

# An Economic & Environmental Analysis of the JetBlue Airways Ground Support Vehicles: A Proposed Implementation of a Cleaner-Burning Fleet

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# Executive Summary

JetBlue Airways Corporation, a Fortune 500 company based in New York City, is an airline that services 87 destinations across the U.S., Caribbean, and Latin America. From 2010 to 2014, JetBlue has made its overall operations increasingly more energy efficient, resulting in an 8.3% decline in greenhouse gas emissions intensity ratio (metric tons CO<sub>2</sub>-eq per 1,000 revenue ton miles flown), which has also saved the company millions of dollars in operating costs. As JetBlue continues to enhance its efforts to couple sustainability with economic value, a logical next step was to evaluate JetBlue's ground fleet for potential improvement.

Our analysis focused on ground support operations at JetBlue's Terminal 5 at John F. Kennedy International Airport (JFK) in New York. Responsible for 13,800 metric tons of CO<sub>2</sub>-eq emissions, the function of ground support equipment (GSE) vehicles is to service the aircraft between flights. Our study included the three most used vehicle types—bag tug, belt loader, and push back tug—as they offered the largest opportunity for savings. Our study explored the economic and environmental opportunities associated with replacing current gasoline and diesel-powered GSE vehicles with electric vehicles, also called eGSE.

This report first provides background on JetBlue Airways, its environmental impacts, and the airline's sustainability program. It provides general emissions trends within the transportation sector before narrowing in on ground vehicles, where it details their specific function and describes emissions standards that apply to off-road GSE.

The report then details the first step within our analysis in which we review JetBlue-provided GSE data, including a system-wide inventory and ground fuel expenditures dataset by airport. This report summarizes this data by describing the composition of JetBlue's JFK ground vehicles by function, quantity, and energy inputs.

We then consider energy reduction strategies for the GSE fleet by describing available alternative fuel sources and evaluating relevant efforts by other airlines and airports. The next stage of our analysis consisted of interviews with JetBlue employees and associated business partners and stakeholders, whose commentary and feedback have been integrated into the report. Data was also recorded on the ground at JFK to better understand the operation and retrieve accurate daily vehicle usage data.

In the final stage of the analysis, all data was synthesized into a model that estimated how much gasoline or diesel the average bag tug, belt loader, and push back tug is using, as well as how much JetBlue spends per vehicle in powering it annually. Based off data from a GSE manufacturer, we calculated what the energy costs savings would be if all vehicles would run off of electricity instead of gasoline or diesel. Lastly, we modeled eight scenarios in which JetBlue would change a portion of their fleet to electric, and for each scenario the model projected fuel costs and emissions savings.

Based on the incentives described in this report, we recommend the following for JetBlue's GSE fleet at JFK:

1. Pursue push back electrification secondary to bag tug and belt loader
2. Launch pilot to test 1 charger, 2 belt loaders, and 1 bag tug at JFK
3. Apply for the FAA's Voluntary Airport Low Emissions Program (VALE) funding
4. Set goal of 20% electric bag tugs and belt loaders in 3-year period (by 2019), replacing vehicles as they retire. In a worst case scenario where JetBlue receives no funding and pays the higher cost for all new vehicles instead of refurbished, JetBlue will save roughly \$1.7 million and 36,500 metric tons of CO<sub>2</sub>-eq emissions across a 14-year timeline.
5. Set goal of 50% electric belt loaders and bag tugs in a 7-year period (by 2023), replacing vehicles as they retire. In a worst case scenario where JetBlue receives no funding and pays the higher cost for all new vehicles instead of refurbished, JetBlue will save roughly \$4.3 million and 89,200 metric tons of CO<sub>2</sub>-eq emissions across a 14-year timeline.
6. Research feasibility of retrofitting 100% electric belt loaders, bag tugs, and push backs, replacing vehicles as they retire. This can maximize the opportunity to save roughly \$7 million in fuel costs (assuming funding is received) and over 60,000 metric tons of CO<sub>2</sub>-equivalent emissions over 14 years.

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# 1. Introduction

## 1.1 Overview of Project

This analysis describes the energy use associated with JetBlue Airways' ground support equipment (GSE) and evaluates options by which the airline may reduce both energy costs and related environmental impacts. The analysis benchmarks JetBlue Airways' ground support equipment (GSE) fleet and fuel consumption, details the technical and regulatory landscape of ground support vehicle emissions and energy use, provides recommendations for reducing the costs and emissions associated with their GSE fleet, and presents implementation options for financing the retrofit and updating airport operations to accommodate alternative fuel vehicles.

### **Problem Statement**

JetBlue seeks to reduce both cost and environmental impact of its ground operations.

## 1.2 Research Objective

This report seeks to solve a two-fold problem:

### **1. Reduce the cost of ground operations at JetBlue.**

Given the significant operating costs, airlines operate on a thin profit margin and are very receptive to cost saving measures. Currently, 96% of JetBlue's GSE are powered by gasoline and diesel, which to date are more expensive on a per energy unit basis than electricity. Further, electricity is less susceptible to changing prices, whereas gasoline and diesel exhibit large and uncertain cost variability.

### **2. Reduce the environmental impact of ground vehicles.**

The ground vehicles that constantly drive around airports to service aircraft have a significant environmental impact. Operating JetBlue's GSE fleet at JFK results in roughly 13,800 metric tons of CO<sub>2</sub>-eq emissions. In addition, reducing ground criteria pollutant emissions from ground vehicles could lessen the presence of related NO<sub>x</sub> and particulate matter in the air surrounding the ramp area, potentially enhancing the working conditions of ground operations crewmembers.

# 2. Client Introduction

## 2.1 JetBlue Airways: An Overview

Our client is JetBlue Airways Corporation, a Fortune 500 company that operates out of 87 destinations in the U.S., Caribbean, and Latin America as of December 2014. Its primary operations, called "Focus

Cities”, are New York City, NY; Boston, MA; Fort Lauderdale/Hollywood, FL; Los Angeles (Long Beach), CA; Orlando, FL; and San Juan, Puerto Rico. JetBlue carries more than 32 million revenue passengers, with an average of 825 flights per day (JetBlue Airways, 2015).

JetBlue operates three types of narrow-body aircraft, with a fleet comprised of the following aircraft as of December 31, 2014:

- 130 Airbus 320 (150 passengers)
- 13 Airbus 321 (either 159 or 190 passengers)
- 60 Embraer 190 (100 passengers)

For 2014, JetBlue reported \$5.8 billion in operating revenue, with \$401 million in net income (JetBlue Airways). This significant difference is in part due to the high costs of jet fuel and labor, challenges that all commercial airline carriers face.

## 2.2 JetBlue Sustainability Program

JetBlue operates a Sustainability program that began publishing an annual responsibility report in 2006. In 2013, the airline added a full-time Sustainability Manager to direct the program.

As stated on the program’s website [www.jetblue.com/green](http://www.jetblue.com/green), JetBlue’s Sustainability Program is based on the concept that their operations and success as a business are dependent upon natural resources, such as energy, water, metals that create aircraft, and the beautiful natural destinations they serve.

In order to protect the long-term health of these natural resources, JetBlue Sustainability has established the following initiatives, as detailed on [www.jetblue.com/green](http://www.jetblue.com/green):

- Conserve jet fuel and improve fleet efficiency;
- Offset some aircraft emissions (since 2008, JetBlue has offset more than 350 million pounds of CO<sub>2</sub>-eq emissions)
- Recycle on all domestic flights;
- Compost in JFK’s Terminal 5;
- Report and be transparent about environmental impact data;
- Provide products onboard and sold in terminals that are local to their focus cities, and are sustainably sourced;
- Reduce energy consumption in ground support centers and corporate offices;
- Because 80% of their route network lies along the coast and one-third is to destinations in the Caribbean, develop an ocean conservation strategy and partner with ocean-focused non-profits.

## 2.3 Reported Emissions

In 2014, JetBlue’s operations resulted in over 6.3 million metric tons of CO<sub>2</sub>-eq emissions (JetBlue, 2015). JetBlue normalizes this value by calculating GHG emissions divided by Revenue Ton Miles (RTM) where RTM = weight in tons of revenue traffic transported (customers and cargo) multiplied by miles flown. Table 1 demonstrates a declining trend in GHG emissions on a normalized basis.

Metric Tons CO <sub>2</sub> -eq per 1,000 Revenue Ton Miles*		
Year	Revenue ton miles (RTM)	GHG emissions/RTM (Metric tons CO <sub>2</sub> e/1,000 RTM)
2010	2,856,971,982	1.68
2011	3,095,234,716	1.67
2012	3,376,303,538	1.65
2013	3,612,193,124	1.65
2014	4,113,747,082	1.54

\*Revenue ton miles = weight in tons of revenue traffic transported (customers and cargo) multiplied by miles flown.

Source: JetBlue 2014 Responsibility Report

**Table 1. CO<sub>2</sub>-Equivalent Emissions per 1,000 Revenue Ton Miles, 2010-2014.**

JetBlue’s GHG emissions can also be represented as CO<sub>2</sub>-eq emissions per passenger mile of the total fleet through the following calculation:

$$6,318,653 \text{ GHG emissions} / 37.8 \text{ billion revenue passenger miles} \\ = 0.368 \text{ pounds CO}_2\text{-eq per revenue passenger mile}$$

While the vast majority of the above emissions can be attributed to the emissions associated with the combustion of the petroleum-based jet fuel that powers all their flights, roughly 0.6% of reported emissions are associated with ground operations. Approximately 25,200 metric tons of CO<sub>2</sub>-eq emissions, or 0.4% are Scope 2 emissions associated with generation of electricity that powers their terminals, support centers, and offices. Roughly 13,800 metric tons of CO<sub>2</sub>-eq emissions, or 0.2%, are emissions associated with the combustion of gasoline and diesel for the ground support vehicles that JetBlue operates. This last value is the emissions quantity our analysis aims to reduce.

## 2.4 Fuel Savings Initiatives

Jet fuel remains one of the largest costs to the airline industry. Based on a 2008 survey of 45 major airlines by the International Air Transport Association (IATA), fuel costs represented roughly one-third of

total operating costs (IATA, 2010). A 2013 assessment conducted by Boeing states that fuel costs have nearly doubled in the past 10 years, with fuel representing up to 30 percent for single-aisle aircraft and up to 50 percent for wide body (IAA, 2013). As a response to high fuel expenditures and severe financial pressures, airlines and aircraft manufacturers have significantly increased the fuel efficiency of their planes and operations on a passenger-mile basis. Since the first jets were developed in the 1960s, aircraft have become approximately 70% more fuel efficient per seat-kilometer (ATAG, 2011).

In a consolidated effort to further reduce their fuel burn, the airline launched an internal initiative in 2014 called “Fuel Is Everyone’s Business”. Through this effort, JetBlue introduced changes in the way they purchase, consume, and track fuel. Through the initiative, the airline implemented multiple trials throughout 2014 that together resulted in \$2.5 million in fuel savings, equivalent to roughly 4,900 metric tons of avoided CO<sub>2</sub>-eq emissions with the assumption of \$5 per gallon of jet fuel (JetBlue, The Blue Review - 2014 Responsibility Report).

To date, this emphasis on fuel savings has not extended to the ground support fleet.

## 3. Methodology

### 3.1 Literature research

The first phase of our literature approach consisted of in-depth research into the field of ground support equipment. We focused on governmental reports, with much information being provided by Report 78: Airport Ground Support Equipment (GSE) Emission Reduction Strategies, Inventory, and Tutorial by the Airport Cooperative Research Program (ACRP), sponsored by the Federal Aviation Administration (FAA). Our research focused on understanding the various GSE functions, how the equipment operates technically, regulations GSE might be subject to, and opportunities for funding or partnerships. The second phase of our literature research consisted of a competitive analysis of what other airlines and airports have done in the space while considering alternative fuel GSE.

### 3.2 Internal and external interviews

We held informational interviews with employees within JetBlue as well as some of its suppliers and associated stakeholders. We spoke with JetBlue employees across multiple teams and functions, including representatives from JetBlue’s JFK Ground Operations staff, General Managers from multiple airports, and the Sourcing, Finance, and Sustainability teams at JetBlue’s corporate headquarters. External interviews included conversations with one of JetBlue’s suppliers of GSE vehicles as well as a representative from the Port Authority of New York and New Jersey.

### 3.3 Ground observations and data analysis

We analyzed JetBlue-provided GSE data, including a system-wide inventory and ground fuel expenditures dataset by airport. This report summarizes this data by describing the composition of JetBlue’s JFK ground vehicles by function, quantity, and energy inputs. In order to gather additional data, a day was spent at JFK on the tarmac gathering vehicle usage data and viewing the operations from the ground.

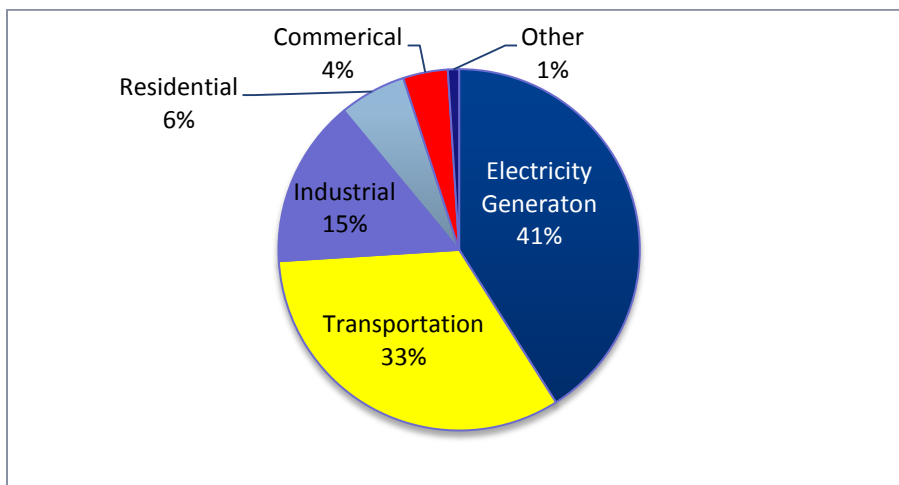
### 3.4 Financial and environmental modeling

We developed a model to synthesize all our collected data, develop a baseline calculation, and project the environmental and financial impact if JetBlue were to pursue alternative fuel options for their GSE fleet. Specifically, the model estimated how much gasoline or diesel the average bag tug, belt loader, and push back tug use on an annual basis, as well as how much is spent per vehicle in powering each GSE unit. Based off data from a GSE manufacturer, we then modeled what the energy costs would be if the vehicles ran the exact same distance but instead using electricity as an energy input. Further, we modeled eight scenarios in which JetBlue would change a portion of their fleet to electric, and for each course of action we projected fuel costs and emissions savings.

## 4. Summary of Literature Research

### 4.1 Trends in Transportation Emissions

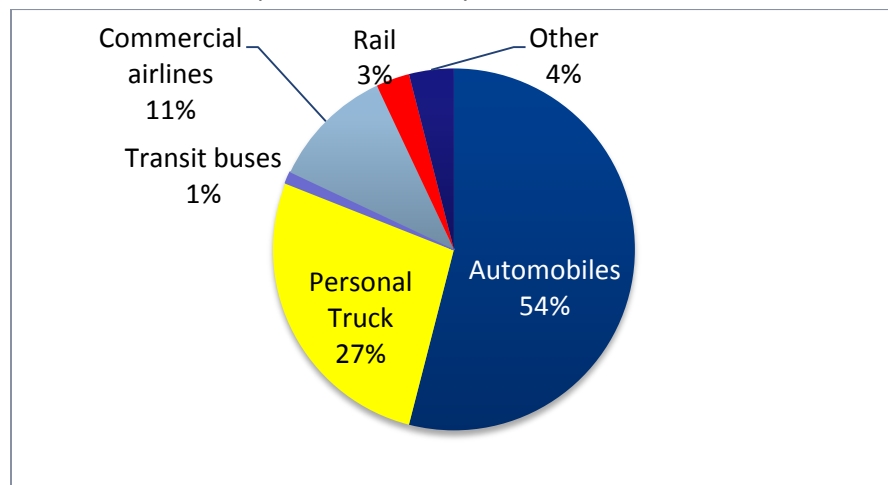
The transportation sector is the second biggest source of greenhouse gas emissions (GHG) in the United States, accounting for 33% as of 2009 (Figure 1).



Source: ACRP Report 11 (2009)

Figure 1. U.S. GHG Emissions by Sector.

The aviation industry accounts for 11% of transportation emissions (ACRP, 2012). Of total transportation GHG emissions, ground vehicles (which are mostly on-road but also include airport GSE) comprise 56% (Figure 2), making it the largest source of transportation GHG emissions. These emissions associated with ground vehicles use the atmosphere as a sink, which is the most significant sustainability issue material to the transportation industry.



Source: ACRP Report 11 (2009)

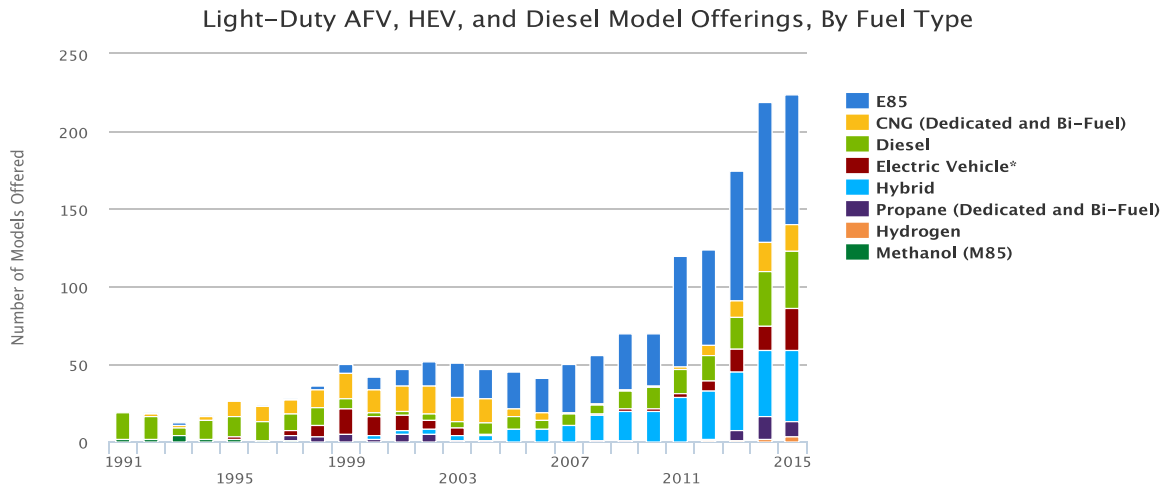
Figure 2. U.S. GHG Emissions in Transportation Sector by Mode.

## 4.2 A Growing Aviation Industry

The aviation industry is steadily growing, with airlines expecting global passenger demand to increase by 31% - thus an additional 930 million customers - between 2012 and 2017 (IATA, 2013). As the industry grows to accommodate this demand, we assume growth in associated airline operations on the ground will be necessary. For the average gate at JetBlue, two belt loaders, one bag tug and one push back (for description of these vehicle functions, see Section 4.4.2. Most Common GSE Vehicles)) is dedicated to an aircraft between flights. If JetBlue grows according to IATA projections, then they will have an additional 256 flights per day. While some existing ground vehicles can be used to service these additional flights, in many airports vehicles are already used to capacity and more will need to be purchased to meet this growing demand. If current operations remain unchanged, we would thus expect the associated greenhouse gas emissions from gasoline and diesel-powered GSE vehicles to also increase.

## 4.3 Increases in Alternative Fuel Vehicles

Due to various incentives, regulations, and concerns about emissions that are outside the scope of this project, alternative fuel vehicle purchases and offerings have significantly increased. Figure 3 from the US Department of Energy's Alternative Fuels Data Center displays the increase of available light-duty vehicles that are powered off a non-gasoline source in the last 25 years.



(Source: <http://www.afdc.energy.gov/data/10303>)

**Figure 3. Light-Duty Alternative Fuel Vehicles (AFVs), Hybrid Electric Vehicles (HEVs) and Diesel Model Offerings, by Fuel Type**

Similarly, in recent years, availability of alternative fuel GSE have entered the market.

## 4.4 Introduction to Ground Support Equipment (GSE)

### 4.4.1 GSE Definition

Ground Support Equipment (GSE) includes all equipment that services a plane on the ground during its “turn”, or while it is at the gate between flights. Ground support equipment can be motorized or non-motorized; our analysis applies only to motorized vehicles, as they require an energy input to operate. Many activities occur during a plane turnaround that adhere to a strict schedule, including unloading and loading passengers and luggage, refueling, and cleaning and restocking the plane.

### 4.4.2 Most Common GSE Vehicles

There are many GSE vehicles that serve a variety of airport needs. The following are the top three vehicle types (by quantity) that are owned by JetBlue and the average commercial airline:

#### 1. Bag Tug/Tractor

Bag tugs are the most recognizable GSE vehicle, and are used to transport baggage, cargo, mail, or other miscellaneous items between the airport and aircraft. They do so by connecting to a rolling non-motorized bag cart that physically holds the goods. When a passenger checks his or her bag at the terminal, it will be transported to a bag cart, which will be connected to a bag tug, and next driven to the aircraft to be loaded.

#### 2. Belt Loader

Belt loaders are used to load and unload baggage and cargo into and out of an aircraft. A belt loader consists of a conveyor that can be elevated so the bags are lifted to the belly of the plane.

### 3. Pushback Tug/Tractor

Pushback tugs are used to reverse aircraft out of a gate before taxiing to the runway. Conventional pushback tugs have towbars that connect to the airplane's nose wheel and push it out of the gate. As an alternative, towbarless pushbacks lift the nose wheel off the ground to reverse the aircraft. Though airplanes are capable of moving in reverse, doing so would cause a "jet blast" at the rear of the plane, which could damage the ground equipment and airport infrastructure (ACRP, 2012). Pushback tugs are often also used to move aircraft around the airport, such as to a hangar for maintenance.

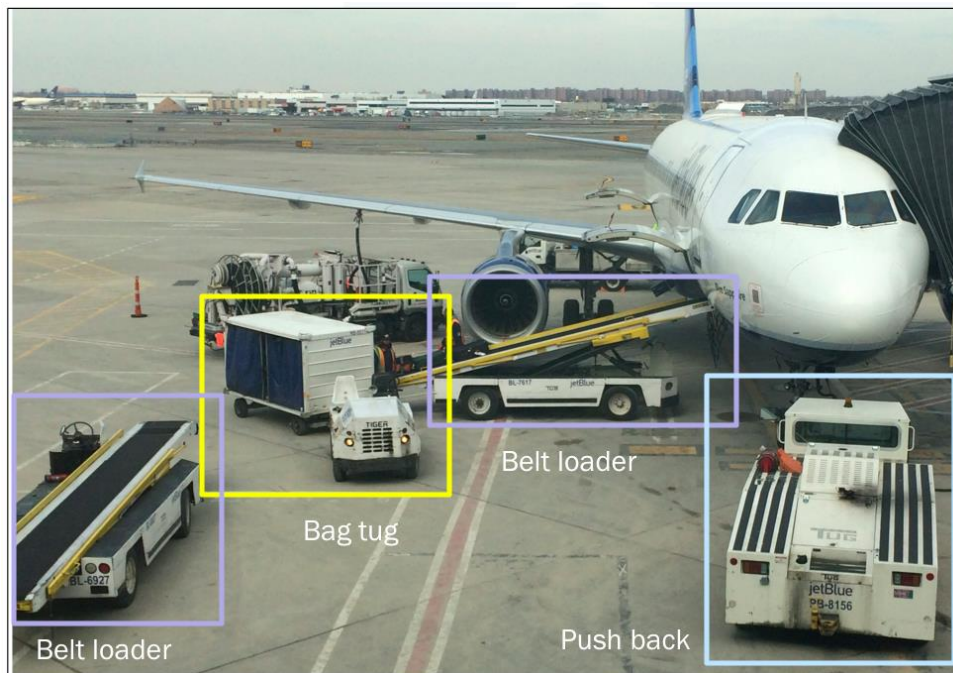


Figure 4: JetBlue Bag Tug, Belt Loader, and Push Back Servicing an Aircraft

#### 4.4.3 Regulations on GSE Emissions: Clean Air Act

One key difference between ground support and aircraft emissions in the United States is that those generated by GSE are subject to regulation.

The federal Clean Air Act (CAA) grants the US Environmental Protection Agency (EPA) the ability to set limits on ambient air quality, called National Ambient Air Quality Standards or NAAQS, for the EPA-specified criteria pollutants as detailed previously.

Regions within the U.S. are designated as to whether they meet the NAAQS by "attainment", "nonattainment", or "maintenance" if in transition. If it is determined that a region is in



“nonattainment”, state and local agencies must submit state implementation plans (SIPs) to the federal government that sets out a course of action for reaching the NAAQS. New York, where JFK is located, is currently in nonattainment status.

#### 4.4.4 Federal GSE Emissions Standards

The EPA has set emissions standards for stationary and mobile sources of criteria pollutants, where are as follows:

- Ground level ozone (O<sub>3</sub>)
- Carbon monoxide (CO)
- Particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>)
- Nitrogen dioxide (NO<sub>2</sub>)
- Sulfur dioxide (SO<sub>2</sub>)
- Lead (Pb)

As moving vehicles, airport GSE would be classified as mobile sources of emissions. GSE are further classified as non-road vehicles (as opposed to on-road vehicles) as they do not travel on public roadways. Emissions standards on non-road vehicles are more lenient, meaning higher allowable emissions. It’s important to note that some airport GSE such as catering trucks and crew vans, are also used on-road, and are thus subject to on-road standards. However, these vehicles are outside the scope of this study.

Emissions standards for non-road vehicles differ depending on whether they are compression-ignition (CI, typically fueled with diesel) or spark-ignition (SI, typically fueled with gasoline). For both categories, different standards exist depending on the manufacturing date and vehicle horsepower. The responsibility to meet these standards is largely borne by the manufacturer, though it is also up to the operators to ensure the vehicles they are using are meeting their respective engine standards.

#### 4.4.5 California GSE Emissions Standards

The Clean Air Act does not allow states to set their own vehicle emissions standards, with California being the only exception. California is allowed to adopt different emissions standards for mobile sources, with the stipulation that the standards they adopt are at least as stringent as the federal standards. Exercising this right, the Air Resources Board within the California Environmental Protection Agency has introduced the In-Use Off-Road Diesel Vehicle Regulation, which sets more stringent standards for diesel particulate matter and oxides of nitrogen (NO<sub>x</sub>) (California Environmental Protection Agency, 2014).

#### 4.4.6 Health Implications of Diesel and Gasoline Exhaust

A significant motivation for the Clean Air Act’s emissions standards is to reduce the impacts on human health from diesel and gasoline exhaust that is emitted when the fuel is combusted. Ground operations

are a concentrated source of NO<sub>x</sub>, ozone precursor, and particulate matter. Of particular concern is diesel exhaust; the California Office of Environmental Health Hazard Assessment notes over 40 toxic air contaminants in diesel exhaust, including benzene, formaldehyde, and arsenic, which are all suspected carcinogens. The particles and potentially hazardous substances are suspended in air, and are thus impossible to avoid breathing in if working on the ground.

#### 4.4.7 Reducing GSE Emissions Through Add-On Technologies

One strategy of reducing GSE emissions is through add-on emission control technologies. Control devices can collect and treat engine exhaust and convert them to less environmentally harmful compounds. Examples include oxidation catalysts, three-way catalytic converters, and particulate traps. For this assessment, we are not considering add-on devices, as it will not allow for simultaneous cost savings and emissions savings.

#### 4.4.8 Alternative Fuel Technologies

An option to reduce emissions associated with GSE involves using vehicles powered by alternative fuels, which are GSE using non petroleum-based fuels. Many U.S. airlines have converted a portion (20-30%) of their ground support fleet to alternative fuel vehicles, proving that it is a working model.

#### 4.4.9 Defining Alternative Fuels

Alternative fuels are fuels that serve as an alternative to gasoline and diesel. The Energy Policy Act of 1992 lists the following as alternative fuels:

- Gaseous fuels:
  - Hydrogen
  - Natural gas
  - Propane (Liquefied petroleum gas, LPG)
- Alcohols:
  - Ethanol
  - Methanol
  - Butanol
- Blends of 85% or more alcohol and gasoline
- Vegetable or waste oils
- Electricity (US EPA, 2013)

Not all of the above alternative fuels are appropriate or available for ground support equipment. An overview of the above alternative energy sources and details around their cost and environmental impact are detailed in Appendix B.

#### 4.4.10 Electric GSE (eGSE)

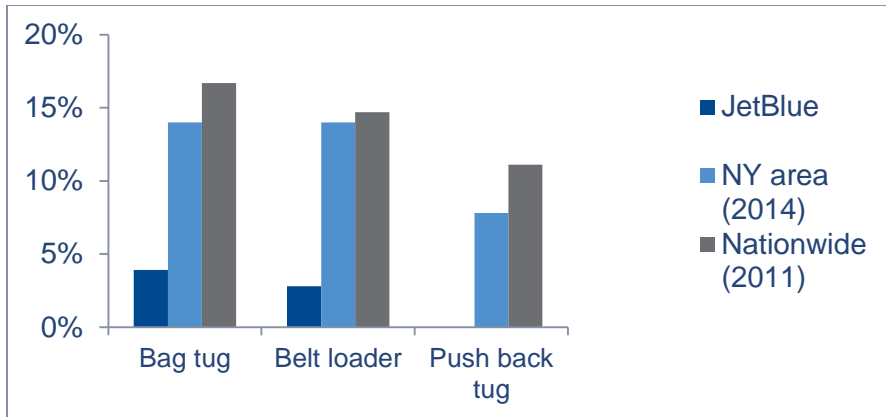
Electric vehicles use one or more electric motors to power the car, and do not possess an internal combustion engine. The vehicles contain a battery that is charged via an outlet and also through regenerative braking that stores kinetic energy from braking into potential energy to power the vehicle.

More GSE units in the United States are electric than any other alternative fuel type. As of 2012, approximately 10% of all GSE units, or 7,200 units, in the United States are electric (ACRP, 2012). The following characterize electric vehicles:

- **Lower operational costs:** Electricity price is more stable than fossil fuel prices and the cost to power an electric vehicle is usually less expensive than that for gasoline or diesel vehicle per unit of energy provided. Overall, electric vehicles have lower operational costs and less price volatility.
- **Lower maintenance costs:** Electric vehicles require less maintenance than internal combustion engine (ICE) vehicles, or vehicles powered by fossil fuels. This is mostly due to fewer moving parts in an electric vehicle, reducing the need for replacing spare parts, performing oil changes, or emission testing. Regenerative braking also reduces wear on brake pads.
- **Performance comparable to ICE vehicle:** Electric vehicles have comparable performance (speed and handling) to that of ICE vehicles. Electric vehicles are much quieter than ICE vehicles, reducing the health risk associated with noise exposure and helping adhere to U.S. Occupational Safety and Health Administration (OSHA) Standards 1910.95(a) (OSHA, 2015). However, electric GSE currently have limited abilities towing and hauling loads up ramps. For this reason, our study did not include GSE with large towing responsibilities (e.g., towing an aircraft).

#### 4.4.11 Airline Industry Trends in GSE Electrification

By far, the most common alternative fuel GSE vehicles are powered by electricity. As displayed in Figure 5, many commercial carriers have retrofitted their bag tugs, belt loaders, and push backs to roughly 10-20% electric. Electric GSE are thus a proven working model, as they have been shown across many regions to function as well as their internal combustion engine counterparts, and thus don't interfere with GSE operations.



Source: Port Authority of New York and New Jersey

**Figure 5. JetBlue GSE Electrification Comparison to New York and Nationwide Trends**

Figure 5 compares the portion of JetBlue’s bag tugs, belt loaders, and push back tugs that are electric powered, compared to commercial carriers across the New York and New Jersey area (John F. Kennedy International Airport, LaGuardia Airport, Newark Liberty International Airport, Stewart International Airport) and the U.S.. Note that the nationwide eGSE averages across all commercial carriers, as provided by ACRP Report 78 previously referenced, are from 2011. We expect this number to now be higher given the many eGSE projects that have been pursued since 2011.

Based on the fact that eGSE are already widely adopted across multiple airlines and airports – far more than any other source of alternative fuel – our study chose to only look at electric vehicles as an alternative fuel source for JetBlue’s JFK GSE fleet.

The majority of airlines who have retrofitted their GSE to alternative fuel use electricity as the alternative energy source, though there also exist some GSE vehicles powered by compressed natural gas, and liquid petroleum gas (propane). Airlines who use eGSE include Alaska Airlines, American Airlines, Continental Airlines (pre-United), Delta Airlines, Horizon Air, Southwest Airlines, US Airways, United Airlines, and United Parcel Service. Appendix X provides a list of U.S. airlines’ alternative GSE efforts that have been made public, with two airports exhibiting significant eGSE action described below.

**Alaska Airlines and Seattle-Tacoma International Airport (Sea-Tac)**

Alaska Airlines and their regional carrier, Horizon Air, are one of the leaders in the United States for ground support electrification. In 2013, Alaska set a goal to increase the percent of their ground support fleet electrified to 30% across their system (Alaska Air Group, 2013). They started this by undertaking a project to replace over 200 GSE vehicles to electric over a two-year period. Alaska estimated this initiative would save roughly \$800,000 annually in fuel, as well as 2,000 metric tons of CO<sub>2</sub>. Horizon Air reports that roughly 60% of their ground support fleet is electric, making them the airline with the highest percent of electric GSE in the United States. Since 2010, Sea-Tac has received four Voluntary Airport Low Emissions (VALE) grants (more information in “Voluntary Airport Low Emissions (VALE)

Federal Funding Program” section below) from the FAA totaling \$27.6 million to reduce airport emissions (Highline Times, 2010).

In March 2014, Sea-Tac announced plans to further increase their electric GSE projects. With the assistance of VALE and additional state funding, they plan to convert most of the remaining bag tugs, belt loaders, and pushback vehicles to electric. They will be purchasing 600 charging stations to support this. The project is estimated to save \$2.8 million in GSE fuel costs and avoid 10,000 tons of greenhouse gas emissions.

### **Los Angeles International Airport (LAX)**

As described in Section 4.4.3., Regulations on GSE Emissions: Clean Air Act (California Environmental Protection Agency, 2014), California is subject to the In-Use Off-Road Diesel Vehicle Regulation that sets tighter emissions standards around NOx and particulate matter for off-road vehicles, including airport GSE. Among other requirements, airlines cannot add older vehicles into their fleet starting in 2014, and are required to reduce fleet average emissions by retrofitting or replacing existing vehicles. Requirements and compliance dates vary by fleet size, and specific regulations are enforced at different times, with restrictions already in place for idling, reporting, and adding emissions control strategies for older vehicles.

As a result, many California airports, including Los Angeles International Airport (LAX), have worked with the airlines and their various tenants to meet these standards. In the Los Angeles World Airports (LAWA) 2008 Sustainability Plan, LAWA set a goal to convert 100% of diesel GSE to electric or the cleanest available technology by 2015.

### **4.4.12 Voluntary Airport Low Emissions (VALE) Federal Funding Program**

In 2004, the Vision 100 - Century of Aviation Reauthorization Act led to the creation of the Federal Aviation Administration (FAA) Voluntary Low Emissions Program (VALE, 49 U.S.C. §§ 40117, 47139 and 47140), with the purpose of offering funding for voluntary efforts to reduce criteria emissions at commercial service airports in regions that are in either non-attainment or maintenance status with the National Ambient Air Quality Standards (NAAQS) of the Clean Air Act.

Projects eligible for funding include emissions reduction efforts for vehicles or airport infrastructure. This report explores the possibility of utilizing the VALE program to help offset costs from switching to an electric GSE fleet. In this case, VALE funding can cover 100% of infrastructure costs (e.g., charging station purchase and installation costs).

Airport sponsors, typically a region’s Port Authority or a local governmental agency, can receive funding through two tracks: either through Passenger Facility Charges (PFCs) or Airport Improvement Programs (AIP) grants. Approved VALE projects generate Airport Emission Reduction Credits (AERCs) that can be used to meet future emission regulation requirements.

Typical VALE projects include providing preconditioned air and gate power; remote ground power; installing hydrant fueling stations; geothermal power; and GSE electrification (FAA). In 2014, nine VALE grants were awarded, ranging from \$102,456 for four compressed natural gas (CNG) vehicles in Atlanta, Georgia to \$3,687,168 for preconditioned air and gate power for 7 gates at Yeager Airport in Charleston, West Virginia (FAA, 2015). In 2014, AIP VALE funding totaled \$16.6 million.

Airport sponsors must agree to four conditions upon accepting VALE funding:

1. All VALE-provided equipment must stay at the airport for the entirety of its useful life
2. The airport sponsor must track VALE-provided use
3. The airport sponsor must maintain the VALE-provided equipment throughout its lifetime by fixing damaged equipment
4. The airport sponsor must put an emblem on any VALE-provided equipment that reads “Funded with the Voluntary Airport Low Emissions Program” (FAA)

## 5. Baseline Analysis

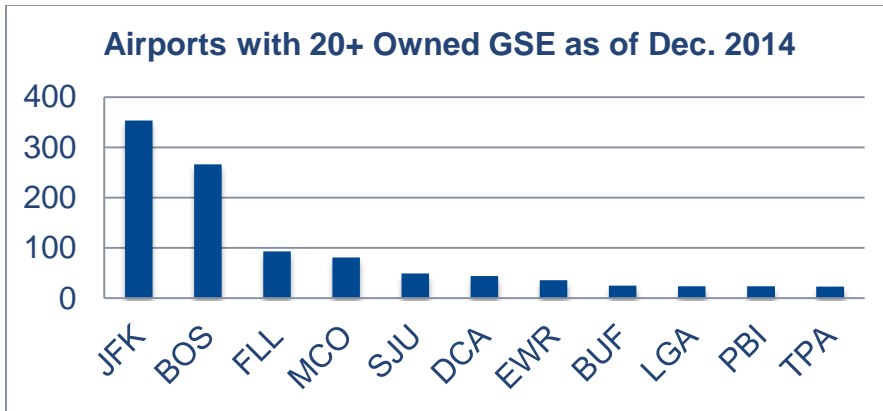
To begin our baseline analysis, we considered the following criteria to narrow the scope of GSE for our study:

1. Where does JetBlue spend the most money on GSE?
2. Is the region of interest eligible for VALE funding?
3. Which vehicles demand the most fuel/incur the most costs?
4. Which vehicles are offered in alternative fuel versions (e.g., electric)?

### 5.1 JetBlue Current GSE Fleet

JetBlue owns 2,936 units of ground support equipment across 76 airports. In many airports where JetBlue operates just a few flights a day, the airline contracts GSE work to a third party. In these locations, JetBlue owns just a few or no GSE.

Among the 2,936 GSE units JetBlue owns, 1,253 are motorized. These vehicles are found across 35 airports. Figure 4 demonstrates the distribution of GSE across airports owning at least 20 units of GSE. This highlights the fact the JFK Airport is JetBlue’s largest operation, has the largest concentration of owned motorized GSE vehicles, and, thus, has the greatest opportunity for fuel cost and greenhouse gas emission savings from an alternative fuel GSE retrofit. Note that additional GSE units leased or operated by business partners are excluded from the scope of this study.



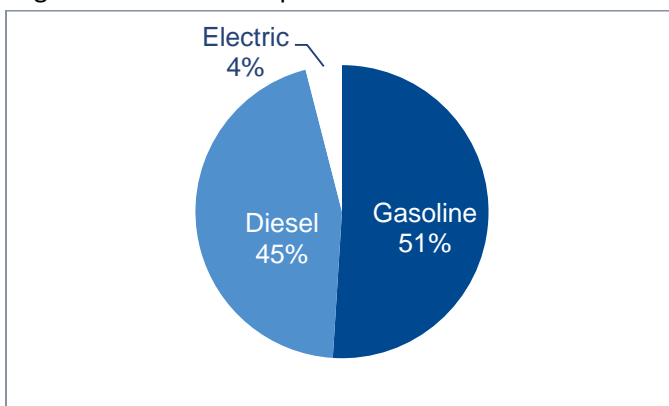
Source: JetBlue GSE Inventory

Figure 6. Quantity of owned motorized GSE units by airport (2014)

Across the entire system of JetBlue-owned motorized GSE, 96% of vehicles are gasoline or diesel powered, with the remaining 4%, or 48 vehicles, built with electric motors.

## 5.2 Long Beach Electric Vehicles

Most of the 48 electric vehicles across the system can be found in Long Beach International Airport (LGB); they currently possesses 6 electric belt loaders, 9 bag tugs, 4 golf carts, and 5 A/C carts. As part of the City of Long Beach’s efforts to reduce energy consumption and air pollution, in 2008 the Long Beach Airport installed 5 Dual Port SuperCharge stations for JetBlue and US Airways to use for electric bag tugs and belt loaders. The City of Long Beach’s Office of Sustainability estimated that this would provide charging for up to 40 GSE vehicles. They state that electric GSE can reduce annual fuel costs by 70 - 80% and can lower total operating costs by 30 - 40% when compared with conventional GSE (City of Long Beach, 2015). The remaining eGSE are electric scissor lifts, golf carts, and forklifts at JFK and Boston Logan International Airport.



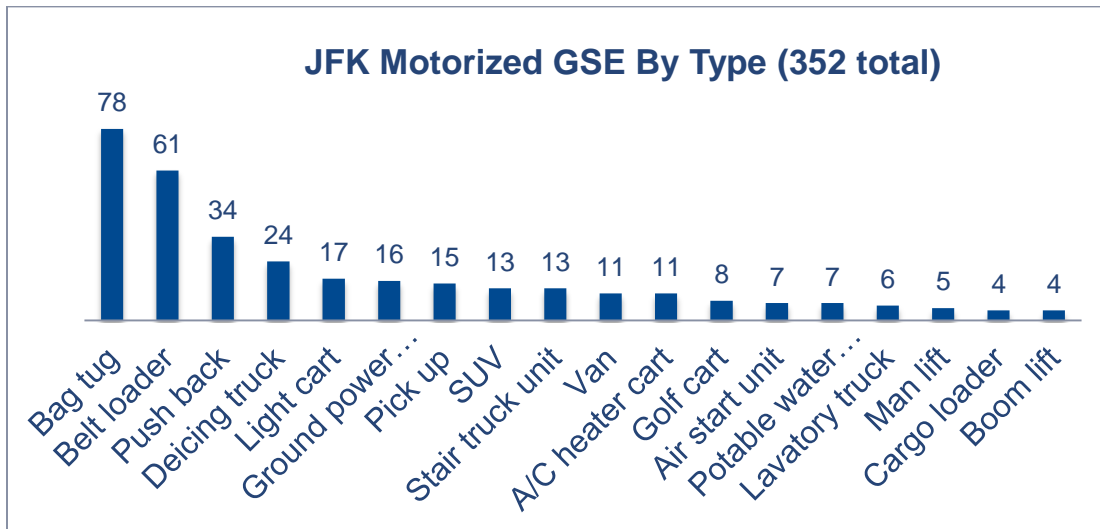
Source: JetBlue GSE Inventory

Figure 7. GSE Vehicles by Energy Type (2014).

### 5.3 GSE by Vehicle Type at JFK Airport

Figure 6 illustrates the breakdown by vehicle function of the 352 motorized GSE units at JFK. Here we again narrow the study scope to include only the three vehicle types JetBlue has the most of:

- Bag tug
- Belt loader
- Push back tug



Source: JetBlue GSE Inventory

Figure 6. JFK Motorized GSE by Vehicle Type.

We selected these three vehicle types for three primary reasons:

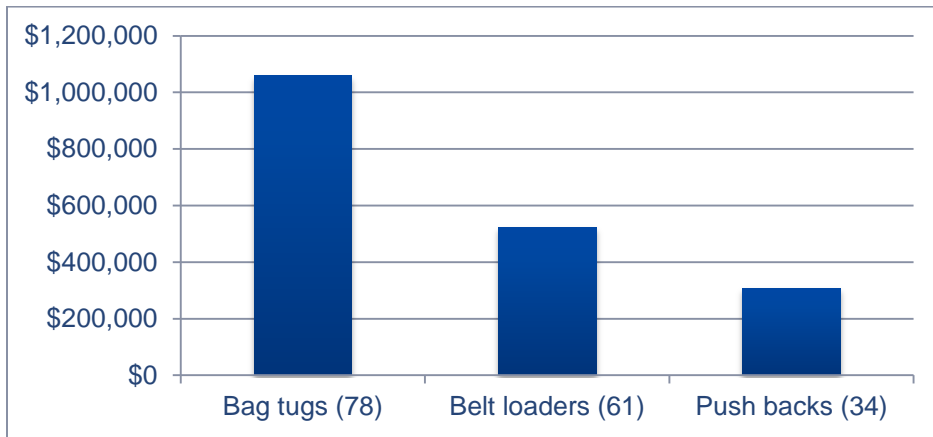
- 1.) An electric version of the existing vehicle model is available;
- 2.) They are the most used vehicles so have the highest energy savings potential;
- 3.) Based on our competitive analysis, they are the most common vehicle types other airlines have chosen to retrofit.

In 2014, JetBlue spent over \$2 million on diesel and gasoline fuel for GSE at JFK Airport. Consequently, the focus of the study is restricted to JFK International Airport, since this is where the most money on GSE fuel is spent. Additionally, this location is eligible for VALE funding, thus elevating the business case.

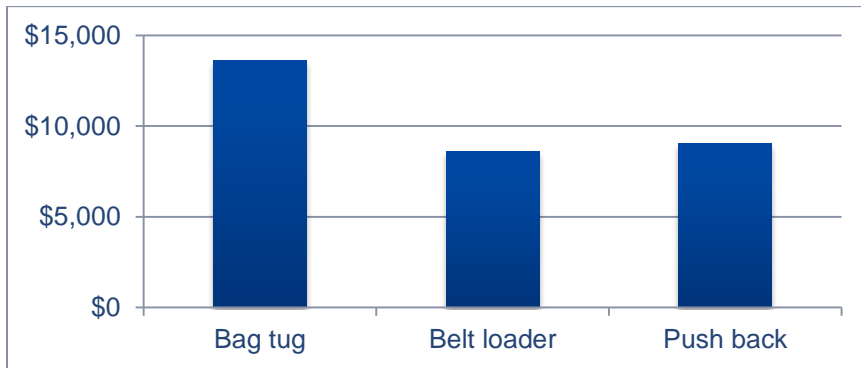
We estimate JetBlue spends over \$1.5 million annually powering their 34 push backs, 61 belt loaders and 78 bag tugs at JFK. The breakdown of total fuel cost per vehicle type at JFK is illustrated below (Figure 7). The values listed are based off our recorded vehicle run hours multiplied by vehicle energy efficiency data (for example, gallons consumed per hour of running) multiplied by the cost of the respective fuel (gasoline or diesel). Bag tugs consume the most fuel by GSE type, and account for roughly half of the total GSE fuel expenditures at JFK. Combined, we estimated that bag tugs, belt loaders and push backs make up over three-quarters of total GSE fuel expenditures at JFK Airport.



However, because there are more baggage tractors than there are belt loaders, pushbacks and lavatory trucks, we also considered the fuel cost of GSE on a per-vehicle basis (Figure 8).



**Figure 7. Approximate Total Annual Fuel Expenditures at JFK by GSE Type (2014)**



**Figure 8. Approximate Per Vehicle Annual Fuel Spend at JFK by GSE Type (2014)**

#### 5.4 Baseline Greenhouse Gas (GHG) Emissions

We consider the following pollutants material to JetBlue’s operations and sustainability commitments:

- Carbon dioxide (CO<sub>2</sub>)
- Methane (CH<sub>4</sub>)
- Nitrous Oxides (N<sub>2</sub>O)

From JetBlue’s total operations (aviation and ground), JetBlue’s 2014 greenhouse gas footprint was roughly 6.3 million tons of CO<sub>2</sub> equivalent (CO<sub>2</sub>e) (Table 2). The CO<sub>2</sub> equivalent of CH<sub>4</sub> and N<sub>2</sub>O was calculated using emissions factors from the EPA (US EPA, 2015) and the Climate Registry (The Climate Registry, 2015) and their respective GWPs, or Global Warming Potentials (US EPA, 2012). These emissions factors and GWPs are summarized in (Table 3).

	Total Emissions (metric tons)				CO <sub>2</sub> Equivalent (CO <sub>2</sub> e) Emissions (metric tons)			
	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total
Air Fleet	6,218,650	0	198	6,218,650	6,218,650	0	61,294	6,279,944

Ground Fleet (Total)	13,655	0.78	0.35	13,656	13,655	16.29	107.79	13,779
Ground-Diesel	6,145	0.35	0.16	6,145	6,145	7.33	48.51	6,201
Ground-Gasoline	6,458	0.28	0.06	6,459	6,468	5.87	18.24	6,482
TOTAL	6,232,305	0.78	198	6,323,306	6,232,305	16	61,401	6,293,723

**Table 2. Air and Ground Emissions (2014)**

Emission Type	Global Warming Potential (GWP)
CO <sub>2</sub>	1
CH <sub>4</sub>	21
N <sub>2</sub> O	310

**Table 3. Emission Type by Global Warming Potential (GWP)**

From the 6.3 million tons of CO<sub>2</sub>e emissions, approximately 0.2% is from ground emissions. Although this may seem like a small number compared to emissions from aviation, this number is not insignificant. The CO<sub>2</sub> emissions from the GSE fleet is roughly equivalent to:

- 32,807,143 miles driven by passenger vehicles in the U.S. in one year (US EPA, 2007).
- Electricity provided to 1,895 homes in the U.S. in one year (US EPA, 2007).
- 14,800,215 pounds of coal burned (US EPA, 2007).
- 200 one-way flights on a 150-seat plane between JFK and LAX<sup>2</sup>

## 5.5 CO<sub>2</sub>-eq and pollutants at JFK Airport

	Total fuel use (gallons)	Emissions (metric tons)				CO <sub>2</sub> equivalent (metric tons)			
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Total
JFK Airport									
<b>Diesel</b>	265,931	2,715	0.15	0.07	2,715	2,715	3.24	21.43	2,740
<b>Gasoline</b>	299,880	2,633	0.11	0.02	2,633	2,633	2.39	7.44	2,643
<b>Total</b>	565,811	5,348	0.27	0.09	5,348	5,348.10	5.63	28.87	5,383

**Table 4. Annual Emissions and CO<sub>2</sub>-eq Emissions at JFK Airport from GSE Fuel Use (2014)**

<sup>2</sup> Using Carbon Fund calculator, assuming one-way flight from JFK to LAX, which is equivalent to 0.46 tons of CO<sub>2</sub>/passenger. Assuming using Airbus 320, which has approximately 150 passenger seats.

## 6. Financial and Environmental Modeling Approach

To perform an analysis of the GSE fleet, we built a model using Microsoft Excel for the purpose of providing the answers to the following questions:

1. How much will it cost to retrofit the fleet under various scenarios?
2. What will be the cost savings and additional environmental benefits under various retrofit scenarios?

The model uses the following inputs:

- 1. Airport location:** This is used to determine energy price, VALE funding eligibility and the CO<sub>2</sub> intensity of the grid.
- 2. Energy Costs:** For JFK, we assumed
  - a. Electricity price (2014): \$0.094/kWh
  - b. Gasoline price (2014): \$3.60/gallon
  - c. Diesel price (2014): \$3.99/gallon
- 3. GSE fleet composition:** A user-input section, the model takes into account how many push back tugs, belt loaders and bag tugs are in the current GSE inventory, further organized by fuel type (electric, gasoline or diesel).
- 4. GSE purchasing decision:** This input accounts for how many vehicles from the current fleet will be retrofitted.
- 5. Operational costs:** The model accounts for how much current GSE and electric GSE vehicles cost to operate using assumptions on run hours, vehicle efficiency, and energy prices.
- 6. Investment costs:** Cost of new and refurbished GSE and eGSE were taken from Tug Technologies list prices. We assumed that the price of a charging stations were equivalent to what JetBlue paid for their charger at Long Beach, and that one charging station would be required for every 3 eGSE vehicles.
- 7. Grid CO<sub>2</sub> intensity factor:** The US EPA released the CO<sub>2</sub> intensity of grid electricity by state listed in Appendix A-4. This was used to determine CO<sub>2</sub> emissions and potential savings for different scenarios.
- 8. VALE funding eligibility**

See Appendices A-2 to A-7 for further details of assumptions.

Using the above inputs, the model provides the following outputs:

1. Total cost of retrofit
2. Cost of vehicle acquisition
3. Cost of new charging stations
4. Annual maintenance costs
5. Annual expenditures using baseline fleet
6. Annual expenditures using retrofitted fleet
7. Return on Investment (ROI)

We use the model for the analysis described later in this report to evaluate JFK, though it was built for the purpose of being applied to the 16 JetBlue airports that own a significant number of GSE.

### 6.1 Maintenance and training costs

Due to difficulties in estimating these costs for our analysis, we assumed that no maintenance and training costs would exist if JetBlue were to pursue electrifying a portion of their fleet. However, in reality we would expect for this to not be the case. For maintenance, we would expect that fewer maintenance events would be required as electric vehicles have fewer moving parts, but for these events to be more expensive as it may be costly to have an electric vehicle specialist on site. However, we would expect for the per-event maintenance costs gradually decline as the airline acquires a significant eGSE fleet. If JetBlue were to pursue eGSE, we would recommend investing in comprehensive training for their staff. This value would need to be input into the model and updated from the \$0 we assume.

### 6.2 Scenario Analyses

There are multiple options to introduce electric vehicles to JetBlue’s GSE fleet. We modeled various scenarios to manipulate number of vehicles purchased, whether funding was received, and to integrate additional uncertainties.

#### Scenario A. 100% Retrofit of Belt Loaders, Bag Tugs and Pushbacks Within First Year

In Scenario A, JetBlue discards all existing GSE, and purchases an entirely electric fleet.

**Scenario A** assumes the following:

- All eGSE are purchased in one year (2016) to replace current GSE fleet.
- No value is recovered from the discarded existing fleet.
- All eGSE are purchased as new.
- VALE funding is received to cover 100% of infrastructure costs

The total number of vehicles to be retrofitted is as follows:

<b>Bag tugs</b>	78
<b>Belt loaders</b>	61
<b>Push backs</b>	34

**Table 5. Scenario A: Total Number of Vehicles to Retrofit**

#### Scenario B. 100% Retrofit of Belt Loaders and Bag Tugs Within First Year

**Scenario B** assumes the same assumptions as in Scenario A, but *does not retrofit pushback GSE*. The reason for this is because of the high cost of pushback GSE and significantly lower annual run hours compared to the other vehicle types, resulting in a longer vehicle payback period. Electric pushbacks are

more than twice as expensive as electric belt loaders, and nearly four times as expensive as electric bag tugs, with similar fuel savings.

Scenario C. 100% Retrofit of Belt Loaders, Bag Tugs and Pushbacks as Current Fleet

Retires

From Scenario C on, we consider the costs JetBlue would have to incur in a business as usual case as GSE in their fleet retire and need to be replaced.

**Scenario C** assumes the following:

- All eGSE are purchased as the old fleet is retiring, based on the replacement schedule outlined in Table 6.
- All eGSE are purchased as new.
- VALE funding is received.

Our model took into account the purchasing needs for JetBlue at JFK Airport. Many GSE vehicles will retire and need to be replaced within a few years. After analyzing JetBlue’s current GSE fleet at JFK, we found that over the next 13 years, 28 pushbacks, 44 Belt loaders and 56 bag tugs will need to be replaced. This is an opportunity to purchase new eGSE and realize energy savings when current GSE needs to be replaced. The needs for new purchasing are outlined in Table 6 and the total number of vehicles that need to be retrofitted is listed in Table 7. The analysis was based on GSE lifetime assumptions (Appendix A-5).

Vehicles due to be replaced	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Pushbacks	3	2	7	5	1	0	3	0	0	5	1	1
Belt loader	1	5	11	13	0	5	0	0	7	0	2	0
Bag tug	0	5	10	1	12	11	6	0	6	0	3	2

**Table 6. Scenario C Purchasing Schedule**

<b>Pushback</b>	28
<b>Belt loaders</b>	44
<b>Bag Tugs</b>	56

**Table 7. Scenario C: Total Number of Vehicles to Retrofit**

This scenario is important because it represents a more realistic eGSE retrofit scenario than in Scenarios A and B. It is unlikely that JetBlue will replace their belt loader, bag tug and pushback vehicles all at once 2016 since the vast majority of their GSE are not set to retire for many years.

### Scenario D. 100% Retrofit of Belt Loaders and Bag Tugs as Current Fleet Retires

Scenario D assumes the same assumptions as in Scenario C, but *does not retrofit Pushback GSE*.

### Scenario E. 20% Retrofit of Belt Loaders, Bag Tugs and Pushbacks as Current Fleet Retires

Scenario E assumes the same assumptions as in Scenario C, but analyzes up to a 20% retrofit of the current fleet. The purchasing decision is outlined in Table 8 (note that eGSE vehicle purchasing stops in 2018):

Vehicles due to be replaced	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Pushbacks	3	2	7	0	0	0	0	0	0	0	0	0
Belt loader	1	5	9	0	0	0	0	0	0	0	0	0
Bag tug	0	5	10	0	0	0	0	0	0	0	0	0

**Table 8. Scenario E eGSE Purchasing Schedule**

The total number of vehicles to be retrofitted is as follows:

<b>Pushback</b>	12
<b>Belt loaders</b>	15
<b>Bag Tugs</b>	15

**Table 9. Scenario E: Total Number of Vehicles to Retrofit**

### Scenario F. 20% Retrofit of Belt Loaders and Bag Tugs as Current Fleet Retires

Scenario F assumes the same assumptions as in Scenario E, but analyzes up to a 20% retrofit of the current fleet and *does not retrofit Pushback GSE*. The purchasing decision is outlined below (note that eGSE vehicle purchasing stop on 2018):

Vehicles due to be replaced	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Pushbacks	0	0	0	0	0	0	0	0	0	0	0	0
Belt loader	1	5	9	0	0	0	0	0	0	0	0	0
Bag tug	0	5	10	0	0	0	0	0	0	0	0	0

**Table 10. Scenario F: eGSE Purchasing Schedule**

<b>Pushback</b>	0
<b>Belt loaders</b>	15
<b>Bag Tugs</b>	15

**Table 11. Scenario E: Total Number of Vehicles to Retrofit**

Scenario G. 50% Retrofit of Belt Loaders, Bag Tugs, and Pushbacks as Current Fleet

Retires

Scenario G assumes the same assumptions as in Scenario C, but analyzes up to a 50% retrofit of the current fleet. The purchasing decision is outlined in Table 16 (note that eGSE vehicle purchasing stops in 2021):

Vehicles due to be replaced	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Pushbacks	3	2	7	5	1	0	0	0	0	0	0	0
Belt loader	1	5	11	13	0	3	0	0	0	0	0	0
Bag tug	0	5	10	1	12	11	0	0	0	0	0	0

**Table 12. Scenario G Purchasing Schedule**

<b>Pushback</b>	18
<b>Belt loaders</b>	33
<b>Bag Tugs</b>	39

**Table 13. Scenario G: Total Number of Vehicles to Purchase**

Scenario H. 50% Retrofit of Belt Loaders and Bag Tugs as Current Fleet Retires

Scenario H assumes the same assumptions as in Scenario G, but analyzes up to a 50% retrofit of the current fleet and *does not retrofit Pushback GSE*. The purchasing decision is outlined below (note that eGSE vehicle purchasing stops in 2021):

Vehicles due to be replaced	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Pushbacks	0	0	0	0	0	0	0	0	0	0	0	0
Belt loader	1	5	11	13	0	3	0	0	0	0	0	0
Bag tug	0	5	10	1	12	11	0	0	0	0	0	0

**Table 14. Scenario H Purchasing Decision**

<b>Pushback</b>	0
<b>Belt loaders</b>	33
<b>Bag Tugs</b>	39

**Table 15. Scenario H: Total Number of Vehicles to Purchase**

## 7. Results

### 7.1 Scenario Analysis Results

In the below scenarios, we graph out two courses of action:

- **ICE (blue line):** This represents costs for a business-as-usual case, where JetBlue operates an internal combustion engine fleet (gasoline or diesel).
- **Electric (green line):** This represents costs for an alternate scenario where JetBlue purchases electric vehicles to replace ICE vehicles, ranging from 0% to 100% per vehicle type.

We graph **total operating costs** for both potential courses of action, which include:

- Costs of fueling the vehicles (either gasoline/diesel, electric, or a combination of both)
- Costs of acquiring new vehicles
- Cost of the charging stations if VALE is not received

Note that total operating costs are compounding, meaning they sum from year to year. **Annual operating costs** represent the operating costs for each year graphed.

#### Scenario A. 100% Retrofit of Belt Loaders, Bag Tugs and Pushbacks Within First Year

This scenario tells us the overall savings opportunity in the GSE fleet electrification. An immediate 100% retrofit of the belt loader, bag tug and pushback GSE vehicles to electric would reduce average annual fuel expenditures by 46%. This does not consider savings in maintenance from eGSE, which, in this study, is assumed to be equal to maintenance costs for gasoline/diesel-powered GSE. Additionally, the retrofit would abate over 4,600 metric tons of CO<sub>2</sub>-equivalent emissions.

The breakeven point for this project will occur after 12 years. This means that in 12 years, the total cost of operating the electric fleet is less than the cost of operating the business-as-usual ICE fleet.

Thus, this is the point where investing in eGSE where JetBlue becomes profitable and total operating costs for eGSE is cheaper than operating costs of ICE GSE.

It is important to note that this is an unrealistic scenario, as it is highly unlikely that JetBlue would discard their entire fleet of functioning vehicles and purchase brand new ones.



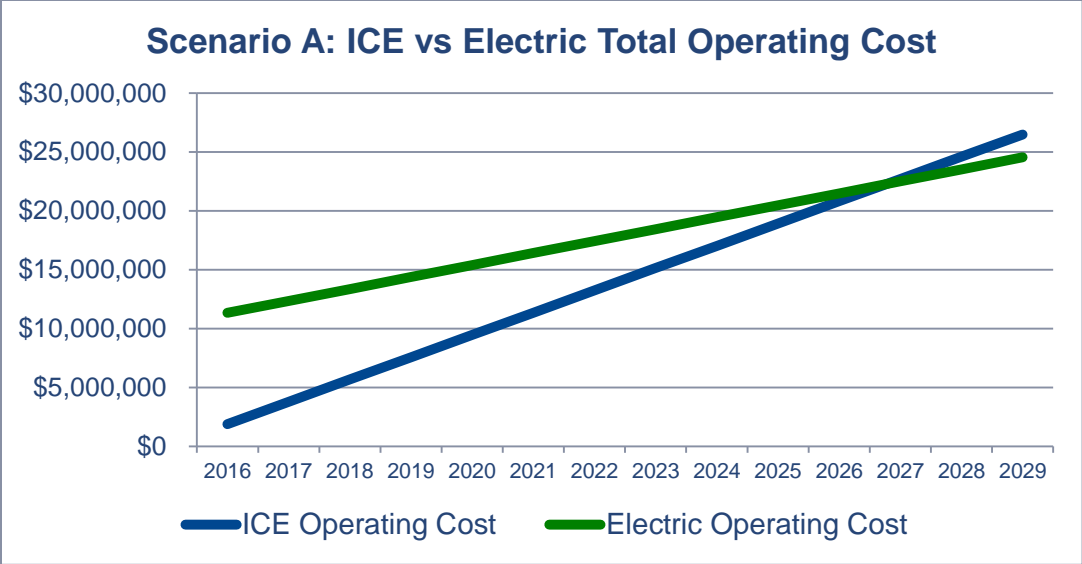


Figure 9. Scenario A: Comparison of Accrued Operating Costs, ICE vs. Electric

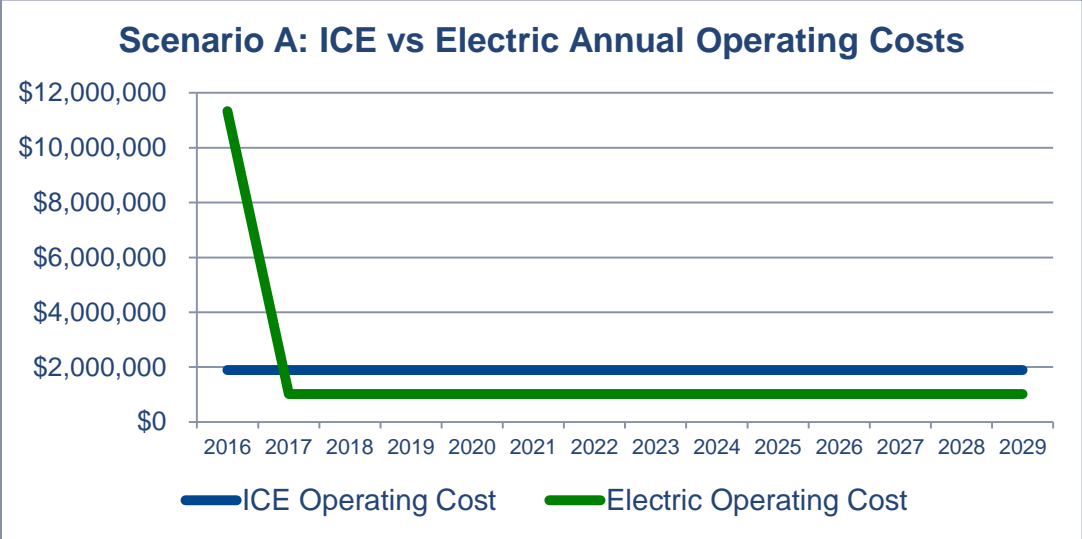


Figure 10. Scenario A: Comparison of Annual Operating Costs, ICE vs. Electric

CapEx	\$10.3 Million
Annual Fuel Savings (Average)	\$876,661
Breakeven Point (Yrs)	12
Accrued Savings (Over 14 Years)	\$1.95 Million
CO2e Emission Savings (metric tons/yr)	4,642

Table 16. Scenario A: Financial Summary

### Scenario B. 100% Retrofit of Belt Loaders and Bag Tugs Within First Year

This scenario is similar to Scenario A, except *Pushback GSE are not retrofitted*. This gives us slightly lower annual fuel savings of \$733,912. Although lower in energy savings, this project requires significantly less capital than in Scenario A with a quicker breakeven point of 8 years.

Similar to Scenario A, this is also a very unlikely scenario, as it would also require JetBlue discarding the majority of their fleet in one year to purchase brand new vehicles.

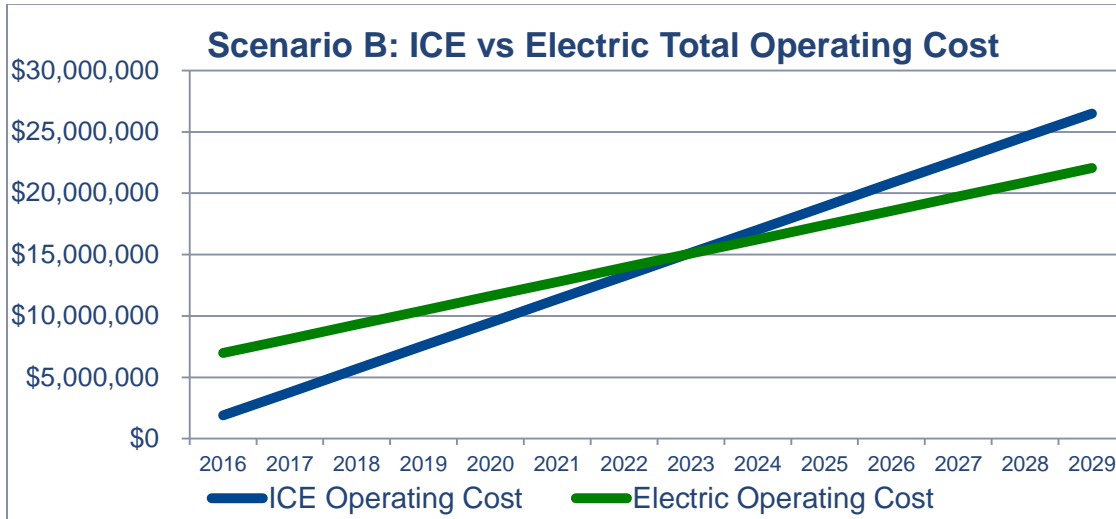


Figure 11. Scenario B: Comparison of Accrued Operating Costs, ICE vs. Electric

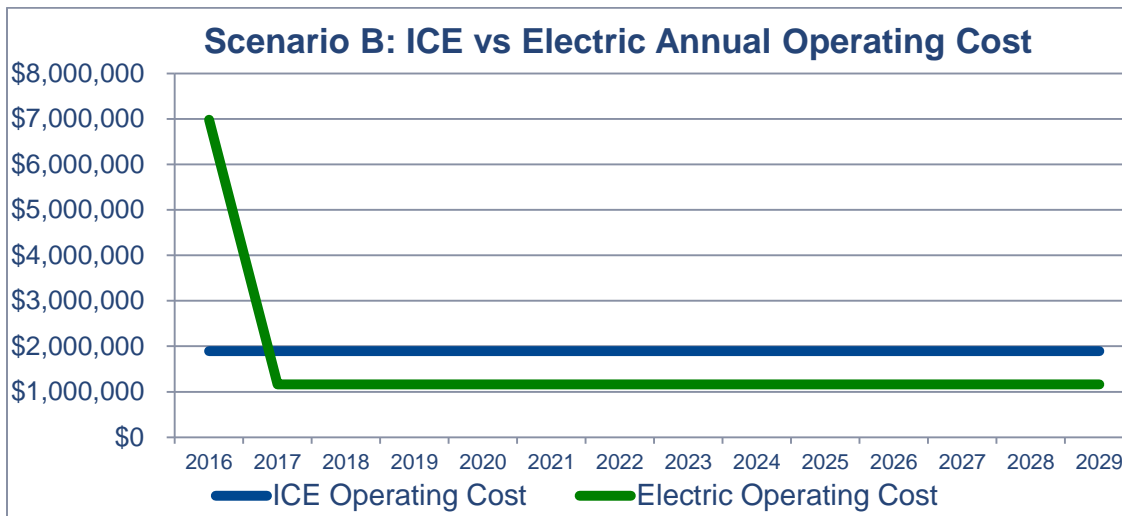


Figure 12. Scenario B: Comparison of Annual Operating Costs, ICE vs. Electric

CapEx	\$5.8 Million
Annual Fuel Savings (14 Year Average)	\$733,912
Breakeven Point (Yrs)	8
Accrued Savings (Over 14 Years)	\$4.45 Million
CO2e Emission Savings (metric tons/yr)	4,344

**Table 17. Scenario B: Financial Summary**

### Scenario C. 100% Retrofit of Belt Loaders, Bag Tugs and Pushbacks as Current Fleet Retires

In Scenario C on, eGSE is only purchased as vehicles in the current fleet retire and need to be replaced anyway. Here, JetBlue’s operating costs while using a portion of electric vehicles is always lower than using ICE vehicles (Figure 14) and the difference becomes larger as more electric vehicles are added to the fleet (Figure 13). This difference is due to the cheaper cost of electricity than gasoline and diesel.

We introduce this scenario because it is a more realistic approach to eGSE purchasing than in Scenario A and B, as it factors in the costs JetBlue is scheduled to incur on new ICE vehicles. The 100% immediate retrofit in Scenarios A and B is unrealistic since many of the vehicles being replaced still have a lot of life left in them. Additionally, it requires significant up-front capital cost: capital expenditures in Table 18 is amount spent over a 13-year time period, whereas capital expenditures in Tables 16 and 17 for Scenarios A and B, respectively, are required within the first year. Additionally, Scenarios A and B are risky projects: if JetBlue runs into logistical problems with the electric vehicles, then they may face trouble with everyday operations since pushback, belt loader and bag tugs, essential GSE at every gate.

As opposed to Scenarios A and B, the number of electric vehicles in operation changes each year, as they are introduced slowly throughout the 14 year timeline. **Thus, our calculation for total operating costs changes** – for each year of each electric scenario, total operating costs include the electricity costs for the electric vehicles currently in operation, and the gasoline and diesel costs for the vehicles that are not retrofitted. These are summed to the total operating costs displayed in all graphs. ICE total operating costs, or business-as-usual, consistently show the cost of gasoline and diesel to power the fleet, as well as the cost of acquiring new ICE vehicles that are scheduled to retire. Spikes within the operating costs graphs represent a year that many new vehicles are retiring and require replacement.

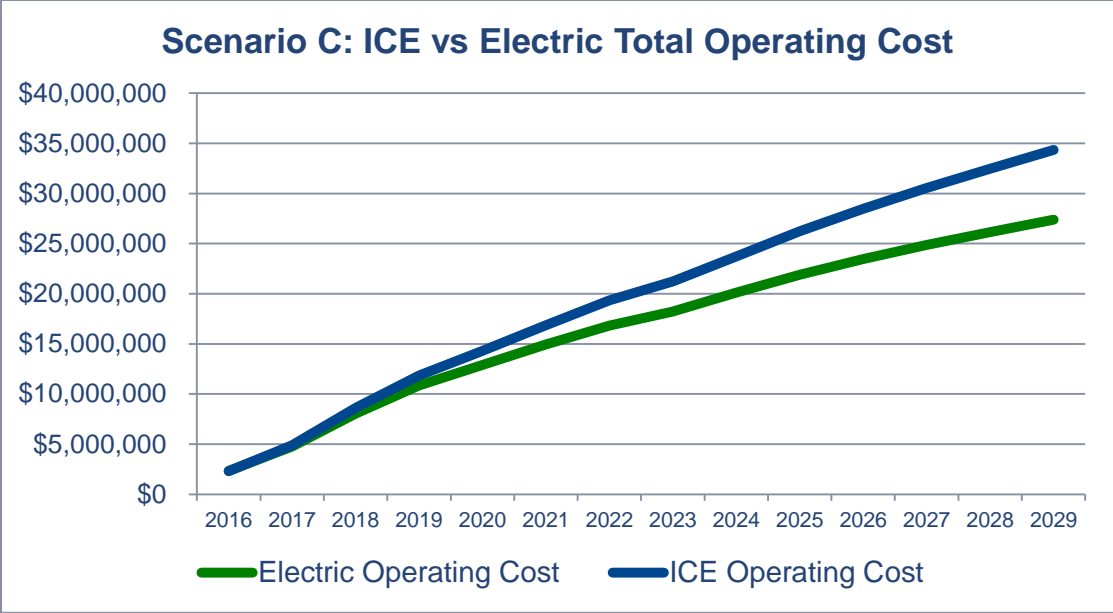


Figure 13. Scenario C: Comparison of Accrued Operating Costs, ICE vs. Electric

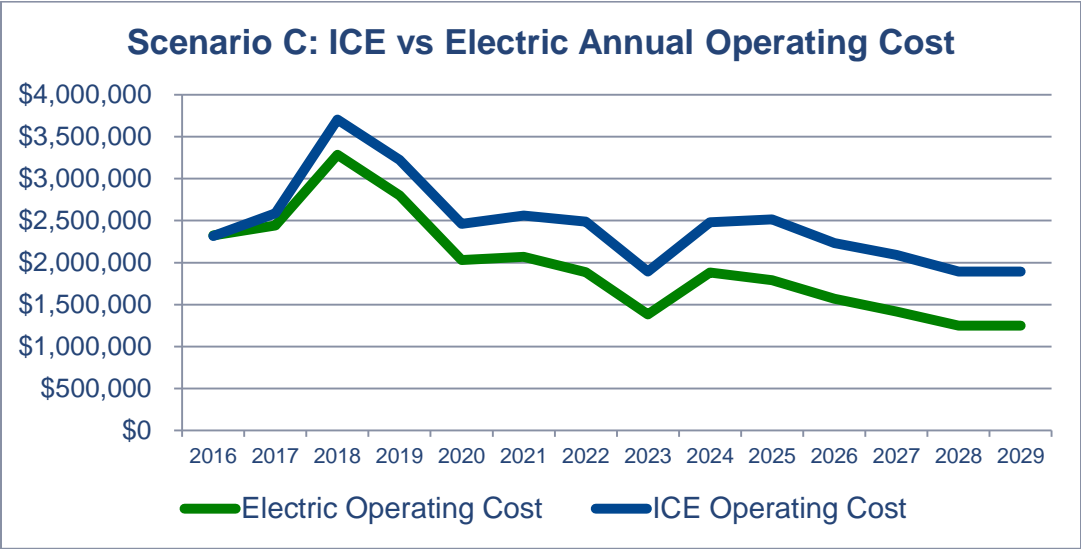


Figure 14. Scenario C: Comparison of Annual Operating Costs, ICE vs. Electric

CapEx	\$7.89 Million
Annual Fuel Savings (14 Year Average)	\$442,031
Breakeven Point (Yrs)	2
Accrued Savings (Over 14 Years)	\$6.96
CO2e Emission Savings (metric tons/yr)	3,820

Table 18. Scenario C: Financial Summary

### Scenario D. 100% Retrofit of Belt Loaders and Bag Tugs as Current Fleet Retires

This scenario is similar to Scenario C above, except pushback eGSE are not purchased. This requires a lower capital expenditure than in the previous scenario with a quicker breakeven point of one year. Similar to Scenario C, total and annual operating costs when using electric vehicles are lower than when using only ICE vehicles. Since pushbacks remain diesel-powered in our alternative scenario, the costs of purchasing diesel have been incorporated into the total operating costs graphed below.

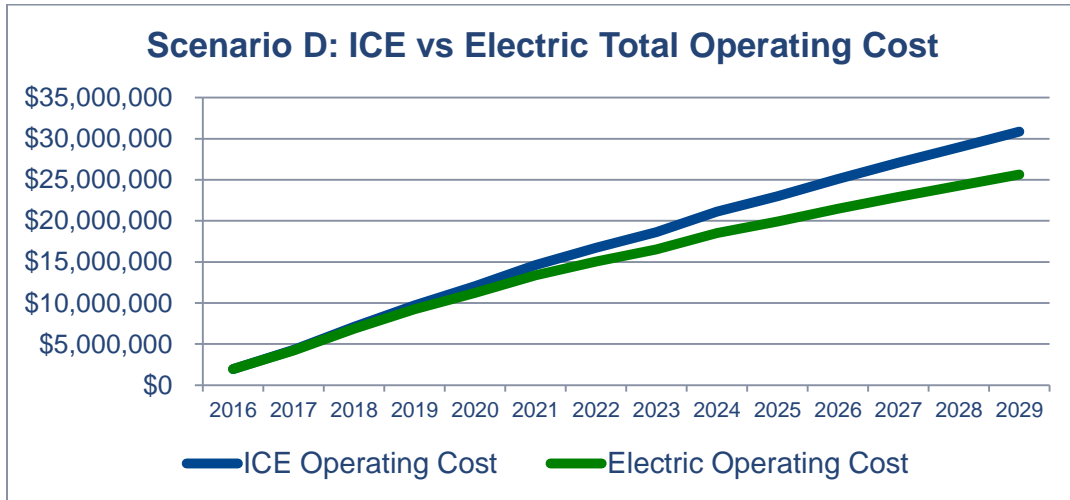


Figure 15. Scenario D: Comparison of Accrued Operating Costs, ICE vs. Electric

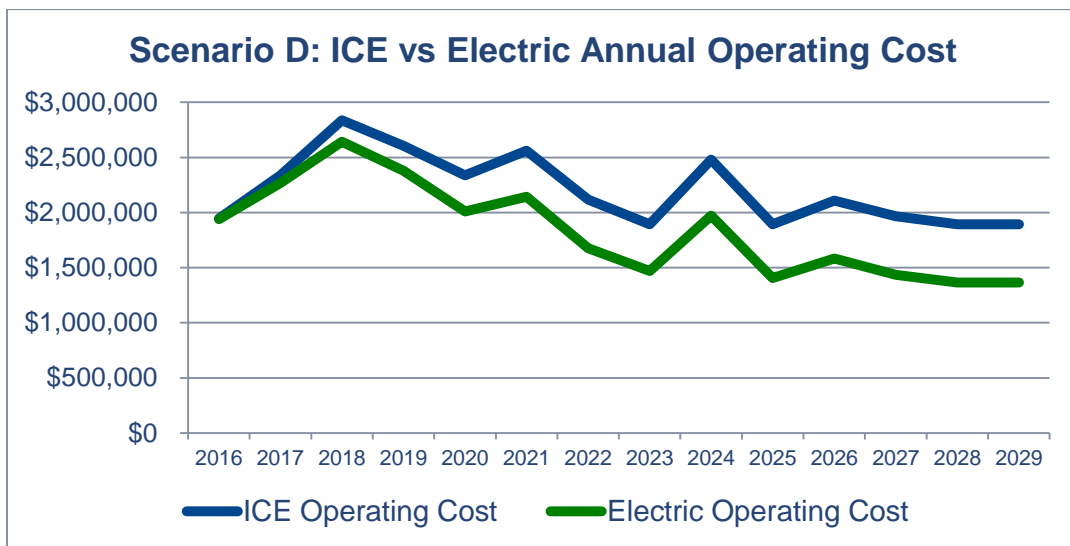


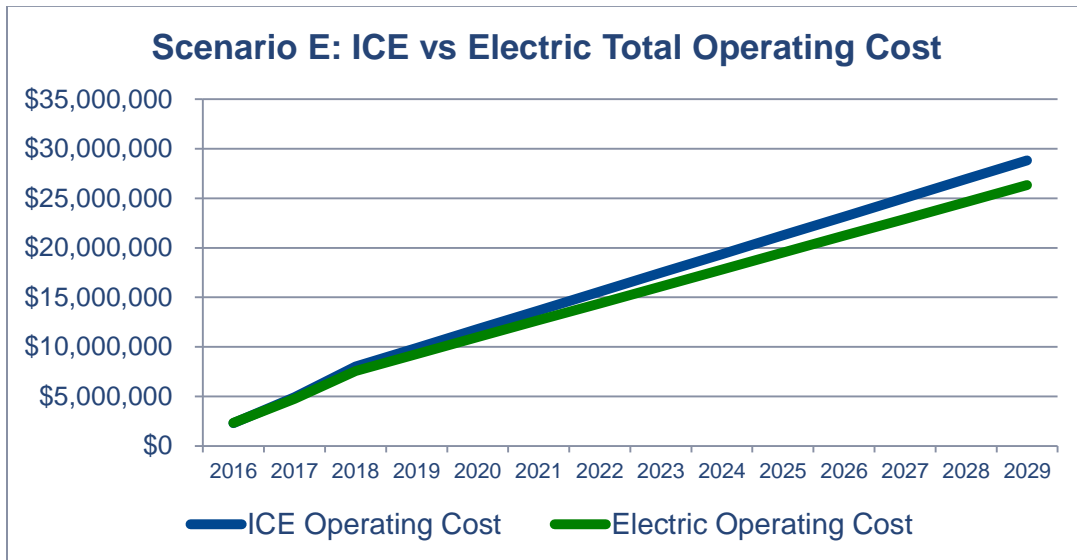
Figure 16. Scenario D: Comparison of Annual Operating Costs, ICE vs. Electric

CapEx	\$4.19 Million
Annual Fuel Savings (14 Year Average)	\$360,160
Breakeven Point (Yrs)	1
Accrued Savings (Over 14 Years)	\$5.21 Million
CO2e Emission Savings (metric tons/yr)	3,120

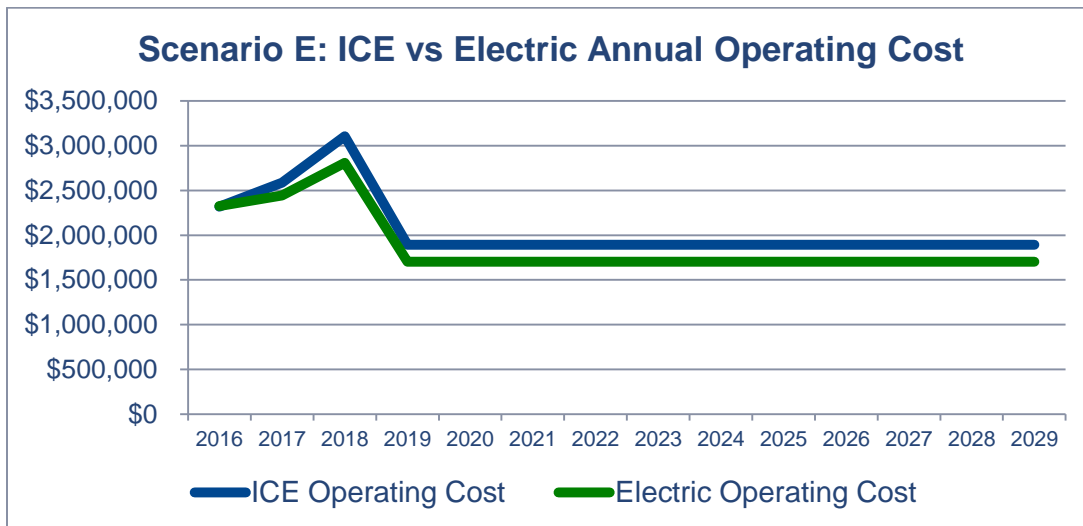
**Table 19. Scenario D: Financial Summary**

Scenario E. 20% Retrofit of Belt Loaders, Bag Tugs and Pushbacks as Current Fleet Retires

This scenario serves to understand the profitability of a 20% electric retrofit of the current GSE fleet. Similar to the previous scenarios, eGSE is only purchased as the current ICE GSE vehicles are retiring. This project requires a smaller overall capital expenditure at \$2.35 million over 14 years with a quick breakeven point of 2 years.



**Figure 17. Scenario E: Comparison of Accrued Operating Costs, ICE vs. Electric**



**Figure 18. Scenario E: Annual and Total Annual Fuel Savings**

CapEx	\$2.35 Million
Annual Fuel Savings (14 Year Average)	\$167,548
Breakeven Point (Yrs)	2
Accrued Savings (Over 14 Years)	\$2.49 Million
CO2e Emission Savings (metric tons/yr)	1,100

**Table 20. Scenario E: Financial Summary**

### Scenario F. 20% Retrofit of Belt Loaders and Bag Tugs as Current Fleet Retires

This project is similar to the previous scenario, but does not consider pushback eGSE. Further, **this is the first scenario in which JetBlue does not receive VALE funding.** Thus, JetBlue pays for their charging stations valued at \$22,950 per station, with one station servicing 3 vehicles. Note that JetBlue currently owns one charging station, so we assume this cost begins to incur with the purchase of vehicle 4. This assumption holds true for any future scenario where VALE funding is not received.

Scenario F thus represents a worst-case scenario for a 20% belt loader and bag tug retrofit, as VALE funding would eliminate the charging station costs. This cost is therefore factored into the “CapEx” value in Table 21. Regardless, this scenario requires the smallest capital expenditure of all the scenarios at \$1.49 million over 14 years with a breakeven point of year 1. This is because JetBlue immediately begins to realize fuel savings, coupled with the fact that the vehicles themselves are cheaper in electric versus ICE. However, the savings are less pronounced than in other scenarios, as JetBlue gradually must purchase charging stations for every three vehicles purchased. This is evident in Figure 18, where the ICE vehicle operating costs are very closely aligned with the electric vehicle operating costs. However, Figure 19 displays only the fuel savings to demonstrate the benefit from the eGSE when the charging station costs are not considered.

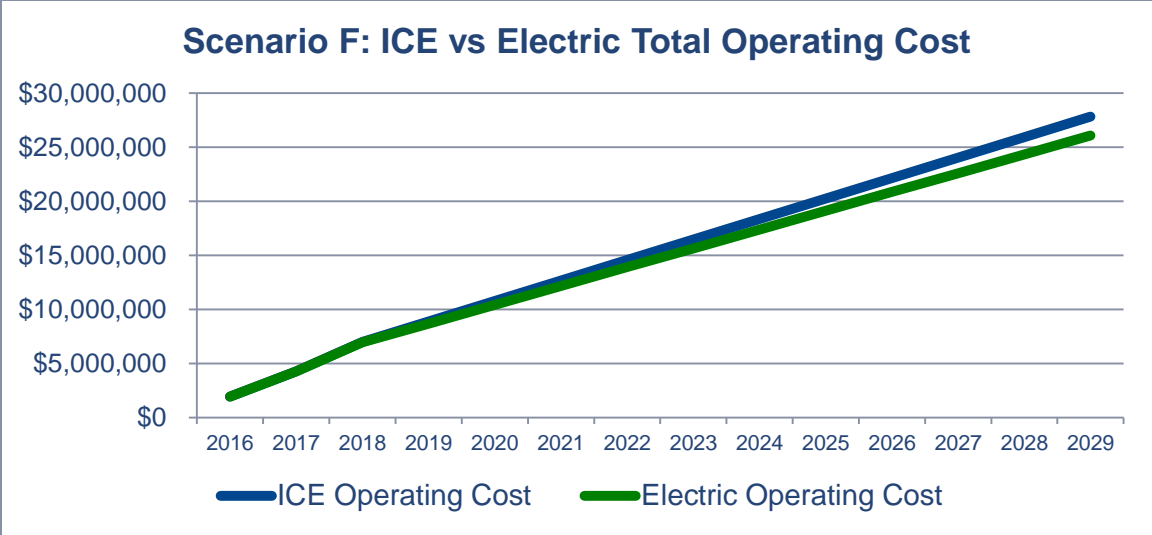


Figure 19. Scenario F: Comparison of Accrued Operating Costs, ICE vs. Electric

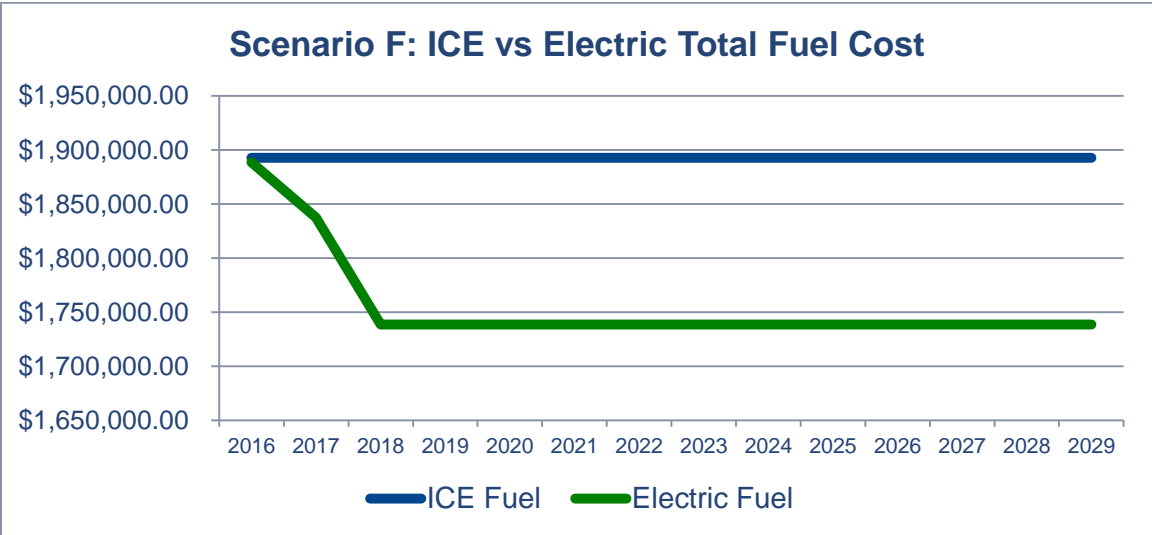


Figure 20. Scenario F: Comparison of Annual Operating Costs, ICE vs. Electric

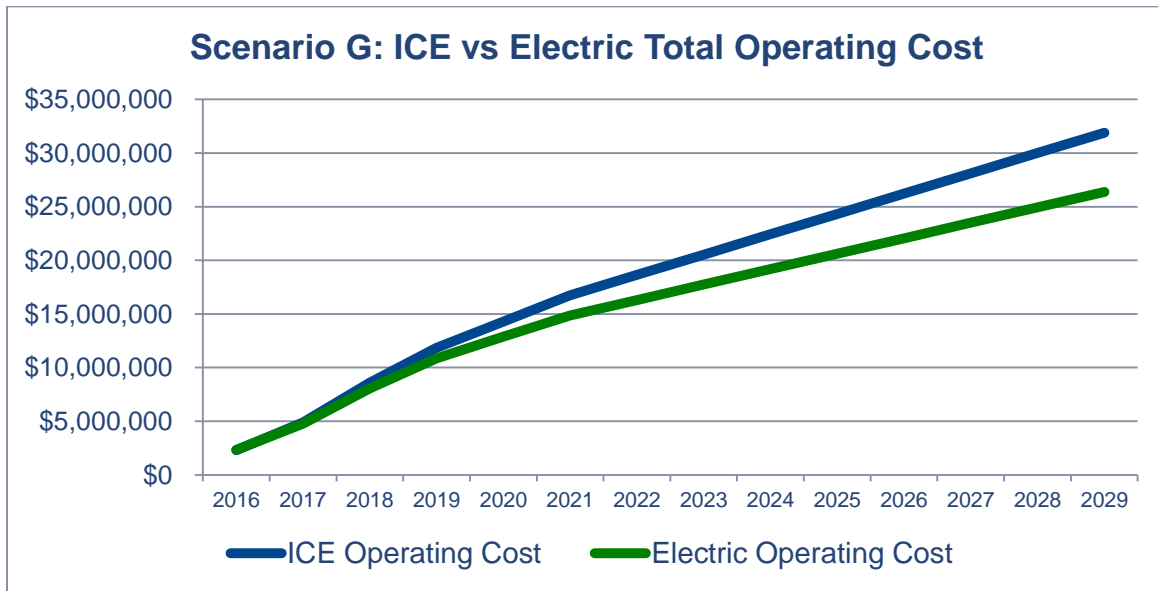
CapEx	\$1.49 Million
Annual Fuel Savings (14 Year Average)	\$136,359
Breakeven Point (Yrs)	1
Accrued Savings (Over 14 Years)	\$1.75 Million
CO2e Emission Savings (metric tons/yr)	912

Table 21. Scenario F: Financial Summary



Scenario G. 50% Retrofit of Belt Loaders, Bag Tugs, and Pushbacks as Current Fleet Retires

This scenario is similar to Scenario E, except the project explores retrofitting up to 50% of the current GSE fleet to electric, purchasing eGSE vehicles as the current vehicles in the fleet retire. Similar to previous scenarios, we see energy savings great enough to keep the operating costs of electric vehicles lower than the operating costs of ICE vehicles. Energy savings increase as more electric vehicles are procured (Figure 21).



**Figure 21. Scenario G: Comparison of Accrued Operating Costs, ICE vs. Electric**

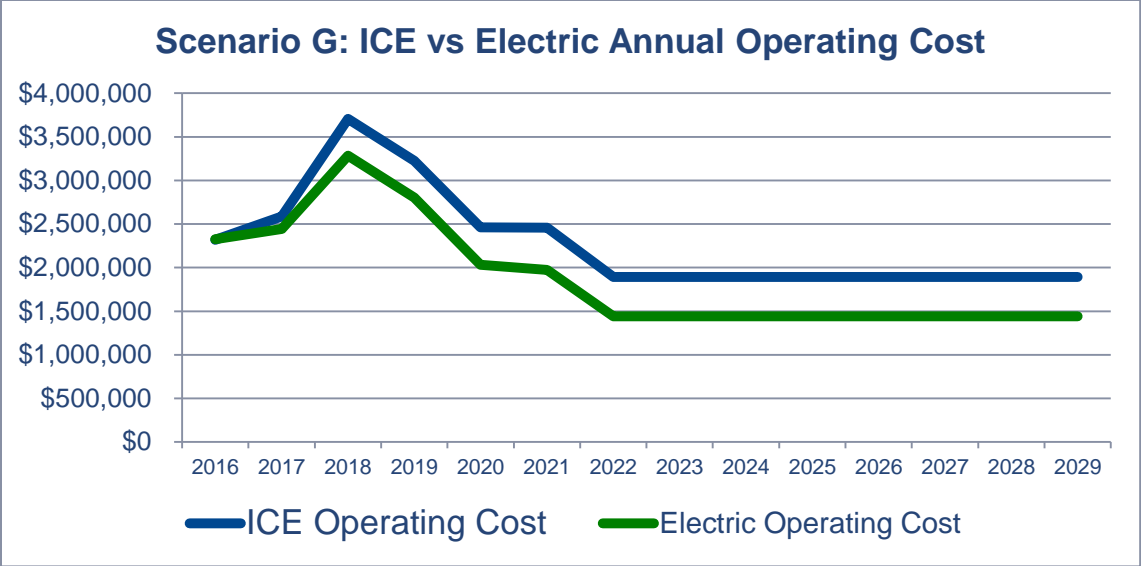


Figure 22. Scenario G: Comparison of Annual Operating Costs, ICE vs. Electric

CapEx	\$5.42 Million
Annual Fuel Savings (14 Year Average)	\$360,029
Breakeven Point (Yrs)	2
Accrued Savings (Over 14 Years)	\$5.51 Million
CO2e Emission Savings (metric tons/yr)	2,678

Table 22. Scenario G: Financial Summary

Scenario H. 50% Retrofit of Belt Loaders and Bag Tugs as Current Fleet Retires

Scenario H is similar to the Scenario G, except this project does not consider pushback eGSE.

**Additionally, this scenario assumes no VALE funding has been received.**

The total capital expenditure over 13 years is smaller at approximately \$3 million with a breakeven point of 0 years. This means that within the first year of purchasing electric vehicles, JetBlue will be profitable.

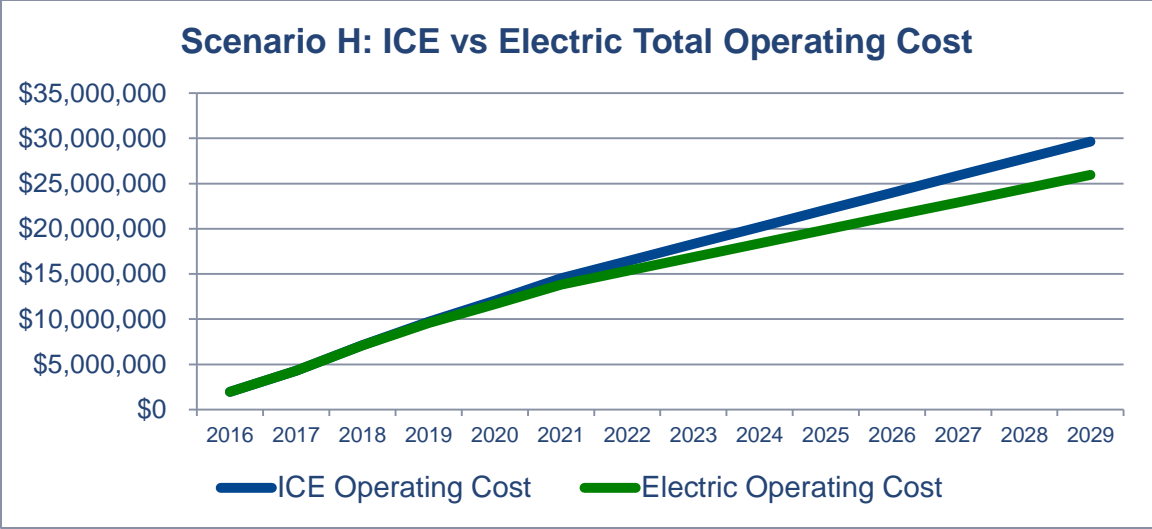


Figure 23. Scenario H: Comparison of Accrued Operating Costs, ICE vs. Electric

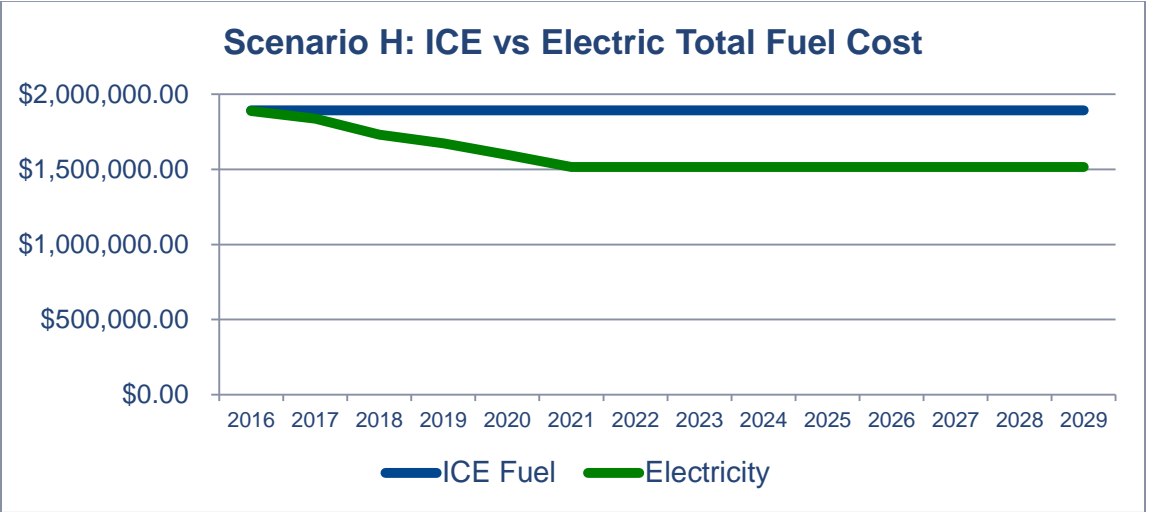


Figure 24. Scenario H: Comparison of Annual Operating Costs, ICE vs. Electric

CapEx	\$3
Annual Fuel Savings (14 Year Average)	\$303,641
Breakeven Point (Yrs)	1
Accrued Savings (Over 14 Years)	\$4.25 Million
CO2e Emission Savings (metric tons/yr)	2,231

Table 23. Scenario H: Financial Summary

## 7.2 Summary of Scenario Analysis Results

Scenario	A	B	C	D	E	F	G	H
Total CapEx (\$M)	\$10.3	\$5.8	\$7.9	\$4.2	\$2.4	\$1.5	\$5.4	\$3
Annual Fuel Savings (Average)	\$876,661	\$733,912	\$442,031	\$360,160	\$167,548	\$136,359	\$360,029	\$303,641
Breakeven Point (Yrs)	12	8	2	1	2	1	2	1
Accrued Savings (\$M Over 14 Yrs)	\$1.95	\$4.45	\$6.96	\$5.21	\$2.49	\$1.75	\$5.51	\$4.3
CO <sub>2</sub> e Emission Savings (Metric Tons/Yr)	4,642	4,344	3,820	3,120	1,100	912	2,678	2,230

Table 24. Summary Table of Scenario Analysis Results

## 8. Discussion

### 8.1 Recommendations

#### 1. Pursue pushback electrification secondary to bag tug and belt loader.

From an economic perspective, we recommend not retrofitting any pushback GSE vehicles initially. Due to their expensive list price and small fuel savings due to fewer run hours, it does not make economic sense to retrofit these vehicles at this stage. However, if the goal of the retrofit were specifically to reduce particulate matter and NO<sub>x</sub> emissions that are characteristic of diesel exhaust (for example to meet standards in California), then we would reintroduce push back electrification because all are diesel-powered.

#### 2. Launch pilot to test 1 charger, 2 belt loaders, and 1 bag tug at JFK.

We recommend JetBlue begin with retrofitting one gate at JFK Airport to achieve a proof of concept. This would consist of 2 electric belt loaders and 1 bag tug—the number of belt loaders and bag tugs that are dedicated to one gate during a plane’s turn. This would instantly give JetBlue savings, realized after the third month of implementation. Replacing 2 gasoline belt loaders and 1 gasoline 3,375 metric tons of CO<sub>2</sub>-equivalent emissions and \$195,000 over the vehicles’ respective lifetimes.

#### 3. Apply for VALE funding.

Pending a successful trial, JetBlue should pursue VALE funding. Currently, the costs of electric bag tugs and belt loaders are either cheaper or the same as their gasoline or diesel counterparts. If VALE were to cover the costs of the charging stations, JetBlue would begin realizing immediate savings due to the 57% reduction in energy costs when using electric. Previously awarded VALE grants range from \$25,000 to \$18.3 million, offering significant flexibility in how much funding JetBlue can be eligible to receive. JetBlue can apply to have 100% of the cost of charging stations funded with VALE grants.

**4. Set goal of 20% electric bag tugs and belt loaders (Scenario F) in 3 year period (by 2019), replacing with electric vehicles as current GSE vehicles retire.**

This consists of JetBlue purchasing an electric vehicle rather than purchasing a gasoline or diesel option every time they are due for a replacement –until they reach 20% electric bag tugs and belt loaders (Scenario F). This corresponds to an electric retrofit of 17 belt loaders and 15 bag tugs. Even with no VALE funding received, as is the case in Scenario F, JetBlue will achieve roughly \$1.75 million in savings over a 14 year period, and a reduction of 36,500 metric tons of CO<sub>2</sub>-equivalent emissions over the vehicles' full lifetimes (15 years for belt loaders, 12 years for bag tugs). Thus, we recommend JetBlue to follow Scenario F to set an initial first step towards 100% GSE electrification and to work out any operational issues. This scenario is especially appealing as savings are realized in year 1.

**5. Set goal of 50% electric belt loaders and bag tugs by 2023, replacing with electric vehicles as current GSE vehicles retire (Scenario H).**

Continuing along JetBlue's vehicle retirement schedule, roughly half their belt loaders and pushbacks at JFK will need to be replaced by 2023. This corresponds to 33 belt loaders and 39 bag tugs replaced. Replacing 33 retired gasoline belt loaders and 39 retired bag tugs with electric vehicles would result in a reduction of 89,238 metric tons of CO<sub>2</sub>-equivalent emissions over the vehicles full lifetimes and roughly \$4.3 million in savings over a 14 year period. Similar to Scenario F detailed in Recommendation 4, Scenario H is especially appealing as savings are realized in year 1.

**6. Research feasibility of retrofitting 100% electric belt loaders, bag tugs, and push backs, replacing vehicles as they retire. (Scenario C).**

If JetBlue finds that electric GSE are operating well, they can choose to extend the goal of vehicles to retrofit to 100% of bag tugs, belt loaders, and push backs across the 14-year time scale. If funding were received, this approach would maximize fuel savings to achieve roughly \$7 million savings via reduced avoided fuel costs and over 60,000 metric tons of CO<sub>2</sub>-equivalent emissions abated over 14 years.

## 8.2 Additional considerations

### **Range anxiety, charging and operational considerations**

Electric vehicles are limited in their battery storage capacity. However, most electric GSE vehicles can run up to 8 hours on one charge, which is sufficient for average daily use at JFK. Electric vehicles can fully charge within 4-8 hours, although fast-charging stations are available and could be purchased for emergency charging. These fast-charging stations could charge a vehicle up to 80% of the full battery capacity within 15 minutes (ACRP, 2012). To efficiently charge the eGSE vehicles, charging stations can be strategically placed to share power at passenger-boarding jet ways and charge vehicles when the jet way is not in use. Since the jet ways are only powered for only a few minutes per hour, the electricity provided to jet ways can be used to charge stations during break periods (ACRP, 2012). Additionally, eGSE can be charged overnight to take advantage of off-peak electricity rates, decreasing the operating costs of eGSE.

Additionally, it should be noted that using electric GSE introduces a change to the ground operations at JFK. Employee training must be undertaken to ensure that ground crew is fully aware of how to use, charge, and store the vehicles. We would expect this to incur a cost that has been omitted from our analysis.

### **Cold weather performance**

The performance of batteries, especially lead-acid batteries, may be adversely affected by cold weather (ACRP, 2012). Using battery insulation or block heating systems can mitigate this risk. However, advances in battery technology have greatly reduced the risk of degradation of batteries in cold weather. Lithium ion batteries, the most common battery used in electric vehicles, can operate between -30°C to 70°C (Tikhonov & Koch). This means that the most common battery type used for electric vehicles can withstand cold weather well below freezing (0°C). Additionally, new battery technologies are being rolled out. In Calgary, WestJet Airlines unveiled a baggage tug that runs on lithium polymer batteries, the first of its kind (PR Newswire, 2012). This battery technology requires no maintenance and is able to operate in extreme hot or cold weather. To date, many airlines operate electric GSE in regions colder than New York without issue.

### **Power output and performance**

It is widely accepted that eGSE vehicles handle, accelerates and performs in a way that is equivalent to or better than its gasoline and diesel-powered counterparts (ACRP, 2012). However, eGSE vehicles may be limited in their towing capacity, which is measured by their “drawbar pull”, in pounds. The Tug Tech MZ (electric push back tractor) has a drawbar pull of 4,500 pounds (Tug Technologies, 2014), versus the MT12 (diesel push back tractor), which has 12,000-pound drawbar pull capacity (Tug Technologies, 2014)

### **Maintenance**

Generally, electric vehicles require less maintenance than ICE vehicles. This is due to fewer moving parts: electric vehicles only have a battery, motor and associated electronic parts that do not require regular maintenance (US DOE, 2014). Electric vehicles do not require regular oil changes, belt and spark plug replacements. They do not require emissions testing due to zero emissions at the tailpipe. Additionally, regenerative braking technology on electric vehicles reduces wear on brake pads (ACRP, 2012). As stated previously, maintenance costs were not included in our analysis due to difficulty in estimating what it might be for JetBlue.

### **Operational ease of charging at gate**

Electric charging stations are more convenient for the ground operations at JFK Airport. Typically, ICE GSE vehicles are driven to refueling stations that may be far away from gates. This requires employees to take time to drive multiple vehicles to be refueled, pump gasoline or diesel, and drive back to their respective gates. When using electric vehicles, charging stations can be placed near the gates, reducing the time wasted driving to and from refueling stations.

### 8.3 Applicability of recommendations to other locations

Though the scope of this study focused on JFK, we recommend JetBlue consider additional airports for GSE electrification given the positive business case demonstrated at JFK. We recommend focusing on high-use airports with at least 20 units of owned GSE so the full benefit of energy costs savings can be achieved. This includes Boston Logan International Airport (BOS), Fort Lauderdale-Hollywood International Airport (FLL), Orlando International Airport (MCO), San Juan, Puerto Rico Luis Muñoz Marín International Airport (SJU), Ronald Reagan Washington National Airport (DCA), Newark Liberty International Airport (EWR), Buffalo Niagara International Airport (BUF), LaGuardia Airport in New York (LGA), Palm Beach International Airport (PBI), and Tampa International Airport (TPA).

An additional consideration would be whether the airport is in a Clean Air Act “nonattainment” region, and thus qualify for VALE funding. This reduces the list to BOS, DCA, EWR and LGA. In all regions outside of JFK, we would expect inputs to change, such as electricity cost and original GSE inventory, which would slightly change the business case.

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# Appendices

## Appendix A-1: Airport Names and Abbreviations

Airports Code	Airport Name
BDL	Bradley International Airport
BOS	Boston – Logan International Airport
BTV	Burlington International Airport
BUF	Buffalo Niagara International Airport
DCA	Ronald Reagan Washington National Airport
EWR	Newark Liberty International Airport
FLL	Fort Lauderdale–Hollywood International Airport
IAD	Washington Dulles International Airport
JFK	John F. Kennedy International Airport
LAS	McCarran International Airprot
LGA	LaGuardia Airport
LGB	Long Beach Airport
MCO	Orlando International Airport
OAK	Oakland International Airport
PBI	Palm Beach International Airport
ROC	Greater Rochester International Airport
RSW	Southwest Florida International Airport
SFO	San Francisco International Airport
TPA	Tampa International Airport

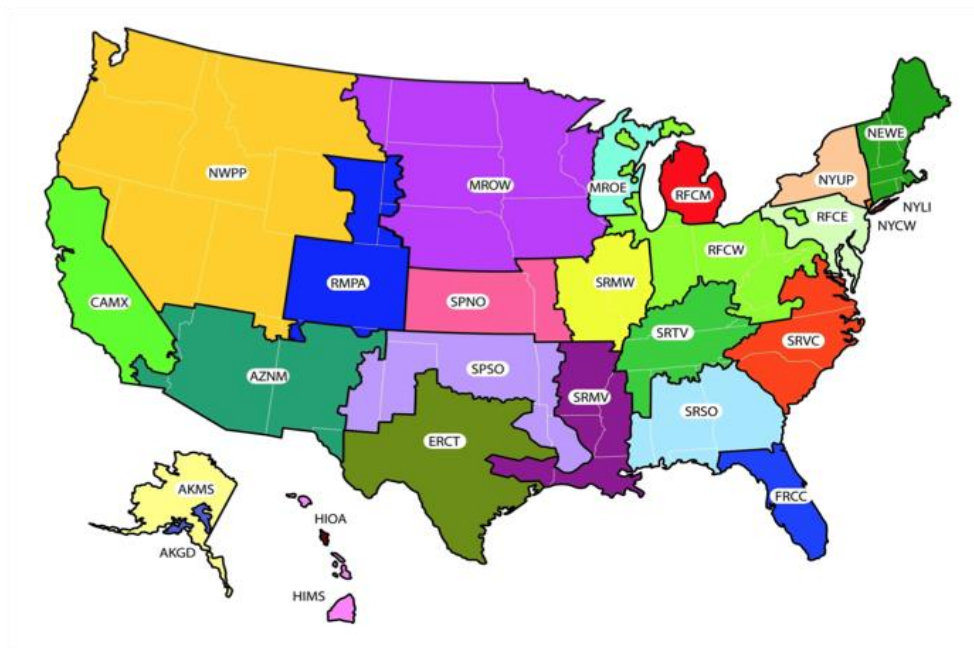
## Appendix A-2: Energy Price Assumptions by Airport location

Airports	\$/gallon gasoline	\$/gallon diesel	\$/kWh
BDL	3.467	4.007	0.094
BOS	3.397	4.007	0.094
BTV	3.467	4.007	0.094
BUF	3.598	3.987	0.094
DCA	3.433	3.987	0.094
EWR	3.433	3.987	0.094
FLL	3.463	3.767	0.094
IAD	3.433	3.987	0.094
JFK	3.598	3.987	0.094
LAS	3.491	3.848	0.094
LGA	3.598	3.987	0.094
LGB	3.433	3.987	0.094

MCO	3.463	3.767	0.094
OAK	3.745	4.004	0.094
PBI	3.463	3.767	0.094
ROC	3.598	3.987	0.094
RSW	3.463	3.767	0.094
SFO	3.901	4.004	0.094
TPA	3.463	3.767	0.094

Source: EIA Short Term Energy Outlook 2014 (<http://www.eia.gov/forecasts/steo/report/>)

### Appendix A-3: US EPA eGrid Subregions



Source: US EPA (<http://www.epa.gov/cleanenergy/energy-resources/egrid/>)

### Appendix A-4: CO<sub>2</sub> Intensity Factors by Airport Location

Airports	lbs CO <sub>2</sub> /kWh
BDL	1.107
BOS	1.107
BTV	1.107
BUF	1.254
DCA	1.563
EWR	1.563

FLL	1.277
IAD	1.563
JFK	1.132
LAS	1.34
LGA	1.132
LGB	0.933
MCO	1.277
OAK	0.933
PBI	1.277
ROC	1.254
RSW	1.277
SFO	0.933
TPA	1.277

Source: US EPA (<http://www.epa.gov/cleanenergy/energy-resources/eqrid/>)

#### Appendix A-5: GSE Lifetime

Vehicle type	Lifetime (Years)
Pushback	13
Beltloaders	15
Bag Tugs	12

Source: Tug Technologies.

Assumes lifetime of ICE GSE is equivalent to lifetime of eGSE.

#### Appendix A-6: New and Refurbished Purchasing Price

	Gasoline/Diesel		Electric	
	New	Refurb	New	Refurb
Pushback	\$124,000	\$93,000	\$132,000	\$99,000
Beltloader	\$52,000	\$39,000	\$52,000	\$39,000
Bag Tug	\$37,000	\$28,000	\$34,000	\$26,000

Source: Tug Technologies

#### Appendix A-7: JetBlue GSE Inventory

Airport	# of Gates	Motorized GSE Vehicles	Pushback	Bag Tug	Belt Loader
JFK	26	353	37	78	61
BOS	17	266	25	62	44
MCO	9	81	6	21	17
LGB	6	83	4	18	12
FLL	7	93	10	21	19

<b>SJU</b>	6	49	6	13	12
<b>EWR</b>	2	36	3	9	7
<b>DCA</b>	2	44	3	8	8
<b>IAD</b>	3	14	1	3	2
<b>BUF</b>	2	25	2	6	4
<b>PBI</b>	2	24	2	7	6
<b>LGA</b>	1	24	2	6	5
<b>OAK</b>	2	17	2	4	3
<b>TPA</b>	2	23	2	5	4
<b>LAS</b>	1	14	2	5	4
<b>RSW</b>	2	19	2	6	5
<b>ROC</b>	1	10	1	2	3
<b>BDL</b>	1	16	1	3	3
<b>BTV</b>	1	13	1	3	2
<b>TOTAL</b>	93	1,204	109	280	221

Source: JetBlue GSE Inventory

## Appendix B: Other Alternative Fuels Considered

### Additional Fuels Considered

#### Compressed Natural Gas, CNG

Compressed natural gas (CNG) is compressed methane, and is colorless odorless, and noncorrosive. It is burned in vehicles in a similar way that gasoline is used in conventional vehicles. It is widely available in the US, with natural gas fueling 27% (EIA, 2015) of electricity generation in the United States. However, only .1% of the natural gas supply is used as a transportation fuel.

Compressed natural gas was initially considered in the scope of this study. However, we were informed that CNG would not work logistically at JFK. The only appropriate spot for a fueling station would be located across the airport, requiring the vehicles to drive across an active aircraft space. This option has not been further pursued given the considerable safety risk it would pose. Further, we would expect much of the emissions savings from the CNG to be cancelled out by the additional driving that would be done back and forth from the terminal to the fueling station.

#### Ethanol

Ethanol is produced from fermenting biomass carbohydrates (sugars). Low-level blends of ethanol (E10, or blends of gasoline with 10% ethanol) are approved for use in vehicles without engine modification. E85, a blend of gasoline with 85% ethanol and 15% gasoline, is priced lower than gasoline, but lowers fuel efficiency.

#### Biodiesel, B20 or B100

Fermenting biomass fats, such as vegetable oil, animal fats, and cooking grease, produces biodiesel. There are two commercially available types: B20, which is 20% biodiesel and 80% petroleum based diesel) and B100 which is 100% biodiesel. Soybean and recycled cooking oils are commonly used in the United States for biodiesel production.

One issue with biodiesel is around low-temperature gelling, which can occur around 8 degrees Fahrenheit, though the exact temperature depends on the feedstock. Using B100 is not recommended as cold temperature gelling can occur around 32 degrees Fahrenheit.

### Liquefied Petroleum Gas (LPG)/Propane

Liquefied petroleum gas consists of a mixture of a propane and/or butane gases. Though there are more than 10 million LPG vehicles globally, they have declined and no dedicated LPG passenger car or truck has been produced commercially since 2004.

### Comparing Fuel Types

The following chart breaks down the criteria that impacted our decision for selecting alternative fuels to pursue.

\* Fuel costs = Conversion Factor to \$/Gallon of Gasoline Equivalent

Fuel Type	Emissions Reductions				
	CO2	CO	PM	NOx	HC
Compressed Natural Gas (CNG)	30%	80%	-	41%	30 - 50%
Ethanol (E85)	25%	90%	-	-	90%
Propane (Liquefied Petroleum Gas or LPG)	15%	20 - 55%	-	25 - 80%	60 - 97%
Biodiesel (B20)	Variable	9 - 81%	53%	30%	27 - 55%
Biodiesel (B100)					
Hybrid Electric Vehicles (HEVs)	Emissions reductions very variable depending on characteristics of the means by which electrical energy is supplied to the vehicle as well as the type of fossil fuel with which it is hybridized.				
Electric Vehicles (EVs)	42-75%	96.4-100%	88-99%	97-99%	92.4-99.9%
Plug-in Electric Vehicles (PHEVs)	-	-	-	-	-

Source: (ACRP, 2012)

**Table 25. Summary of Emissions Reductions from Different Fuel Sources.**