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RECOMMENDATIONS TO REDUCE CARBON EMISSIONS

JETBLUE AIRWAYS - TERMINAL 5 JFK AIRPORT

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1. Introduction

Since 2013 JetBlue has participated in the New York City Mayor's Office of Sustainability Carbon Challenge, a voluntary program in which companies, universities and hospitals within NYC commit to reduce their building emissions, and collaborate to share best practices. Initially, JetBlue met its reduction target by moving its headquarter offices to a newer, LEED certified building, therefore decreasing energy use by 82% (1). Now, JetBlue wishes to extend its participation to include its main operations hub in New York, becoming the first airport to participate in the challenge. The motivations for this project are to identify drivers of cost reduction and to secure affordable, reliable, clean energy sources, as well as to enhance JetBlue's relationship with several important stakeholders, such as the NYC Mayor's Office, the Port Authority of New York and New Jersey, elected officials, financial stakeholders and the general public.

With that in mind, the company partnered with the S-Lab course in MIT Sloan School of Management to start a project to develop a target and a strategy for reducing CO2 emissions in its operations at JFK Airport – Terminal 5 (T5). The three main goals of this project are to develop a specific target for CO2 emission reduction at JFK that JetBlue can formally submit to the Mayor's Carbon Challenge, to identify recommendations to meet this target, and to review existing practices and efforts in other airports.

JetBlue initially proposed three different potential areas of its operation to be studied, later expanded to four, which are: emissions associated with power generation for building electricity use, emissions from ground support vehicles that service aircraft, emissions from aircraft parked at the gate, and emissions associated with heating and cooling the terminal building.

With this information, we prepared a report that included the following sections:

- Literature review of actions taken by other airports
- Carbon inventory, including the main sources of energy use at JFK – T5
- High level description of eight potential activities JetBlue could take to reduce its energy use and CO2 emissions
- A proposed emission reduction target to be achieved in 2021

As future steps, we recommend further detailing the solutions proposed, which were only evaluated at a high-level, identifying the ones with highest gain potential, and implementing those.

2. Company Description and Sustainability Efforts

JetBlue is a Fortune 500 airline founded in 2000, with headquarter in New York, and is a leading carrier in Boston, Fort-Lauderdale-Hollywood, Los Angeles (Long Beach), Orlando, and San Juan. In 2014, JetBlue carried more than 32 million customers to 93 cities in the US, Caribbean, and Latin America, with an average of 900 daily flights (2).

The company had in 2015 reported revenue of US$ 6.4, with a net income of US$ 677 million, and had by the end roughly 12,000 employees. (3)

JetBlue's 2014 Sustainability report highlighted five main values for the company: safety, caring (related to employee satisfaction), integrity (which includes its ethical and diversity goals), passion (which includes customer relations, environmental and community relations) and fun (2).

In its climate change mitigation goals, the company aligns with three industry-wide targets:

- Improve fuel efficiency by an average of 1.5 percent per year from 2009 to 2020
- Cap aviation CO2 emissions in 2020 (post-2020 growth must be carbon neutral)
- Reduce CO2 emissions by 50 percent by 2050, relative to 2005 levels

The latest sustainability report indicated a reduction in GHG emissions per Revenue-ton-mile from 1.65 to 1.54 metric tons CO2e/RTM from 2013.

2.1. JFK Airport – T5

T5 at JFK Airport was originally founded in 1962 as the TWA Flight Center, a neo-futuristic building designed by architect Eero Saarinen that is registered in the US National Register of Historic Places.

In December 2005 the Port Authority of New York and New Jersey (PANYNJ) started building a new terminal facility for JetBlue, which opened in 2008 in a building adjacent to the old TWA building. An aerial view of the building can be seen below:

Figure 1 Aerial view of T5 at JFK Airport (4)

T5, at 635,000 square feet, was designed to handle up to 20 million passengers per year. JetBlue's international arrivals expansion added 145,000-square-feet in 2015 (5). As shown in Figure 2, the terminal includes 29 gates, with over 20 food concessions and over 30 retail stores (6).

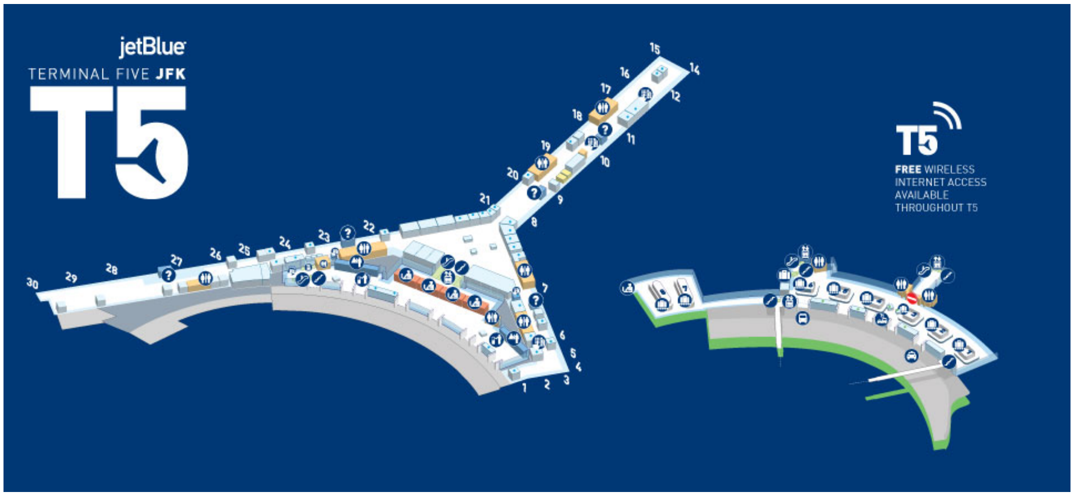

Figure 2 Diagram representation of T5 at JFK Airport (7)

JetBlue is the sole operator of Terminal 5 (T5), and is therefore responsible for all its costs, including energy. Despite this, JFK's electricity supply and the requirements for thermal energy to heat and cool JFK terminals are leased to Kennedy International Airport Co-Generation Partners (KIAC Partners). KIAC's current system is located in the middle of the central terminal area of JFK and consists of a 107 MW natural gas-fired cogeneration facility, which consists of two identical GE LM 6000 combustion turbine generation sets, plus associated equipment for hot and chilled water with a capacity of 250 MMBTU/h for chilled water and 225 MMBTU/h for hot water, plus support equipment. Since peak demand for the airport is 60 MW, the excess electricity is sold to the market. (8) This system generates all the electricity used in the airport, and by contract all terminals must purchase electricity from the company until 2020. JetBlue is restricted to purchase these energy sources to KIAC, but the end of this contract presents an opportunity for JetBlue to change its electricity and thermal water sources. These prices are currently too expensive compared to the regular NYC prices (40-60 USD/MBTU) (9).

3. Literature Review

There is extensive literature on building efficiency, on-site electricity generation and strategies to reduce carbon emissions. Yet, specifically for airport operations, the main source of information was FAA reports as well as other government bodies. We reviewed successful case studies of greenhouse gas emissions reduction programs worldwide. Moreover, we explored the types of strategies that exist and the different factors considered to prioritize what practices to implement.

3.1. Review of Airport Solutions

3.1.1. Airport facility boilers, heaters, and generators

Examples：Antalya Airport (AYT), Dublin (DUB) & Cork (ORK) Airports

AYT had updated its old chiller system, which saved 30% energy when compared to the old one.

In DUB **& ORK** the pier's 12 Air Handling Units (AHU) were originally installed with carbon filters. After precise investigation it was discovered that these AHU were not required and then subsequently removed. Additionally, Dublin & Cork improvements resulted in a lower restriction to air flow, reducing the fixed speed of Variable Speed Drives (VSDs) to be slower whilst still achieving the same air change rate. The actions had saved approximately 380,000 kWh equivalents in energy consumption per annum (10).

3.1.2. Maintenance activities

Example：Seattle Tacoma International Airport

Between 2010 and 2013, **Seattle Tacoma International Airport** converted constant volume air handlers to variable volume, upgraded to more efficient lighting and escalators, optimized chiller sequencing, and implemented main terminal airside heat recovery. Though these actions **the airport** reduced total terminal electricity consumption by 7% (10).

3.1.3. Electrical consumption

Examples：Airports of Thailand, Antalya Airport, Toronto Airport, Columbus International Airport Honolulu International Airport

Airports of Thailand replaced old air conditioning with more energy efficient air-cooled chiller, and had also replaced the old light bulbs with LEDs in 2014 (10).

Antalya Airport implemented two major practices to reduce energy consumption in IT systems: First is the replacement of CRT monitors at check-in desks and gate areas. These monitors change automatically onto stand by and offline modes if there are no flights. The second practice is the use of "Thin Client PCs" in all terminals for FIDS monitors. Moreover, Antalya Airport had replaced all lights with LED lighting technologies at offices and general areas in the terminals. With this project, a 66% energy saving was achieved.

Toronto Airport had removed one T8 bulb from every two-lamp fixture, eliminating 2,000 bulbs, without customer complaints about inadequate lighting. Through this practice the Toronto Airport reduced by 40 percent the amount of energy for lighting in its terminal (10)

In addition, the energy-management system at **Port Columbus International Airport** in Columbus, Ohio, is programmed to turn off lighting and mechanical systems in gate areas where no flights are scheduled so that energy is not wasted on unoccupied areas of the building (10).

Voltage controllers and soft start controls can also reduce energy consumption and maintenance costs by varying the voltage to the motor during startup and according to the load. They are especially effective when motors run for long periods with minimal load. For example, **Honolulu International Airport** installed soft-start controls on 56 escalators and saved 281,921 kWh per year. This translated into annual cost savings of $525 for each "up" escalator and $496 per "down" escalator (11).

3.1.4. Ground Operations:

Examples：Airport of Thailand, Antalya Airport

Airport of Thailand encourages its drivers to turn off vehicle engines when not needed; to control vehicle speed to save fuel; and have a regular maintenance for fuel efficiency. In addition, the current car fleet of Airport of Thailand is due to be replaced by hybrid cars in the near future (10).

Starting from 2014, the company staff in **Antalya Airport** had already begun to use electric car-vehicles for transportation in/between terminals (10).

3.1.5. Ground Support Equipment (GSE)

Example：Aena S.A.

Adolfo Suárez Madrid-Barajas had reduced its electricity consumption in the Automated Baggage Handling System (SATE) by 2,369 MWh during 2012-2014, reducing 1,833 tons of CO_2 (10) by optimizing the system circuits and an expanded use of timers and photo sensors to control circuits.

3.1.6. Renewable Energy: Solar Energy Technologies and Airport Applications

Solar photovoltaic costs have dropped significantly in the last decade, going from a niche technology to price parity with traditional sources. Figure 3 shows the locations where solar energy has reached grid parity.

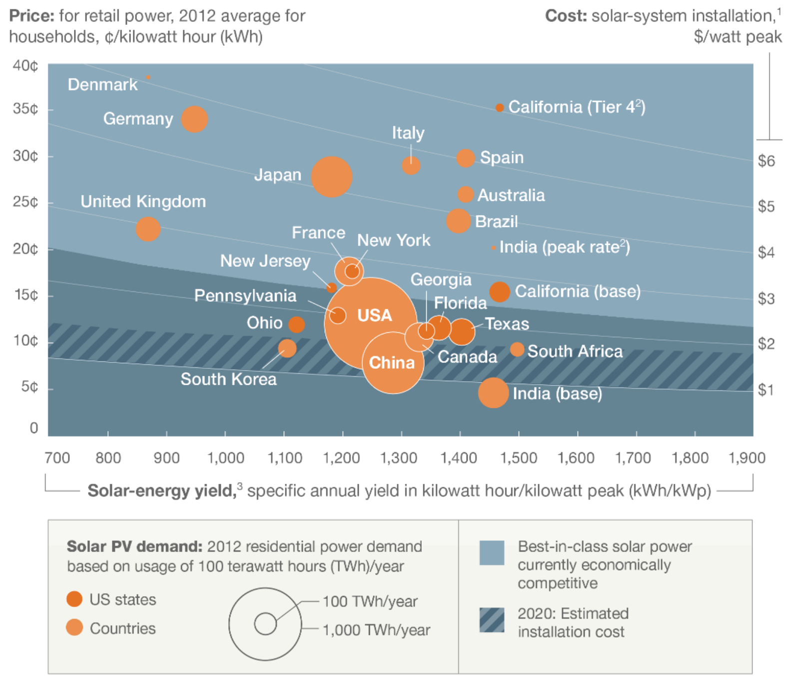

Figure 3 Solar Energy Grid Parity Potential (12)

As the cost of installing solar panels decreased, airports have been seen as prime location for installing solar systems, since they usually have large areas un-obstructed by shade and have access to federal funding. Table 1 lists several examples of solar panel installations in different airports (13) (14).

Table 1 Examples of Airports with solar panel installations

Airport	Capacity Installed	Notes
Indianapolis International Airport in Indianapolis, Indiana	12.5 MW	Operating as of 2013
Fresno Yosemite Airport in Fresno, California	2 MW	Constructed in 2008, meets 60% of the electricity demand at the airport
Gatwick Airport in London, England	50 kW	Installed in 2012, just 150 meters from the runway, after 6 months of negotiation with the British aviation authorities to guarantee it did not affect airport safety
Birmingham Airport in Birmingham, England	50 kW	In the rooftop of the terminal
Athens International in Athens, Greece	8 MW	Installed in 2004 with a two-stage design to assure safety compliance

Airport	Capacity Installed	Notes
Ancona Falconara Airport in Falconara Marittima, Italy	45 kW	System was built around the tower, with several analytical studies to show it did not affect safety
Denver International Airport	8 MW	See description below
Manchester-Boston Regional Airport	530 kW	See description below
Cochin International Airport	12 MW	This airport became fully powered by solar panels in 2015

Examples： Denver International Airport and Manchester-Boston Regional Airport

Furthermore, there are two specific examples of larger solar systems installed in airports. The first is the Denver International Airport (DIA). This airport is the 11th busiest in the world by passenger traffic and installed three different systems. Through a series of public-private partnerships, three different companies installed and operated a part of the system (Table 2 (13)). A fourth stage is in development. In the references consulted no financial information was provided.

Table 2 Specifications of the Systems installed in DIA

	DIA I	DIA II	DIA III
Capacity	2 MW DC	1.6 MW DC	4.3 MW DC
Annual Production	3.5 MWh	2.4 MWh	6.9 MWh
System	Flat single axis tracking	25 degree fixed tilt	25 degree fixed tilt
Total Panels	9,254 panels	7,250 panels	18,980

The second detailed example given was from the Manchester-Boston Regional Airport (MHT), in Manchester, NH (see Table 3). This system was designed to save $100,000 in energy cost for the airport and was budgeted in $3.5 million, of which 95% was funded by the FAA’s Voluntary Airport Low Emissions Program (VALE) (15). In the references consulted no financial information was provided.

Table 3 Specifications of the System installed in MHT

	MHT
Capacity	530 kW DC
Annual Production	650,000 kWh

System	20 degree fixed tilt
Total Panels	2,210 panels

This project, however, did suffer from some problems due to glare (see Figure 4). Air traffic controllers complained within a month that for 45 minutes in the morning there would be glare in the tower. The system is being renovated to adjust to these problems.

Figure 4 Glare Effects at MHT (Source Sandia National Laboratory, apud. NREL (13))

A glare study tool was developed by the Sandia National Laboratory called SGHAT tool. This tool, which works as a web-application, allows airports and solar systems designers to input the location of the airport and the panel installation to calculate the effect of glare on the tower and aircraft at approach.

With the use of the tool, MHT decided to redirect the panels that were causing the glare 90°. It was calculated that this would decrease energy production by the solar panels by 10%.

3.2. Strategies to reduce carbon emissions

The Airport Corporate Research Program (ACRP) identified and categorized a list of strategies to reduce greenhouse gas emission for airports. These strategies were classified in Airfield Design and Operations, Business Planning, Construction, Carbon Sequestration, Energy Management, Ground Service Equipment, Ground Transportation, Materials and Embedded Energy, Operations and Maintenance, Performance Measurement, Renewable Energy (on-site) and Refrigerants, which are shown in Table 4. Additionally, the ACRP team developed tool called AirportGear, to prioritize the different strategies identified, making financial considerations such as capital costs, operation and maintenance costs, estimated payback period; and implementation considerations, such as airport control, implementation timeframe and maturity of reduction strategy (16).

Table 4 Categories of greenhouse gas emission reduction strategies (9)

Category	Category Abbreviation	Number of Strategies	Coverage
Airfield Design and Operations	AF	18	Strategies that directly address emissions associated with airfield design and aircraft operations
Business Planning	BP	11	Airport administrative strategies designed to aid in emission reduction
Construction	CN	5	Construction process emission reduction strategies
Carbon Sequestration	CS	4	Strategies designed to capture carbon dioxide from the atmosphere and provide long-term storage
Energy Management	EM	39	Strategies designed to reduce facility energy consumption and provide alternative energy supplies
Ground Service Equipment	GS	1	Strategies designed to reduce emissions from vehicles that support aircraft and airport maintenance
Ground Transportation	GT	17	Strategies associated with the movement of passengers, employees, and goods/services to and from the airport
Materials and Embedded Energy	ME	4	Strategies associated with procurement and waste streams
Operations and Maintenance	OM	3	Strategies designed to address the operation and maintenance of airport facilities
Performance Measurement	PM	5	Strategies designed to evaluate performance of emission reduction plans and actions
Renewable Energy(on-site)	RE	14	Strategies to generate various forms of renewable energy(un, wind, geothermal, gas, etc.)
Refrigerants	RF	4	Strategies designed to address refrigerant use at airports and the associated greenhouse gases

4. Methodology

In order to estimate a greenhouse gas emissions reduction target, we interviewed professors within MIT to get their expertise and better understanding of our project (see details in Appendix A). We identified strategies and practices performed by other airports and airlines to review with JetBlue's stakeholders. We visited JFK-T5 and spoke with multiple stakeholders. Lastly, we estimated a current inventory of greenhouse gas emissions and the impact of a set recommendations to reduce carbon emissions (see Figure 5).

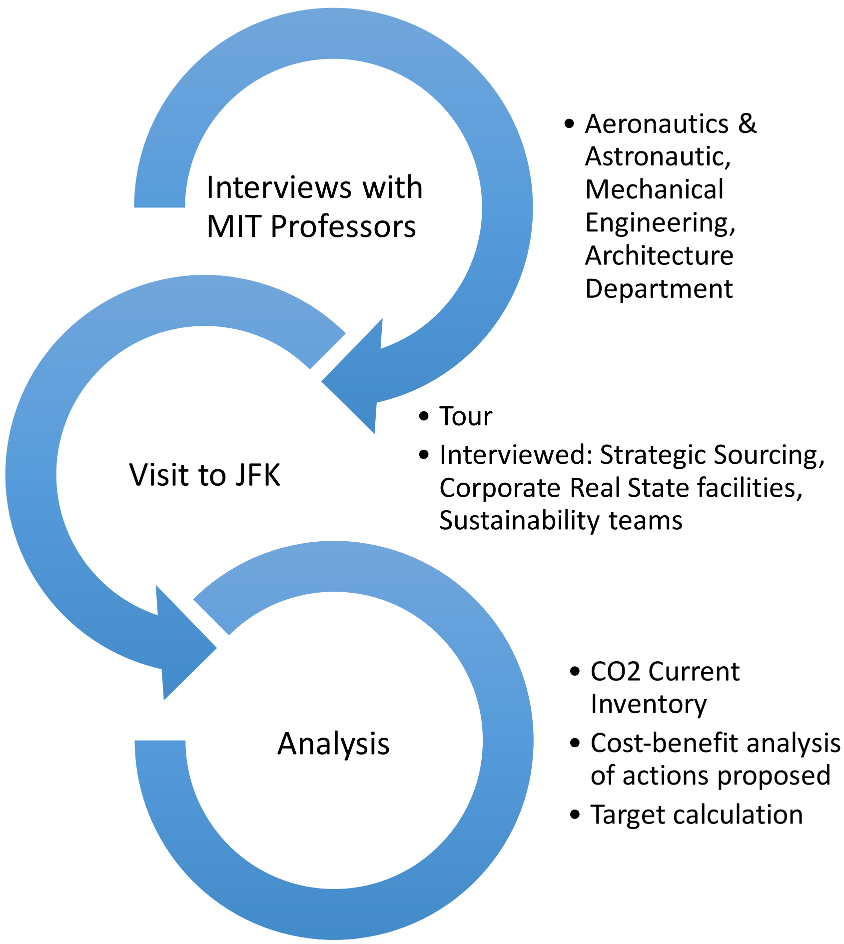

Figure 5 Methodology

5. Greenhouse Gas Emissions Inventory at JFK-T5

Airlines account for around 2% of the global greenhouse emissions (17). Airlines' greenhouse emissions are largely driven by the jet-fuel burn by aircrafts. Although aircrafts spend between 10-30% of the time taxiing, that time only represents 5-10% of the emissions produced by the aircraft (18).

Since the scope of the project is specifically defined as JetBlue's emissions at JFK-T5, we decided to define the boundaries of the problem as the emissions they can manage working together with the Port Authority. Emissions out of JetBlue's decision making scope of action, such as public or private transportation going to and from the airport, emissions from the LTO cycle (take-off, climb, approach and landing processes) and taxi in/out were left aside for JetBlue's purposes, even when we recognize the narrow view of this particular scope.

Thus, as shown in Figure 6, the scope of this project includes: 1. Energy generation, considering specifically the Co-Gen plant on site; 2. Building efficiency and 3. Ground Operations, including the GSE and parked aircraft.

We estimated JFK T5 CO2 emissions by source (Table 5), using conversion factors applied in the case studies reviewed.

Table 5 Sources of CO2 emission

	Source	**Description**
Non Jet Fuel related	Electricity	Generated by the Co-Gen plant and bought by the airport. Billed monthly to JetBlue, used for the operation of the building and part of the ground operations
	Chilled water	Generated by the Co-Gen plant and bought by the airport. Billed monthly to JetBlue, used to cool the building as part of the HVAC system.
	Medium temperature water	Generated by the Co-Gen plant and bought by the airport. Billed monthly to JetBlue, used to heat the building and to meet medium temperature water demand from lavatories and other.
	Ground Support Equipment	The equipment and vehicles that support the operation of the airport, such as trucks, tractors, tugs, belt loaders, etc. It produces direct emission by the combustion of Diesel and Gasoline.
Jet Fuel Related	Aircraft - APU	The APU is a small engine that may remain on during the parking time at the airport to feed the aircraft with energy for controls and the HVAC system. It can be substituted by the GPU unit. It produces direct emission by the combustion of Jet-Fuel.

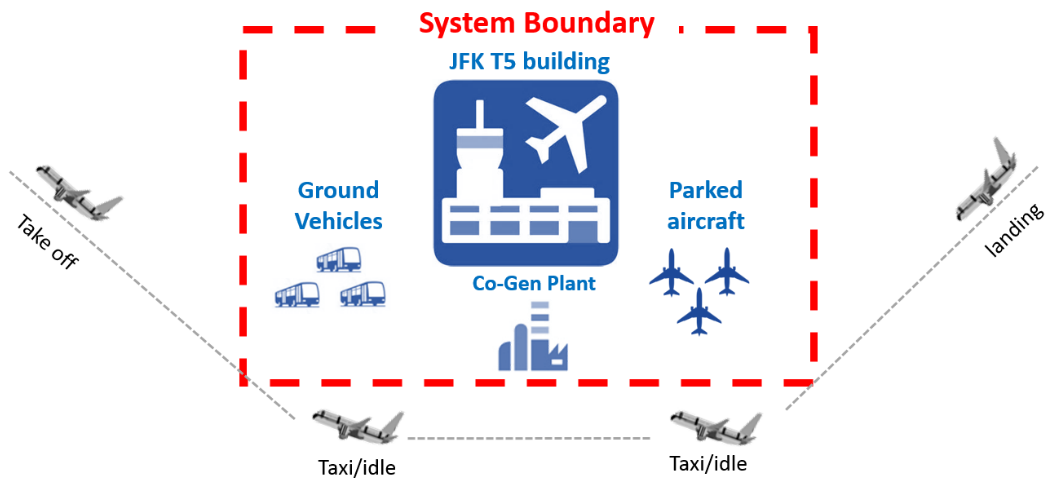

Figure 6 Scope of Greenhouse Gas emissions Inventory at JFK Terminal 5

The current CO2e inventory in JFK T5 taking into account JetBlue's operation only, is presented in Table 6. For further details, we included the calculations made to create this baseline and the assumptions in Appendix C. Though we limited the scope, our methodology seems to be robust and the results are in line with studies performed in other airports.

Table 6 Current CO2e Inventory in JFK T5, JetBlue scope

	Consumption / year		CO2e Metric Tons / year
Building Electricity Use	29,401,440	[KWh]	18,159
Chilled Water	73,068	[MBTU]	5
Mid Temperature Water	96,000	[MBTU]	8,500
Ground Support Vehicles	565,811	[Gallon diesel, gasoline]	5,383
APU	657,518	[Gallon jet-fuel]	6,474
Total			**38,521**

The main assumptions made to calculate APU emissions and their implications are shown below:

- Turnaround time: Depending on the fleet (35 min for A320, 40 min for A321 and 30 min for E190).
- Adherence of 50% in the GPU usage
- Delays were not considered; therefore, these emissions might be underestimating the actual emissions.

We delivered an automated Excel spreadsheet file to JetBlue, so they can fine tune the inputs with actual data from their databases to increase the accuracy of the estimates.

Figure 8 represents the inventory breakdown graph that JetBlue can present to its stakeholders, including the NYC Mayor's office in order to participate in the Carbon Challenge.

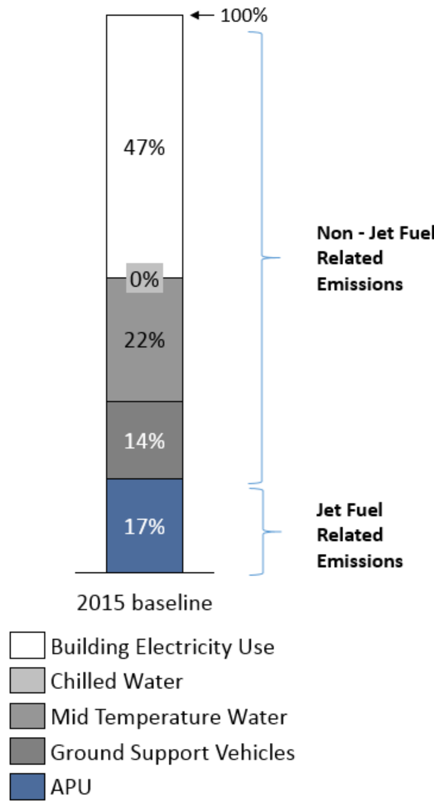

Figure 7 Inventory Breakdown

6. Actions Proposed

6.1. Energy Generation on Site: Installation of Solar Panel

To calculate the potential for solar panel installation at JFK-T5, we used a tool developed by the National Renewable Energy Laboratory (NREL) called PV Watts (19), which uses historical weather data and geographical information to measure potential generation of solar. Considering the area of the rooftop of T5, we estimated a potential for a 3,500 kW DC installation of 2-Axis tracking solar panels. Solar panel technology was chosen due to its higher efficiency, but different energy generation technologies should be evaluated to achieve the highest return on investment. According to the results of the tool, presented in Figure 8, a solar panel system could generate roughly $600K of energy value per year, at the current price 10 cents per kWh.

RESULTS

Print Results

5,976,504 kWh per Year *

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Energy Value ($)
January	3.78	356,746	35,675
February	4.99	417,910	41,791
March	5.63	510,539	51,054
April	6.71	575,926	57,593
May	7.05	614,078	61,408
June	7.80	643,341	64,334
July	7.71	651,021	65,102
August	7.19	612,862	61,286
September	6.29	524,194	52,419
October	5.33	470,150	47,015
November	3.32	292,087	29,209
December	3.32	307,650	30,765
Annual	**5.76**	**5,976,504**	**$ 597,651**

Figure 8 Electricity generation with a 3,500 kW DC system in the JFK area (19)

The capital investment was estimated based on average prices ($/kW DC) from databases. NREL lists for NY a capital investment of $2.6 / W DC for solar systems, though the investment would possibly be higher due to the 2-Axis tracking system chosen for the simulation. At this level, total investment would be at about $9 million. This price, however, considers the full price of installation, not including any government subsidy for clean energy. The FAA has the Voluntary Airport Low Emissions Program (VALE). This program allows airports to use Airport Improvement Program (AIP) funds and Passenger Facilities Charges (PFC) to finance clean energy projects, often funding over two-thirds of the total investment (20).

Assuming that JetBlue can access these funds, it could achieve 14% emission reduction per year (Table 7). This evaluation only considers the installation of solar panels on the rooftop of T5.

Table 7 Summary of Potential Solar System project

Current Electricity Price ($/kWh)	$0.10
System Capacity (kW DC)	3500
Investment per kW DC	$2,600.00
Total Investment	$9,100,000.00
VALE and other grants funding	70%
JetBlue Investment	$2,730,000.00
Annual Energy Generation (kWh/year)	5,976,504

Cost Savings per Year	$600,000
Pay-back Period	4.55
Emission Reduction per Year	14%

At JFK Airport there are other areas with a large potential for solar panel installation. To the Southeast of T5 there is a large area between the two main runways, which could house a large utility-scale solar energy plant. Using the NREL tool, we estimated that there is a potential for a 12,000 kW DC installation in that area, producing 85 GWh/year of electricity. Since this would be an installation too large for JetBlue to implement alone, it should be evaluated as a potential add-on to the new co-gen facilities.

6.1.1. Additional considerations: End of Lease of the Current Co-Generation Plant

We assumed that after 2020 (see Section 3.1.6), even if a new cogeneration plant is installed on site, JetBlue will be allowed to purchase electricity on the competitive market. There are two potential actions related to the end of the co-generation plant contact. The first is to use the large area between the two runways to install a large solar power generation facility. The second is to use the lower electricity prices from the competitive market to finance the purchase of renewable energy credits.

a. Large Solar Power Installation

Using the PV Watts tool mentioned above, we calculated the electricity potential for the large are between the two runways at JFK Airport, see Figure 9.

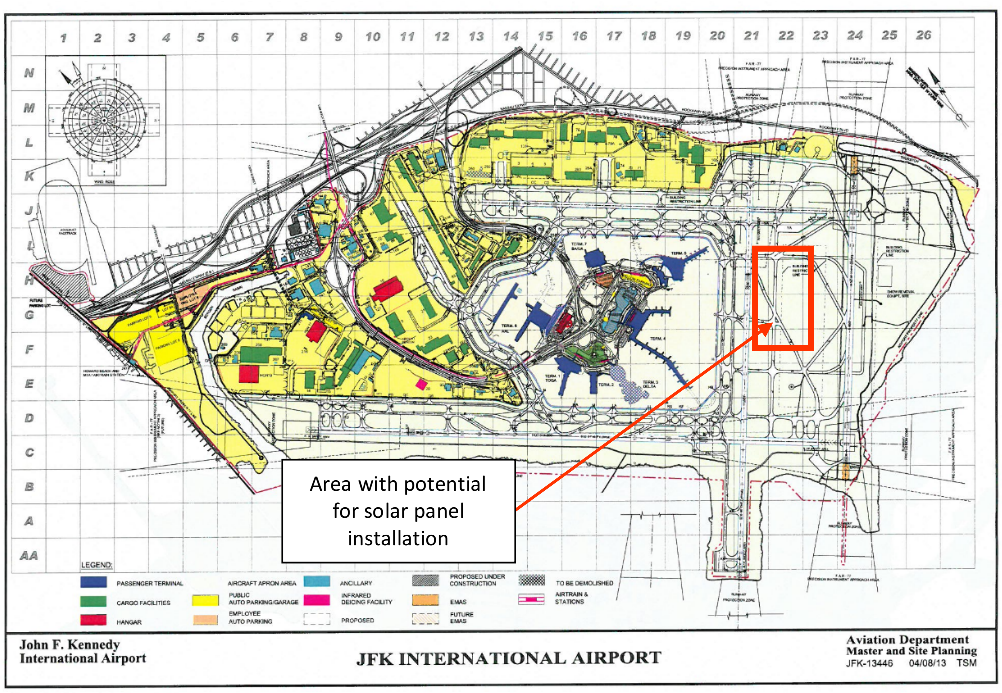

Figure 9 Map of the JFK Airport (Source JFK)

The estimated power that could be generated using this area is 48,000 kW DC. Even considering a loss from height restrictions, a solar power plant with a capacity for 40,000 kW DC is technically feasible. Additionally, considering weather variations, the expected electricity produced from this system could reach 68M kWh/year (Figure 10).

RESULTS

Print Results

68,366,360 kWh per Year *

System output may range from 64,715,596 to 72,639,258kWh per year near this location.
Click HERE for more information.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Energy Value ($)
January	3.78	4,080,916	408,092
February	4.99	4,780,167	478,017
March	5.63	5,840,183	584,018
April	6.71	6,588,158	658,816
May	7.05	7,024,588	702,459
June	7.80	7,359,337	735,934
July	7.71	7,447,196	744,720
August	7.19	7,010,687	701,069
September	6.29	5,996,383	599,638
October	5.33	5,378,164	537,816
November	3.32	3,341,285	334,128
December	3.32	3,519,302	351,930
Annual	5.76	68,366,366	$ 6,836,637

Figure 10 Electricity Generation at the large area between the runways (19)

Subsequently, we compared the capacity of this solar system with the capacity of the current system (Table 8).

Table 8 Capacity Comparison between solar system proposed and current system

Current Co-gen system power	107	MW
Hours per Year	8497.2	h
Current Total Electricity Production	909,200,400	kWh/y
Potential solar energy generation	68,366,360	kWh/y
Potential fraction of energy from solar	7.5%	

With this new system 7.5% of the electricity produced in the airport and purchased by JetBlue would come from a carbon-neutral source.

It is important to note that this system would produce three times the amount of electricity that JetBlue uses. It also requires a large upfront investment from JetBlue, in an area beyond its control, thus it should work with other stakeholders to create the financial conditions for it. A complete proposal for replacement of the cogeneration plant is beyond the scope of this report, including its financial implications and a business case.

b. Renewable Energy Credits

If JetBlue were to purchase electricity in the open market, the company could procure renewable energy credits to offset reduce local emissions.

The price of renewable energy credits in New York is 1 to 2.5 cents per kWh (21). For the purpose of this simulation we assumed that JetBlue could purchase credits for 1 cent per kWh due to the company's capacity of making large purchases.

According to the US Energy Information Agency, electricity prices for commerce and industry in the Northeast area are 9.5 and 7.5 cents per kWh respectively, which are lower than the current 10 cents per kWh paid by JetBlue (22). Part of the savings resulted from changing to the open market could be directed to renewable energy credits. Table 9 below describes this business case.

Table 9 Description of Business Case for Renewable Energy Credits

Current Electricity Price	10	¢/kWh
Electricity Price in the open market in 2020	9	¢/kWh
Price of Renewable Credits	1	¢/kWh
Percentage of savings from lower electricity prices used to purchase renewable energy credits	50%	
Fraction of Electricity from Renewables	5%	

6.2. Building Efficiency

This section will explore the potential actions for emission reductions for the building operations at JFK-T5.

6.2.1. Data Analytics Technology for HVAC Control

One of the main drivers of energy cost and emissions for building operations at JFK Airport – Terminal 5 is the heating, ventilation and air conditioning (HVAC) system, totaling one third of the emissions generated by the building.

Optimizing the operation and maintenance of the system is one of the main drivers to achieve lower costs and better use over long periods of time. Degradation in the HVAC system can be a large source of preventable emissions, even in the new T5 building.

Several new solutions have been created recently, leveraging current information systems and proposing data analytics to improve the operation and maintenance of HVAC systems. We recommend JetBlue to evaluate the wide range of intelligent building energy management systems. One example of such solutions is Clockworks™, which is a software developed by a start-up called KGS Buildings that specializes in energy efficiency for buildings.

The software uses data collected from existing commercial building management to predict maintenance needs and potential operational improvements. Figure 11 includes a diagram with the architecture of such software.

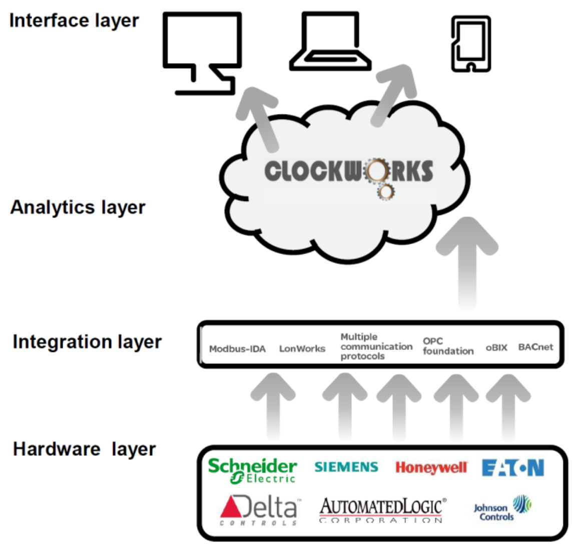

Figure 11 Architecture of the Clockworks software (Source: KGS Buildings)

A case study presented in the company's website claims that the software identified faulted sensors that were generating simultaneous heating and cooling, as well as a number of small air leakages that increased the load across the system, even at a relatively new building. Two case-studies are presented in

Table 10.

Table 10 Clockworks case-studies (23)

Building Type	Area	Building Age	Reported Savings	Percent Improvement
Research Laboratory	450,000 sq. ft.	5 years	$286,000 per year	8%
University Campus	10,000,000 sq. ft.	Variable	$1 million per year	Not Informed

JetBlue buys heating and cooling water from the cogeneration plant so T5 does not have individual heating and cooling equipment. As such, to be conservative, we assumed that implementing this or a similar system could generate potential energy savings of half of the improvement achieved in the case exposed, shown in Table 11. Therefore, this system will cut current CO2 emissions by 339 tons/year.

Table 11 Potential CO2 savings using Clockworks or a similar system

Current CO2e Emission from the HVAC System	8,472 metric Tons/year
Reduction Potential	4%
Potential CO2 emission savings	339 metric tons/year

6.2.2. Air Leaks

Air leakage control is an important part of energy efficient buildings, but it is also very easy to be ignored. However, a tight structure of the building can help the airport to save on HVAC costs due to less heat loss, have a more effective ventilation system, protect the building from mold and rot from excess humidity, and reduce required HVAC capacity.

Air infiltration is a major source of wasted energy. Infiltration means the unintentional or accidental introduction of outside air into the building, typically through cracks in the building envelope and through use of doors for passengers. It is caused by wind, stack effect due to the temperature difference of the indoor and outdoor, and mechanical equipment such as blowers and ventilation which can generate pressure difference in the building (24).

During our visit to T5 we noticed several air leakage spots, especially from gaps in emergency exit window & door frames. Also, we saw a gate door opened allowing cold air coming into the building before starting passenger boarding (see Appendix D). Those leaks can be reduced by simple measures such as closing the door in time and replacing the old material in the frame. But air leakage can also be found in ventilation and air sealing. To control air leakage, we suggest that the airport consider using aerosol (spay foam) sealing on the existing units. Lawrence Berkeley National Laboratory testing demonstrated that aerosol sealing can reduce leakage by a factor of 5 to 8. Aerosol duct sealing is easy to use compared with traditional methods, such as applying mastic, because it eliminates the need to open wall, floor, and ceiling cavities to access hard-to-reach leaks (25).

6.2.3. Lighting Efficiency

According to the Energy Information Agency, 19% of the electricity used in commercial buildings in the US is used for lighting (26). Though specific numbers for T5 were not available for this report, we assumed that JetBlue uses the same proportion of total electricity for lighting.

From interviews performed during our visit, we learned that no LED are used in T5, that all lighting is fluorescent and that, given the non-stopping operations, lights needed to be on the entire day due to JetBlue policy regarding consumer experience. Hence, we in the following subsections we describe two actions to increase energy efficiency: updating the light bulbs to LED lighting and/or installing lighting sensors.

a. LED Lights

LED lights use 10 W of power for the same illumination capacity of a 15 W fluorescent bulb (27). Such bulbs also have an advantage in terms of bulb life, with an average life of 25,000 hours, compared to the 10,000 of fluorescent bulbs. The lower energy consumption and longer life significantly reduce the operational cost of lighting compared to the current alternative. However, JetBlue's facilities team mentioned that a previous study showed that replacing the current bulbs before the end of their useful life is not economically feasible due to labor costs.

One strategy is to replace the light bulbs to LED bulbs as they need to be changed. Considering a life of 10,000 hours and assuming that at least 50% of light bulbs need to be replaced every year, we estimate a 3.2% of energy savings in the first year and 6.3% in the second year (Table 12).

Table 12 Energy Savings from Replacing Lighting

Fraction of Bulbs Replaced in the First Year	50%
Fraction of Bulbs Replaced in the Second Year	100%
Fraction of Electricity Used for Lighting	19%
Power of Current Bulbs	15 W
Power of LED Bulbs	10 W
Energy Savings in the First Year	3.2%
Energy Savings in the Second Year	6.3%

b. Sensors for Lighting Control

During our visit to T5 we noticed that despite good lighting from natural sources, most light bulbs were still on (Figure 12).

Figure 12 Lights on during a bright day in an area with natural lighting (Source: Authors)

We understood that JetBlue is not willing to use motion sensors in the passenger space because during the night customers could feel uncomfortable. Thus, we propose the use of light sensors to dim or turn off the lights during bright days in areas where natural lighting is available. We estimate that the potential energy savings for this solution will be around 2% of the current energy consumed in lighting (see Table 13).

Table 13 Potential Savings with lighting sensors

Fraction of Electricity Used for Lighting	19%
Average Hours per Day with Adequate Natural Lighting	8 hours
Percentage of bulbs in areas with adequate natural lighting	30%
Potential Savings	2%

6.3. Ground Operations

In this section we included the solutions involving operational changes. First we analyzed the acquisition of GSE powered by alternative fuel vehicles, then we briefly describe other operational changes, which benefits are harder to quantify.

a. Purchasing electric GSE

According to our review of the different actions taken by airports and airlines, there is a wide range of possibilities to reduce greenhouse emissions in terms of GSE. Among these practices, a common measure is to replace the use of Air Conditioning Units (ACUs), Ground Power Units (GPUs) and Air Start Units (ASUs), traditionally diesel-powered, by fixed preconditioned air (PCA) systems and 400 Hz electrical systems, which use electricity from the gate/building. Traditionally, because GSE are non-road vehicles, regulations are not stringent and GSE do not have retro-fitted “closed-loop”, which are emission control technologies to improve emissions on older diesel engines. So, a company might have different “low-hanging fruit” initiatives that can reduce carbon emissions. These initiatives include the implementation of exhaust after-treatments, such as oxidation catalysts, three-way catalytic converters and particulate traps. Moreover, incentivizing and training operators to turn off the engine of these vehicles, and avoiding idling longer than five minutes could reduce emissions in the long-term.

Nonetheless, airlines and airports are increasingly updating and/or converting their GSE to alternative fuel vehicles. Higher greenhouse gas emission reduction is achieved by eliminating the use of diesel or gasoline all together. Considering the variety of alternative fuel vehicles available, the most usual and effective practice is to change to vehicles powered by electricity (see Table 14). The greatest benefit of using electric vehicles is the reduction of energy and maintenance. Also, shifting to electricity eliminates the dependence on fossil fuels—if the electricity is produced from renewable sources.

Table 14 Examples of Airlines and Airports using alternative fuels in GSE (28)

Fuel	Type of Implementer	Implementer
Biodiesel	Airport	Lambert-St. Louis International Airport (STL)
CNG	Airport	Dallas-Fort Worth International Airport (DFW)
		Portland International Airport (PDX)
CNG, electric, biodiesel and hybrid	Airport	Denver International Airport (DIA)
		Phoenix Sky Harbor Airport (PHX)
		Salt Lake City International Airport (SLC)
Electric	Airline	American Airlines
		Continental Airlines
		Delta Air Lines
		Horizon Air
		Southwest Airlines
		United Airlines
		United Parcel Service
		US Airways
	Airport	Boston Logan International Airport (BOS)
		Charlotte Douglas International Airport (CLT)
		Detroit Metropolitan Wayne County Airport (DTW)
		George Bush Intercontinental Airport (Houston) (IAH)
		John Wayne Airport (SNA)
		Lehigh Valley International Airport (ABE)
		Louisville International Airport (SDF)
		New York LaGuardia Airport (LGA)
		Oakland International Airport (OAK)

		Philadelphia International Airport (PHL)
		Sacramento International Airport (SMF)
		San Francisco International Airport (SFO)
		Seattle-Tacoma International Airport (SEA)
		Westchester County Airport (HPN)
Hybrid	Airline	Alaska Airlines
Solar-powered hydrant carts	Airport	Indianapolis International Airport (IND)
Initiative/Fuel	Airport	Atlanta Hartsfield-Jackson International Airport (ATL)

A major drawback is the upfront capital cost, but this cost can be offset depending on multiple factors, such as the type of GSE, the purchase price, available funding, type of fuel used, life-cycle cost savings, and infrastructure costs. When no funding is provided, the payback time for electric GSE ranges from 3 to 7 years. The payback time can be reduced by sharing costs with other airlines and/or applying to the multiple existing grants, namely the VALE program (28).

According to the inventory of GSE (**Error! Not a valid bookmark self-reference.**), 50% of the motorized GSE owned by JetBlue operating in JFK airport are either Bag Tug, Belt Loader or Push Back.

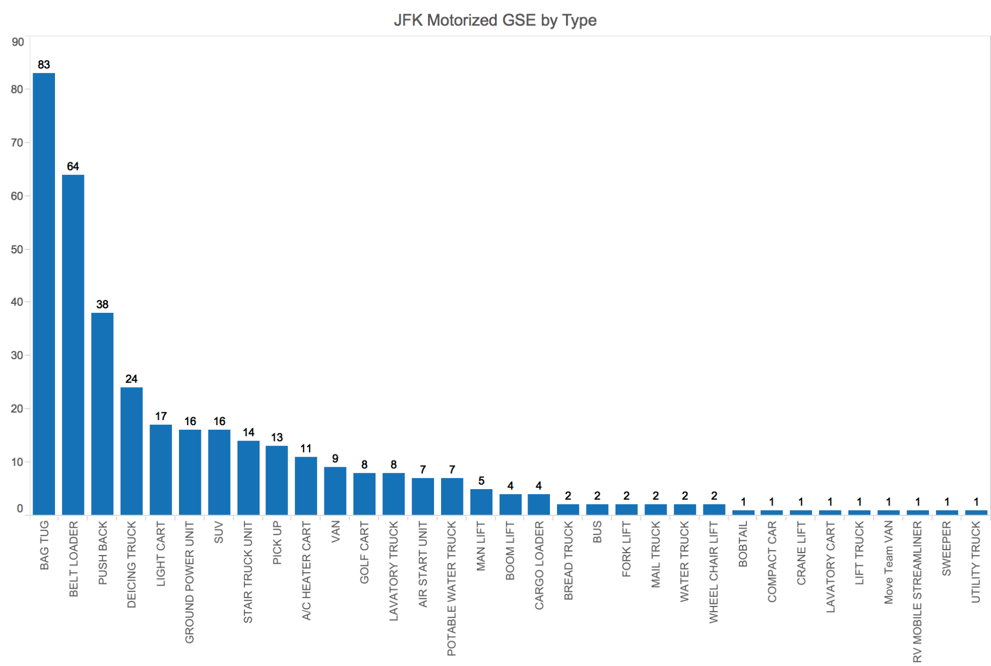

Figure 13 JFK Motorized GSE by Type (Source: JetBlue)

Following the methodology use by Lindenfeld (29), we estimated the Net Present Value of the acquisition of electric vehicles. From conversations with JetBlue we knew that around 70% of the total gallons of diesel and gasoline were consumed by Bag Tugs, Belt Loaders and Pushback Tugs. Therefore, in our analysis we only considered the purchase of these types of equipment. According to an average useful life of 13-year and other assumptions detailed in Appendix E, such as a 20% of salvage value of the equipment to be used in other airports; the NPV for this initiative is positive at a 15% discount rate, even without considering governmental grant. The potential savings of this solution will be roughly 32% of CO2 emissions (Table 15).

Table 15 Potential savings from purchasing GSE electric vehicles

Capital investment	$(5,818,147.45)
Fuel savings	$6,019,465.14
Electricity cost	$(2,260,510.85)
Operational & Maintenance cost savings	$1,743,293.73
Salvage cost (20% of new equipment)	$1,452,020.00
Total NPV (average useful life of this vehicles = 13 years)	$134,810.00
% CO2 emissions saved (metric ton)	32%

Worth noting that JetBlue started a pilot acquiring 2 electric belt loaders, 1 bag tug and a charger station in 2015 and that the results of this pilot are successful so far. JetBlue is planning to complete its application to a VALE grant for this project, which could cover the cost of charging stations not included in this analysis.

b. Jet–Fuel related actions

Jet fuel is the most important source of carbon emissions for airlines in general, but for this inventory we only considered the emissions associated to the use of APU to generate energy while the aircraft is parked.

The literature in aviation is rich in practices and methods to decrease taxi times and thus emissions. However, the problem normally is the operational complexity and the coordination that is needed among different airlines to push any new procedure.

Several best practices are being implemented by different operators around the globe. A brief description of the most relevant actions the industry is integrating as part of the recommended practices are shown below.

Single Engine Taxi

Aircraft movement while on the ground typically represents 10 to 15 percent of total aircraft emissions. When aircraft taxi, the use of power from all engines is not required. To reduce fuel consumption and emissions, some aircraft can taxi on a single engine, turning off one engine or reduced engine power. Additionally, the engine that is running will operate at a higher number of RPM, which results in a more efficient operation, and lower emissions of hydrocarbons and carbon.

Airport operators are not allowed to mandate single engine taxi because of safety reasons, given that some aircrafts are not able to move forward safely with only one engine. Instead, collaborative discussions are the common way to approach this issue encouraging single engine taxi when possible, getting support of several carriers since it represents also fuel consumption reduction.

JetBlue stated that this practice is being done regularly, but the team has not had access to adherence data at the moment of writing this report.

Reduction of Airport congestion on surface

Airport surface congestion increases not only taxi times –which is annoying for customers– but also increases the time while the aircraft is burning fuel with no value, besides producing a huge amount of carbon emissions. Therefore, reduction of the congestion is key to minimize the greenhouse emissions at airports.

Researchers from MIT published in 2011 a study called "Demonstration of Reduced Airport Congestion Through Pushback Rate Control" (30) that controls the rates pushbacks are released to move aircrafts from gates to avoid the airport to enter into a *congested state,* plus avoiding unnecessary time spent taxiing to the runway. This procedure was tested in Boston Logan airport with positive results; and JetBlue's Operations team stated that they knew about the findings, they have already a system in place managed by the Port Authority and a contractor called Sensis, which during peak departure periods manages the length of the queue for takeoff at the runway by metering. In order to reduce time and congestion on the taxiways, flights are held on the gate or in the ramp area until a designated slot time, which is somehow similar to the procedure tested in Boston Logan.

Ground Power Unit

This activity is the only one affecting the current inventory. While at the gate, aircraft require energy to power control systems and the HVAC system. When no backup system is in place, aircraft use the APU (Auxiliary Power Unit), which is basically a small turbo-shaft engine that runs on jet fuel, burning 35 gallon of jet fuel per hour of operation. Diesel or kerosene engines are more efficient in providing this energy (in terms of cost and carbon emissions, burning 1.7 gallons per hour), thus, the maximization of the use of the GPU unit (Ground Power Unit) is key to reduce carbon emissions.

Assuming an 10% increase on the usage of the GPU, JetBlue could reduce the carbon emissions associated to the use of APU by 20%.

Operational adherence

The majority of the main initiatives in terms of fuel consumption reduction have been adopted by JetBlue (GPU usage, Single Engine Taxi, limited reverse thrust usage). Nevertheless, the team could not have access to operational data that shows how well these initiatives have been implemented. This does not seem to be related to access to sensible or confidential data, but more with the difficulty to obtain it, meaning it is not highly visible. Given the sensitivity of the emissions to the jet fuel burn, it is indispensable make this information visible to everyone, make them embedded in the performance targets of the related teams and push for operational excellence in those terms.

7. Target recommended and Conclusions

Considering the inventory and the potential actions presented previously, we calculated the target for emission.

The first step is to calculate the total emission reduction potential of all the actions proposed should they be adopted fully. Table 16 show the distribution of emission for each type of energy source, as used in the inventory above.

Table 16 Distribution of emission for each type of energy source

Type of Energy	Electricity	Chilled Water	Mid Temp.	Gasoline /Diesel	APU	Total
Total Emissions	18,159	5	8,500	5,383	6,474	38,521
Fraction of Total Emissions	47%	0.01%	22%	14%	17%	100%

Table 17 shows the potential of reduction of each action to each type of energy.

Table 17 Reduction of each action per type of energy

Solution	Electricity	Chilled Water	Mid Temp.	Gasoline /Diesel	APU	Total
Solar Panels	-14%	0%	0%	0%	0%	-7%
Purchase of Renewable Credits	-5%	0%	0%	0%	0%	-2%
Large Solar Installation	-8%	0%	0%	0%	0%	-4%
Data Analytics Technology for HVAC Control	0%	-4%	-4%	0%	0%	-1%
Lighting - LED Bulbs	-6%	0%	0%	0%	0%	-3%
Lighting - Sensors	-2%	0%	0%	0%	0%	-1%
Switch to Electric GSE	10%	0%	0%	-70%	0%	-5%
Operation Adherence and use of GPU	0%	0%	0%	0%	-20%	-3%
Total Savings	**-25%**	**-4%**	**-4%**	**-70%**	**-20%**	**-26%**

Since the percentages presented in Table 17 are relative to each source of energy, we estimated the percentage of carbon emissions relative to the total amount of carbon emissions produced currently in T5. The breakdown of CO2 emission reduction per energy source and our recommended target is shown in Figure 14.

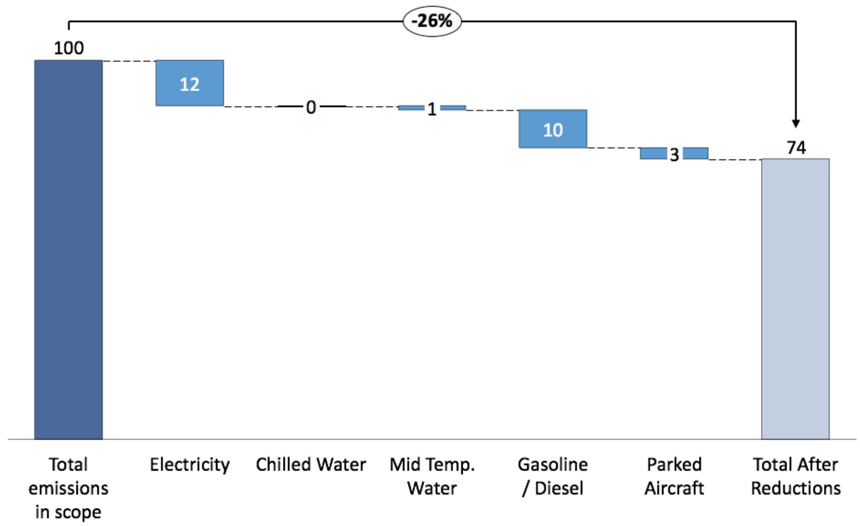

Figure 14 Breakdown of CO2 emission reduction by energy source

It is important to note that this reduction assumes all actions are put in place. Table 18 shows a potential implementation schedule of those actions, which would result on a paced reduction of CO2e emissions.

Table 18 Implementation Schedule

Adoption of Each Action	2016	2017	2018	2019	2020	2021
Solar Panels	0%	30%	60%	100%	100%	100%
Purchase of Renewable Credits	0%	0%	0%	0%	50%	100%
Large Solar Installation	0%	0%	0%	0%	0%	100%
Data Analytics Technology for HVAC Control	0%	100%	100%	100%	100%	100%
Lighting - LED Bulbs	0%	50%	100%	100%	100%	100%
Lighting - Sensors	0%	100%	100%	100%	100%	100%
Switch to Electric GSE	0%	0%	50%	100%	100%	100%
Operation Adherence and use of GPU	100%	100%	100%	100%	100%	100%
Total Emission Reduction	**-3%**	**-9%**	**-15%**	**-20%**	**-21%**	**-26%**
Emissions as a Fraction of Current	97%	91%	85%	80%	79%	74%

As presented in Figure 15, the emissions from JFK-T5 over the next years will decrease to 74% of its current carbon emissions.

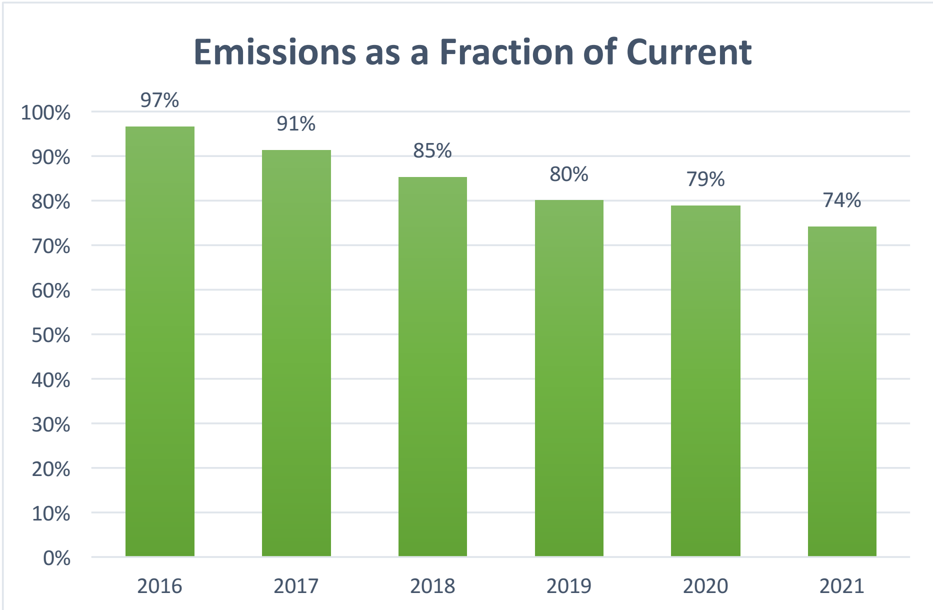

Figure 15 Projection of Emissions at JFK - T5 with this adoption strategy

To summarize, JetBlue has a potential to reduce its emissions related to the operations in JFK T5 by 26% in the next five years. We hope that this result serves as a basis to present a reasonable target to its stakeholders, specially the NYC Mayor's Office. Through these changes, JFK T5 would also be at the same level as the most advance airports in terms of technologies for carbon reduction.

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Appendix A: List of Greenhouse Gas Reduction Strategies

Priority	Numerical Score*	Greenhouse Gas Reduction Strategy Name and Number	
1	81	RE-03	Install Solar Thermal Systems for Hot Water Production
2	81	EM-08	Use Thermal Imaging to Identify Energy Losses
3	81	EM-06	Develop and Market an Energy Conservation Program for Building Users
4	81	BP-03	Develop a Climate Action Plan (CAP)
5	81	RF-01	Replace Refrigerants with Natural or Lower Global Warming Potential (GWP) Gases
6	78	CS-04	Invest in Terrestrial Carbon Sinks
7	78	CN-03	Implement a Construction Vehicle Idling Plan
8	78	BP-08	Use Airport-Specific Sustainable Planning, Design, and Construction Guidelines
9	78	EM-18	Implement a Lighting System Energy Conservation Program
10	78	BP-10	Set a Policy for Green Building Certification for Buildings
11	78	EM-31	Purchase ENERGY STAR Equipment
12	78	EM-38	Install Window Awnings or Sunshades
13	78	EM-39	Utilize Sophisticated Energy Models for Building Design
14	75	EM-37	Incorporate Use of Natural Ventilation and Economizer Control
15	75	EM-10	Change Set Points or Exclude Selected Zones from Heating and Cooling
16	75	RF-02	Incorporate Intelligent Fault Diagnosis for HVAC Refrigerant Systems
17	75	RF-04	Install Microchannel Components and Heat Exchangers
18	72	GS-01	Support Alternatively Fueled Ground Service Equipment (GSE)
19	72	EM-01	Develop a Strategic Energy Management Plan
20	72	EM-07	Evaluate Fuel Mix
21	72	RE-01	Install Building Integrated Photovoltaic (BIPV) Panels
22	72	EM-24	Install Variable Speed Drives (VSD) and Optimize Controls of Pumps for Air Handling Units
23	72	EM-30	Reduce Transmission Losses in Electrical Wires
24	72	EM-03	Develop Energy Performance Contracting Partnerships
25	72	EM-25	Install Evaporative Cooling Systems
26	72	RE-14	Utilize Local Landfill Gas
27	72	EM-13	Install a Cool Roof
28	72	EM-14	Design Building Orientation for Energy Use Reduction
29	72	AF-12	Support Modernization of Air Traffic Management (ATM)
30	72	RE-12	Install Sewer Heat Recovery Systems
31	72	AF-17	Support Fuel Efficiency Targets for Aircraft
32	69	EM-21	Install High-Efficiency Equipment and Controls
33	69	EM-29	Design for Larger Diameter Piping
34	69	EM-17	Install LED Runway and Taxiway Lighting
35	69	EM-22	Integrate Thermal Storage into Heating and Cooling Systems
36	69	BP-05	Create a Carbon Offset Purchasing Strategy
37	69	RF-03	Use Hydronically Coupled Vapor-Compression Heat Pumps
38	69	EM-28	Install a Heat Recovery System
39	69	RE-13	Construct a Hydrogen Fueling and Generation Station
40	69	RE-02	Install Building-Mounted or Ground-Mounted Solar Photovoltaic (PV) Panels
41	69	CN-05	Specify Energy Efficient Temporary Lighting During Construction
42	69	CN-02	Recycle and Reuse Construction and Demolition Materials
43	69	OM-01	Create a Detailed Operations and Maintenance Manual
44	69	EM-09	Improve Insulation of Building Envelope
45	69	EM-02	Specify Energy Efficiency Requirements for Equipment in Contract Agreements
46	69	GT-15	Support Conversion of Tenant Fleet Vehicles to Alternatively Fueled Vehicles
47	67	GT-02	Provide Preferential Car/Vanpool Parking for Employees
48	67	AF-14	Support Single/Reduced Engine Taxiing
49	67	GT-17	Support Alternatively Fueled Taxis
50	67	GT-03	Promote Public Transit to the Airport
51	67	EM-11	Restrict Heating and Cooling to Lowest 10 ft of Indoor Space
52	67	EM-32	Enhance Piping Insulation

Priority	Numerical Score*	Greenhouse Gas Reduction Strategy Name and Number	
53	67	AF-04	Design Runways, Taxiways, Ramps & Terminals to Reduce Aircraft Taxiing Distances
54	67	GT-16	Support Alternatively Fueled Vehicles for Rental Cars and Commercial Vehicles
55	67	GT-13	Promote Bicycle Use by Employees
56	67	GT-14	Convert Airport Fleet Vehicles to Alternatively Fueled Vehicles
57	67	EM-35	Install Energy Efficient Elevators, Escalators and Autowalks
58	67	BP-01	Use Greenhouse Gas Impact Evaluations as Decision-Making Criteria
59	67	EM-23	Evaluate and Upgrade the Central Plant and Distribution System Equipment
60	67	AF-18	Support the Use of Paperless Ticket Technology
61	67	BP-06	Develop and Apply or Sell Carbon Offsets
62	67	RE-09	Install Building-Mounted Wind Turbines
63	67	CN-01	Use Warm Mix Asphalt (WMA) in Place of Hot Mix Asphalt
64	67	EM-16	Apply Thermochromic Coatings on Buildings
65	67	EM-19	Install a Building Automation System (BAS)
66	67	EM-15	Apply Solar Reflective Paint
67	67	AF-09	Implement Emission-Based Incentives and Landing Fees
68	67	AF-11	Support Optimized Departure Management on Existing Runways
69	64	GT-10	Allow Flexible Work Schedules for Employees
70	64	PM-01	Conduct Regular Greenhouse Gas (GHG) Emission Inventories
71	64	ME-01	Develop an Integrated Solid Waste Management Plan
72	64	GT-01	Provide Priority Vehicle Parking for Emissions Friendly Vehicles
73	64	ME-04	Separate and Compost Food Waste
74	64	ME-02	Start or Enhance a Waste Reduction or Recycling Program
75	64	AF-02	Minimize the Use of Auxiliary Power Units (APUs)
76	64	BP-02	Develop an Airport Expansion and Development Greenhouse Gas Emission Policy
77	64	EM-12	Install Green Vegetated Roofs for Greater Building Insulation
78	64	CN-04	Specify Low-Emission Construction Vehicles and Equipment
79	64	AF-03	Design Airside Layout to Reduce Aircraft Delay and Surface Vehicle Congestion
80	64	EM-27	Install Ultraviolet-C (UVC) Lights in Air Handling Units (AHUs) for Continuous Coil Cleaning
81	64	CS-01	Install Sustainable, Long-Term Vegetation
82	64	GT-06	Alter Parking Pricing Structures for Employees and Passengers
83	61	AF-08	Create Partnerships with Intercity Rail Services to Optimize Passenger and Cargo Movement
84	61	BP-11	Support the Use of Customer Self-Service Equipment in Terminal Design
85	61	EM-20	Periodically Recommission HVAC Systems and Control Systems
86	61	OM-03	Use a Computerized Maintenance Management System (CMMS)
87	61	RE-07	Install a Geothermal Snow and Ice Melting System
88	61	EM-36	Optimize Passenger and Baggage Handling System
89	61	GT-07	Implement "On-foot" Payment for Parking
90	61	GT-08	Implement a Traffic Management System
91	58	RE-08	Use Seawater and Natural Water Bodies for Cooling
92	58	PM-02	Perform Energy Audits
93	58	GT-04	Provide Transit Fare Discounts and/or Alternative Mode Subsidies
94	58	GT-09	Allow Telecommuting for Employees
95	58	RE-04	Use Solar Desiccant Air Conditioning Systems
96	58	EM-26	Install Energy Efficient Chillers
97	58	OM-02	Develop a Measurement and Verification Plan
98	58	AF-16	Support Push Back Tugs to Transport Planes to Taxiways, Runway Ends and/or Take-off Areas

Priority	Numerical Score*	Greenhouse Gas Reduction Strategy Name and Number	
99	58	AF-07	Provide Fixed Gate Infrastructure for Aircraft Underground Supply and Evacuation Systems
100	53	AF-15	Support Alternative Passenger Boarding Procedures
101	53	BP-04	Develop Climate Change and Energy Communication Materials and/or Information Center
102	53	BP-09	Participate in a Greenhouse Gas Registry and/or Accreditation Program
103	53	AF-05	Consider Longer Runways to Reduce the Use of Reverse Thrust
104	53	AF-01	Provide Infrastructure for Pre-Conditioned Air (PCA) and Ground Power
105	53	PM-05	Work with Airport Industry to Develop Benchmarking Databases
106	53	ME-03	Start or Enhance a Green Procurement Program (GPP)
107	53	GT-12	Construct a Personal Rapid Transit (PRT) System
108	53	RE-06	Install Ground-Source or Geothermal Heating and Cooling System
109	50	PM-04	Track Energy Use
110	50	EM-04	Enter into a Green Power Purchasing Agreement
111	47	AF-13	Support the Development of Alternative Fuels for Aircraft
112	47	GT-05	Increase Mass Transit Access to the Airport
113	47	EM-05	Evaluate "Take or Pay" Contract Provisions
114	47	GT-11	Build a Consolidated Rent-A-Car Facility (ConRAC)
115	47	AF-06	Install or Expand Hydrant Fueling System
116	47	AF-10	Install a Jet Fuel Pipeline
117	47	RE-10	Install a Waste-to-Energy System
118	44	BP-07	Offer Voluntary Carbon Offsets for Passengers
119	44	PM-03	Install Tenant Energy Sub-Metering Systems
120	44	EM-34	Use Methane from Anaerobic Bioreactor Treatment Systems for Deicing Fluids
121	42	CS-02	Add Mineral Carbonation Systems to Exhaust Streams
122	42	RE-11	Install a Tidal Energy System
123	31	EM-33	Construct a Cogeneration or Trigeneration Energy System
124	28	CS-03	Implement or Support Carbon Dioxide Capture and Storage Processes
125	28	RE-05	Use On-site Biomass Energy Systems

* Numerical scores are normalized to be within 0 and 100 and consider all evaluation criteria to be weighted equally. Higher scores indicate more desirable strategies.

Appendix B: Interviews with MIT faculty

John Hansman T. Wilson Professor of Aeronautics & Astronautics, Director of MIT International Center for Air Transportation	**Aircraft** He explained the difference between GPU and APU. Pointed out that to reduce emissions, the use of APU must be minimized. He proposed the following practices: - Minimize the airplane in queue (He suggested us to refer to Prof. Balakrishnan's work) - Towing the airplane to the runway to avoid using the Airplane's engines - Electric motors on the wheels (evaluate if adding extra-weight is beneficial) - Single engine-taxing, only turn on the second engine five minutes before taking-off - Measure how the airplane is warmed, in the first flight **Ground operations** Change to electric vehicles because usually these vehicles are not moving and are parked close to the charging point.
Leon R. Glicksman Professor of Building Technology and Mechanical Engineering and Head of Building Technology Program in Mechanical Engineering and Architecture Department	**Building efficiencies** He recommended us to verify or ask the following: - How is the building control system? - Where are the places to turn-off the lights during the day? - Does the airport allow open ventilation during the night in Summer? - How the ventilation is controlled? - Does the airport use recirculation of the air? (It is cheaper to have recirculated air than bringing fresh air.) - About Displacement ventilation, is there a low velocity distribution at the bottom to avoid cooling a lot of air because of the high ceilings? - About insulation. Evaluate for faults in the HVAC (A startup from MIT called KGS Building sets up sensors to evaluate where the HVAC is failing and improve maintenance) - Check for shading in the windows, the orientation of the shades - Is the lighting still fluorescent? - Check the efficiency of the Kitchens Evaluate the possibility to change electricity generation to: - Solar panels - Wind, evaluate restrictions on the height of the building
Nathan Collin Brown Graduate student who has expertise in the design of energy efficient airport	He suggested us to check the State Technical Resource Manual to: - Find documents with the metrics that they use for building efficiencies, indication of ranges of payback times.

buildings (Introduced by Professor John Ochsendorf)	- Insulating mechanical equipment and pipes - Evaluate overcapacity in conveyor belts to move baggage to check whether they operate in full capacity?
Hamsa Balakrishnan Associate Professor of Aeronautics and Astronautics	She provided different research papers on strategies to reduce emissions on airports. She explained about past attempts to reduce fuel consumption for taxi operations. And she also suggested to look at what has been done om similar airports, for example LAX.
John Sterman Jay W. Forrester Professor of Management. Director, MIT System Dynamics Group	As our project advisor, he provided insights on building efficiencies and challenges regarding carbon emissions reductions.

Appendix C: CO2 Emission Estimates

TAXI IN / OUT*

		JFK Lo	JFK Hi	JFK Ave	Jetblue Ave
	Number of flights [flights/day]	164	225	180	825
		20%	27%	22%	
		Source: http://mediaroom.jetblue.com/~/media/Files/J/Jetblue-IR/fact-sheet-documents/jetblue-focus-cities.|			
Operation Size & Time of Engine working	Flights In	180	Assumption: Average operation size is 80% of the maximum operation		
	Flights Out	180	Assumption: Same number of departures and arrivals		
	Taxi in average time [min]	10	Assumption: In line with http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publicati		
	Taxi out average time [min]	15			
	Total time taxi in/out [hr/day]	75			
Emissions	Emissions per time in ground [kg CO2e / day]	219,495			
	Emissions per time in ground [Mton CO2e / yr]	**60,087**			
	JetBlue emissions [Metric tons / yr]	6,903,710			
	% of Jetblue Emissions	0.9%			
Key Assumption	% Single Engine Taxi	50%	This number changes the total amount of emissions. I.e . A 100% of use of		

	Fleet	#	%	TA time	
Composition of fleet	A-320	130	60%	35	Assumption: JetBlue's standard times (TBC)
	A-321	28	13%	40	Assumption: JetBlue's standard times (TBC)
	E-190	60	28%	30	Assumption: JetBlue's standard times (TBC)
	Total	218		34.3	Assumption: the fleet flying from/to JFK is in the same
	http://www.airfleets.net/flottecie/JetBlue%20Airways.htm				

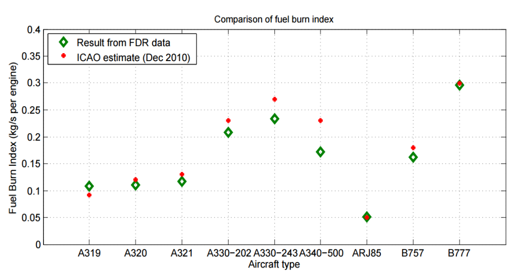
		Fuel Burn Index	Engines	Kg/day 2-engi	Kg/day single	Gallon/day 2-e	Gallon/day sin
Conversion from time of engine on to gallons of jet fuel	A-320	0.125	2	40,252	20,126.15	13,225.78	6,613
	A-321	0.13	2	9,017	4,508.26	2,962.58	1,481
	E-190	0.125	2	18,578	9,288.99	6,104.21	3,052
				67,847	33,923	22,293	11,146
						6102590	Gallon/yr

EMISSIONS FACTORS

Jet fuel (Jet A or A-1)

		Factor	Units	GHG potential	Emissions Equivalent Emissions/day 2-engine taxi	
Conversion from gallons to Ton CO2e	CO2	9.75	kg/gallon fuel	1	217,353	kg CO2e / day
	CH4	0.00	g/gallon fuel	21	-	kg CO2e / day
	N2O	0.31	g/gallon fuel	310	2,142.32	kg CO2e / day
					219,495	kg CO2e / day

Time to kg of fuel factors



ICAO fuel burn rates

7%	taxi
30%	approach
85%	climb-out
100%	take off

APU USAGE

	JFK Lo	JFK Hi	JFK Ave	Jetblue
Operation Size [flights/day]	164	225	180	825
	20%	27%	22%	

http://mediaroom.jetblue.com/~/media/Files/J/Jetblue-IR/fact-sheet-documents/jetblue-focus-cities.pdf

Operation Size & Time of Engine working	Flights In	180	Assumption: Average operation size is 80% of the maximum operation
	Flights Out	180	Assumption: Same number of departures and arrivals
	Taxi in average time [min]	10	Assumption: In line with http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publicati
	Taxi out average time [min]	15	
	Turn around time [min]	34.3	
	Total APU time [hr/day]	51.4	
Emissions	Emissions per time in ground [kg CO_2e / day]	17,737	
	Emissions per time in ground [Mton CO_2e / yr]	**6,474**	
	JetBlue emissions [Metric tons / yr]	6,903,710	
	% of Jetblue Emissions	0.1%	
Key Assumption	% GPU usage	50%	This number is an assumption of what percentage of the TAT the APU is o

	Fleet	#	%	TA time	
Composition of fleet	A-320	130	60%	35	Assumption: JetBlue's standard times (TBC)
	A-321	28	13%	40	Assumption: JetBlue's standard times (TBC)
	E-190	60	28%	30	Assumption: JetBlue's standard times (TBC)
	Total	218		34.3	Assumption: the fleet flying from/to JFK is in the same

http://www.airfleets.net/flottecie/JetBlue%20Airways.htm

Conversion from kg of fuel burnt to gallons	Fuel burn [kg per 45 min TAT instance]	80	
	Fuel burn [Kg Jet Fuel / hr]	107	
	Density Jet A-1	0.804	kg/l
	Litre to Gallon	0.264172	l/gallon
	Fuel burn [Gallon Jet Fuel / hr]	35	

EMISSIONS FACTORS

Conversion from gallons of jet fuel to CO_2e	Jet fuel (Jet A or A-1)	Factor	Units	GHG potential	Emissions Equivalent APU Emissions	
	CO_2	9.75	kg/gallon fuel	1	341.7	kg CO_2e / hr
	CH_4	0	g/gallon fuel	21	0.0	kg CO_2e / hr
	N_2O	0.31	g/gallon fuel	310	3.4	kg CO_2e / hr
					345.1	kg CO_2e / hr

Chilled Water

Bill readings

Consumption	6089	MBTU/mo	June
Bill	683536	$/mo	
Rate	112.3	$/MBTU	
Consumption [MBTU/yr]	73068		
Consumption [ton-hr/yr]	6089		
ton-hour refrigeration	12	MBTU	

			Factor	kg CO_2e/yr	ton CO_2e/yr
Emissions CO_2	0.884	kg/ton-hour	1	5382.676	5.38
Emissions CH_4	0.083	g/ton-hour	21	10.613127	0.01
Emissions NO	0.002	g/ton-hour	310	3.77518	0.00
Total					**5.40**

Energy Product	Carbon Dioxide	Methane	Nitrous Oxide
Steam or Hot Water			
Units of Measure	kg/MMBtu	g/MMBtu	g/MMBtu
Value [a]	88.18	8.169	0.603
Chilled Water			
Units of Measure	kg/ton-hours cooling	g/ton-hours cooling	g/ton-hours cooling
Absorption Chiller Using Natural Gas [b]	0.884	0.083	0.002
Engine-Driven Chiller Using Natural Gas [b]	0.590	0.056	0.001
Electric-Driven Chiller [b]			
Units of Measure	kg/ton-hours cooling	g/ton-hours cooling	g/ton-hours cooling
Domestic			
1999-2002 [c]	0.629	0.017	0.010
1991-1994 [c]	0.639	0.019	0.011
Foreign	See Note 2 below	See Note 2 below	See Note 2 below

[a] Weighted average based on Energy Information Administration's (EIA) 1998 Manufacturers Energy Consumption Survey data on the quantities of natural gas, coal, and residual and distillate fuel oils consumed as boiler fuel, emission factors from Appendix H of these instructions, and EIA/OIAF efficiency assumptions of 80, 81, and 82 percent for natural gas, coal and petroleum boilers, respectively. Factors also assume 10 percent losses during transmission.
[b] Chilled water efficiencies based on California Climate Action Registry, *General Reporting Protocol* (October 2002). Factors also assume 10 percent losses during transmission.
[c] Use 1999-2002 factors to calculate emissions and reductions for Start Year reports for 2002 or later and Reporting Year reports for 2003 or later. Use 1991-1994 factors to calculate emissions and reductions for Start Year reports for 1990 through 2001 and Reporting Year reports for 1991 through 2002. Factors also assume 10 percent losses during transmission.

Mid Temperature Water

Bill Readings

Consumption		8000	MBTU/mo	Source: Interview with
Bill	N/I		$/mo	
Rate	N/I		$/MBTU	
Consumption		96000	MBTU/yr	

			Factor	kg CO2/yr	ton CO2/yr
Emissions CO2	88.18	kg/MBTU	1	8465280	8465.28
Emissions CH4	8.169	g/MBTU	21	16468.7	16.5
Emissions NO	0.603	g/MBTU	310	17945.3	17.9
Total					**8499.7**

Electricity

Site: JFK Terminal 5 (Location: JFK - eGRID subregion: NYLI)					
		Regional factor (lb/kWh)			
Year	ergy use (kWh	CO2	N2O	CH4	
2014	29,401,440	1.33611	0.00008149	0.00001028	
		Emissions (lb)			
		CO2	N2O	CH4	Total
		39,283,558	2,396	302	39,286,256
		CO2e emissions			
		CO2	N2O	CH4	Total
		39,283,558	742,736.24	6,347	40,032,641

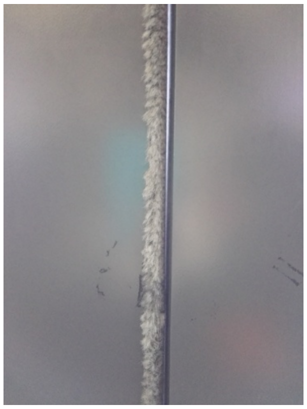
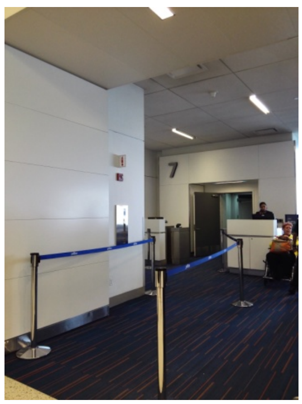
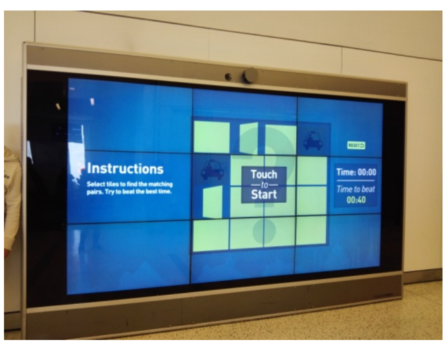
Source: JetBlue 2015 GHG Emissions excel file

Emissions [lb CO2e/yr]	40,032,641
Emissions [Metric ton CO2e/yr]	**18,197**

Conversion

lb/kg 2.2

Appendix D: Photos of findings during Site Visit

	There are several spots of air leakage through the door frame. See the white line between the gap of the door.
	The gate door is opened even when no one is going through the the passage.
	The advertisement LED could be turned off when no passengers passing by.

Appendix E: GSE cost-benefit analysis

a. Ballpark GSE purchase costs (28)

Type	Fuel Type	Costs
Ground Power Unit	Diesel	$17,000
Baggage Tractor	Gasoline	$26,000
	Diesel	$28,000
	Electric	$35,500
Belt Loader	Gasoline	$28,500
	Diesel	$32,200
	Electric	$38,800
Pushback Tug	Diesel	$86,200
	Electric	$93,000
Cargo Loader	Diesel	$475,000

b. Assumptions for the analysis

Percentage of fuel consumed by bag tug, belt loader and pushback	70%	
Operational & Maintenance cost savings ($)	$2,000.00	
% Salvage Cost	6%	
Electricity consumed by GSE (KWH per gallon)	12	California Department of Transportation (Caltrans), 1998
Discount rate	15%	JetBlue
Average useful life	13	U.S. Department of Transportation FAA, 2010

	# vehicles	Purchase Price per vehicle	
Bag Tug - Gasoline	77	$26,000.00	ACRP 078
Belt Loader - Gasoline	59	$28,500.00	
Bag Tug - Diesel	5	$28,000.00	
Belt Loader - Diesel	5	$32,200.00	
Push Back - Diesel	38	$86,200.00	

Total Vehicles Gasoline	136	
Total Vehicles Diesel	48	
CO2 emissions coefficient (kg CO2 per gallon) - Gasoline	8.89	U.S. Energy Information Administration estimates
CO2 emissions coefficient (kg CO2 per gallon) - Diesel	10.16	U.S. Energy Information Administration estimates
CO2 Intensity Factor JFK (kg CO2/KWh)	0.51	US EPA (http://www.epa.gov/cleanenergy/energy-resources/egrid/)
Electricity price ($/kwh)	$0.10	JetBlue
Gasoline price (($/gallon)	$3.11	JetBlue
Diesel price ($/gallon)	$3.29	JetBlue

c. Vehicle purchasing plan

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Bag tug - Diesel	0	**5**	0	0	0	0	0	0	0	0	0	0	0
Belt loader - Diesel	**5**	0	0	0	0	0	0	0	0	0	0	0	0
Push back - Diesel	0	**38**	0	0	0	0	0	0	0	0	0	0	0
Bag tug - Gasoline	0	**77**	0	0	0	0	0	0	0	0	0	0	0
Belt loader - Gasoline	0	**59**	0	0	0	0	0	0	0	0	0	0	0

d. Estimations of NPV

JetBlue GSE Replacement Pro Forma

	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Revenue	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Old Equipment sold		$ 32,200	$1,419,820											$ 766,540
Total	$ -	$ 32,200	$1,419,820	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 766,540
Operating Costs														
Extra Electricity Cost		$ 23,269	$ 475,281	$ 475,281	$ 475,281	$ 475,281	$ 475,281	$ 475,281	$ 475,281	$ 475,281	$ 475,281	$ 475,281	$ 475,281	$ 475,281
Fuel Savings		-$ 63,796	-$1,265,278	-$1,265,278	-$1,265,278	-$1,265,278	-$1,265,278	-$1,265,278	-$1,265,278	-$1,265,278	-$1,265,278	-$1,265,278	-$1,265,278	-$1,265,278
Operational & Maintenance Cost Savings		-$ 10,000	-$ 368,000	-$ 371,680	-$ 371,680	-$ 371,680	-$ 371,680	-$ 371,680	-$ 371,680	-$ 371,680	-$ 371,680	-$ 371,680	-$ 371,680	-$ 371,680
Total	$ -	-$ 50,527	-$1,157,997	-$1,161,677	-$1,161,677	-$1,161,677	-$1,161,677	-$1,161,677	-$1,161,677	-$1,161,677	-$1,161,677	-$1,161,677	-$1,161,677	-$1,161,677
EBITDA	**$ -**	**$ 82,727**	**$2,577,817**	**$1,161,677**	**$1,161,677**	**$1,161,677**	**$1,161,677**	**$1,161,677**	**$1,161,677**	**$1,161,677**	**$1,161,677**	**$1,161,677**	**$1,161,677**	**$1,928,217**
Depreciation		$ 38,800	$1,533,080	$1,533,080	$1,533,080	$1,533,080	$1,494,280							
EBIT	$ -	$ 43,927	$1,044,737	-$ 371,403	-$ 371,403	-$ 371,403	-$ 332,603	$1,161,677	$1,161,677	$1,161,677	$1,161,677	$1,161,677	$1,161,677	$1,928,217
Interest														
Taxes	$ -	$ 15,374	$ 365,658	-$ 129,991	-$ 129,991	-$ 129,991	-$ 116,411	$ 406,587	$ 406,587	$ 406,587	$ 406,587	$ 406,587	$ 406,587	$ 674,876
Net Income	$ -	$ 28,552	$ 679,079	-$ 241,412	-$ 241,412	-$ 241,412	-$ 216,192	$ 755,090	$ 755,090	$ 755,090	$ 755,090	$ 755,090	$ 755,090	$1,253,341
Capex	$ -	$ 194,000	$7,471,400	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Working capital	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Changes in working capital	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Cash flows by year	**$ -**	**-$ 126,648**	**-$5,259,241**	**$1,291,668**	**$1,291,668**	**$1,291,668**	**$1,278,088**	**$ 755,090**	**$ 755,090**	**$ 755,090**	**$ 755,090**	**$ 755,090**	**$ 755,090**	**$1,253,341**
Present value of cash flows by year	$ -	-$ 110,128	-$3,976,742	$ 849,293	$ 738,515	$ 642,187	$ 552,553	$ 283,866	$ 246,840	$ 214,644	$ 186,647	$ 162,301	$ 141,132	$ 203,703
NPV of all cash flows	**$ 134,810**													

Tax	0.35
r	0.15