	94.10
	Total	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**212.72**

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

8.2 Emission Reduction Strategies and Scenarios

Since rail is generally considered to be more efficient at transporting cargo than using heavy-duty diesel trucks, one option for reducing overall emissions is to encourage the intermodal shift of cargo from truck to rail. An intermodal shift from truck to rail is the only rail strategy considered in this analysis, given the cleaner technology already used in FECR's line-haul fleet and that Port Everglades does not have switcher locomotives. Because Port Everglades does not have direct control over implementing these strategies, this hypothetical scenario is predicated on the assumption of the coordination and collaboration of various maritime industry stakeholders for implementation.

The maximum design capacity of the ICTF is the primary constraint on the amount of cargo that can be shifted from truck to rail at Port Everglades. The on-port rail strategy scenario summarized in Table 8-4 is characterized by the increases in ICTF throughput and assumed implementation rates shown in Table 8-5. The ratio between the annual TEU rail throughput and ICTF design capacity[103] for each scenario year is the adjustment factor used to calculate the increase in locomotive emissions associated with maximizing the throughput of the ICTF.

[102] Starcrest Consulting Group, LLC, *Port Everglades 2015 Baseline Air Emissions Inventory*, December 2016.
[103] Port Everglades, *FEC Unveils New Rail Facility at Port Everglades*, July 2014, http://www.porteverglades.net/articles/post/fec-unveils-new-rail-facility-at-port-everglades.

Table 8-4. Summary of On-port Rail Emission Reduction Scenarios

Strategy	Scenario	Implementation Rate			Notes
		2025	2035	2050	
Truck-to-Rail Intermodal Shift	High	43%	66%	100%	Percentages represent ICTF operations relative to its maximum design throughput

Table 8-5. Increases in ICTF Throughput from Truck-to-Rail Intermodal Shift

Year	BAU TEUs Handled by ICTF	Implementation Rate	Scenario TEUs Handled by ICTF	Rail TEU Adjustment Factor of Scenario Relative to BAU
2025	123,267	43%	193,621	1.57
2035	151,270	66%	296,173	1.96
2050	183,311	100%	450,000	2.45

Under this scenario, train operations were linearly increased between the activity presented in the 2015 On-port Baseline Inventory and the ICTF maximum design capacity of 450,000 lifts in 2050, which will be approximately five times the 2015 throughput of the ICTF. Table 8-5 presents the number of TEUs handled by the ICTF in this hypothetical scenario. The number of containers diverted to rail corresponds to 5.4 percent fewer containers moved by truck in 2025, 9.0 percent in 2035, and 13.7 percent in 2050. Therefore, hypothetical emission reductions were calculated by reducing the BAU truck emissions by these fractions, and the results are presented in Table 8-6.

Table 8-6. Total Reductions from BAU On-port Onroad Truck Emissions from Truck-to-Rail Intermodal Shift

Year	Scenario	Emission Reductions (tons/year)							
		NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e
2025	High	1.27	0.07	0.07	0.07	0.07	0.03	0.11	732.54
2035	High	1.38	0.05	0.05	0.05	0.05	0.01	0.10	1,472.30
2050	High	--[a]	--	--	--	--	--	--	2,699.70

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

However, to calculate the net emission reductions from the intermodal shift of cargo from truck to rail, the increased rail emissions must be considered together with the corresponding decrease in truck emissions. To account for the changes in locomotive emissions in this scenario, the BAU rail emissions were increased using the factors shown in Table 8-5. The resulting increases in locomotive emissions due to this scenario are presented in Table 8-7.

Table 8-7. Increases from BAU On-port Rail Emissions from Truck-to-Rail Intermodal Shift

Year	Mode	Emissions Increases (tons/year)							
		NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e
2025	Idling	0.50	0.01	0.01	0.01	0.01	0.01	0.11	57.34
	Transit	0.47	0.01	0.01	0.01	0.01	0.01	0.23	62.13
	Total	**0.97**	**0.02**	**0.02**	**0.02**	**0.02**	**0.01**	**0.35**	**119.48**
2035	Idling	0.80	0.02	0.02	0.02	0.02	0.01	0.44	109.99
	Transit	0.64	0.02	0.02	0.02	0.02	0.01	0.35	87.25
	Total	**1.44**	**0.04**	**0.03**	**0.04**	**0.03**	**0.02**	**0.78**	**197.24**
2050	Idling	--[a]	--	--	--	--	--	--	172.58
	Transit	--	--	--	--	--	--	--	136.90
	Total	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**309.47**

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

8.3 Emission Reduction Scenario Results and Lessons Learned

The net emission reductions for the intermodal shift strategy are presented in Figure 8-1, Figure 8-2, Figure 8-3, and Table 8-8. This includes the emission reductions associated with the removal of onroad truck traffic as well as the increase in emissions associated with the shift of truck cargo to rail. Emission impacts change over time and vary depending on the pollutant. All emissions are initially reduced in 2025, and while PM and CO_2e reductions increase over time, NOx emissions increase slightly in 2035. These net reductions are also presented in Table 8-9 as percentage reductions relative to the total on-port onroad BAU emissions (see Table 7-3).

As described above, additional cleaner locomotive technologies were not considered for this analysis since FECR has already made significant investments in its fleets as well as in the construction of the Intermodal Container Transfer Facility.[104] It is also important to note that due to the timing of this analysis, the conversion of locomotives to dual fuel diesel/LNG engines was assumed to take much longer than what occurred in practice. Consequentially, the projected locomotive emissions in future years for both the BAU case and the emissions reduction scenario are expected to be less than presented here. Additionally, the reduction scenario assumed that all locomotive activity, including idling, would increase proportionally with rail throughput. Having more detailed assumptions regarding the implementation of this strategy could improve this analysis. Furthermore, lacking information on the local truck age distribution, as noted in Section 6, limits the analysis of truck emission reductions associated with this scenario. It is important to note that this analysis did benefit from having detailed cargo throughput data received from FECR through consultation with Port Everglades. Taken

[104] Replacing older diesel locomotives, such as switchers, is an effective emission reduction strategy to consider. For further general information about other rail strategies, see EPA's *National Port Strategy Assessment* at: https://www.epa.gov/ports-initiative/national-port-strategy-assessment-reducing-air-pollution-and-greenhouse-gases-us.

together, further refinements to this analysis are likely to show additional benefits to the truck-to-rail intermodal shift strategy.

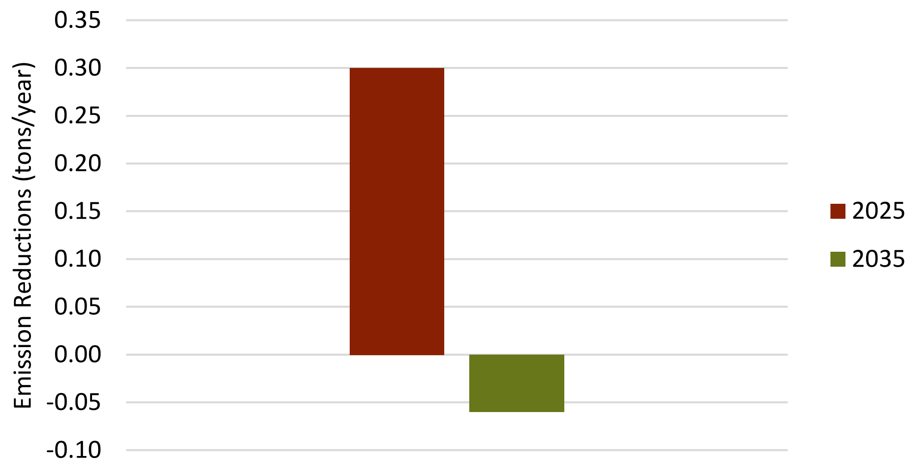

Figure 8-1. On-port Truck-to-Rail Intermodal Shift NOx Reductions

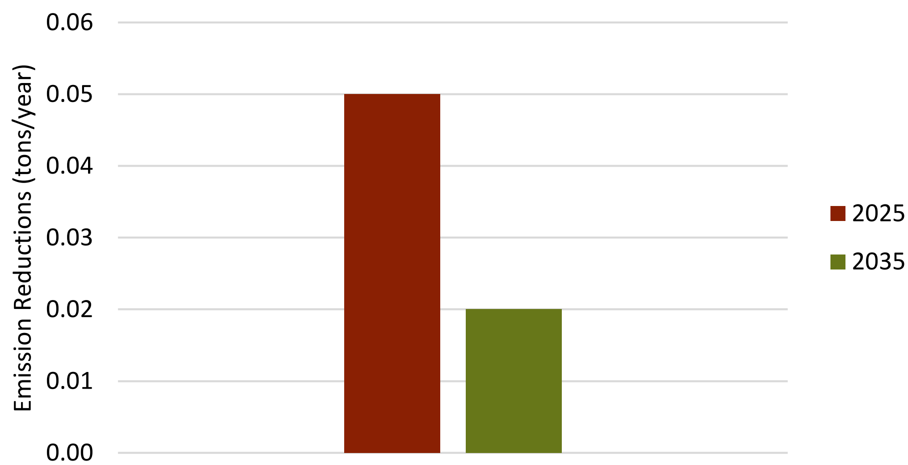

Figure 8-2. On-port Truck-to-Rail Intermodal Shift $PM_{2.5}$ Reductions

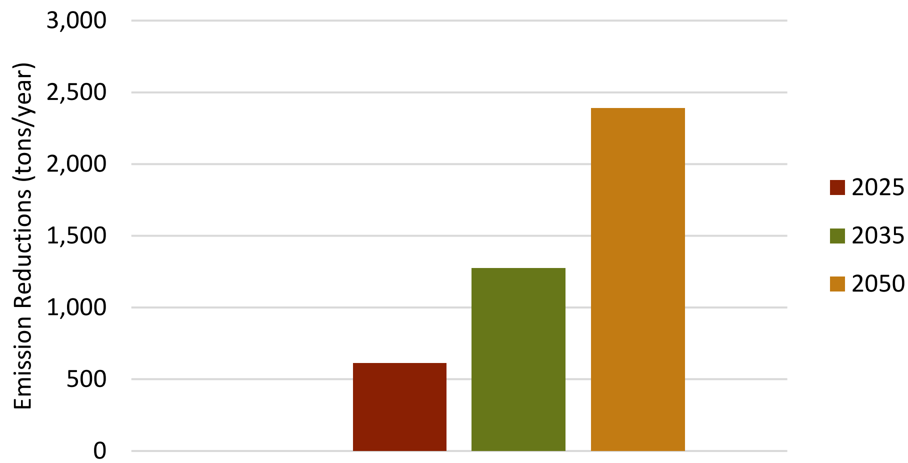

Figure 8-3. On-port Truck-to-Rail Intermodal Shift CO_2e Reductions

Table 8-8. On-port Emission Reductions from Truck-to-Rail Intermodal Shift

Year	Strategy	Emission Reductions (tons/year)[a]							
		NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e
2025	Onroad	1.27	0.07	0.07	0.07	0.07	0.03	0.11	732.54
	Rail	−0.97	−0.02	−0.02	−0.02	−0.02	−0.01	−0.35	−119.48
	Net Reduction	**0.30**	**0.05**	**0.05**	**0.05**	**0.05**	**0.02**	**−0.24**	**613.06**
2035	Onroad	1.38	0.05	0.05	0.05	0.05	0.01	0.10	1,472.30
	Rail	−1.44	−0.04	−0.03	−0.04	−0.03	−0.02	−0.78	−197.24
	Net Reduction	**−0.06**	**0.01**	**0.02**	**0.01**	**0.02**	**−0.01**	**−0.68**	**1,275.06**
2050	Onroad	--[b]	--	--	--	--	--	--	2,699.70
	Rail	--	--	--	--	--	--	--	−309.47
	Net Reduction	--	--	--	--	--	--	--	**2,390.23**

[a] Negative numbers indicate an increase in emissions.
[b] A double dash ("--") represents a value that was not calculated as part of this analysis.

Table 8-9. Percent Reductions from BAU On-port Rail Emissions from Truck-to-Rail Intermodal Shift

Year	Percent Reductions from BAU Emissions[a]							
	NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e
2025	1.23%	3.52%	3.81%	3.55%	3.84%	3.30%	−10.65%	4.15%
2035	−0.39%	1.78%	3.84%	1.80%	3.90%	−13.99%	−58.65%	7.26%
2050	--[b]	--	--	--	--	--	--	11.52%

[a] Negative numbers indicate an increase in emissions.
[b] A double dash ("--") represents a value that was not calculated as part of this analysis.

9. OFF-PORT CORRIDOR ANALYSIS

As part of this analysis, EPA examined three off-port transportation corridors to estimate emissions from port-related vessel and vehicle activity occurring outside of the Port. The off-port corridors included in this analysis were a marine corridor, a truck corridor, and a rail corridor.

EPA conducted this off-port analysis to learn more about the local data that can be used to quantify mobile source emissions for port-related transportation corridors (i.e., corridors that are related to port activity but outside of the Port). This work will inform EPA's future update of its Port Emissions Inventory Guidance by providing hypothetical examples and technical methods for analyzing such corridors, which may be important for people living and working near ports and coastal areas. Additionally, analyzing emissions in transportation corridors can provide insight into the benefits of emission reduction strategies that could be realized beyond the boundaries of a port.

The selection of which corridors to include in the analysis and the definition of their boundaries required careful consideration, as these decisions can have a significant impact on the results. Corridors were defined so that the analysis only captured port-related activity, and were of sufficient length to apply data and methods in a credible way. EPA acknowledges that its off-port analysis covers only a portion of the off-port activity related to Port Everglades cargo and passenger throughput. Note that EPA's analysis included hypothetical strategies and scenarios over which Port Everglades has no direct control. The analysis methodology used for each scenario does not make assumptions regarding the details, logistics, and costs of how or by which entity or entities each emissions reduction strategy would be implemented. Furthermore, the scenarios do not consider jurisdiction or geographical boundaries, except when determining if the emission reductions would occur on-port or off-port.

These corridors were chosen so that Business as Usual (BAU) inventories and emission reduction strategies could be analyzed for each of the sectors with off-port activity (e.g., ocean going vessels [OGVs], harbor craft, onroad vehicles, and rail). The three selected off-port corridors are further described as follows:

1. Marine corridor: The marine corridor accounted for OGV and harbor craft activity occurring from the state/federal waters boundary located 3 nautical miles offshore to the international border with the Bahamas (i.e., the continental shelf boundary), which is approximately 20 to 25 nautical miles from shore.

2. Truck corridor: The onroad freight corridor focused on heavy-duty diesel truck activity on the I-595 spur from I-95 into the port boundary.

3. Rail corridor: The off-port rail corridor covered the 10 kilometers of a railway line operated by Florida East Coast Railway (FECR) extending north of the Intermodal Container Transfer Facility (ICTF) spur.

The off-port analysis included the same pollutants as the on-port analysis. Baseline emissions for 2015 were calculated for each corridor, and then hypothetical BAU emission inventories were estimated for the years 2025, 2035, and 2050,[105] based on the Port's anticipated growth in throughput and past fleet turnover rates. Table 9-1 summarizes the off-port emission reduction strategies considered in EPA's analysis. Although these future emission inventories are based on local information, they are purely hypothetical for the purposes of EPA's analysis and are not intended to form the basis for policy recommendations.

Table 9-1. Off-port Emission Reduction Strategies

Mobile Source Sector	Strategy Descriptions
OGV	• Vessel speed reduction • Lower sulfur fuels and alternative fuels
Harbor Craft	• Engine replacement (to Tier 3) • Vessel replacement (to Tier 4)
Onroad	• Truck replacement to MY2010+ and battery electric vehicle (BEVs)
Rail[a]	• Intermodal shift of cargo from truck to rail

[a] Note that the rail strategy was only qualitatively included in the off-port analysis. See Section 9.4 for more information.

A description of how the off-port corridors were selected, the methodology applied to calculate baseline and BAU projected off-port emission inventories, the associated baseline/BAU results, and the various emission reduction strategies analyzed are presented below for OGVs (Section 9.1), harbor craft (Section 9.2), onroad trucks (Section 9.3), and rail (Section 9.4).

9.1 Off-port Marine Corridor: Ocean Going Vessels

The off-port marine corridor for OGVs was chosen to complement the on-port OGV geographical boundary, which extends 3 nautical miles from the shoreline to the state/federal waters boundary and covers the entire north/south extent of Broward County (see Figure 1-1). Specifically, the off-port marine corridor begins at the state/federal waters boundary and extends to the international boundary with the Bahamas. The international boundary, which is approximately 20 to 25 nautical miles from shore, was chosen as the outer boundary of the analysis so that the focus would be on vessel operations in U.S. waters only. While not identical, the off-port north/south boundaries are similar to those of the on-port marine geographical domain. Figure 9-1 delineates the off-port marine corridor in yellow, the Port in red, and shipping lanes based on U.S. Department of Transportation shape files in light blue. Descriptions of the vessels included in this analysis are given in Section 4.

[105] Note that for 2050, only CO_2e inventories and reductions were quantified.

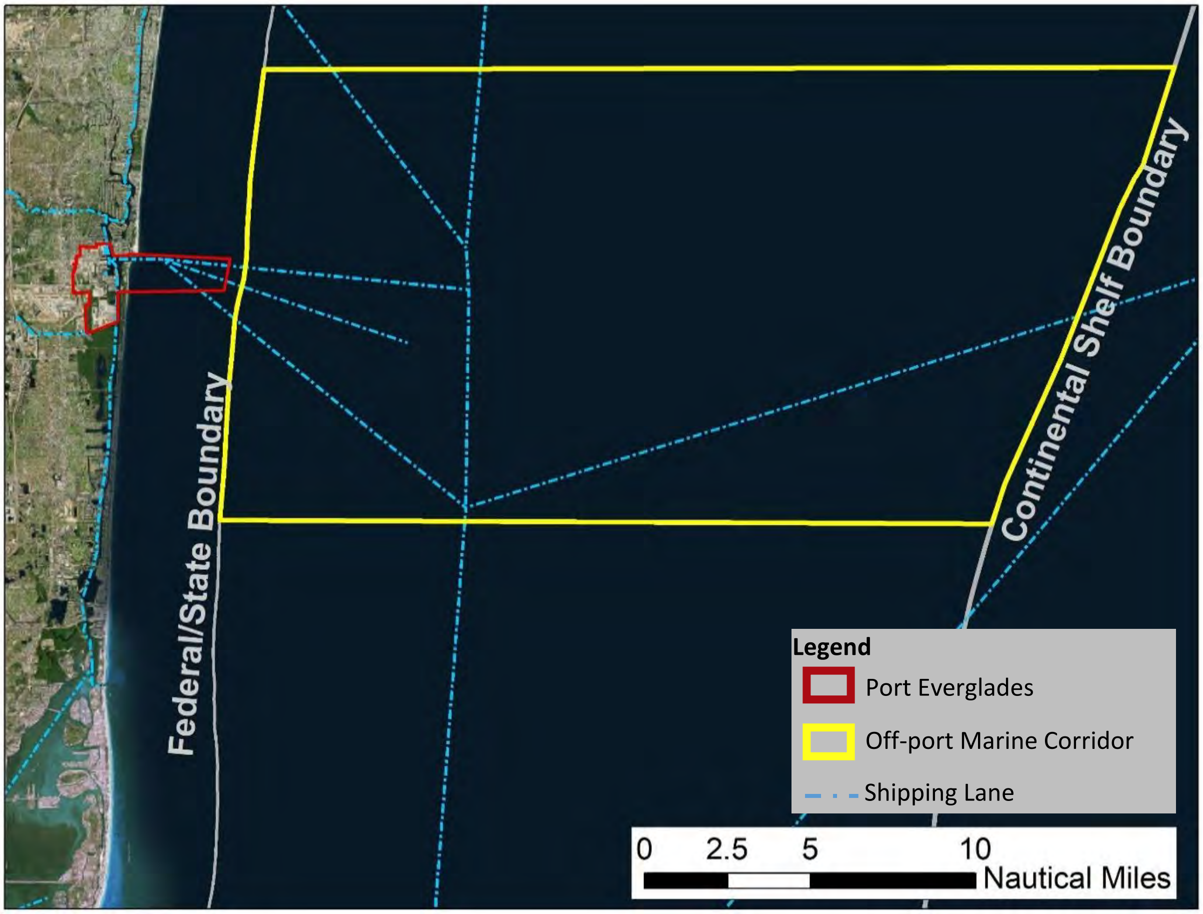

Figure 9-1. Off-port Marine Corridor

The remainder of this sub-section presents the off-port baseline emissions inventory and the projected BAU emissions for OGVs (Section 9.1.1), the considered strategies to reduce emissions (Section 9.1.2), and a summary of the associated results (Section 9.1.3). Note that the same vessel types included in the on-port analysis and listed in Table 4-1 were included in this off-port analysis.

9.1.1 Baseline and Projected Business as Usual Inventories

The 2015 baseline inventory and future BAU projection methodologies used to estimate off-port OGV emissions were consistent with the on-port emission methodologies, as described in Section 4.1. To ensure consistency of the on-port and off-port results, the same vessels were included in both analyses based on the Port's non-confidential vessel call log. This has the advantage of including emissions from only those vessels that call on the Port and excluding emissions from other vessels that may be operating in "innocent passage" and that are not directly related to activities at Port Everglades. Additionally, the same activity data sources were used for both the on-port and off-port analyses, namely U.S. Coast Guard automatic identification system (AIS) data, Information Handling Services' (IHS) Register of Ships, Starcrest's Vessel Boarding Program, wharfinger vessel call data, and Port Everglades' *2014*

Master/Vision Plan. In addition to ensuring consistency between the on-port and off-port analyses, using AIS data in the off-port analysis will inform EPA's future update of its Port Emissions Inventory Guidance.

EPA obtained AIS data for the year 2015 for the off-port marine corridor from the U.S. Coast Guard Navigation Center, summarized into 5-minute averages for each vessel.[106] This initial pre-processing step reduced the computational complexity for the subsequent analyses described below. At 5-minute aggregation, a vessel traveling at 12 knots would be observed in the data at every nautical mile of travel. The aggregated AIS vessel observations are presented in Figure 9-2.[107]

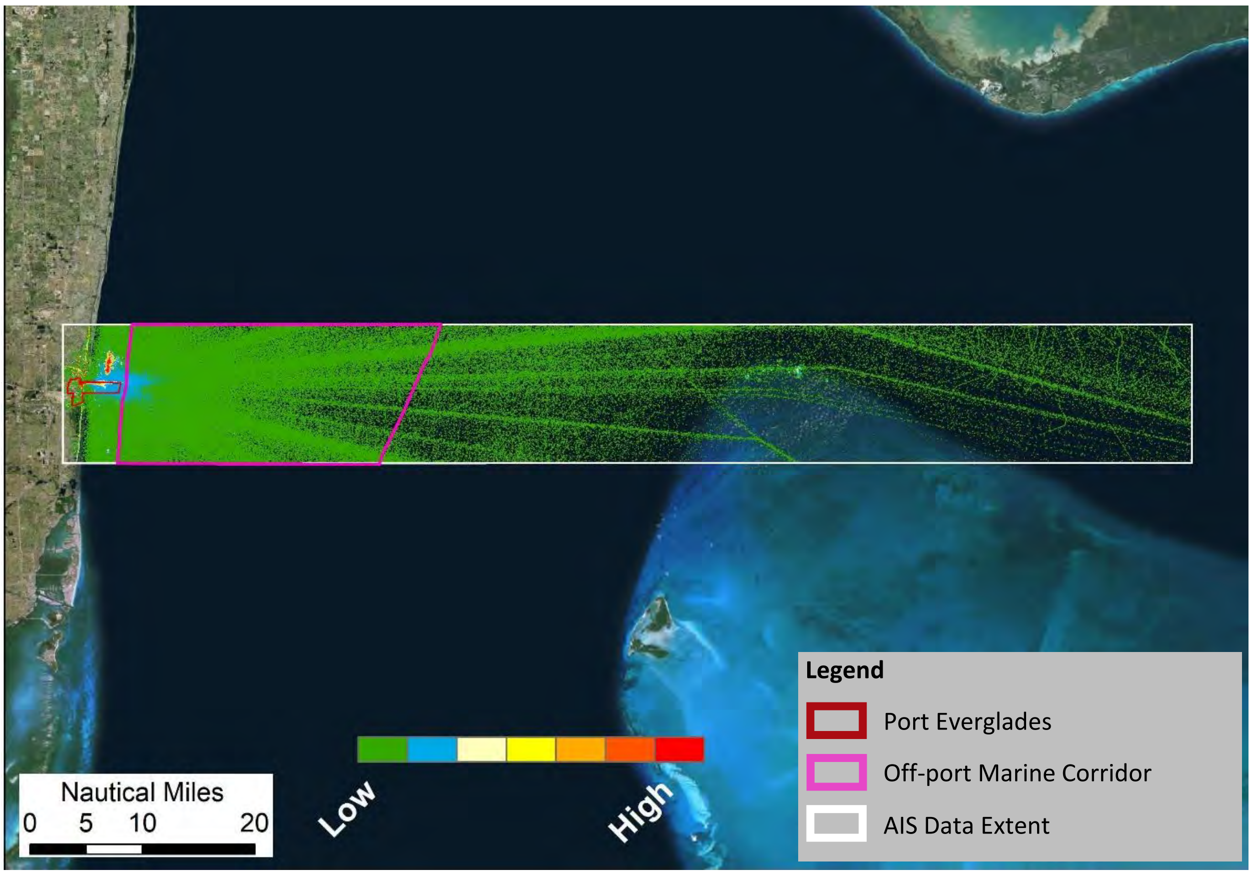

Figure 9-2. Aggregated AIS Observations

These data were used to determine vessel movements, estimate hours of operation, and quantify propulsion engine loads. Note that in reviewing the data, it was discovered that some of the vessel observations were from vessels that called at Port Everglades at some point in the year 2015 but undertook separate trips through the analysis area that were unrelated to Port Everglades activity (i.e., some of their trips were "innocent passage"). This resulted in some non-Port Everglades activity that was not successfully filtered out of the dataset; however, this

[106] For more information, see https://www.navcen.uscg.gov.

[107] Note that AIS data were available for a larger north/south cross-section; however, the data extent used by EPA in this analysis (see the white box in Figure 9-2) was limited to reduce the computational complexity.

activity accounted for 1 percent or less of the total observations. Given the level of effort required to improve this filtering, no adjustments were made to the traffic data. Therefore, port-related emissions may be slightly less than the calculated emissions presented below.

In general, the 2015 baseline emissions for off-port OGVs were calculated using the following equation:

$$E = MCR \times LF \times HR \times EF \times LLAF \times UCF \qquad \textbf{Eq. 9-1}$$

Where:

E	=	Emissions (tons)
MCR	=	Maximum continuous rated engine power (kW)
LF	=	Load factor (dimensionless)
HR	=	Hours of operation (hr)
EF	=	Emission factor (g/kW-hr)
LLAF	=	Low load adjustment factor (dimensionless)
UCF	=	Unit conversion factor (1.102×10^{-6} ton/g)

In the off-port marine corridor, transit (or “at-sea”) was the only considered mode of operation for OGVs, as the modes of operation considered in the on-port analysis were not applicable. The following subsections describe the derivation of each of the components of Eq. 9-1, which was used to calculate emissions on a per-vessel basis for both propulsion and auxiliary engines and boilers.

9.1.1.1 Maximum Continuous Rated Engine Power and Engine Loads

The maximum continuous rated engine power was determined for most vessels’ propulsion engines by cross referencing the Port’s vessel call log and the AIS dataset with IHS’s Register of Ships.[108] Table 9-2 presents the number of vessels that could be successfully matched with a propulsion engine power rating.

108 No vessel-specific data are presented in this analysis since IHS requires the removal of vessel identifiers or the aggregation of vessel characteristics data by vessel type to protect the confidentiality of individual vessels.

Table 9-2. OGV Match Rates for Propulsion Engine Power and Vessel Speed

Vessel Type	Total Count	Count with Propulsion Engine Match	Percent with Propulsion Engine Match	Count with Max. Speed Match	Percent with Max. Speed Match
Auto Carrier	3	3	100%	3	100%
Bulk Carrier	36	35	97%	35	97%
Container	124	124	100%	124	100%
Cruise	45	44	98%	44	98%
General Cargo	76	75	99%	76	100%
Miscellaneous	8	7	88%	6	75%
Roll-On/Roll-Off (RORO)	6	6	100%	6	100%
Tanker	161	153	95%	158	98%
Total	**459**	**447**	**97%**	**452**	**98%**

Vessels that could not be matched were assigned the average value by vessel type. Propulsion engine loads were determined by applying load factors to the maximum continuous rated engine power as described in Section 9.1.1.2 below.

Other information was used to characterize auxiliary engines and boilers. Since IHS data do not necessarily include information on auxiliary engines and boilers, the primary data source for these power ratings was Starcrest's Vessel Boarding Program. Because transiting load defaults were not available, this analysis relied on the maneuvering load defaults for auxiliary engines and boilers presented in the 2015 On-port Baseline Inventory[109] for all vessel types except cruise ships, which used the defaults presented in Table 9-3. The cruise ship defaults assumed in this analysis for transit operations generally fall between the maneuvering and hotelling loads, as presented in the 2015 On-port Baseline Inventory. See Section 4.1 for further background.

[109] Starcrest Consulting Group, LLC, *Port Everglades 2015 Baseline Air Emissions Inventory*, December 2016.

Table 9-3. Cruise Ship Auxiliary Engine Load Defaults (kW)

Passenger Capacity (range)	Transit Operations (kW)
0–1,499	3,500
1,500–1,999	7,000
2,000–2,499	10,500
2,500–2,999	11,000
3,000–3,499	11,500
3,500–3,999	12,000
4,000–4,499	12,500
4,500–4,999	13,000
5,000–5,499	13,500
5,500–5,999	14,000
6,000–6,499	14,500
6,500 +	15,000

9.1.1.2 Load Factors

Since vessel engines do not always operate at their maximum continuous power rating, load factors are needed to estimate their actual power output. The Propeller Law, which estimates that propulsion engine load varies with the cube of vessel speed,[110] was used in this analysis as a simplifying assumption to determine load factors for propulsion engines:

$$LF = (AS/MS)^3 \qquad \textbf{Eq. 9-2}$$

Where:

LF = Load factor
AS = Actual vessel speed
MS = Maximum vessel speed

The actual vessel speed was derived from the AIS dataset, and the maximum vessel speed was determined for most vessels by cross referencing the Port's vessel call log and AIS dataset with IHS's Register of Ships. Table 9-2 above presents the number of vessels that could be successfully matched with a maximum speed rating. Vessels that could not be matched were assigned the average value by vessel type.

Note that since the auxiliary engine and boiler loads, as described above, already represent the actual power demand, calculating a load factor for these sources is unnecessary.

[110] MAN Diesel & Turbo, *Basic Principles of Ship Propulsion*, December 2011.

9.1.1.3 Hours of Operation

To estimate hours of OGV operation in the off-port marine corridor, the duration between consecutive observations for each vessel in the AIS dataset was calculated. As a quality assurance check, the distribution of these durations was inspected, as shown in Table 9-4.

Table 9-4. Vessel Duration Profile for Off-port Marine Corridor

Duration	Percent of Observations
0 min (point of entry into the marine corridor)	0.4%
5 min	88.5%
10 min (missing one transmission)	4.3%
15 min (missing two transmissions)	0.2%
20 min (missing three transmissions)	0.1%
25 min (missing four transmissions)	0.1%
30 min (missing five transmissions)	0.1%
35-60 minutes (missing six or more transmissions)	0.3%
1–2 hours	0.2%
2–3 hours	0.1%
Greater than 3 hours	5.7%

As expected, most observations were captured at 5-minute intervals; however, approximately 10 percent of the observations were associated with longer durations between consecutive transmittances. These longer durations could have been caused by a vessel leaving the area of interest or because a vessel transmitter malfunctioned, was turned off, or failed to link up to the AIS receiver. Because most of these longer duration observations appear around the boundaries of the off-port marine corridor, they were attributed to a vessel leaving the area of interest and returning later. To account for this, observations associated with durations longer than 30 minutes were assigned a duration of 5 minutes when calculating hours of operation to represent the last observation before leaving the boundaries of the corridor.

9.1.1.4 Emission Factors

Emission factors for propulsion and auxiliary engines and boilers vary by engine type, engine speed, tier, and fuel type. The emission factors used in this analysis are the same as those used for the 2015 On-port Baseline Inventory. These primarily come from the ENTEC 2002 study,[111] except for PM and greenhouse gas emission factors, which were derived from the IVL Swedish Environmental Research Institute 2004 study.[112]

[111] Entec UK Limited, *Quantification of emissions from ships associated with ship movements between ports in the European Community, European Commission Final Report*, July 2002, http://ec.europa.eu/environment/air/pdf/chapter1_ship_emissions.pdf.

[112] IVL Swedish Environmental Research Institute, *Methodology for Calculating Emissions from Ships: Update on Emission Factors*, February 2004.

9.1.1.5 Low Load Adjustment Factors

Low load adjustment factors were applied to the emission factors when propulsion engines were determined to be operating at or below 20 percent load using Eq. 9-2 above. This is because diesel engines are known to have higher emissions per kilowatt hour when operating in this range. The low load emission adjustment factors used in this analysis vary by load and pollutant, and are the same as those used in the 2015 On-port Baseline Inventory analysis.

9.1.1.6 Projected Business as Usual Inventories

To estimate BAU emissions from OGVs for future years, the same BAU scenario developed for the on-port analysis was used for the off-port analysis, based on Port Everglades' *2014 Master/Vision Plan*.[113] Hypothetical BAU emission inventories were estimated for 2025, 2035, and 2050[114] by starting with the 2015 off-port baseline inventory (as described in sub-sections 9.1.1.1 through 9.1.1.5). Then, growth factors were applied by vessel or cargo type and adjustment factors were applied based on expected changes in the fleet emission factors, consistent with the on-port methodology. See Section 4.1 for additional details.

The 2015 off-port baseline inventory is presented in Table 9-5, and the BAU emission projections for 2025, 2035, and 2050 are presented in Table 9-6, Table 9-7, and Table 9-8, respectively. These results show that cruise ships are the largest category, followed by containerships and tankers. This is consistent with the on-port inventory estimates. Note that results are not presented by mode as in the on-port analysis, because transit activity is the only off-port mode of operation considered. Over time, BAU emissions for almost all considered pollutants are projected to increase due to the anticipated growth in marine freight and cruise traffic. The exception is for NOx emissions, which are projected to decrease in 2035 due to assumed fleet turnover to vessels with engines that comply with the Emission Control Area (ECA) NOx standards.[115] However, these results are highly dependent on the assumptions described in Section 4.1 regarding OGV fleet turnover, and future emissions will depend largely on the actual engine tier distribution of vessels calling on Port Everglades.

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[113] Port Everglades, *2014 Master/Vision Plan* reports, June 24, 2014.

[114] Note that for 2050, only CO_2e inventories and reductions were quantified.

[115] U.S. Environmental Protection Agency, *Regulatory Impact Analysis: Control of Emissions of Air Pollution from Category 3 Marine Diesel Engines*, EPA-420-R-09-019, December 2009, https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1005ZGH.txt.

Table 9-5. 2015 Baseline Emissions for Off-port OGVs by Vessel Type

Vessel Type	Annual Emissions (tons/year)								
	NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	SO_2	VOC	CO_2e
Auto Carrier	1.02	0.02	0.02	0.02	0.02	0.01	0.03	0.04	42.05
Bulk Carrier	7.24	0.12	0.12	0.12	0.12	0.09	0.20	0.32	315.47
Container—1000	110.07	2.02	1.94	1.99	1.91	1.49	3.44	4.76	5,412.79
Container—2000	18.77	0.32	0.31	0.31	0.30	0.24	0.52	0.90	815.42
Container—3000	36.71	0.62	0.59	0.60	0.58	0.46	0.97	1.79	1,526.24
Container—4000	30.60	0.54	0.52	0.52	0.50	0.40	0.82	1.69	1,295.41
Container—5000	26.81	0.46	0.44	0.45	0.43	0.34	0.70	1.33	1,106.43
Container—6000	28.70	0.51	0.49	0.49	0.47	0.38	0.74	1.73	1,167.48
Container—9000	0.52	0.01	0.01	0.01	0.01	0.01	0.01	0.04	18.60
Cruise	495.12	9.70	9.30	9.70	9.30	7.16	16.70	21.60	26,219.95
General Cargo	43.65	0.82	0.79	0.81	0.77	0.61	1.43	1.82	2,249.44
Miscellaneous	2.65	0.05	0.05	0.05	0.05	0.04	0.09	0.12	144.21
RORO	31.72	0.62	0.59	0.61	0.59	0.45	1.06	1.42	1,657.45
Tanker	23.15	0.40	0.38	0.38	0.36	0.29	0.65	1.04	1,021.96
Tanker—Chemical	40.16	0.69	0.67	0.66	0.64	0.51	1.15	1.85	1,804.75
Tanker—Handysize	13.14	0.22	0.21	0.21	0.20	0.16	0.37	0.57	575.44
Tanker—Panamax	8.17	0.15	0.15	0.14	0.14	0.11	0.24	0.50	375.98
Tanker—Suezmax	0.71	0.01	0.01	0.01	0.01	0.01	0.02	0.04	30.27
Total	**918.91**	**17.28**	**16.59**	**17.08**	**16.40**	**12.76**	**29.14**	**41.56**	**45,779.34**

Table 9-6. 2025 BAU Emissions for Off-port OGVs by Vessel Type

Vessel Type	Annual Emissions (tons/year)								
	NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	SO_2	VOC	CO_2e
Auto Carrier	1.24	0.02	0.02	0.02	0.02	0.02	0.03	0.06	53.87
Bulk Carrier	5.52	0.15	0.14	0.15	0.14	0.11	0.24	0.39	376.99
Container—1000	113.74	2.74	2.62	2.69	2.58	2.02	4.66	6.44	7,328.91
Container—2000	17.63	0.44	0.42	0.43	0.41	0.32	0.70	1.22	1,104.08
Container—3000	44.30	0.84	0.80	0.81	0.78	0.62	1.31	2.43	2,066.53
Container—4000	30.02	0.76	0.70	0.71	0.68	0.54	1.11	2.29	1,753.99
Container—5000	35.41	0.612	0.59	0.60	0.58	0.46	0.95	1.80	1,498.11
Container—6000	20.77	0.69	0.66	0.66	0.64	0.51	1.00	2.34	1,580.76
Container—9000	0.70	0.01	0.01	0.01	0.01	0.01	0.02	0.05	25.18
Cruise	598.08	13.64	13.07	13.64	13.07	10.07	23.48	30.37	36,865.25
General Cargo	24.95	1.05	1.01	1.03	0.99	0.78	1.83	2.33	2,881.54
Miscellaneous	2.65	0.07	0.06	0.07	0.06	0.05	0.12	0.15	184.73
RORO	38.04	0.79	0.76	0.78	0.75	0.58	1.35	1.82	2,123.19
Tanker	15.58	0.46	0.44	0.45	0.43	0.34	0.76	1.22	1,195.69
Tanker—Chemical	22.76	0.81	0.78	0.78	0.74	0.60	1.34	2.16	2,111.56
Tanker—Handysize	4.74	0.26	0.24	0.24	0.23	0.19	0.43	0.67	673.27
Tanker—Panamax	3.68	0.18	0.17	0.17	0.16	0.13	0.28	0.59	439.90
Tanker—Suezmax	0.19	0.01	0.01	0.01	0.01	0.01	0.02	0.04	35.42
Total	**979.99**	**23.53**	**22.50**	**23.25**	**22.28**	**17.36**	**39.63**	**56.37**	**62,298.97**

Table 9-7. 2035 BAU Emissions for Off-port OGVs by Vessel Type

Vessel Type	Annual Emissions (tons/year)								
	NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	SO_2	VOC	CO_2e
Auto Carrier	1.54	0.03	0.03	0.03	0.03	0.02	0.05	0.07	70.82
Bulk Carrier	4.46	0.29	0.27	0.28	0.27	0.21	0.46	0.75	727.48
Container—1000	125.04	3.36	3.22	3.30	3.17	2.48	5.71	7.91	8,990.64
Container—2000	9.30	0.54	0.52	0.52	0.50	0.40	0.86	1.49	1,354.41
Container—3000	18.63	1.03	0.99	0.10	0.96	0.76	1.61	2.98	2,535.09
Container—4000	26.35	0.90	0.87	0.87	0.83	0.66	1.36	2.81	2,151.68
Container—5000	27.77	0.76	0.73	0.74	0.71	0.56	1.17	2.21	1,837.78
Container—6000	13.78	0.85	0.81	0.81	0.78	0.63	1.23	2.87	1,939.18
Container—9000	0.86	0.02	0.02	0.02	0.01	0.01	0.02	0.06	30.89
Cruise	398.99	14.74	14.12	14.74	14.12	10.87	25.36	32.81	39,828.11
General Cargo	24.21	1.38	1.32	1.36	1.30	1.02	2.41	3.07	3,788.06
Miscellaneous	1.84	0.09	0.09	0.09	0.08	0.07	0.15	0.20	242.84
RORO	49.56	1.04	0.99	1.03	0.99	0.76	1.78	2.40	2,791.14
Tanker	6.81	0.49	0.47	0.48	0.46	0.36	0.81	1.30	1,276.43
Tanker—Chemical	11.94	0.87	0.83	0.83	0.79	0.64	1.43	2.30	2,254.13
Tanker—Handysize	3.75	0.27	0.26	0.26	0.25	0.20	0.46	0.72	718.73
Tanker—Panamax	2.48	0.19	0.18	0.18	0.17	0.14	0.30	0.63	469.60
Tanker—Suezmax	0.20	0.02	0.02	0.01	0.01	0.01	0.02	0.05	37.81
Total	**727.51**	**26.87**	**25.74**	**25.65**	**25.43**	**19.80**	**45.19**	**64.63**	**71,044.82**

Table 9-8. 2050 BAU Emissions for Off-port OGVs by Vessel Type

Vessel Type	Annual CO_2e Emissions (tons/year)
Auto Carrier	78.64
Bulk Carrier	787.42
Container—1000	10,895.94
Container—2000	1,641.44
Container—3000	3,072.33
Container—4000	2,607.66
Container—5000	2,227.25
Container—6000	2,350.13
Container—9000	37.44
Cruise	42,135.47
General Cargo	4,206.46
Miscellaneous	269.66
RORO	3,099.42
Tanker	1,393.95
Tanker—Chemical	2,461.68
Tanker—Handysize	784.90
Tanker—Panamax	512.84
Tanker—Suezmax	41.29
Total	**78,603.92**

9.1.2 Emission Reduction Strategies and Scenarios

The following off-port emission reduction strategies were selected in consultation between EPA and Port Everglades:

- Vessel speed reduction during transit
- Use of lower sulfur fuels (500 ppm or 200 ppm sulfur content)
- Use of liquefied natural gas (LNG)

Because Port Everglades does not have direct control over implementing these strategies, the hypothetical scenarios for each are predicated on the assumption of the coordination and collaboration of various maritime industry stakeholders for implementation. Additionally, the scenarios do not consider jurisdiction or geographical boundaries. Table 9-9 summarizes the implementation assumptions for each scenario. The anticipated reduction values for each strategy scenario are presented in Table 9-10. Hypothetical emission reductions were calculated for every emission reduction strategy and low/high implementation scenario relative to the total off-port OGV BAU emissions. Additional details on the selected emission reduction strategies and scenarios are presented in Sections 9.1.2.1 through 9.1.2.3.

Table 9-9. Summary of Off-port Emission Reduction Scenarios for OGVs

Strategy	Affected Vessel Types	Scenario	Implementation Rates			Notes
			2025	2035	2050	
Vessel speed reduction during transit	All OGVs	Low	50%	50%	50%	Max speed 12 knots
		High	90%	90%	90%	
Lower sulfur fuels	All OGVs	Low	10% use of 500 ppm	25% use of 200 ppm	N/A	
		High	25% use of 500 ppm	50% use of 200 ppm	N/A	
LNG	Containerships	Low	1%	2%	5%	
		High	5%	10%	15%	

Table 9-10. Off-port OGV Emission Reduction Factors by Scenario

Strategy	Scenario	Notes	NOx	PM_{10}	$PM_{2.5}$	DPM	VOC	SO_2	CO_2	CH_4	N_2O
Vessel speed reduction during transit	Low/High		Emission reductions vary by individual vessel, depending on speed of travel. Please see Section 9.1.2.1 for more details.								
Lower sulfur fuels	Low	500 ppm	--[a]	5.9%	5.9%	5.9%	--	50.0%	--	--	--
	High	200 ppm	--	11.8%	11.8%	11.8%	--	80.0%	--	--	--
LNG	High		87.7%	82.4%	82.4%	82.4%	16.7%	99.0%	22.4%	--	26.7%

[b] A double dash ("--") represents a value that was not calculated as part of this analysis.

9.1.2.1 Vessel Speed Reduction

Reducing vessel speed is an effective way to reduce ship fuel consumption and emissions because it lowers the power demand on the vessel's main engines.[116] For this analysis, the following assumptions were made:

- The vessel speed reduction zone covers all the off-port marine corridor (approximately 20 to 25 nautical miles from shore, as shown in Figure 9-1)[117]
- Vessels would voluntarily slow down to 12 knots or less within the corridor[118]
- All vessel types would be covered by the program
- Vessels would not change their trajectories due to the program
- The low and high implementation scenarios for this analysis assume 50 percent and 90 percent participation rates, respectively

To analyze the impacts of this strategy on emissions, actual vessel speeds were derived from the 2015 AIS dataset. It was determined that 22 percent of all OGVs had average speeds greater than 12 knots, as shown in Table 9-11. While the implementation details of this hypothetical strategy are not considered in this analysis, it is important to note that most vessels affected by this strategy are cruise ships.

Table 9-11. Summary of Off-port OGV Speeds

Vessel Type	Count of Vessels with Average Speeds > 12 knots	Percent of All Vessels Calling at Port Everglades
Auto Carrier	1	0.2%
Bulk	1	0.2%
Containership	19	4.4%
Cruise	42	9.7%
General Cargo	15	3.5%
Miscellaneous	0	0.0%
RORO	1	0.2%
Tanker	18	4.1%
Total	**97**	**22.4%**

Emission reductions from this strategy were estimated by calculating the hypothetical reductions in propulsion engine load using the Propeller Law (see Section 9.1.1.2). In addition, when a vessel's reduced speed engine load factor was calculated to be less than 20 percent,

[116] In addition to reducing engine load, slow-steaming has the potential to reduce time spent waiting for berth or crane availability. While this would reduce auxiliary engine use, this co-benefit was not included in this analysis for simplicity.

[117] In practice, it would be logical for a voluntary vessel speed reduction zone to cover a radius from the port, tracing geographic semi-circle. However, because of the limited extent of the AIS data used in this analysis, the emission reductions associated with the vessel speed reduction strategy were only calculated for the highlighted range in Figure 9-1.

[118] The speed reduction to 12 knots was chosen based on vessel speed reduction programs at California ports.

low load adjustment factors were applied, as described in Section 9.1.1.5. While adjustments were not made to the time spent by vessels in each mode (i.e., to account for the slower transit speeds), the average delay was estimated to be approximately 10 minutes, assuming all vessels transit the full length of the corridor at reduced speed.

9.1.2.2 Use of Lower Sulfur Fuels

For this strategy, a proportion of ships were assumed to use fuel with a sulfur concentration of 500 ppm in 2025 and 200 ppm in 2035. The assumed implementation rates for the low and high implementation scenarios are listed in Table 9-9, and the emission reductions associated with the lower sulfur fuels are listed in Table 9-10. See Section 4.2.3 for additional information on this strategy.

9.1.2.3 Use of LNG

The LNG rates of implementation for containerships from Table 9-9 and the emission reductions noted in Table 9-10 were applied to the projected BAU containership emissions to evaluate the anticipated changes in emissions. See Section 4.2.4 for additional information on this strategy.

9.1.3 Emission Reduction Scenario Results and Lessons Learned

The modeled emission reductions for each scenario are summarized in Figure 9-3, Figure 9-4, Figure 9-5, and Table 9-12 for off-port operations. Table 9-13 shows the relative percent emission reductions for each scenario. The percent reductions are shown relative to the total off-port OGV emissions, as there is only one off-port mode of operation.

The analysis for the voluntary vessel speed reduction strategy suggests it may be effective at significantly reducing OGV emissions for all pollutants outside of the Port. However, because specific implementation details for this strategy were not considered, there is uncertainty as to what the actual vessel emission reductions would be if such a strategy were to be implemented. For example, it is unclear how many vessels would reduce their speed.

The fuel strategies were also shown to be effective at reducing emissions outside the port, particularly the lower sulfur fuels strategy for reducing PM emissions. The percent reductions for the LNG strategy appear low; however, this strategy was only applied to a fraction of containerships and the comparison is presented against all off-port OGV emissions.

This analysis could be further improved by refining the geographical bounds of the analysis zone (i.e., choosing a semi-circle centered at the port extending to the international waters boundary), refining vessel speed reduction targets by vessel type (e.g., setting a different speed limit for certain vessels), and accounting for longer travel durations in the off-port corridor due to slower transit speeds. This analysis benefited from having a highly detailed baseline inventory based on AIS data and the Port’s non-confidential vessel call records.

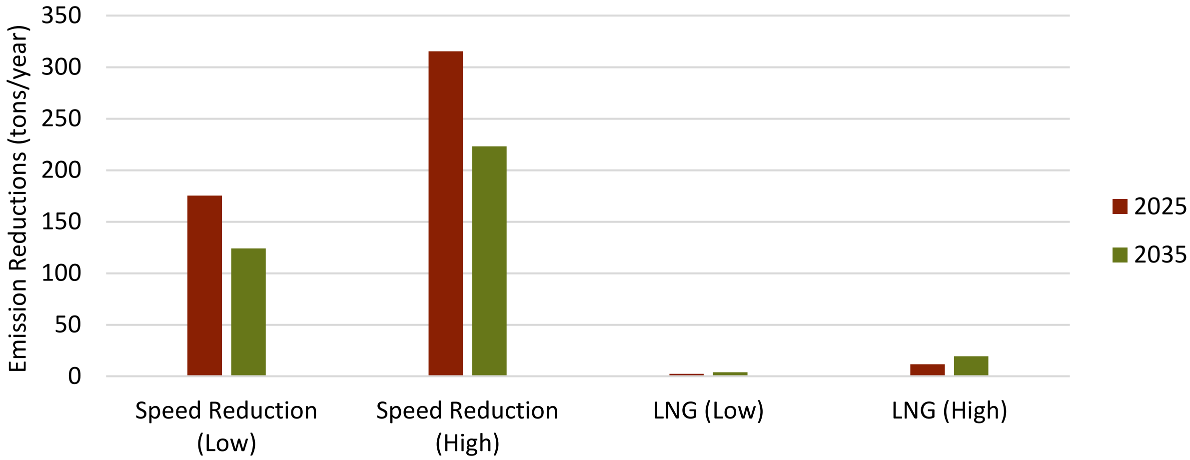

Figure 9-3. Off-port OGV NOx Reduction Strategies

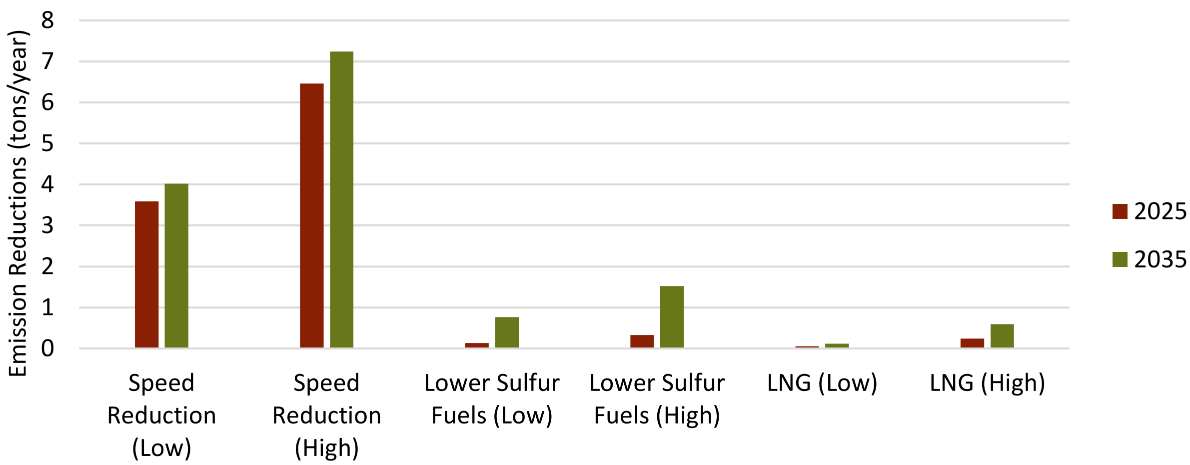

Figure 9-4. Off-port OGV $PM_{2.5}$ Reduction Strategies

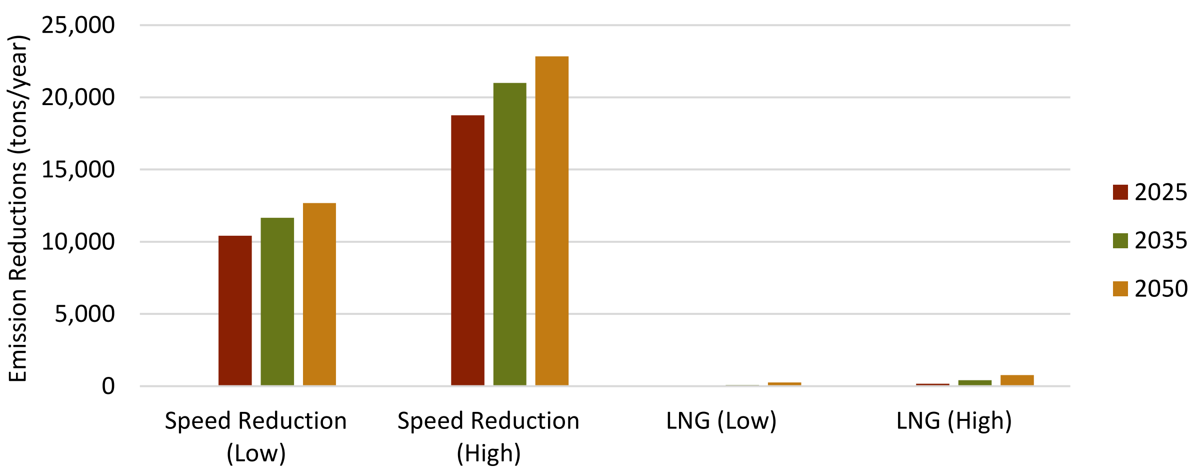

Figure 9-5. Off-port OGV CO_2e Reduction Strategies

Table 9-12. Total Reductions from BAU Off-port OGV Emissions by Scenario

Year	Strategy	Scenario	Emission Reductions (tons/year)								
			NO_x	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	SO_2	VOC	CO_2e
2025	Vessel Speed Reduction During Transit	Low	175.19	3.74	3.59	3.76	3.61	2.76	6.65	7.80	10,417.25
		High	315.34	6.74	6.46	6.77	6.49	4.97	11.97	14.03	18,751.04
	Lower Sulfur Fuels	Low	--[a]	0.14	0.13	0.14	0.13	0.10	1.98	--	--
		High	--	0.35	0.33	0.34	0.33	0.25	4.95	--	--
	LNG	Low	2.30	0.05	0.05	0.05	0.05	0.04	0.10	0.03	34.48
		High	11.51	0.25	0.24	0.24	0.23	0.18	0.48	0.14	172.40
2035	Vessel Speed Reduction During Transit	Low	124.05	4.20	4.02	4.22	4.05	3.10	7.44	8.77	11,661.24
		High	223.29	7.56	7.24	7.60	7.29	5.57	13.40	15.79	20,990.23
	Lower Sulfur Fuels	Low	--	0.79	0.76	0.78	0.75	0.59	9.04	--	--
		High	--	1.58	1.52	1.57	1.50	1.17	18.08	--	--
	LNG	Low	3.89	0.12	0.12	0.12	0.11	0.09	0.24	0.07	84.60
		High	19.45	0.61	0.59	0.60	0.57	0.45	1.18	0.34	422.98
2050	Vessel Speed Reduction During Transit	Low	--	--	--	--	--	--	--	--	12,689.28
		High	--	--	--	--	--	--	--	--	22,840.70
	LNG	Low	--	--	--	--	--	--	--	--	256.31
		High	--	--	--	--	--	--	--	--	768.94

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

Table 9-13. Percent Reductions from BAU Off-port OGV Emissions by Scenario

Year	Strategy	Scenario	Percent Reductions from BAU Emissions								
			NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	SO_2	VOC	CO_2e
2025	Vessel Speed Reduction During Transit	Low	17.88%	15.92%	15.93%	16.18%	16.19%	15.93%	16.78%	13.83%	16.72%
		High	32.18%	28.66%	28.67%	29.13%	29.14%	28.67%	30.20%	24.89%	30.10%
	Lower Sulfur Fuels	Low	--[a]	0.59%	0.59%	0.59%	0.59%	0.59%	5.00%	--	--
		High	--	1.48%	1.48%	1.48%	1.47%	1.48%	12.50%	--	--
	LNG	Low	0.23%	0.21%	0.21%	0.21%	0.21%	0.21%	0.24%	0.05%	0.06%
		High	1.17%	1.06%	1.06%	1.05%	1.05%	1.06%	1.22%	0.25%	0.28%
2035	Vessel Speed Reduction During Transit	Low	17.06%	15.65%	15.65%	15.92%	15.93%	15.65%	16.48%	13.59%	16.42%
		High	30.70%	28.17%	28.18%	28.66%	28.67%	28.18%	29.67%	24.45%	29.56%
	Lower Sulfur Fuels	Low	--	2.95%	2.95%	2.95%	2.95%	2.95%	20.01%	--	--
		High	--	5.90%	5.90%	5.90%	5.90%	5.90%	40.02%	--	--
	LNG	Low	0.53%	0.46%	0.46%	0.45%	0.45%	0.46%	0.52%	0.11%	0.12%
		High	2.67%	2.29%	2.29%	2.26%	2.26%	2.29%	2.62%	0.53%	0.60%
2050	Vessel Speed Reduction During Transit	Low	--	--	--	--	--	--	--	--	16.14%
		High	--	--	--	--	--	--	--	--	29.06%
	LNG	Low	--	--	--	--	--	--	--	--	0.33%
		High	--	--	--	--	--	--	--	--	0.98%

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

9.2 Off-port Marine Corridor: Harbor Craft

The off-port marine corridor for harbor craft is the same corridor for OGVs described above in Section 9.1 and shown in Figure 9-1. This section presents the baseline emissions inventory and projected BAU emissions for harbor craft in this corridor (Section 9.2.1), the considered strategies to reduce emissions (Section 9.2.2), and a summary of the associated results and lessons learned (Section 9.2.3). Note that the same vessel types included in the on-port harbor craft analysis, as listed in Table 5-1, were included in this off-port analysis. Due to the nature of harbor craft, these vessels have limited activity in the off-port marine corridor relative to OGVs. However, this section describes the harbor craft activity in the corridor that was observed in the AIS data.

9.2.1 Baseline and Projected Business as Usual Inventories

The baseline and BAU projection methodologies for estimating off-port harbor craft emissions is consistent with the methodologies for estimating on-port emissions as described in Section 5.1. To ensure consistency, the same vessels were included in both analyses, based on the Port's non-confidential vessel call log. Additionally, the same activity data sources were used for both the on-port and off-port analysis, namely U.S. Coast Guard AIS data, IHS's Register of Ships, Starcrest's Vessel Boarding Program, wharfinger vessel call data, and Port Everglades' *2014 Master/Vision Plan*. While not all harbor craft are required to have AIS transponders, a comparison between the AIS data and the wharfinger vessel call data showed that the majority of relevant vessels appeared in the AIS data. In addition to ensuring consistency between the on-port and off-port analyses, using AIS in the off-port analysis will inform EPA's future update of its Port Emissions Inventory Guidance.

The raw AIS data were summarized into 5-minute averages for each vessel by the U.S. Coast Guard Navigation Center. This initial pre-processing step reduced the computational complexity for the subsequent analyses described below.

In general, the baseline emissions for off-port harbor craft were calculated similarly as those for off-port OGVs (described in Section 9.1.1) using the following equation:

$$E = MCR \times LF \times HR \times EF \times UCF \qquad \textbf{Eq. 9-3}$$

Where:

E	=	Emissions (tons)
MCR	=	Maximum continuous rated engine power (kW)
LF	=	Load factor (dimensionless)
HR	=	Hours of operation (hr)
EF	=	Emission factor (g/kW-hr)
UCF	=	Unit conversion factor (1.102×10^{-6} ton/g)

In the off-port marine corridor, transit was the only considered mode of operation for harbor craft, as the modes of operation considered in the on-port analysis were not applicable. The following subsections describe the derivation of each of the components of Eq. 9-3, which was used to calculate emissions on a per-vessel basis for both propulsion and auxiliary engines.

9.2.1.1 Maximum Continuous Rated Engine Power and Engine Loads

The maximum continuous rated engine power was determined for most vessels' propulsion engines by cross referencing the Port's vessel call log and the AIS dataset with IHS's Register of Ships. Table 9-14 presents the number of vessels that could be successfully matched with a propulsion engine power rating. Vessels that could not be matched were assigned the average value by vessel type, as given in the 2015 On-port Baseline Inventory.

Table 9-14. Harbor Craft Match Rates for Propulsion Engine Power and Vessel Speed

Vessel Type	Total Count	Count with Propulsion Power Match	Percent with Propulsion Power Match	Count with Max. Speed Match	Percent with Max. Speed Match
Articulated Tug Barge	17	17	100%	9	53%
Assist Tug	1	1	100%	0	0%
Towboat	30	26	87%	13	43%
Total	**48**	**44**	**92%**	**22**	**46%**

All auxiliary engine characteristics came from Starcrest's Vessel Boarding Program. Engine loads for both propulsion and auxiliary engines were determined by applying load factors to the maximum continuous rated engine power as described in the following section.

9.2.1.2 Load Factors

Harbor craft propulsion engine load factors were calculated similarly as those for off-port OGVs (described in Section 9.1.1.2) using the Propeller Law. The actual vessel speed was derived from the AIS dataset, and the maximum vessel speed was determined where possible by cross referencing the Port's vessel call log and the AIS dataset with IHS's Register of Ships. Table 9-14 above presents the number of vessels that could be successfully matched with a maximum speed rating. Vessels that could not be matched were assigned the average value by vessel type. Load factors for harbor craft auxiliary engines came from the 2015 On-port Baseline Inventory.

9.2.1.3 Hours of Operation

Harbor craft hours of operation in the marine corridor were derived similarly as in the off-port OGV case (described in Section 9.1.1.3) by calculating the duration between each AIS observation for each vessel.

9.2.1.4 Emission Factors

Emission factors for harbor craft propulsion and auxiliary engines vary by engine power rating and tier. The emission factors used in this analysis are the same as those used in the 2015 On-port Baseline Inventory.

9.2.1.5 Projected Business as Usual Emissions

To estimate BAU emissions from harbor craft for future years, the same BAU scenario developed for the on-port analysis was used for the off-port analysis, based on Port Everglades' *2014 Master/Vision Plan*.[119] Hypothetical BAU emission inventories were estimated for 2025 and 2035 by starting with the 2015 baseline emissions, applying the growth factors, and then applying adjustment factors based on expected changes in the fleet emission factors. Emission inventories were not calculated for 2050, as only greenhouse gases were included for that year in this analysis, and the selected emission reduction strategies (discussed below) do not address greenhouse gases.[120] See Section 5.1 for additional details on this analysis.

A summary of the baseline and BAU projected emissions is presented in Table 9-15. Based on the assumptions in this analysis, emissions are projected to increase for all pollutants from the 2015 baseline year due to the anticipated increase in marine freight traffic.

[119] Port Everglades, *2014 Master/Vision Plan* reports, June 24, 2014.

[120] Note that there are technologies involving electrification that do address greenhouse gases that were not included here. For more information, see EPA's *National Port Strategy Assessment*, https://www.epa.gov/ports-initiative/national-port-strategy-assessment-reducing-air-pollution-and-greenhouse-gases-us.

Table 9-15. 2015 Baseline and 2025 and 2035 BAU Emissions for Off-port Harbor Craft

Year	Vessel Type	Annual Emissions (tons/year)							
		NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e
2015	Articulated Tug Barge	12.75	0.61	0.59	0.61	0.59	0.45	0.60	737.72
	Assist Tug	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.52
	Towboat	10.64	0.39	0.38	0.39	0.38	0.29	0.43	586.50
	Total	**23.40**	**0.99**	**0.97**	**0.99**	**0.97**	**0.75**	**1.02**	**1,324.75**
2025	Articulated Tug Barge	13.53	0.64	0.62	0.64	0.62	0.48	0.65	881.58
	Assist Tug	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.62
	Towboat	11.29	0.41	0.40	0.41	0.40	0.31	0.47	700.87
	Total	**24.82**	**1.04**	**1.02**	**1.04**	**1.02**	**0.79**	**1.13**	**1,583.07**
2035	Articulated Tug Barge	22.80	1.05	1.03	1.05	1.03	0.79	1.15	1,701.18
	Assist Tug	0.02	0.00	0.00	0.00	0.00	0.00	0.00	1.20
	Towboat	19.02	0.67	0.66	0.67	0.66	0.51	0.83	1,352.47
	Total	**41.84**	**1.73**	**1.69**	**1.73**	**1.69**	**1.30**	**1.98**	**3,054.86**

9.2.2 Emission Reduction Strategies and Scenarios

The following off-port emission reduction strategies were selected in consultation with Port Everglades:

- Engine replacement (to Tier 3)
- Vessel replacement (to Tier 4)

These are the same emission reduction strategies selected in the on-port harbor craft analysis. Information on why these strategies were selected can be found in Section 5.2. Because Port Everglades does not have direct control over activity in the off-port marine corridor, the hypothetical scenarios for each are predicated on the assumption of the coordination and collaboration of various maritime industry stakeholders for implementation.

The emission reduction values presented in Table 9-16 were applied to the BAU inventories for the number of engines or vessels replaced with cleaner diesel technology under each scenario as summarized in Table 9-17.

Table 9-16. Off-port Harbor Craft Per Vessel Emission Reduction Factors by Strategy

Strategy	Notes	NOx	PM_{10}	$PM_{2.5}$	DPM	BC	VOC
Engine Replacement	Per vessel reductions from replacing Tier 0 with Tier 3	44.7%	80.6%	80.6%	80.6%	80.6%	--[a]
Vessel Replacement	Per vessel reductions from replacing Tier 0 with Tier 4	86.4%	94.4%	94.4%	94.4%	94.4%	62.0%

[a] VOC emission reductions from engine replacement were not calculated as part of this analysis.

Table 9-17. Summary of Off-port Emission Reduction Scenarios for Harbor Craft

Strategy	Scenario	Implementation Rates		Notes
		2025	2035	
Engine Replacement	Low	20% (8 vessels)	20% (6 vessels)	Replacing Tier 0 engines with Tier 3 engines
	High	30% (13 vessels)	30% (8 vessels)	
Vessel Replacement	Low	10% (4 vessels)	10% (3 vessels)	Replacing Tier 0 vessels with Tier 4 vessels
	High	20% (8 vessels)	20% (6 vessels)	

9.2.3 Emission Reduction Scenario Results and Lessons Learned

The projected off-port emission reductions by scenario are summarized in Figure 9-6, Figure 9-7, and Table 9-18. Table 9-19 shows the percent emissions reduction for each scenario relative to the total off-port harbor craft BAU emissions.

This analysis benefited from knowing the age distribution of the tug and towboat fleets operating at Port Everglades. Due to the longevity of tugs and towboats, significant reductions may be possible through voluntary programs that support the replacement of older engines and vessels. While normal fleet turnover to newer emission standards can reduce the BAU growth in emissions, this off-port corridor analysis shows that accelerated diesel engine and vessel replacement have additional long-term benefits beyond the reductions seen on-port.

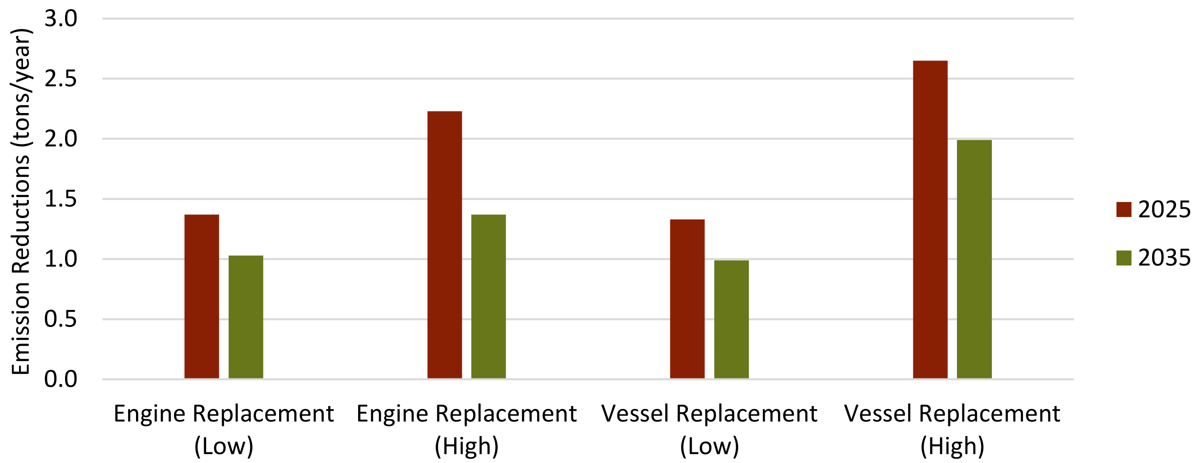

Figure 9-6. Off-port Harbor Craft NOx Reduction Strategies

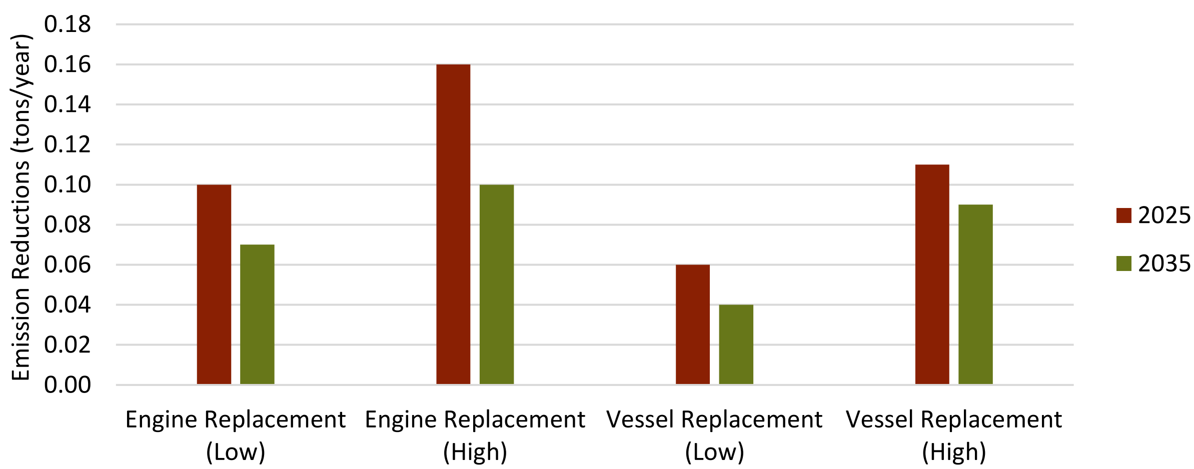

Figure 9-7. Off-port Harbor Craft $PM_{2.5}$ Reduction Strategies

Table 9-18. Total Reductions from BAU Off-port Harbor Craft Emissions by Scenario

Year	Strategy	Scenario	Emission Reductions (tons/year)						
			NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC
2025	Engine Replacement	Low	1.37	0.10	0.10	0.10	0.10	0.08	--[a]
		High	2.23	0.16	0.16	0.16	0.16	0.12	--
	Vessel Replacement	Low	1.33	0.06	0.06	0.06	0.06	0.05	0.03
		High	2.65	0.12	0.11	0.12	0.11	0.08	0.07
2035	Engine Replacement	Low	1.03	0.07	0.07	0.07	0.07	0.05	--
		High	1.37	0.10	0.10	0.10	0.10	0.08	--
	Vessel Replacement	Low	0.99	0.04	0.04	0.04	0.04	0.03	0.03
		High	1.99	0.09	0.09	0.09	0.09	0.07	0.05

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

Table 9-19. Percent Reductions from BAU Off-port Harbor Craft Emissions by Scenario

Year	Strategy	Scenario	Percent Reductions from BAU Emissions						
			NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC
2025	Engine Replacement	Low	5.52%	9.55%	9.55%	9.55%	9.55%	9.55%	--[a]
		High	8.98%	15.51%	15.51%	15.51%	15.51%	15.51%	--
	Vessel Replacement	Low	5.34%	5.59%	5.59%	5.59%	5.59%	5.59%	3.09%
		High	10.68%	11.18%	11.18%	11.18%	11.18%	11.18%	6.18%
2035	Engine Replacement	Low	2.46%	4.31%	4.31%	4.31%	4.31%	4.31%	--
		High	3.28%	5.75%	5.75%	5.75%	5.75%	5.75%	--
	Vessel Replacement	Low	2.38%	2.53%	2.53%	2.53%	2.53%	2.53%	1.32%
		High	4.75%	5.05%	5.05%	5.05%	5.05%	5.05%	2.63%

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

9.3 Off-port Truck Corridor

Since Port Everglades sees significant freight and cruise activity, the off-port onroad emissions inventory included roads frequently travelled by port-related cargo and passenger traffic. Specifically, this inventory included the off-port truck corridor, which is the I-595 highway spur connecting Port Everglades to I-95, as well as several surface streets that connect the Port to the airport and nearby hotels. Figure 9-8 shows the roads included in the off-port emission inventory, where the I-595 off-port truck corridor is highlighted in pink, the selected surface streets are highlighted in blue, and Port Everglades is outlined in red. While other streets, such as SR-84, are used by port-related truck traffic, only I-595 was included for simplicity.

This section presents the baseline off-port onroad emission inventory and the projected BAU emissions (Section 9.3.1), the considered strategies to reduce emissions in the off-port truck corridor (Section 9.3.2), and a summary of the associated results and lessons learned (Section 9.3.3).

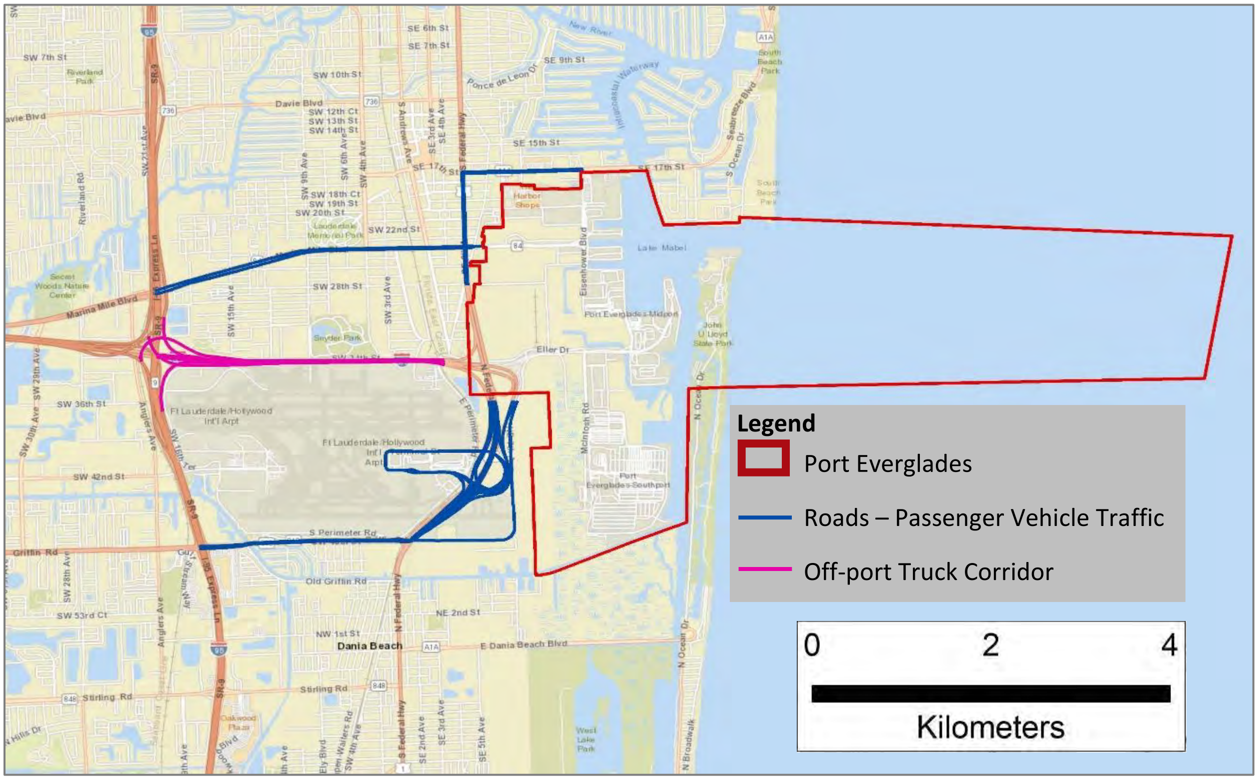

Figure 9-8. Off-port Truck Corridor

9.3.1 Baseline and Projected Business as Usual Inventories

The baseline and BAU projection methodologies for estimating off-port emissions from onroad vehicles are consistent with the methodologies used for estimating the on-port emissions, as described in Section 7.1. To ensure consistency, the same vehicles were included in both analyses, based on gate counts and confidential surveys of terminal and facility operational managers. EPA did not receive any confidential business or terminal-specific information through the partnership.

Off-port onroad emissions were estimated using EPA's MOVES2014a[121] model at the project scale. At this scale, links are defined to represent segments of roads with information about the vehicles operating on the links, including vehicle activity. The I-595 spur, the off-port truck corridor, was modeled as a set of "restricted roadway" links in MOVES. These links captured port-related heavy-duty diesel truck traffic, modeled as combination short-haul trucks and combination long-haul trucks. The numerous surface streets included in the corridor were modeled as a set of "unrestricted roadway" links in MOVES. These captured the majority of cruise passenger traffic, modeled as passenger cars, light commercial trucks, and transit buses.

[121] EPA's MOtor Vehicle Emission Simulator (MOVES) is a state-of-the-science emission modeling system that estimates emissions for mobile sources at the national, county, and project level for criteria air pollutants, greenhouse gases, and air toxics. For more information, see https://www.epa.gov/moves.

An additional link was included to estimate emissions from vehicles idling while waiting to pick up cruise passengers at the airport.

The vehicle mix accounted for by the MOVES links was derived from information about the total number of vehicles from the 2015 On-port Baseline Inventory, combined with information about I-595's traffic volume and vehicle mix in 2015, as reported by Florida Department of Transportation.[122] The resulting link volumes and source type fractions are shown in Table 9-20. MOVES inputs regarding vehicle characteristics such as age and fuel type distributions are the same as what were used for the on-port inventory, since the vehicles are the same in both analyses. This analysis does not account for EPA's Heavy-Duty GHG Phase 2 rule because it is currently not included in MOVES2014a.

Table 9-20. Off-port Link Volumes and Source Type Fractions

Source Type	I-595 Link: Truck Corridor (Urban Restricted Road)		Surface Streets (Urban Unrestricted Road)	
	Volume	**Source Type Fraction**	**Volume**	**Source Type Fraction**
Passenger Car	54,326	13.0%	217,306	19.2%
Light Commercial Truck	36,083	8.7%	144,330	12.8%
Transit Bus	5,399	1.3%	21,597	1.9%
Combination Short-Haul	152,700	36.6%	354,817	31.4%
Combination Long-Haul	168,245	40.4%	390,939	34.6%
Total Link Volume	**416,753**	**100%**	**1,128,988**	**100%**

To estimate onroad BAU emissions for future years, the same BAU scenario developed for the on-port analysis was used for the off-port analysis, based on Port Everglades' *2014 Master/Vision Plan*.[123] Hypothetical BAU emission inventories were estimated for 2025, 2035, and 2050[124] by starting with the 2015 baseline off-port emissions, applying the growth factors by vehicle type, and then applying adjustment factors based on expected changes in the fleet emission factors. See Section 7.1 for details on the methodology used for this step in the analysis. A summary of baseline and BAU projected emissions is presented in Table 9-21. Based on the assumptions in this analysis, emissions are projected to decrease over time for most pollutants (except CO_2e) due to fleet turnover to lower-emitting vehicles.

[122] Florida Department of Transportation, *Florida Traffic Online*, 2015, http://flto.dot.state.fl.us/website/FloridaTrafficOnline/viewer.html.

[123] Port Everglades, *2014 Master/Vision Plan* reports, June 24, 2014.

[124] Note that for 2050, only CO_2e inventories and reductions were quantified.

Table 9-21. Baseline and Projected BAU Emissions for Off-port Onroad Vehicles

Year	Annual Emissions (tons/year)							
	NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e
2015	23.69	1.43	1.31	1.42	1.30	0.61	1.64	6,657.57
2025	10.66	0.51	0.47	0.50	0.46	0.22	0.63	8,251.94
2035	6.76	0.20	0.19	0.20	0.18	0.03	0.31	9,774.84
2050	--[a]	--	--	--	--	--	--	11,530.98

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

9.3.2 Emission Reduction Strategies and Scenarios

Only one emission reduction strategy considered for the on-port inventory also applied to the truck corridor as well. This strategy, to replace trucks with cleaner diesel and electric technologies (e.g., 2007/2010 compliant trucks and battery electric vehicles [BEVs]), was selected in consultation with Port Everglades. It mirrors the truck replacement strategy selected for the on-port onroad analysis. It is the only off-port strategy considered because the other onroad strategies considered for the on-port inventory discussed in Section 7.2, such as idle reduction, did not apply to off-port truck activity. See Section 7.2.3 for background information on this strategy.

Because Port Everglades does not have direct control over implementing this strategy (since the Port does not own these fleets), the hypothetical scenarios for each are predicated on the assumption of the coordination and collaboration of various stakeholders for implementation.

Table 9-22 summarizes applicability and implementation assumptions for each scenario.

Table 9-22. Summary of Emission Reduction Scenarios for Off-port Truck Corridor

Strategy	Scenario	Implementation Rate		
		2025	2035	2050
Truck replacement	Low	Replace 100% pre-2007 trucks with 50% 2007, 50% 2010+	Replace 100% pre-2010 trucks with 2010+ Replace 15% of 2010+ with BEV	Replace 30% of 2010+ with BEV
	High	Replace 100% pre-2007 trucks with 40% 2007-2009, 40% 2010+, 20% BEV	Replace 100% pre-2010 trucks with BEVs Replace 30% of 2010+ with BEV	Replace 50% of 2010+ with BEV

Hypothetical emission reductions were calculated for each scenario relative to the total off-port onroad BAU inventories using MOVES2014a.

9.3.3 Emission Reduction Scenario Results and Lessons Learned

The projected off-port emission reductions by scenario are summarized in Figure 9-9, Figure 9-10, Figure 9-11, and Table 9-23. Table 9-24 shows the percent emission reductions for each scenario relative to the total off-port onroad BAU emissions.

In general, except for emissions of CO_2e, accelerating fleet turnover to cleaner technology through truck replacements has the potential to reduce emissions significantly through 2035, despite the projected growth in truck activity. Truck replacement is especially effective in the year 2025, reducing NOx by about 30 percent and PM by about 70 percent compared to the BAU case. Note that this strategy would not reduce emissions of CO_2e in 2025, as it assumes that trucks would be replaced with newer model year conventional trucks; not until 2035 are BEV replacements assumed. In 2035, truck replacement still shows benefits, as it would reduce emissions of NOx by about 30 percent and PM by about 30 percent compared to the BAU case. Having additional detail, such as the truck age distribution, could have strengthened this analysis further.

Note that the off-port, onroad inventories for 2015 and BAU years included all vehicles visiting the Port within these defined corridors, rather than only heavy-duty diesel trucks. Had the BAU emissions included only trucks, the reductions from the truck replacement strategy would have resulted in an even larger percentage of total emissions.

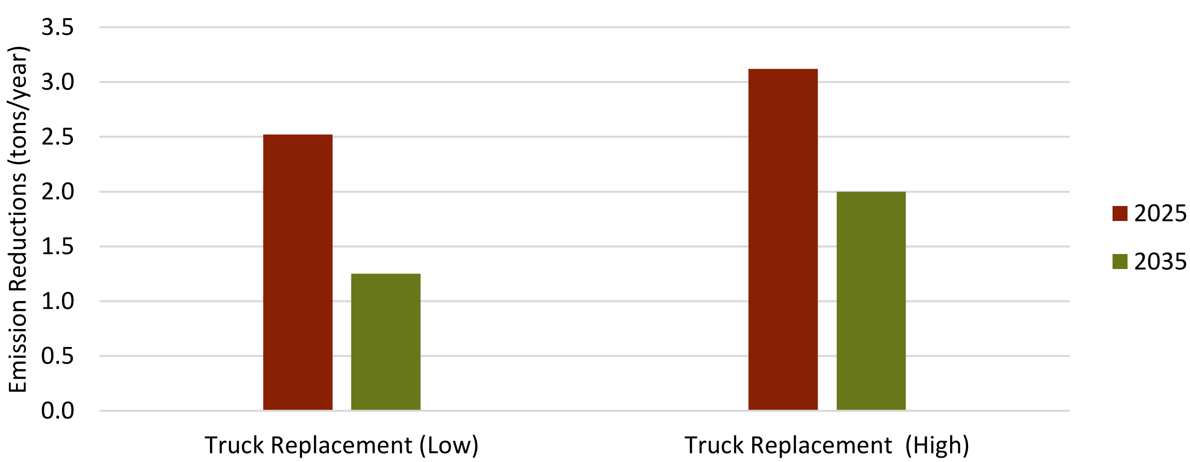

Figure 9-9. Off-port Truck NOx Reduction Strategies

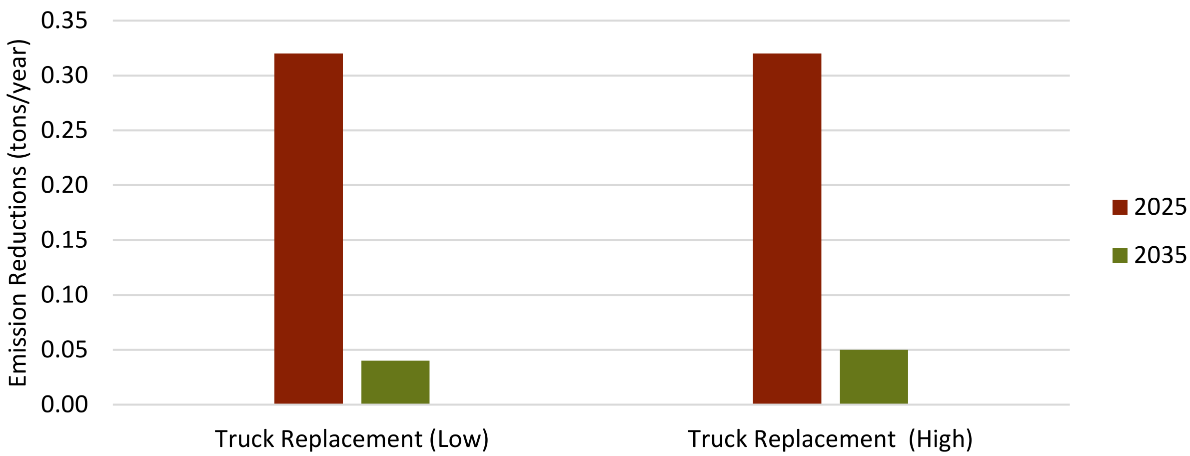

Figure 9-10. Off-port Truck $PM_{2.5}$ Reduction Strategies

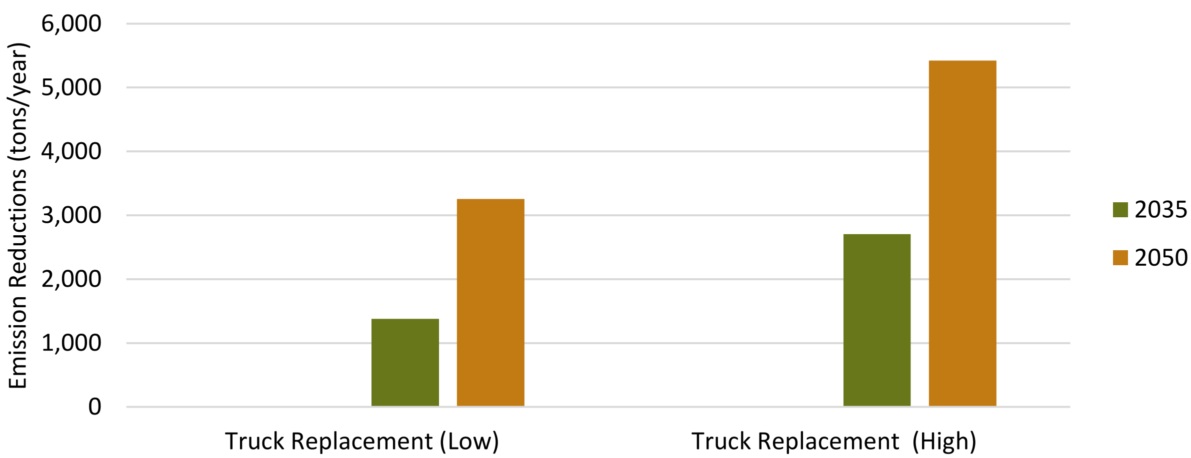

Figure 9-11. Off-port Truck CO_2e Reduction Strategies

Table 9-23. Total Reductions from BAU Emissions for Off-port Truck Replacement Scenarios

Year	Scenario	Emissions (tons/year)							
		NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e
2025	Low	2.52	0.34	0.32	0.34	0.32	0.15	0.33	--
	High	3.12	0.35	0.32	0.35	0.32	0.15	0.33	--
2035	Low	1.25	0.04	0.04	0.04	0.04	0.01	0.06	1,376.60
	High	2.00	0.06	0.05	0.06	0.05	0.01	0.09	2,704.37
2050	Low	--[a]	--	--	--	--	--	--	3,255.01
	High	--	--	--	--	--	--	--	5,425.02

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

Table 9-24. Percent Reductions from BAU Emissions for Off-port Truck Replacement Scenarios

Year	Scenario	Percent Reductions from BAU Emissions							
		NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e
2025	Low	23.65%	66.91%	67.02%	68.04%	68.04%	67.77%	52.08%	--
	High	29.25%	67.67%	67.78%	68.81%	68.81%	68.54%	53.29%	--
2035	Low	18.55%	21.53%	21.55%	22.21%	22.16%	21.52%	18.61%	14.08%
	High	29.56%	29.28%	29.39%	30.20%	30.23%	29.35%	28.02%	27.67%
2050	Low	--[a]	--	--	--	--	--	--	28.23%
	High	--	--	--	--	--	--	--	47.05%

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

9.4 Off-port Rail Corridor

The off-port rail corridor was defined as the rail segment that starts at the on-port boundary of the ICTF spur and extends 10 kilometers north of Port Everglades. The FECR operates both the on-port ICTF as well as the port-related activity in the rail corridor. As with the off-port marine and truck corridors, determining the length of the off-port rail corridor was a challenging but important decision, as it is a primary determinant of the estimated size of the emission inventory and the potential for emission reductions. For this analysis, a length of 10 kilometers was chosen, because it is expected that most trains leaving Port Everglades can reach a steady-state travel speed by this distance. A longer corridor was not selected to simplify the analysis and to keep the scope of the inventories limited to the vicinity of the Port. Figure 9-12 illustrates the rail corridor, highlighted in green, and Port Everglades, outlined in red.

This section presents the baseline emissions inventory and the projected Business as Usual emissions for the off-port rail corridor (Section 9.4.1), a discussion of considered strategies to reduce emissions (Section 9.4.2), and a summary of the related results and lessons learned (Section 9.4.3).

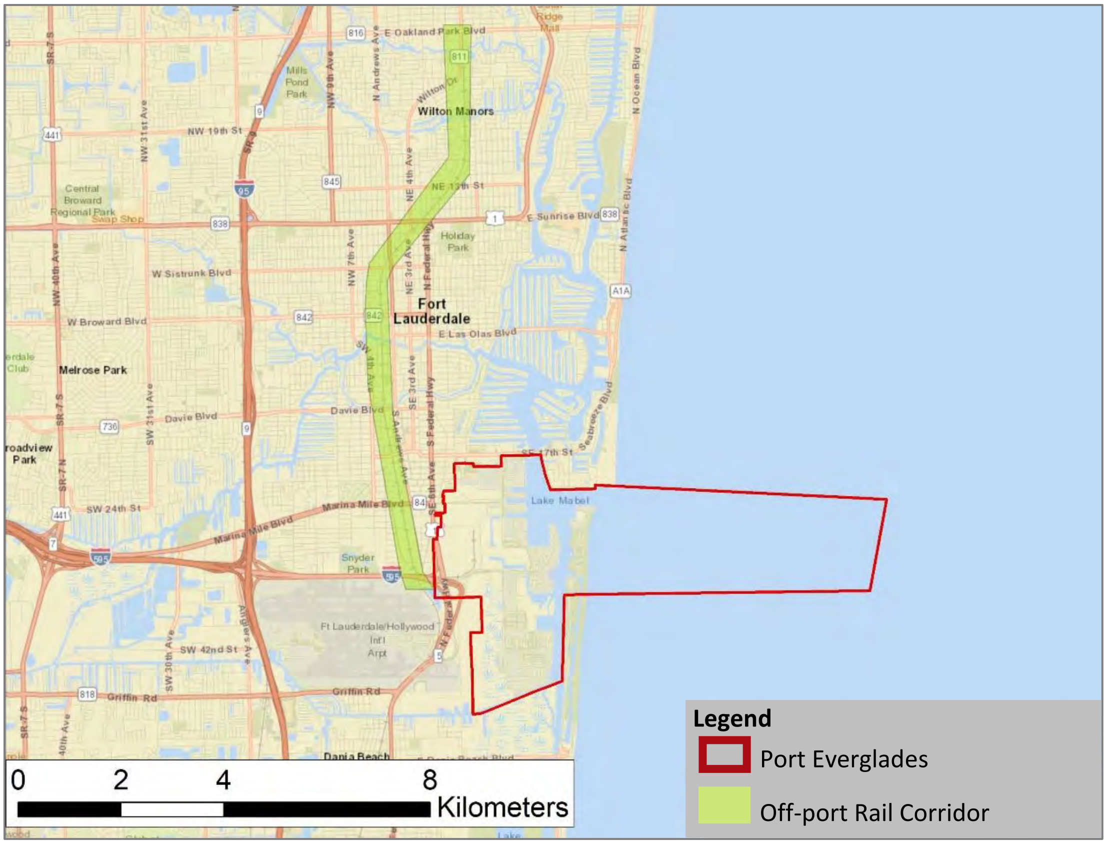

Figure 9-12. Off-port Rail Corridor

9.4.1 Baseline and Projected Business as Usual Inventories

The baseline and BAU projection methodologies used to estimate off-port rail emissions are consistent with the methodologies used to estimate on-port emissions as described in Section 8.1. To ensure consistency, the same rail throughput was included in both analyses. However, unlike in the on-port analysis where both idling and transit activity occur, in the off-port rail corridor, no idling activity was assumed and transit was the only mode of operation included in the analysis.

In general, the 2015 baseline emissions for each train trip were calculated on an activity basis using the following equation:

$$E = L \times GT \times FCF \times EF \times UCF \quad \textbf{Eq. 9-4}$$

Where:

E	=	Emissions (tons)
L	=	Length of rail corridor (km)
GT	=	Gross mass per train (tons)
FCF	=	Fuel consumption factor (gal/ton-km)
EF	=	Emission factor (g/gal)
UCF	=	Unit conversion factor (1.102×10^{-6} ton/g)

Annual baseline off-port rail emissions were determined by defining a rail corridor length of 10 kilometers and using assumptions that are consistent with the 2015 On-port Baseline Inventory, such as the number of annual train trips, gross mass per train, fuel consumption factor, and emission factors.

To estimate BAU off-port rail emissions for future years, the same BAU scenario developed for the on-port analysis was used for this off-port analysis, based on Port Everglades' *2014 Master/Vision Plan*.[125] Hypothetical future emission inventories were estimated for 2025, 2035, and 2050[126] by starting with the 2015 baseline off-port emissions, applying the projected container freight growth factors, and then applying adjustment factors based on expected changes in the fleet emission factors for each future year. See Section 8.1 for further details on this analysis. A summary of baseline and BAU projected emissions for the off-port rail corridor are presented in Table 9-25.

Table 9-25. Baseline and Projected BAU Emissions for Off-port Rail Corridor

Year	Mode	Annual Emissions (tons/year)							
		NOx	PM_{10}	$PM_{2.5}$	DPM_{10}	$DPM_{2.5}$	BC	VOC	CO_2e
2015	Transit	2.59	0.04	0.04	0.04	0.04	0.03	0.07	261.04
2025	Transit	2.88	0.06	0.05	0.06	0.05	0.03	0.66	329.95
2035	Transit	2.76	0.07	0.07	0.07	0.07	0.05	1.49	377.09
2050	Transit	--[a]	--	--	--	--	--	--	389.56

[a] A double dash ("--") represents a value that was not calculated as part of this analysis.

Based on the assumptions in this analysis, emissions are projected to increase for most pollutants due to projected growth in freight throughput. These projections likely overestimate expected future rail emissions because the assumptions regarding FECR's planned increase in the use of dual fuel diesel/LNG powered engines assumed a much longer phase in period.

9.4.2 Emission Reduction Strategies and Scenarios

The only on-port rail emission reduction strategy considered was an intermodal shift of cargo from truck to rail. This serves as an example case where the actions a port takes to reduce emissions on-port can also reduce emissions beyond the boundary of the port itself. However, quantifying the emission reductions for the corridors selected in this analysis is of limited value. Because the truck and rail corridors were defined to be different lengths, emission reductions in the truck corridor due to this strategy are not directly comparable to the associated emission increases in the rail corridor. Therefore, emission reductions resulting from the truck-to-rail intermodal shift strategy are not reported here quantitatively.

Directionally, truck emissions occurring in the off-port onroad truck corridor would be reduced while locomotive emissions in the off-port rail corridor would increase. It is expected that if the

[125] Port Everglades, *2014 Master/Vision Plan* reports, June 24, 2014.

[126] Note that for 2050, only CO_2e inventories and reductions were quantified.

analysis could calculate total emissions for all trips, from origin to destination, for both truck and rail modes, the modal shift from truck to rail would result in net decreases in emissions.

9.4.3 Emission Reduction Scenario Results and Lessons Learned

While of limited use for comparing off-port emission reduction strategies for this analysis, the off-port truck emission inventories and the truck-to-rail intermodal shift strategy emission reduction results, described in Section 8.3, can be instructive and provide an indication of the potential of the strategy for reducing emissions off-port. It is important to note that this analysis benefited from having detailed cargo throughput data to form the basis of these inventories. Data received from FECR through consultation with Port Everglades improved the analysis. However further improvements could be achieved by refining the geographical bounds of the analysis zone to facilitate comparison with the onroad corridor results, as well as accounting for the conversion of locomotives to dual fuel diesel/CNG engines earlier than what was assumed in the BAU scenario.