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Adopting Renewable Diesel for Aviation Ground Support Equipment

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Disclaimer: The MPA in Environmental Science and Policy (ESP) Capstone course is designed to integrate the topics introduced in the program as students and faculty work to address critical environmental sustainability policy and management issues. During the final program semester, ESP students undertake special analytical projects for public and nonprofit agencies to learn how to conduct multidisciplinary policy analysis for clients and to provide a public service. This report was prepared for our client, the Port Authority of New York and New Jersey, and the Columbia Team is solely responsible for its content.

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EXECUTIVE SUMMARY

The Port Authority of New York and New Jersey (PANYNJ) operates critical transportation infrastructure to meet the needs of the region, including five major airports, as well as bridges, tunnels, and marine transport. Over the past decade, PANYNJ has adopted sustainability as a focus area, as evidenced by its commitments to the Paris Climate Accord in 2018 followed by the launch of its Net Zero Roadmap in 2023. The Net Zero Roadmap established ambitious goals to reduce greenhouse gas (GHG) emissions by 50% from 2006 levels by 2030 and achieve net-zero emissions by 2050. This work entails initiatives such as transitioning Aviation Ground Support Equipment (GSE) to zero-emission technologies. Electrification challenges and the absence of direct operational management of airport equipment have prompted the Authority to explore renewable fuels as a viable interim solution.

In January 2023, the Port Authority requested the support of a Capstone[1] Team of graduate students from the Environmental Science and Policy MPA Program at Columbia University, to evaluate the feasibility of using Renewable Diesel (RD) in GSE. The Authority's objective in doing so was to explore renewable diesel as an interim solution to achieve emission reductions as they advance toward complete GSE electrification.

In our research, the Capstone Team focused on John F. Kennedy, LaGuardia, and Newark Liberty airports, reviewing the literature, analyzing data, and interviewing industry experts to assess the viability of RD. Our report finds that RD is a helpful transition fuel because of its compatibility with existing GSE as a drop-in fuel and decreased GHG emissions. However, there are still barriers to RD adoption, including negative environmental externalities, supply chain logistics, and high production costs. To overcome these challenges, our recommendations for PANYNJ include stipulating favorable feedstocks in RD procurement, leveraging existing distribution networks, and combining tenant RD demand to lower costs. These actions aim to align PANYNJ's operational practices with its environmental goals, serving as a model for sustainable transportation management.

I. Introduction

The Port Authority of New York and New Jersey (PANYNJ) was established in 1921 through an interstate compact authorized by the United States Congress. The Authority's stated mission is to "meet the critical transportation infrastructure needs of the bi-state region's people, businesses, and visitors by providing the highest quality and most efficient transportation and port commerce facilities and the services to move people and goods within the region, provide access to the nation and the world, and promote the region's economic development."[2] The Port Authority operates five airports: Newark Liberty, John F. Kennedy, LaGuardia, Stewart, and Teterboro. It also operates many of the tunnels, bridges, ports, and bus terminals in the New York-New Jersey region, as well as the Port Authority Trans-Hudson (PATH) rail system.

Image Source: New York YIMBY

The Authority's vision has evolved over time to prioritize sustainability in its infrastructure throughout the region. In 2018, the PANYNJ was the first public transportation agency in the United States to embrace the Paris Climate Agreement. Five years later, the Authority concretized its commitment to the Agreement when it announced its Net Zero Roadmap to reduce greenhouse gas (GHG) emissions by 50% from 2006 levels by 2030 and achieve net zero emissions by 2050.

One strategy to meet this goal is to transition specialized aircraft ground support equipment (GSE) to zero-emission. However, many zero-emission GSE alternatives are not available given the barriers to electrification and limitations of current hydrogen and battery technologies. The Port Authority has the added complication of not directly controlling the majority of this equipment, as the airport terminals are leased to the tenants, including airlines, GSE operators, and fuel providers. One option to fill this transition gap is with the rapidly developing technology of renewable fuels, specifically renewable diesel.

In the spring of 2024, the Port Authority's Office of Sustainability Management requested a team of graduate students from the Environmental Science and Policy MPA Program at Columbia University to conduct a study that would help the Authority better understand the benefits and limitations of renewable fuels. Specifically, the Authority requested that the team:

Evaluate the viability of renewable fuels at the Port Authority Airports by looking at the benefits of using renewable fuels in place of diesel for hard-to-electrify vehicles and equipment until a true zero-emission option is realized.

This report is the culmination of an in-depth three-month study, including extensive literature review and interviews with experts from government and industry, to address PANYNJ's questions and propose a set of recommendations (please see: Executive Summary and Section X Recommendations). The airports for the study include John F Kennedy (JFK), La Guardia (LGA), and Newark Liberty (EWR). JFK sees the largest volume of both passengers and cargo at 63 million passengers and 1.3 million tons of cargo annually, with EWR being the second largest. With these three airports in mind, our Team reviewed over thirty literature sources, including academic and government reports, and analyzed PANYNJ data to understand the benefits and limitations of renewable diesel adoption. We also interviewed sixteen industry experts to gain insights into the political landscape and major barriers to uptake. The research methodology is detailed in Appendix 1.

II. Background

PANYNJ is committed to environmental sustainability and has pursued ambitious initiatives to transition its operations towards renewable energy sources. With the increasing threat of climate change and the transportation sector accounting for nearly a third of United States (US) GHG emissions, it is critical to reduce the sector's carbon footprint. In 2018, the Port Authority became the first public transportation agency in the United States to embrace the Paris Climate Agreement, committing to cut its carbon emissions by 50% from 2006 levels by 2030 and achieve net zero emissions by 2050. In 2019, the Port Authority saw about a 20% reduction in its direct emissions from 2006, with the majority of the remaining carbon footprint coming from tenant operations (53%) and customers (44%).

Direct emissions come from the Port Authority's own operations and are targeted for a reduction of 35% by 2025, and 50% by 2030. Indirect emissions come from the actions of tenants, customers, and employees operating at PANYNJ facilities and account for 94% of the Port Authority's total GHG emissions. Airport tenants include any company operating on the Port Authority's grounds, including airlines, GSE operating companies, and fuel providers. These company emissions targets are mixed, in terms of levels and timelines for reduction. However, the Port Authority is committed to net zero for all direct and indirect emissions by 2050.

The Port Authority introduced the Zero Emission Airside Vehicles (ZEAV) Rule in 2022 to expedite the shift to zero-emission Ground Support Equipment (GSE) across the three major airports. The rule requires that any tenants operating GSE meet the ZEAV requirements to transition to electric vehicles. Some airlines own and operate their own GSE fleet, while other airlines contract GSE operating companies to service their aircraft. Failure to fulfill the requirement could jeopardize GSE operating agreements. The ZEAV plan entails a phased implementation strategy, involving collaboration with key stakeholders such as airlines and GSE owners. Depending on the GSE type, certain equipment will be mandated to transition to zero-emission by 2027, while the remainder will be required to comply by 2030.

However, the reality is that the actualization and enforcement of ZEAV faces two significant obstacles, both of which are central to achieving net-zero emissions:

Obstacle 1: Technology Limitations

Limitations on current technology, charging logistics, and infrastructure may impede electrification efforts, especially on this accelerated timeline.

- The technology for zero-emission GSE alternatives is not commercially available for larger equipment such as snow plows and emergency equipment
- Charging electric fleets poses significant logistical challenges to allow for charging times with the high frequency of GSE use.
- Electrification poses challenges to infrastructure reliability and resilience, in terms of both the grid's ability to meet increased load demand, the Port Authority's electrical infrastructure capacity, and the operational security concerns associated with interruptions to electricity supply.

Obstacle 2: Operational Control

The second obstacle is that the Port Authority has no direct control over airlines' use of equipment at the airports. As mentioned above, tenants account for 94% of the Port Authority's total GHG emissions. Tenants are responsible for installing charging infrastructure for electric vehicles on their leased property. The Port Authority helps tenants secure grant funding and work towards electrification in some circumstances, but tensions exist around the capacity of the Port Authority's grid infrastructure and the high costs associated with installing charging infrastructure.

The rapidly developing technology of renewable fuels is one option to address these challenges in the interim. This report discusses the feasibility of employing renewable diesel (RD) as an alternative to petroleum diesel for GSE. GSE emissions may only account for 4% of Port Authority's total GHG emissions, but this represents over 250,000 metric tons of CO_2e annually — the equivalent of CO_2 emissions from 59,000 gasoline-powered passenger vehicles driven for one year. Given the substantial environmental impact of GSE emissions, integrating RD as a transition fuel could reduce PANYNJ's carbon footprint until complete electrification is realized. The Port Authority has already been using RD in its personal operating fleet since June 2023 to lower its direct emissions, and they have not faced challenges with this transition. Below, we explore what renewable diesel is and why it is the best renewable fuel for diesel GSE.

III. Renewable Diesel Overview

Renewable diesel (RD) is a biomass-based fuel that can substitute the use of petroleum diesel within an organization's energy portfolio. It can be produced with various feedstocks such as used cooking oils, animal fats, plant oils, and agricultural waste. RD is a hydrocarbon that can be used as a drop-in fuel meeting ASTM D975 specifications, meaning it can be used in existing diesel-fueled engines without any modifications with or without blending because of its chemical equivalency to petroleum diesel.[3] RD is also produced in a similar hydrogenation process as petroleum diesel, enabling producers to convert existing petroleum refining assets for RD production with modest costs. This process entails reacting a lipid feedstock with hydrogen at high temperatures and pressures with a catalyst present. RD can also be produced through pyrolysis, gasification, and other bio- or thermo-chemical processes.[4]

It is important to note that renewable diesel is a different fuel than biodiesel. Biodiesel is another renewable fuel that is often confused with RD, but biodiesel and RD are distinct in several significant ways related to their production, storage, emissions profile, and compatibility. Biodiesel is considered a "first generation" technology, whereas renewable diesel is a "second generation" technology due to several key advantages. In terms of production, RD can be made from a much wider variety of feedstocks than biodiesel which is made via transesterification.[5] Additionally, the ensuing byproduct– propane, in the case of RD, is preferable over glycerol, in the case of biodiesel production.[6] Biodiesel production projects are also more time-consuming and laborious to develop.[7] In addition to the aforementioned infrastructure compatibility benefits, RD contains superior cold-weather properties, making it easier to store and transport than biodiesel.[8] RD is also a more productive fuel in terms of having a higher heating content and cetane number than biodiesel.[9]

Biodiesel does present certain advantages. A 2022 life cycle assessment found that oil-based biodiesel production creates fewer GHG emissions than oil-based RD since transesterification requires less energy than hydro-processing. However, when using high free fatty acids like tallow as feedstocks, biodiesel production results in higher GHG emissions than RD.[10]

positive feature | neutral feature | negative feature

Fuel Type	Feedstock	Emission Reductions	Energy Density	Compatibility	Cost[1], $/gallon	Specification
Conventional Diesel	Crude oil	None	High	Standard for diesel engines	3.94	ASTM D975
Biodiesel	Soybean oil, used cooking oil, animal fats	Up to 75%	Slightly lower than diesel	Blends with diesel for direct use	3.83 – 4.69	ASTM D6751
Ethanol	Corn, sugarcane	up to 50%	Lower than gasoline	Blends with gasoline or direct use	2.55	-
Renewable Diesel (RD)	Animal fats, used cooking oil, plant oils	Up to 80%	High	Direct drop-in replacement	5.37	ASTM D975

Figure 1: Basics of fuel types. Note 1. between January 1 and January 16, 2024
(Source: Clean Cities Alternative Fuel Price Report, January 2024)

Additionally, RD tends to require higher inputs of feedstocks than biodiesel because a higher ratio of material is lost in the RD production process.[11] The difference is slight, with biodiesel requiring 7.5 pounds of feedstock per gallon compared to 8 pounds of feedstock per gallon for RD.[12] However, because of RD's superior cold weather performance and ability to be used as a drop-in fuel in existing vehicles, it is a more feasible renewable fuel option for the Port Authority than biodiesel.

As the Port Authority begins efforts to transition to RD, there are several key stakeholders involved. The consumers of RD are Port Authority's tenants, which includes companies operating at PANYNJ airports, such as airlines and GSE operators. Fuel distributors are the entities that would provide RD to the airports, including companies such as Sprague, Approved Oil, and Global Partners LP. Fuel suppliers manage the distribution and storage of the fuel. These fuel distributors procure RD from fuel producers, which are mainly located outside of the Northeast region. Currently, there are over 16 RD refineries located in the US, managed by 12 different producers, including Neste, Diamond Green Diesel, and Marathon Petroleum Corporation.

This report describes how RD is a helpful transition fuel because of its compatibility with existing GSE as a drop-in fuel and decreased GHG emissions. However, RD presents distinct challenges including supply chain logistics, production procedures, and storage requirements.

Addressing these issues promptly is crucial, not only from the user's standpoint but also from that of the supplier, to justify the transition to RD usage. This report examines the advantages and disadvantages of RD through the viewpoints of producers, distributors, and end users to understand the hurdles associated with transitioning PANYNJ's GSE to RD.

IV. Renewable Diesel Production Process

RD is made through a hydro-processing technique that alters the chemical structure of biomass-based feedstocks to closely resemble conventional petroleum diesel.[13] This process refines the feedstock and maximizes the energy output, making RD a more environmentally friendly and versatile alternative to conventional diesel.[14] RD is made of feedstocks from various sources, including animal fats, used cooking oil, and vegetable oils, such as soybean oil, palm oil, and canola oil.[15] RD producers like Neste and Diamond Green Diesel focus on utilizing a diverse feedstock portfolio, emphasizing recycled and waste materials to reduce environmental impact and enhance sustainability.[16]

The production process begins with feedstock collection and preparation, where waste and residue materials such as agricultural byproducts, waste cooking oils, animal fats, and even municipal solid waste are collected. These materials are prepared for processing, which may involve cleaning, drying, and shredding. Next, in the conversion processes, solid waste undergoes thermal depolymerization or hydrothermal liquefaction, while liquid feedstocks are purified, making them suitable for further processing.

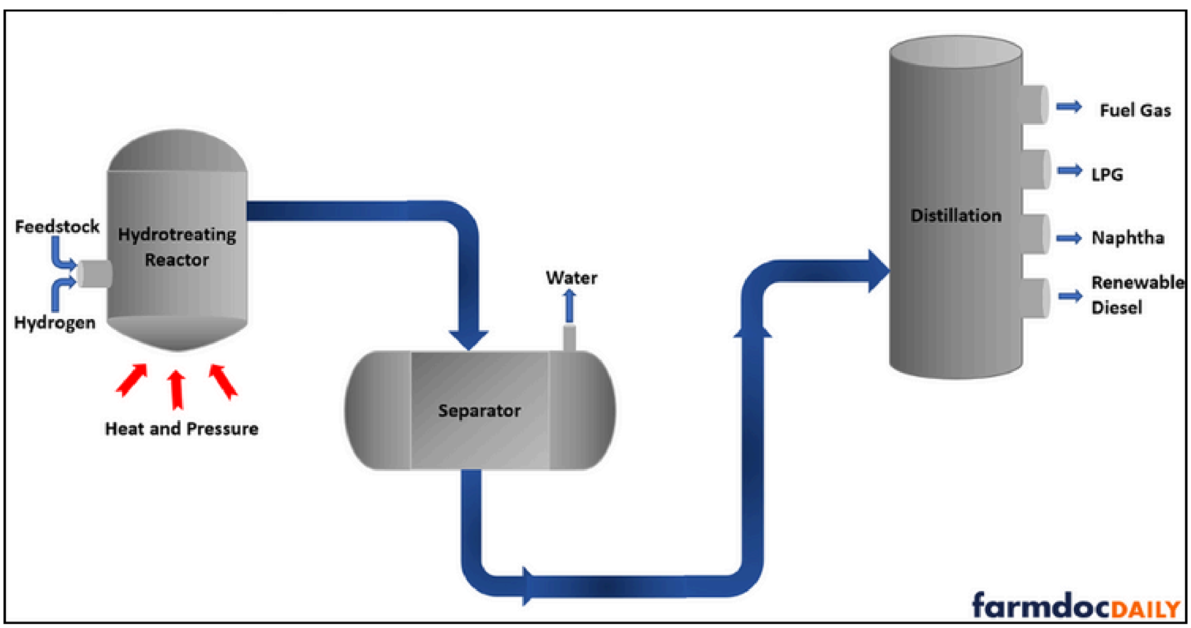

Figure 2: Renewable diesel production process (Source: farmdocDaily)

Hydro-processing, the core process, includes hydrodeoxygenation (removing oxygen from feedstock molecules), hydrocracking (breaking longer hydrocarbon chains into shorter ones), and isomerization (rearranging hydrocarbon molecules), in the presence of hydrogen gas and a catalyst. This converts the feedstock into hydrocarbons resembling those in petroleum. After hydroprocessing, the product mixture is fractionated to separate the renewable diesel molecules from lighter and heavier components, which is further refined to meet diesel fuel standards. Finally, RD may be blended with conventional diesel or additives to enhance properties such as oxidation stability and lubricity.

RD has two major benefits compared to petroleum diesel: decreased GHG emissions and compatibility with existing infrastructure.

1. Environmental

Switching from conventional to renewable diesel has the potential to reduce PANYNJ and its tenants' greenhouse gas emissions. RD produces fewer carbon dioxide and nitrogen oxide emissions compared to conventional diesel. As part of its Low Carbon Fuel Standard (LCFS) program, California's Air Resources Board certified carbon intensities for various fuels and determined that RD reduces carbon intensity by approximately 65%.[17] With the potential to use waste biomass as a feedstock for RD production, this process could further reduce greenhouse gas emissions by diverting waste from landfills.

2. Engine & Infrastructure Compatibility

Since RD is produced, transported, and utilized in the same manner as petroleum diesel, this fuel is highly compatible with existing infrastructure. This prevents the need to retire and replace existing production, transportation, and GSE assets, which can have long lifetimes, thereby generating capital cost savings compared to other carbon-free alternatives.[18] The fact that existing assets can be used means that RD production is easier to scale up.

However, the journey toward RD adoption does come with tradeoffs, primarily environmental.[19] The cultivation of energy crops for RD can lead to deforestation, habitat loss, and competition with food crops, raising concerns about food security and biodiversity. This highlights the importance of sourcing feedstock from waste and residues to mitigate these effects.

Furthermore, the hydrotreatment process requires significant water inputs, which can exacerbate water scarcity issues because of diversion to energy production. This underscores the need for efficient water management practices in RD production facilities to minimize environmental footprints. Further details on the limitations of RD are explained below.

Feedstocks

There are substantial variations in the environmental impacts and financial costs associated with different feedstocks, which in turn, contribute to the costs and externalities associated with RD production. Given these negative externalities, governments have attempted to use life cycle assessments (LCAs) to determine the environmental impact of using different feedstocks for biofuel production. For example, the Dutch government is evaluating feedstocks to incorporate factors such as GHG emissions, biodiversity, competition with food supplies, economic prosperity, and other environmental impacts into LCAs.[20] A recent LCA found that when RD is produced with feedstocks such as soybean, canola, and carinata oils, it can reduce GHG emissions from 40% to 69% compared to petroleum diesel when considering factors such as land-use change.[21] The same 2022 study found that utilizing feedstocks such as tallow, waste cooking oil, and distillers corn oil to produce RD can reduce GHG emissions even further compared to petroleum diesel, at 79% to 86% reduction.[22] A thorough assessment of RD's life cycle should include emissions from crop farming such as fertilizer use and nitrous oxide emissions, as well as energy and chemical inputs needed for oil production. The following are some of the limitations and negative environmental or social impacts of commonly used RD feedstocks.

Competition with Edible Crops

A common concern with biofuel production in general is that diverting edible crops for fuel production can cause competition for food sourcing and increase food prices in areas already facing food insecurity. In the case of RD, feedstocks such as soybean, palm, and rapeseed oils face this potential social and economic drawback.[23] However, in addition to waste biomass, nonedible crops like jatropha can be used to produce RD.

Oil Yield Efficiency

RD feedstocks have varying efficiencies of oil yield, thereby creating inconsistencies in the energy rate produced per acre. For example, soybeans are a less productive crop than others used as feedstock, with about an 18% oil yield.[24] In comparison, rapeseed oil yields are double that of soybean oil, and palm oil yields can be ten times greater. Algae oil yields can be nearly 30 times the rate of palm oil.[25]

Fertilizer Intensity & Water Quality

Cultivation for certain RD feedstock crops requires large inputs of chemical fertilizers. Such fertilizers have negative environmental impacts because they are energy-intensive to produce and cause water pollution when runoff makes it to natural waterways, causing dead zones.[26] For example, rapeseed cultivation requires high nitrogen fertilizer inputs, leading to a higher energy input than soybean oil production and a higher rate of water pollution. An advantage to soybean oil as a feedstock is that the crop is nitrogen-fixing, requiring little to no nitrogen fertilizer inputs to grow.

Deforestation

Given varying oil yield efficiency and crop characteristics, certain feedstock crops require more or less land area to produce. For example, soybean cultivation is a major driver of deforestation in the Amazon Rainforest region of Brazil. Deforestation causes the loss of carbon sinks and reduces the earth's capacity to absorb and offset greenhouse gas emissions, thereby increasing the atmosphere's warming. In Indonesia, peat land conversion to palm oil cultivation resulted in the country becoming the world's third-largest emitter of greenhouse gasses in 2006.[27] Between 1990 and 2005, palm oil cultivation in Indonesia expanded by 4.2 million hectares, contributing to the deforestation of approximately 1.7 million hectares of primary tropical forests.[28]

Ecological Impacts

Cultivation of feedstock crops for RD production can also cause ecological harm in certain circumstances. For example, soybean cultivation can cause drought due to the increased albedo of land cleared for farming which causes higher rates of soil-water evaporation.[29] Additionally, while inedible feedstocks like jatropha do not compete with food sourcing, it is toxic to wildlife and livestock, leading countries like Australia to ban the plant and label it an invasive species in 2006.[30]

While the preceding sections highlight the viability of RD as a preferable option over other biofuels, this assessment hinges on variables such as utilized technology, production expenses, and the choice of feedstock. While certain technologies, such as hydrotreating, boast a closed-loop system ensuring water recycling, this may not be universally applicable across all methods.

Image Source: Litum

V. Renewable Diesel Supply Chain

The RD supply chain is best understood by assessing its production, distribution, and consumption.

Production

European producers currently dominate the global RD market due to early adoption and widespread diesel use. These producers represent 45% of global RD production as of 2021.[31]

In the United States, most RD production is located in the western and central parts of the country, with production concentrated in California and Louisiana.[32] Some sources have projected that domestic RD production will balloon in the coming years: according to the Business & Industry Connection magazine, RD production is expected to grow from 2.7 billion gallons in 2021, to 7.45 billion gallons by 2027.[33] There are 16 RD production plants in the US, and another 16 are expected to be in operation by the end of 2025. However, as of February 2024, there is only one planned refinery in the Northeast which could pose challenges for sourcing. New transportation networks may need to be developed to source RD from other regions. Without local production, transportation costs can be much higher for end-users. The GHG emissions from transportation should also be factored into the total RD cost. The steps of production in the supply chain before consumption are shown below in Figure 3.

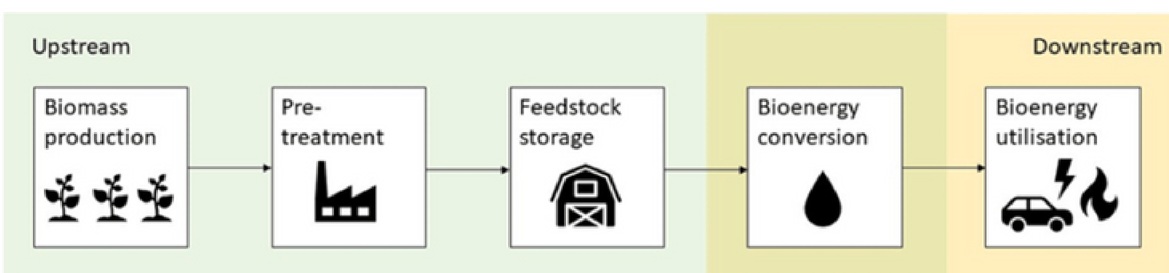

Figure 3: Example of a renewable diesel supply chain illustrating production steps.

Three major RD producers in the United States are Neste, Diamond Green Diesel, and Marathon Petroleum Corporation. Neste, the world's largest RD producer with an annual capacity of 4.5 million tons of renewable products, partnered with PANYNJ on a sustainable aviation fuel (SAF) pilot.[34] Neste RD is produced at Neste plants in Martinez, California; Singapore; Rotterdam, Netherlands; and Porvoo, Finland.[35] Neste RD comprises a variety of feedstocks, but the top three renewable raw material categories used are animal fat waste, used cooking oil, and various wastes and residues from vegetable oil processing. Neste is already partnering with airports globally to supply SAF, used by airlines such as Delta, United, and DHL.

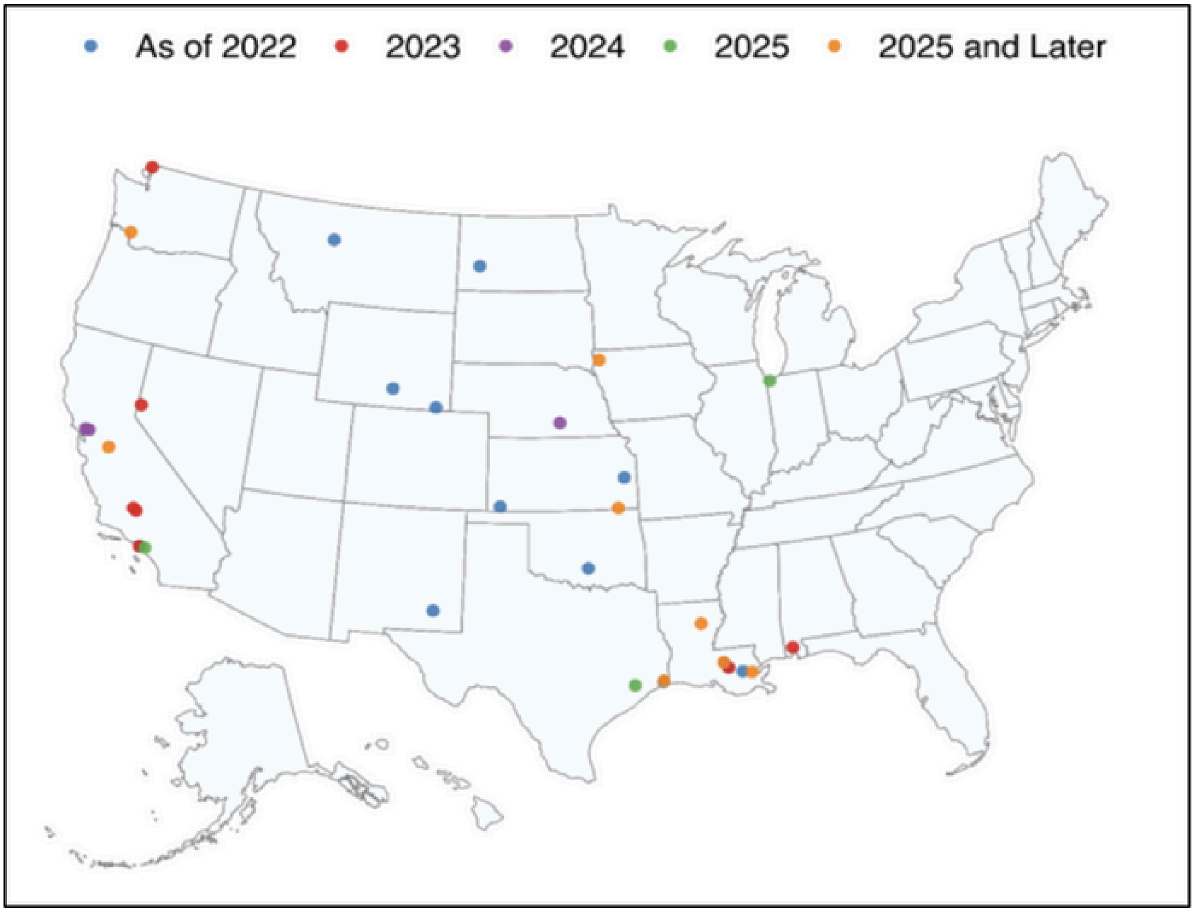

Figure 4. Locations of Renewable Diesel Production Plants in the United States, Actual for 2022 and Projected for 2023-2025 and later. (Sources: EIA, farmdocDaily)

Diamond Green Diesel is the largest renewable producer in North America and the second-largest globally, with a capacity of 1.2 billion gallons per year. They utilize recycled animal fats, used cooking oil, and inedible corn oil as feedstock.[36] Additionally, Diamond Green Diesel processes 10% of the world's inedible meat by-products and is the largest collector and processor of used cooking oil in North America.[37]

Marathon Petroleum Corporation, a leading energy company, operates several renewable fuel projects across the United States. Marathon Petroleum Corporation holds joint ventures with Neste and ADM, contributing 989 million gallons annually. One notable project is the Martinez Refinery in Martinez, California, jointly owned by Neste. The Martinez Refinery boasts a total capacity of 730 million gallons and utilizes 600 million pounds of refined soybean oil annually as feedstock.[38]

Distribution

The major RD distributors in the United States supply a variety of sectors largely driven by the need to meet environmental and sustainability goals, particularly in reducing GHG emissions and complying with renewable fuel standards. California is a particularly significant market due to its robust renewable energy policies and incentives. For these reasons, RD and biodiesel combined reached 59% of total diesel fuel use in California during the first half of 2023.[39]

RD is transported throughout the supply chain in a multimodal manner. Rail is utilized as much as possible given its lower emissions profile. Train tank cars used to transport RD are usually operated by the shipper and leased from companies including Greenbrier, CIT, and UTLX.[40] Feedstocks are also often shipped via rail to RD producers, with Union Pacific Railroad (UP) serving more than one hundred feedstock locations, primarily in the Midwest. Trucking has also been used as needed for smaller shipments and first- or last-mile deliveries.[41] The RD distributors in the NYNJ region, such as Sprague and Approved Oil, primarily source RD through barge transport since producers are not located within the Northeast region. Barge transport has the smallest carbon footprint compared to truck and rail, with rail generating over 30% more CO2 and trucking with over 1000% more CO2 per million-ton miles.[42]

Initially established in 1870 as a coal and petroleum products distributor, Sprague has evolved to become one of the leading independent energy product and related service distributors in the Northeast region of the United States.[43] In June 2023, Sprague introduced RD to the New York Metropolitan Area, making it available for delivery and transport rack loading at their Bronx Terminal, New York City's largest storage and rack loading facility. Sprague prides itself on being the first to offer RD on the East Coast, declaring that its members would have the opportunity to operate their vehicles with a lowered emissions rate of up to 85% compared to petroleum diesel.[44]

Sprague is the primary RD distributor for the PANYNJ fleet. Airport tenants are not using RD currently, and no additional RD supply enters the airports besides the usage from the PANYNJ fleet. Sprague procures its RD from producers in Louisiana, and the fuel arrives by barge to New York Harbor. The Port Authority has RD storage tanks at each airport site that are outsourced to Sprague, and Sprague delivers the RD in large tractor-trailers to their facilities.

Other RD distributors in the Northeast region include Global Partners LP and Approved Oil. Global Partners LP, with its headquarters in Waltham, Massachusetts, operates as a diversified energy supply company, engaging in the distribution of gasoline, distillates, residual oil, and renewable fuels to wholesalers, retailers, and commercial customers throughout the Northeast.[45] In June 2023, Global Partners LP announced that the company is advancing RD availability in New York by introducing RD at its Albany terminal, aimed to support New York State's climate goals and help customers reduce diesel GHG emissions.[46]

Approved Oil, headquartered in Brooklyn, New York, is a leading provider of heating oil, biofuel, and related services in the New York metropolitan area.[47] Approved Oil has been awarded a contract by New York City to supply RD for the fleets of several city departments, including Sanitation, Police, Fire, Environmental Protection, Transportation, Parks and Recreation, and Correction. This strategic plan emphasizes the company's role in reducing carbon emissions and supporting the City's green initiatives. The contract also aligns with New York City's plans to transition all heavy-duty vehicles to renewable fuel by the end of Fiscal Year 2024.[48]

VI. Renewable Diesel Market in the NYNJ Region

The current landscape of RD is characterized by a significant shift towards sustainable energy solutions, especially within sectors with high energy demands and a critical cut down on carbon emissions.[49] At present, the transportation sector emerges as the leading consumer of RD, with heavy-duty vehicles, including trucks, buses, and industrial equipment, utilizing RD to meet both environmental regulations and performance needs. Public transportation entities and logistics companies are at the forefront of this transition, driven by a combination of regulatory requirements and a growing commitment to environmental stewardship.

In New York State, the Clean Fuel Standard (CFS) was proposed in January 2024 to reduce carbon emissions by 30% by 2032 in the transportation sector, with further reductions to be implemented based on advances in technology.[50] This standard would require producers of high-carbon intensity fuels to transition to lower carbon alternatives, such as electricity, hydrogen, and biofuels, using a credit-based system to drive the state towards cleaner transportation options. With successful implementations on the West Coast, a CFS in New York is seen as crucial for meeting ambitious climate goals without significant state expenditure.[51]

Given the proposed CFS and increasing demand for RD to meet emission reduction goals, rising demand signals will likely attract new RD producers and distributors to the NY market over time. However, new entrants face high capital costs and a years-long process of planning, permitting, and constructing new biorefineries locally. RD prices in the NY region may increase in the short-to-medium term before substantial new local production comes online. Competition from new market entrants could eventually moderate pricing, but likely not until new regional plants start operations or large-scale transportation from other states becomes efficient. The federal government could implement targeted subsidies and tax credits to help lower RD prices in the NY region in the short-to-medium term, such as production subsidies for RD manufacturers, incentives for sourcing feedstocks, or funding support for RD infrastructure investments.

As demand for RD continues to grow, the aviation and maritime sectors are set to become substantial users of RD. The aviation industry is under considerable pressure due to its substantial contribution to global greenhouse gas emissions, necessitating urgent measures to adopt cleaner, sustainable fuel alternatives and technologies to mitigate climate impact. Thus, making RD an attractive alternative to conventional jet fuels. Similarly, the maritime sector is turning to RD as a means to meet stringent international emissions standards and reduce the ecological footprint of global shipping operations. These shifts reflect a broader industry movement towards sustainability and compliance with global environmental standards, which are set and pursued by the International Civil Aviation Organization.[52]

In the context of a recommended transition to more sustainable practices, the agricultural and manufacturing sectors are also expected to increase their RD usage.[53] Agriculture, with its reliance on diesel-powered machinery, and manufacturing, particularly in processes requiring high thermal energy, are looking to RD as a solution to reduce emissions without sacrificing operational efficiency. This trend is facilitated by improvements in RD technology and production, which are making RD more accessible and economically viable for a diverse range of industrial applications.

In summary, market demand for RD on a national scale is largely influenced by states like California, Oregon, and Washington, which have implemented advanced fuel standards and environmental policies. These states are not only leading the way in RD adoption but also setting the stage for nationwide uptake, catalyzing demand across various industries. The rigorous fuel standards and incentives for cleaner energy in these regions have created a favorable market for RD, positioning it as a cornerstone in the U.S.' shift towards a more sustainable and low-carbon future. With industries across the board recognizing the environmental and operational advantages of RD, its demand is expected to rise significantly, highlighting the crucial role of RD in meeting national sustainability objectives.[54]

VII. Renewable Diesel Emissions Reduction Analysis

To analyze the impact RD adoption can have on reducing GHG emissions of the GSE fleets in PANYNJ airports, we developed an emissions model that uses the PANYNJ GSE Inventory and the Aviation Environmental Design Tool (AEDT). The PANYNJ has a total of 12,022 GSE in its fleet across JFK, EWR, and LGA. The breakdown of GSE is in Figure 5, and we are focusing on the 4,564 diesel GSE for the purpose of this report.

	Diesel	Gasoline	Propane/CNG	Electric	Methanol
# of GSE	4,564	5,897	487	1,060	14
% of GSE	27	34	3	6	0

Figure 5: Total Motorized GSE by power type (Source: PANYNJ GSE Inventory)

To analyze GHG emission reductions from diesel GSE transitioning to RD, we modeled three RD adoption scenarios: accelerated, intermediate, and business-as-usual, adopting 100%, 50%, and 0% of RD in the GSE fleet respectively. All three adoption scenarios assume that the ZEAV Rule is successfully implemented with phase-outs beginning as early as 2027, but certain vehicle types persist beyond 2035 due to exemptions. The three adoption scenarios are explained below, along with total projected CO2e emissions from 2024 to 2040 (Figure 6).

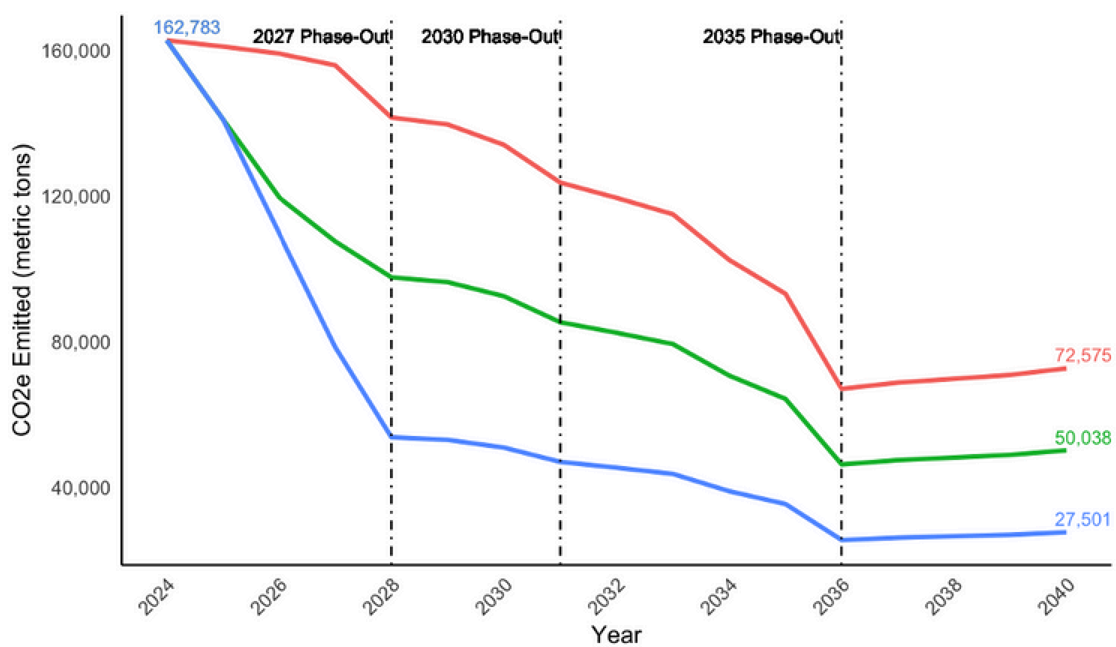

Figure 6: Projected CO2e emissions from 2024-2040 under three different RD adoption scenarios (Source: PANYNJ GSE fleet data)

Business-as-Usual (BAU) Scenario: No Renewable Diesel Adoption (No RD)

Pre-2027/28: Under a BAU scenario, PANYNJ airport tenants begin to phase out certain vehicle types toward the ZEAV 2027 milestone, but other GSE continue to use conventional diesel. This leads to a marginal 1.7% decline in CO2 emissions on average especially as increases in operational activity continue to result in higher emissions. The environmental effects include high levels of local air pollutants and contribution to global CO2 levels, impacting climate change and local air quality.

Pre-2030/31: Without RD, emissions reductions from the phase-out of certain GSE continue but the 3.2% rate of decrease fails to meet targets necessary for PANYNJ to achieve net zero by 2050. PANYNJ may face financial penalties for non-compliance with emerging environmental regulations. Costs could include fines, increased insurance premiums, and potential loss of business if tenants opt for greener airports.

Pre-2050: From 2035, even as emissions are eventually reduced to 72,575 metric tons, roughly a third of 2024 emissions, hard-to-electrify diesel-powered vehicles continue to persist in the airside fleet and PANYNJ emission reductions stagnate, with little outlook toward any future declines. In fact, due to the continued increase in passenger load and decreasing efficiencies of GSE, the emissions slowly rise.

Image Source: Port Authority of New York and New Jersey

Intermediate Scenario: 50% Renewable Diesel Adoption (50% RD)

Pre-2027/28: With 50% RD, a noticeable reduction of 13.2% in CO2 emissions from GSE is expected, as renewable diesel has a lower carbon footprint than conventional diesel. This would result in a corresponding decrease in the environmental impact and may start to show compliance with environmental targets, avoiding some potential costs and penalties.

Pre-2030/31: Continual reduction in emissions (5.6%) as more GSE transitions to RD. The costs associated with RD, such as infrastructure changes and possibly higher per-gallon fuel costs, could be offset by lower emissions-related costs and improved public relations.

Pre-2050: A sustained commitment to RD can lead to long-term environmental benefits, including a significant reduction in 517,000 metric tons of CO2e emissions. The cost savings from avoided penalties, reduced healthcare costs, and potentially lower operational costs due to improved GSE efficiency could be substantial.

Accelerated Scenario: Full Renewable Deployment (100% RD)

Pre-2027/28: Early adoption of Full RD could lead to a rapid 24.3% reduction in emissions, potentially placing PANYNJ ahead of environmental regulations and setting a standard for airport operations. Initial costs may be high due to infrastructure upgrades and fleet transitions.

Pre-2030/31: With full deployment, PANYNJ should see a substantial decrease in CO2 emissions, with emissions reduced to less than a third by 2030. Financially, while upfront costs for complete RD adoption are significant, the long-term operational savings and reputational gains could be considerable.

Pre-2050: Over the long term, the full transition to RD should result in minimal CO2 emissions from GSE, with a total projected reduction of over 965,000 metric tons CO2e compared to no RD adoption. The projected emissions of around 27,500 metric tons in 2040 are less than half that of a 0% RD scenario. The enduring environmental benefits include contributing to the fight against climate change and promoting healthier local communities. Economically, substantial cost savings are likely due to the reduction in fuel costs, maintenance, and healthcare expenses, as well as potential revenues from green initiatives.

The emissions model above reveals three key findings:

The ZEAV Rule is not enough.

The ZEAV Rule will be the main driver of GSE emissions reductions at PANYNJ airports. Nevertheless, due to the barriers to electrification that will result in some diesel-powered vehicles continuing to persist past 2030, and the substantial emissions that will be produced before respective phase-outs, more can be done to minimize the GSE emissions at PANYNJ airports. Specifically, it is estimated that between 2025-2040, even with ZEAV fully implemented, the GSE fleet will emit 1.96 million metric tons of CO2e.

RD is critical to meeting emission goals.

Full adoption of RD for diesel-powered GSE will result in as much as a 49.3% decrease in GHG emissions. In a 15-year period, that translates to 965,000 metric tons of CO2e that are not emitted, just from the diesel-powered GSE fleet alone.

Partial RD adoption is better than none.

Tenants might face various issues in fully transitioning to RD for its diesel-powered GSE fleet. Nevertheless, tenants should leverage RD's 'drop-in' qualities that allow it to be mixed with any quantity of petroleum diesel by pursuing partial adoption. The emission analysis finds that even a partial adoption can lead to significant emission reductions and should not be ignored. For example, 50% RD adoption will lead to a 26.4% reduction in CO2e emissions.

Image Source: Victory GSE

VIII. Challenges to RD Adoption at PANYNJ Airports

Despite the many benefits of RD adoption, PANYNJ and relevant stakeholders, such as tenant airlines and GSE operating companies, face challenges that limit RD uptake. Our team conducted in-depth interviews with these stakeholders to better understand the roadblocks to RD adoption at PANYNJ airports. These include both real challenges and misconceptions about what it would entail to adopt RD.

Noting the policy signals, tenant airlines and shipping companies are currently focused on investing in electrification equipment and infrastructure. Airlines are, indeed, interested in lower-emission alternatives, but there are currently few incentives for them to adopt RD before transitioning to electric GSE alternatives. Furthermore, these stakeholders cited higher costs and a lack of RD availability at airports as barriers to uptake. Higher costs stem from varying feedstocks and the lack of local RD production, adding transportation fees that make it more expensive to switch from petroleum diesel to RD.

Our research suggests that some tenants seem to have certain misconceptions about RD adoption. Among these misconceptions is a general misunderstanding about what differentiates RD from other biofuels, like biodiesel. A few tenants expressed confusion over whether additional infrastructure is required to transition to RD and if RD could perform well in cold weather. Others were under the impression that RD's emissions profile is only marginally better than petroleum diesel. A few airlines discussed concerns that investing in RD adoption competes with simultaneous electrification efforts. As the following case study (Section IX) describes, it is important to note that all tenants operating out of California airports are using RD for GSE at those locations and frequently cited California as a successful example of transitioning to RD. Port Authority tenants can look to California's GSE transition to RD as an example and to assuage tenants' concerns.

IX. Case Studies on RD Usage

To better understand the drivers of RD usage in California airports and other examples in the NYNJ region we looked at two different case studies detailed below: San Francisco International Airport and New York City's Department of Citywide Administrative Services.

San Francisco International Airport

Around 20% of San Francisco International Airport's (SFO) greenhouse gas (GHG) emissions stem from Ground Support Equipment (GSEs), totaling approximately 259,000 metric tons of carbon dioxide annually, second only to emissions from aircraft activity. In alignment with SFO's Zero Emissions Vehicle Readiness (ZEV) roadmap, the objective is to annually reduce GHG emissions from GSEs by 18,000 metric tons by 2030.[55] Like the challenges faced by airports under the jurisdiction of the Port Authority, the SFO's electric infrastructure is presently inadequate for an immediate transition to net zero. The existing infrastructure comprises 306 electric vehicle (EV) charging ports, 256 charging ports dedicated to GSEs, and the introduction of its inaugural fleet of electric buses.

Following the implementation of the Low Carbon Fuel Standard (LCFS) program in 2011, RD has replaced over 5.3 billion gallons of petroleum diesel due to California's policy preference for RD production. Data from the first quarter of 2023 indicates that approximately 49% of California's diesel is now sourced from RD.[56] In California, RD is priced at $5.37 per gallon, only marginally higher than petroleum diesel at $5.25 per gallon. The adoption of RD has contributed to emissions reduction efforts while SFO proceeds with a full transition to electrification. The primary supplier of renewable diesel to SFO is Neste's Singapore production plant, with an annual production capacity of approximately 330 million gallons. Neste has been supplying renewable fuels to California since the inception of the LCFS.

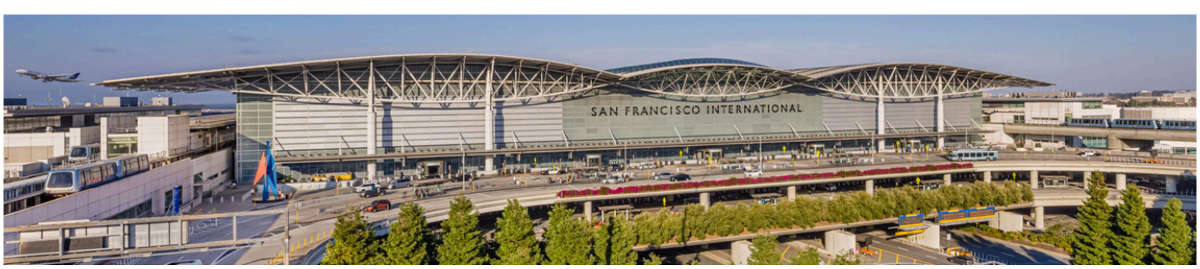

Image Source: San Francisco International Airport

New York City Department of Citywide Administrative Services

To adhere to the commitments of the Paris Climate Accord signed in 2015, New York City (NYC) pledged to achieve net-zero fleet emissions by 2050, with a 50% reduction in GHG emissions by 2025 and 80% by 2035, from a 2005 baseline.[57] Similar to the Port Authority, NYC requires a transitional fuel to mitigate emissions while developing the necessary infrastructure for full electrification.

Image Source: NYC DCAS

On November 29, 2023, the NYC Department of Citywide Administrative Services (DCAS) finalized a long-term contract for the supply of RD for its fleet. Currently, approximately 12,600 on-road and off-road trucks in NYC operate on petroleum diesel, and DCAS consumes over 16 million gallons of RD annually.[58] By the conclusion of the fiscal year 2024, all of these fleets will have completed the transition to RD. This transition is anticipated to result in annual emission reductions of approximately 128,000 metric tons CO2e.[59] However, the end goal is for the entire truck fleet to be fully electric by 2038.[60] To lower the environmental impact of RD feedstocks, DCAS stipulated in its procurement contract with Approved Oil that palm oil could not be used, and there must be at least a 60% reduction in carbon intensity compared to petroleum diesel. The RD also is transported by barge from Louisiana, and currently is only made of waste cooking oils.

X. Recommendations

According to our findings, RD is a viable option to reduce GHG emissions. As depicted in Figure 7 below, RD has significant emission reductions compared to petroleum diesel. However, barriers such as the environmental impact of feedstocks, high costs, and supply chain challenges must be overcome to ensure effective RD implementation.

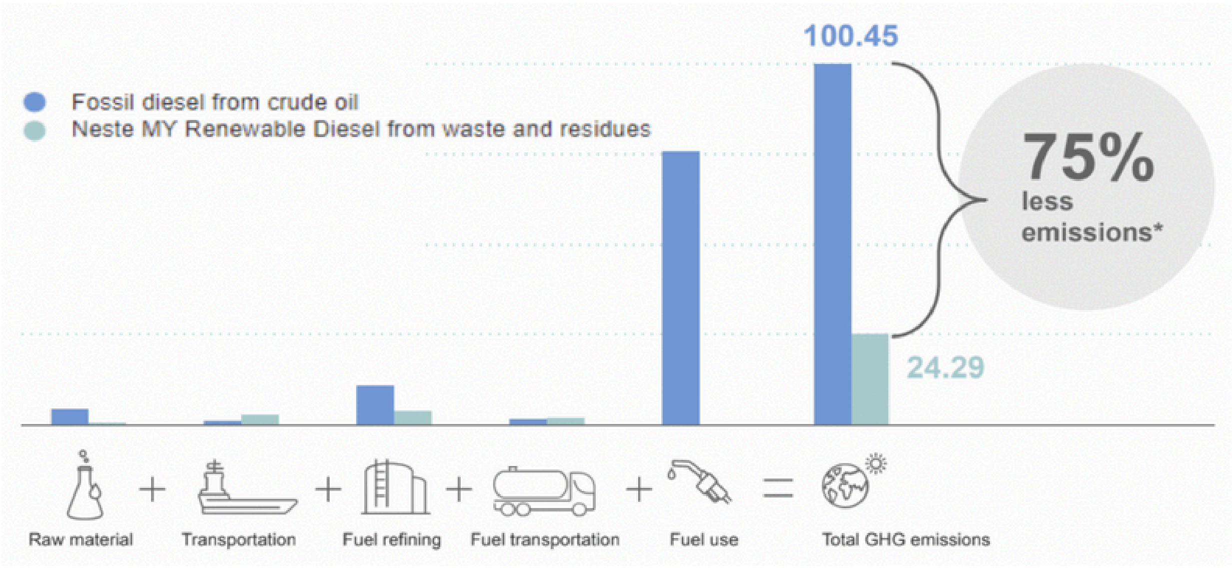

Figure 7: Life Cycle Assessment of Renewable Diesel and Petroleum Diesel (GHG, gCO2 eq/MJ) (Source: Neste. Numerical values are for illustrative purposes only, as GHG emission reduction varies depending on the region-specific legislation that provides the methodology for the calculations, and the feedstock mix used.)

To mitigate harmful environmental impacts from RD, PANYNJ can stipulate in RD procurement contracts which feedstocks are allowed, such as waste cooking oils, and preferred modes of transport, such as barge. To help with higher costs, PANYNJ can orchestrate purchase bundling so all airport tenants can buy ROAD together and lower overall costs. As there is already existing RD distribution infrastructure in the New York and New Jersey region, using those same distribution channels for tenant RD demand will lower costs and minimize operational concerns. Further details on these recommendations are below.

Environmental Recommendations

Promote Low Environmental Impact Feedstocks:
Encourage the use of feedstocks that minimize biodiversity, land use, and water intensity concerns and are cultivated using sustainable farming practices. Prioritize partnerships with RD producers that have a proven track record of minimal negative environmental externalities with at least a 60% carbon intensity reduction compared to petroleum diesel.

Monitor and Report Emissions Reductions:
Implement a comprehensive monitoring system to regularly measure and report the reductions in GHG emissions and other pollutants as a result of transitioning to RD. Transparency in reporting these reductions will highlight the environmental benefits and spur further investment in RD.

Infrastructure Recommendations

Utilize Existing RD Distribution Networks:
Since there are already at least three RD distributors in the NYNJ region, including Sprague, Global Partners, and Approved Oil, new distribution networks do not need to be established. Harnessing this existing infrastructure will lower costs and minimize operational concerns.

Expand RD-Compatible Fueling Infrastructure:
Incentivize the expansion of RD-compatible fueling infrastructure within PANYNJ airports. This can include upgrading existing fueling stations or constructing new ones specifically designed for RD.

Financial Recommendations

Financial Incentives for Early Adopters:
Build on internal financial incentives such as the Cleaner Cargo Handling Equipment policy and advocate for state-level tax breaks and subsidies for GSE operators who transition to RD early. This can help offset the initial higher costs of RD and encourage widespread adoption among tenants.

Volume-based Pricing Agreements:
Negotiate volume-based pricing agreements with RD suppliers. By aggregating the demand from all tenants, PANYNJ can leverage better prices, minimizing the cost differential between RD and petroleum diesel.

Recommended Implementation Strategy

Immediate Actions (2024-2027)

Stakeholder Engagement:
Continue and deepen outreach efforts with airlines, cargo operators, and GSE owners to align goals, share technological advancements and RD adoption information, and address barriers to zero-emission vehicle adoption.

Explore Mandating RD for Select GSE Types:
Evaluate the feasibility of incorporating RD requirements into the ZEAV rule. Mandating GSE that are exempt from ZEAV to use RD will help PANYNJ and its tenants meet emission reduction goals in light of electrification barriers.

Mid-Term Goals (2027-2030)

Establish Fuel Consortium:
Establishing a fuel consortium for tenants to express interest in RD will create momentum around increasing the supply of RD at airports that can be presented to distributors to obtain cost estimates.

Financial Incentives and Support:
Implement a range of financial incentives, such as grants, low-interest financing, and rebates, to assist GSE owners in purchasing zero-emission vehicles and related infrastructure.

Long-Term Vision (2030-2050)

Advocate for RD Adoption:
Continue conducting outreach with tenants and stakeholders to advance efforts that will increase RD availability in the NYNJ region and incentivize RD use at airports in place of non-renewable fuels.

Complete Transition to Zero Emissions Vehicles (ZEVs):
Achieve the goal of a fully zero-emission GSE fleet at all PANYNJ facilities by 2030. This includes extending ZEV requirements to all categories of GSE, supported by a robust network of charging and fueling infrastructure. As RD still emits GHG and should not be a long-term solution, it is crucial to still work towards net-zero GSE.

XI. Conclusion

The Port Authority is committed to environmental sustainability and has pursued ambitious initiatives to transition its operations towards renewable energy sources. With the increasing threat of climate change and the transportation sector accounting for nearly a third of US GHG emissions, it is critical to reduce the carbon footprint of the sector. Part of the Port Authority's sustainability commitments to net-zero is working with airport tenants to transition GSE to net-zero emission alternatives. The lack of electric GSE technologies and structural barriers to electrification illustrate that an interim solution is needed to reduce GHG emissions. Our research illustrates that RD is a viable and effective transition fuel for diesel GSE. Fully adopting RD in diesel GSE along with the Port Authority's ZEAV regulation will result in additional GHG emission reductions of about 965,000 metric tons of CO2e compared to no RD adoption.

While RD adoption significantly reduces emissions, key considerations must be made to address challenges regarding negative environmental externalities, supply chain infrastructure, and higher costs. To mitigate harmful ecological impacts from RD, PANYNJ can stipulate the minimum carbon intensity score in RD procurement contracts. To help with higher costs, PANYNJ tenants can collectively orchestrate a fuel consortium to aggregate purchasing power and drive down RD prices. As there is already existing RD distribution infrastructure in the New York and New Jersey region, using these distribution channels for tenant RD demand will lower costs and minimize operational concerns. Our recommendations will enable PANYNJ's actions to support its sustainability goals and progress towards a cleaner aviation future.

Glossary

Term	Definition
GSE (Ground Support Equipment)	The specialized equipment used at airports to support the operation and maintenance of aircraft on the ground. GSE includes vehicles for towing aircraft, loading and unloading cargo, transporting baggage, and other airport operational tasks. The Port Authority specifically has been focusing on transitioning this equipment to zero-emission alternatives as part of their sustainability goals .
GSE Companies	Companies involved in the supply, operation, and maintenance of ground support equipment.
RD Production Companies	Companies specialize in the production of renewable diesel, a biofuel that can be used as a direct substitute for traditional diesel. Major producers in the United States.include Neste, Diamond Green Diesel, and Marathon Petroleum Corporation.
ZEAV (Zero Emission Airside Vehicle Rule)	ZEAV refers to the Port Authority's electrification regulation for GSE, which includes a phase-out timeline for GSE with commercially available zero-emission alternatives and where electric infrastructure is available.
Diesel	A type of fossil fuel used widely in various forms of transportation, including road vehicles and certain types of aircraft. It is derived from crude oil.
Renewable Diesel	Similar in chemical structure to traditional diesel but made from renewable resources such as vegetable oils and animal fats. Unlike biodiesel, renewable diesel can replace conventional diesel without any modifications to engines.
Biodiesel	A type of diesel fuel derived from biological materials like vegetable oils or animal fats. It can be used in diesel engines but has to be blended with other fuels.

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Appendix 1: Methods of Research

The following Appendix discusses the Team's approaches to research comprised of three parts:

a. Literature review
b. Expert outreach
c. Data analysis

Literature Review

Based on the project description from the client, the team developed three questions to guide our research:

1. What are the incentives and disincentives for using RD in GSE?
2. What are the environmental and financial impacts of transitioning to RD?
3. What supply chain adaptations are needed to support the increased use of RD in GSE?

The team conducted an extensive literature review to gain a general understanding of renewable diesel and ground service equipment and respond to the questions listed above. The team studied over 30 pieces of literature, including thirteen industry reports, eight peer-reviewed articles, five government reports, and five news articles.

Expert Outreach

After an extensive literature review, the team worked with the Port Authority to identify experts in the aviation and renewable diesel fields to better understand the localized incentives and disincentives among producers, distributors, and consumers in the renewable diesel supply chain. The team interviewed 16 experts falling within four categories: airport tenants, renewable diesel producers, renewable diesel distributors, and NYNJ renewable diesel users. The organizations interviewed can be found below in Table A. Unique interview questions were developed depending on the expert's expertise, and included topics such as RD cost and usage, GSE sustainability goals, policy incentives, and RD transportation and infrastructure. A sampling of interview questions are listed below in Table B.

Airport Tenants	Fuel Distributors	RD Producers	RD Users
United DHL FedEx American Southwest UPS Dnata PrimeFlight	Sprague Global Partners LP Atlantic Aviation Signature Aviation	Neste	PANYNJ Staff NYC Department of Citywide Administrative Services

Table A: Experts Interviewed

Airport Tenants	Do you have a plan to decrease aviation ground support equipment (GSE) emissions?
	Do you have any maintenance or operational concerns with using renewable fuel for GSEs?
	What electrification challenges are you facing?
	Does your company track and disclose GSE emission data?
Fuel Distributors	How is fuel transported and stored at each airport?
	Do you have any specific challenges maintenance or operational wise/concerns with using renewable fuel for GSE?
	Given the current geopolitical and economic climate, what is the situation of fuel supply in NY/NJ areas? How stable is the fuel supply chain in the NY/NJ area? What contingency plans are in place to handle potential disruptions?
RD Producers	What are some main issues encountered in implementing sustainable and sufficient feedstocks such as bio-based feedstocks or waste materials?
	What are the potential risks or downsides associated with the use of renewable fuels in an airport setting?
	Are there challenges to maintaining a consistent renewable fuels supply chain?
RD Users	How do you accurately measure and report GHG savings from renewable fuels?
	What does your supply chain of renewable diesel look like and how does it compare to diesel? (e.g. where is the fuel coming from, how is it transported etc)?
	Are there supply challenges in meeting renewable diesel demand?

Table B: Sample Expert Interview Questions

Appendix 1: Methods of Research

Data Analysis
The basis of the emissions inventory and forecast is calculated using the generic equation shown below.[60] This calculation is completed for each GSE vehicle type (as per the AEDT GSE profile), using the California Air Resources Board (CARB) Off-Road Emissions Inventory tool.

Emissions = Population * Activity * HP * LF * EF

Where:
Population = Count of equipment
Activity = Time the engine is running in hours per year
HP = Average maximum brake horsepower of the engine
LF = Load factor (Average fraction of maximum power rating of engine during operation)
EF = Emission Factor (grams per brake horsepower-hour) specific to horsepower, engine build year, and the specific pollutant. The emission factor includes a deterioration factor based on the age of the equipment, and a fuel correction factor.

Data Sources
The GSE inventory for 2023 were provided by the Port Authority for the three large international airports (i.e. JFK, EWR, and LGA). This inventory provides information about the make-up of the GSE fleet, the number of units by equipment type, and model year.

As per the method Port Authority's GHG Inventory employs, a crosswalk was developed to establish correspondence between equipment types as reported by airlines and the equivalent equipment type in AEDT GSE profile (provided by Port Authority since the team did not have access). This enabled the assignment of default GSE parameters for activity, HP and LF. EF was separately calculated using CARB's Low Carbon Fuel Standard pathways, and then applied to gallons of fuel consumed.

Forecasting
In most inventories, an overall growth rate is used to project the increase in population or activity of all equipment in future years. For example, passenger load, industry spending and population growth have been used to project future growth rates. For this inventory, the team reviewed historical GSE emissions from 2015 to 2019 and applied a positive growth rate of 2.56%.[61]

The team used the baseline inventory with the existing Zero-Emission Airside Vehicle (ZEAV) Rule as a starting point to estimate the emissions expected under various RD adoption scenarios. The projected staggered phase-out schedule was provided by the Port Authority. It is noted this is an estimated timeline of when vehicle types will be determined to be subject to the ZEAV Rule. To factor in the assumption that the phase-out of vehicle types would happen over a period of a few years, the team applied a negative growth rate to overall emissions for the particular phase-out category beginning 4-7 years prior to the phase-out due date. For example, for vehicles projected to be subject to ZEAV by 2030, emissions from this tier of vehicles decrease annually beginning 2026.

To calculate the emissions reductions under various RD scenarios, the team adjusted the total emissions based on the percentage of RD adopted. Moreover, for both the 50% and 100%, RD adoption was gradually scaled up over a number of years. For example, for the 100% adoption scenario, full adoption is only achieved in 2028.

Appendix 2: Capstone Team Members

Emma Oonk (Manager)

Emma is passionate about urban sustainability and air quality, hoping to pursue a career in government. Before graduate school, she managed the delivery of federal leadership development programs aimed at improving efficiency and collaboration across government agencies. She is from Michigan and has a BA in Mathematics and Environmental Economics from Hope College.

Ian Kang Choo (Deputy Manager)

Ian has a background in urban studies and public policy. He is passionate about urban infrastructure and is committed to moving cities (particularly his home, Singapore) toward a net-zero future. His current interests lie in sustainable land use planning, energy policy, and climate finance.

Christina Lee Morano

Christina is from Secaucus, New Jersey, and is an Environmental and Marine conservation biologist as well as an environmental policy maker. Before her time at Columbia, she served as a Legal Intern for Judge Joseph A Turula at the New Jersey Superior Court Hudson Division. She also completed a transportation water pollution research project at Florida Southern College her alma matter.

Appendix 2: Capstone Team Members

Dina Chuteneva

Dina is originally from Kazakhstan and is a graduate of LSE. With a professional background spanning five years at KPMG, her focus includes banking, macroeconomic, and energy projects. Over the past three years, she has dedicated her time to a social mentoring project for girls from Central Asia, supporting around 80 participants. Post-graduation, she aims to contribute to the adoption and expansion of renewables, whether in project management, structured finance, or related areas.

Ellie Alter

Ellie is a native New Yorker who has worked at the intersection of urban sustainability, public health, and immigrants' rights for the last decade. She is interested in sub-nationals' role in promoting equity in the transition to renewable energy. She holds an MA in Human Rights & Advocacy from New York University, and a BA in Sociology from Fordham University.

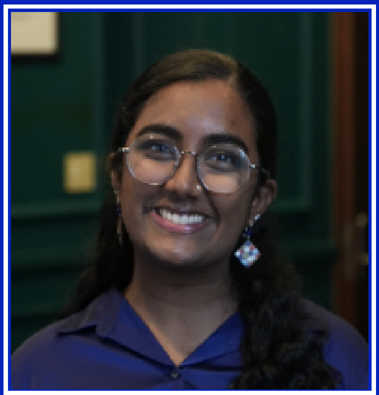
Yilin (Kim) Kong

Kim is a dual master's candidate at Columbia University (M.P.A. in Environmental Science and Policy, M.S. in Enterprise Risk Management) and is expected to graduate in 2024. She holds a B.S. in Mathematics and a B.A. in Psychological Science from UC Irvine. She has interned at Z&Y Legend Consulting and Mushin Academy, demonstrating skills in mental health initiatives and project management and experience in risk analysis and AI-driven projects.

Appendix 2: Capstone Team Members

Tarun George

Tarun is a graduate student from India, focusing on environmental science policy. His coursework has consisted of clean energy finance, energy systems, GHG accounting, and life cycle assessments. His professional experience includes banking, NGO operations, and small-scale consulting projects. After graduation, he wants to work either in clean energy financing projects or sustainability consulting.



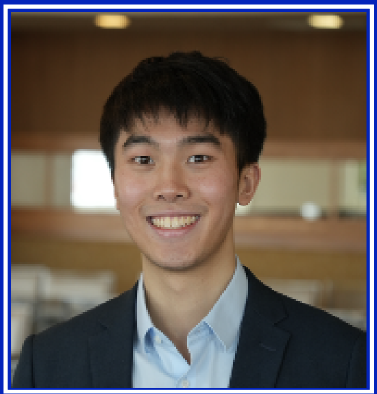
Vasu Jayanthi

Vasu is a recent graduate of Brown University, where she studied Environmental Science on the Air, Climate, and Energy track. She wrote her senior thesis on the role of hyperlocal air quality in motivating youth environmental engagement while serving as a research assistant on an air quality monitoring project called Breathe Providence. Vasu is currently most interested in a career in urban sustainability incorporating her passion for public transit, air quality, and environmental equity.

Oliver Xu

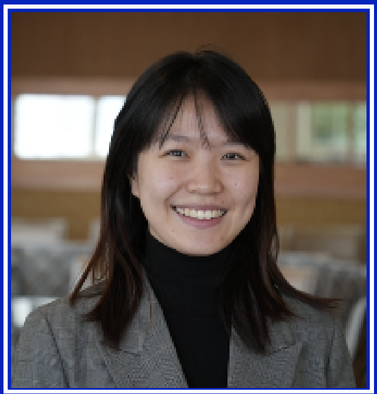
Oliver is from Beijing, China, and majored in environmental science with a specialization in ecosystem restoration at the Ohio State University. Before joining the MPA-ESP program, he worked as a lab assistant in OSU soil and as a water environmental laboratory and environmental scientist/engineer in two consulting companies back in China.

Appendix 2: Capstone Team Members



Wing Shun (Vincent) Tang

Vincent has a background in Environmental Management and Technology with experience working in ESG strategy, finance, and working with Intergovernmental organizations. He is passionate about driving impact in climate change and sustainability, especially in sustainable development policy and investment.



Yuxin (Kelsey) Tu

Kelsey holds a master's degree in Environmental Engineering from the National University of Singapore. With experience in environmental consulting, energy accounting, and Life Cycle Assessment, Kelsey is dedicated to advancing sustainable development strategies, focusing on impactful water managment, climate resilience and GHG Protocol.

Dr. Nancy Degnan (Faculty Advisor)

Nancy served as Assistant Dean at SIPA and as the Associate Director at the School of Architecture, Planning and Preservation. She is currently the Executive Director of the Center for Environmental Research and Conservation (CERC). At CERC, Dr. Degnan spearheads initiatives and programming in education, training and applied research STEM (science, technology, engineering and math). Her research and writing has focused on community-based initiatives in education, sustainable development and redevelopment, as well as microfinance and enterprise development. She is also a member of Columbia Business School's Deming Board, Chazen Institute.