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Memorandum

To: NYC Department of Sanitation

From: Sharon Paul Carpenter

Date: June 14, 2016

Re: Private Carting Air Emissions Analysis

INTRODUCTION

Commercial waste collection vehicles travel along roadways within the five boroughs of New York City in order to pick up and haul solid waste and recyclables to appropriate transfer stations in the region. Refuse and single-unit short haul trucks are considered mobile sources of air pollution. An estimation of 2016 air emissions was performed based on vehicle-miles-traveled (VMT) for current collection routes and carting fleet characteristics provided by the Business Integrity Commission (BIC). To provide an alternative method of comparing the existing air quality conditions with zoned conditions, traffic engineers created an optimized existing conditions scenario, where the stops in a route are reordered to generate the lowest possible VMT, while ignoring all other considerations of developing a route.

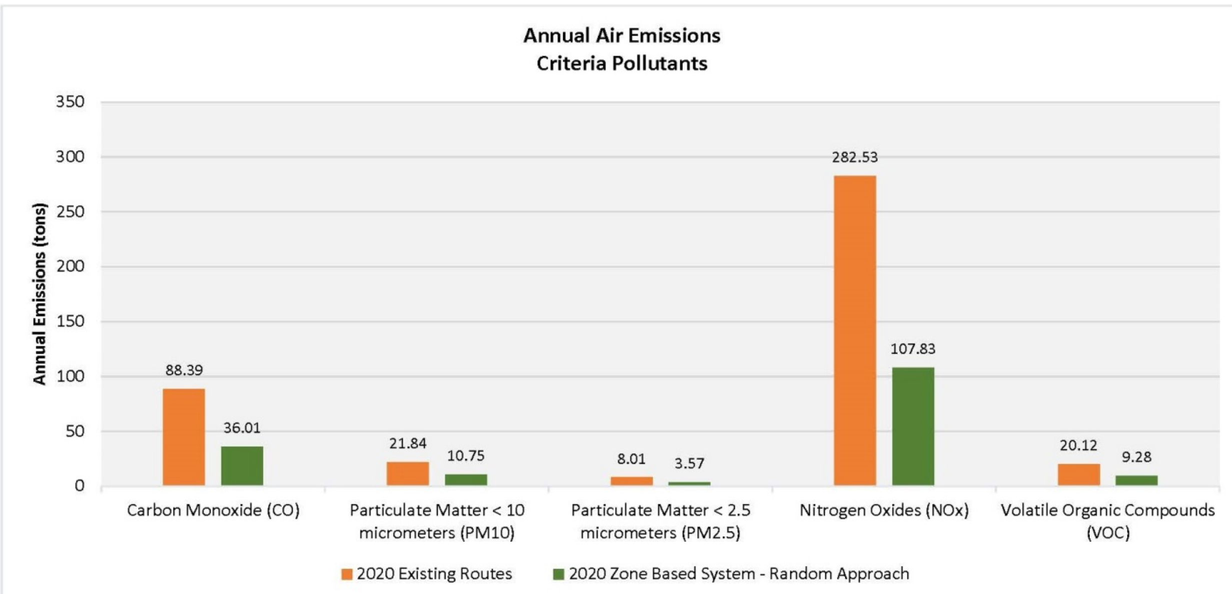
Traffic engineers estimated VMTs for future 2020 conditions assuming two (2) types of zone based systems; random and clustered approaches as detailed within the *Private Carting VMT Analysis, performed by Sam Schwartz Engineering, D.P.C., dated June 2, 2016.* Dual comparison emissions analyses were therefore performed which compared future 2020 existing system emissions with those estimated assuming a zone based system (random approach). In addition, analyses were performed which compared future 2020 emissions as a result of the current optimized collection system with those estimated assuming a zone based system (clustered approach).

RESULTS

Based on methodology detailed within subsequent sections of this memorandum, emissions were estimated for calendar years 2016 and 2020. However, since New York City Local *Law 145 (LL 145) of 2013* goes into effect in 2020, emission comparisons were focused on 2020 results. In comparing 2020 emissions related to the current collection system (as reported and optimized approaches) with those as a result of either zone based system (random and clustered approaches), significant emission reductions are recognized. Emission reductions directly correlate with VMT reductions estimated by the zone based system. Even with slightly higher emission factors resulting from slower speeds (due to additional stops) recognized within a zone based system, the increase does not outweigh significant emissions reductions resulting from significantly lower VMTs.

Figure 1 presents air emission estimates for criteria pollutants. As detailed, a 59% reduction in CO, 51% reduction in PM_{10}, 56% reduction in $PM_{2.5}$, 62% reduction in NO_x and 54% reduction in VOCs is estimated in emission totals comparing the 2020 existing system with implementation of a zone based system (random approach).

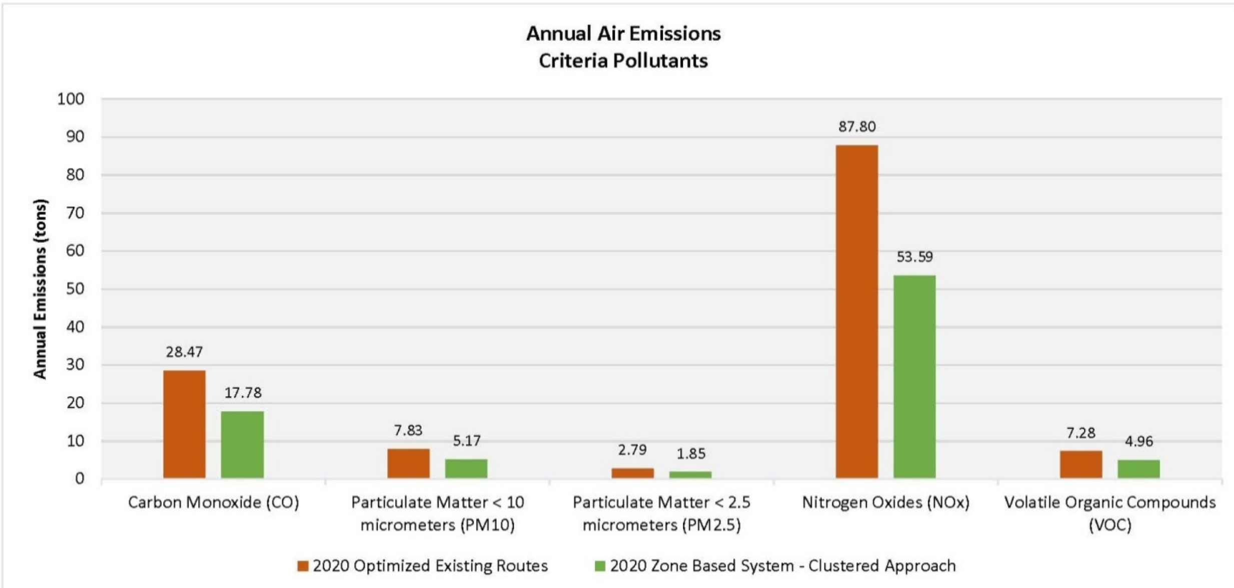
Figure 1: 2020 Existing System and 2020 Zone Based System (Random Approach) Annual Air Emissions Comparison – Criteria Pollutants



A reduction in greenhouse gases, climate forcers and other pollutants was estimated as well. A reduction of 64% in carbon dioxide equivalent (CO_2e), 70% reduction in elemental carbon and 54% reduction in total hydrocarbons is estimated when comparing 2020 existing system emissions totals with implementation of a zone based system (random approach). In addition, fuel consumption was estimated to be reduced from 5.5M gallons to 2.0M, or a 64% reduction in comparing the 2020 existing system with the implementation of a zone based system (random approach).

Figure 2 presents 2020 air emission estimates for criteria pollutants. As detailed, emission reductions of 38% in CO, 34% in PM10 and PM2.5, 39% in NOx as well as 32% reduction in VOCs is estimated in emission totals comparing the 2020 optimized existing system with implementation of a zone based system (clustered approach).

Figure 2: 2020 Optimized Existing System and 2020 Zone Based System (Clustered Approach) Annual Air Emissions Comparison – Criteria Pollutants



A reduction in greenhouse gases, climate forcers and other pollutants was estimated as well. A reduction of 42% in CO2e, 49% in elemental carbon and 32% reduction in total hydrocarbons is estimated when comparing 2020 optimized existing system emission totals with implementation of a zone based system (clustered approach). In addition, fuel consumption was estimated to be reduced from 1.6M to 0.9M gallons, or a 42% reduction in comparing the 2020 optimized existing system with the implementation of a zone based system (clustered approach).

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REGULATORY SETTING

Federal, state and city-wide regulatory measures have been adopted in order to address the dangers of air pollution. Over the past several decades, air quality has improved substantially due to compliance with implemented regulations. Relevant plans, policies, and regulations applicable to this study are discussed within.

Federal Regulations and Standards – Initial air pollutant emission regulations originated from the Federal Clean Air Act (CAA), which was passed in 1955, and formed the basis for national air pollution control. Amendments to the CAA (CAAA) were subsequently passed in 1970 and 1990. The CAA addresses air quality as a result of stationary and mobile sources. Basic elements of the CAA include establishing national ambient air quality standards (NAAQS) for commonly found air pollutants (herein referred to as criteria pollutants), hazardous air pollutants (HAPs) emission standards, state attainment plans, motor vehicle emissions standards, stationary source emission standards and permits, acid rain control measures, stratospheric ozone (O_3) protection and enforcement provisions, as well as working with industries to develop cleaner-burning fuels and more efficient engines, and finally, setting groundwork for public participation in the process.

NAAQS are divided into two tiers: primary standards define air quality levels intended to protect the public health including sensitive populations, such as asthmatics, children and the elderly, with an adequate margin of safety, and secondary standards define levels of air quality intended to protect the public welfare from any known or anticipated adverse effects of a pollutant (e.g. soiling, vegetation damage, material corrosion). The United States Environmental Protection Agency (USEPA) reviews each criteria pollutant every 5 years and determines, based on new information and research, whether revisions to the NAAQS are necessary.

USEPA amended the NAAQS in 1997 to include an 8-hour standard for O_3 (0.08 parts per million [ppm]) and adopted new NAAQS for particulate matter smaller than 2.5 micrometers ($PM_{2.5}$). NAAQS for particulate matter were amended by USEPA in September 2006 to strengthen the 24-hour $PM_{2.5}$ standard from 65 micrograms per cubic meter ($\mu g/m^3$) to 35 $\mu g/m^3$ and revoke the annual NAAQS for particulate matter smaller than 10 micrometers (PM_{10}) due to a lack of evidence linking health problems to long-term exposure to course particulate pollution. Based on new scientific studies and several health risk assessment results, USEPA revised the lead (Pb) NAAQS to provide increased protection for children and other at-risk populations against adverse health effects. The revised standard level for Pb is 0.15 $\mu g/m^3$ over rolling 3-month periods.

Additionally in 2008, USEPA strengthened the 8-hour O_3 NAAQS based on new scientific evidence regarding the negative effects of ground-level O_3 on public health and the environment. The new standard (primary and secondary) for O_3 is 0.075 ppm. In October 2015, USEPA again revised the O_3 standard to 0.070 ppm, however the previous 2008 standard remains in effect in New York. Standards set forth by the USEPA for criteria pollutants are shown in Table 1.

Table 1: National and New York Ambient Air Quality Standards

Pollutant	Averaging Period	National Primary	National Secondary
Carbon Monoxide	1 hour 8 hour	35 ppm 9 ppm	- -
Ozone	8 hour	0.075 ppm	0.075 ppm
Nitrogen Dioxide	Annual 1 hour	0.053 ppm 0.100 ppm	0.053 ppm -
Lead	Rolling 3 month Average	0.15µg/m3	0.15µg/m3
Sulfur Dioxide	3 hour 1 hour	- 75 ppb	0.5 ppm -
Inhalable Particulates (PM_{10})	24 hour	150 µg/m3	150 µg/m3
Fine Particulates ($PM_{2.5}$)	24 hour Annual	35 µg/m^3 12 µg/m^3	35 µg/m^3 15 µg/m^3
Hydrocarbons (non-methane) 6-9 AM	3-hour (6-9am)	-	-
Source: USEPA, 2016			

On December 21, 2000, the USEPA established emission standards for heavy-duty on-road model year 2007 and later engines through promulgation of the *Heavy-Duty Highway Diesel Rule (the "2007 Highway Rule")*[i]. The rule included two components; (1) emission standards and (2) diesel fuel regulations.

Emission standards for PM took full effect in 2007 which required a 0.01 gram per horsepower-hour (g/hp-hr) for new heavy-duty vehicles beginning with model year 2007. The nitrogen oxides (NO_x) and non-methane hydrocarbons (NMHC) standards of 0.20 g/hp-hr and 0.14 g/hp-hr, respectively were required to be phased-in between 2007 and 2010, on a percent-of-sales basis. Vehicle and fuel standards not only reduce these primary resultant pollutants, but secondary pollutants such as air toxics.

A regulation for diesel fuel[ii] limited sulfur content for on-road diesel fuel to a maximum of 15 ppm (ultra-low sulfur diesel), which is down from the previous 500 ppm. This regulation took effect June 1, 2006 with production and import at the refinery level. Beginning October 15, 2006, for retail stations and wholesale purchaser-consumers, highway diesel fuel sold as low sulfur was required to meet the new 15 ppm standard. After 2010, all highway diesel fuel supplied to the market and all highway diesel vehicles must use ultra-low sulfur diesel fuel (i.e. with a sulfur content of 15 ppm).

Greenhouse gases (GHG) cause heat to be trapped within the earth's atmosphere, contributing to global climate change. Other than water vapor, greenhouse gases primarily include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and O_3. Man-made sources of greenhouse gas emissions in the US are primarily caused by burning fossil fuels for electricity, heat and transportation. USEPA collects greenhouse gas emission data, tracks emission trends and identifies opportunities to reduce emissions and increase efficiency.

USEPA has not promulgated explicit guidance or methodology to conduct project-level GHG analyses. However, a draft guidance document[iii] on this topic has been developed for analyzing project level greenhouse gas emissions and considering future climate change impacts. Within this draft guidance document, a reference point of 25,000 annual metric tons of CO_2e was recommended. As suggested, projects with direct CO_2e emission levels below this reference point do not warrant a quantitative GHG analysis when considering impacts related to proposed Federal action projects in accordance with the National Environmental Policy Act (NEPA).

USEPA is working with state, local and tribal governments to reduce air emissions of 187 toxic air pollutants. Mobile sources pollute direct air toxic emissions as well as precursor emissions which react with other emissions to form secondary pollutants. As detailed within *USEPA's 40 CFR Parts 69, 80, and 86, Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicles Standard and Highway Diesel Fuel Sulfur Control Requirements, Final Rule January 18, 2001*, a by-product of heavy-duty diesel vehicle emissions includes several volatile organic compounds (VOCs) such as benzene, 1,3-butadiene, formaldehyde, acetaldehyde, acrolein, polycyclic organic matter (POM), naphthalene, and diesel particulate[iv]. USEPA regulates toxic air pollutants for all industries that emit one or more of the pollutants in significant quantities. In order to address mobile-source air toxics (MSATs), USEPA placed controls on gasoline, passenger vehicles and portable fuel containers intended to significantly reduce emissions of benzene and other mobile source air toxics[v].

New York State Regulations – The 1970 amendments to the Clean Air Act allowed USEPA to delegate responsibility to state and local governing bodies. This allows each state/local government the opportunity to prevent and control air pollution at the source. New York State Air Pollution Control Program institutes several controls such as issuance of permits and technical requirements, provides a statewide air emissions monitoring program, and a Vehicle Inspection and Maintenance Program to ensure vehicle emissions meet regulations. New York Department of Environmental Conservation (NYSDEC) is required to develop a State Implementation Plan (SIP), which demonstrates means related to how the state air pollution control programs will be implemented to reduce air emissions and gain compliance with NAAQS. In addition, New York State is legally obligated to regulate fuels under USEPA guidelines. As such, *Title 6 of the New York Codes, Rules and Regulations, Subchapter A, Part 225-4: Motor Vehicle Diesel Fuel*[vi] declares that any motor vehicle diesel fuel or fuel additives sold or supplied in New York State must conform with provisions provided within 40 CFR Part 80 Subpart I.

According to the requirements of the New York State Vehicle Inspection Program (NYVIP2), on-road diesel-powered vehicles that are model year 1996 or older and have a gross vehicle weight rating (GVWR) of more than 8,500 pounds are exempt from the State's on-board diagnostic system and low-enhanced emissions inspection. However, these vehicles registered in the New York metropolitan area are subject to an annual emission inspection under *Official Compilation of Codes, Rules and Regulations of the State of New York, Title 6, Chapter III, Subchapter A, Part 217, Subpart 217-5*[vii]. The annual emission inspection is performed during the annual NYS Department of Motor Vehicles safety inspection for the vehicle, as required by the New York State Vehicle Safety/Emissions Inspection Program. Further, any heavy-duty diesel-powered vehicle traveling on New York State roadways is subject to a roadside emission inspection[viii].

As per *6 CRR-NY 217-3.1*, heavy vehicles including diesel-powered trucks and buses, are prohibited from idling for more than five minutes at any time. Exceptions include idling during traffic congestion, maintenance purposes, powering an auxiliary function or apparatus, under emergency situations or operating a diesel fueled truck below 25 degrees Fahrenheit for more than 2 hours[ix].

The *2015 New York State Energy Plan*[x] provides strategies to reduce greenhouse gas emissions 40% of 1990 levels along with other goals through use of renewable energy. In addition, nine states, including New York, have established individual CO_2 emissions budgets that are equal and share a regionwide cap. However, statewide programs established to reduce CO_2 emissions focus on the power industry. NYSDEC Policy[xi] addresses greenhouse gas emissions related to Environmental Impact Statements (EIS) pursuant to the State Environmental Quality Review Act (SEQR).

New York City Regulations – In 2007, *PlaNYC* outlined strategies to "achieve the cleanest air quality of any big city in America" by 2030[xii]. Chapter 18 (Greenhouse Gas Emissions and Climate Change) of the New York City *CEQR Technical Manual* (2014 Edition) provides greenhouse gas emissions guidance consistent with *PlaNYC*. As stated within the CEQR guidance document, projects that 'fundamentally change the City's solid waste management system by changing solid waste transport model, distances, or disposal technologies', along with other major sources, may warrant GHG assessments. Guidance related to quantitative greenhouse gas emission assessments refer back to the NYSDEC Policy, *Assessing Energy Use and Greenhouse Gas Emissions in Environmental Impact Statements*, *dated July 15, 2009*, as well as tools such as the USEPA's Waste Reduction Model (WARM), Northeast Recycling Council Environmental Benefits Calculator and USEPA's Municipal Solid Waste Decision Support Tool, which estimate CO_2e (metric tons) reductions related to different waste management practices.

In order to address air quality concerns related to refuse and single-unit short haul trucks, New York City adopted Local *Law 145 (LL 145) of 2013*, amending the administrative code of the City of New York by adding a new section 24-163.11[xiii]. Beginning January 1, 2020, LL 145 requires all refuse trucks (> 16,000 lbs) to use best available retrofit technology (BART) or be equipped with an engine certified to the applicable 2007 USEPA standard for particulate matter set forth in *40 CFR 86.007-11*[xiv]. As defined within LL 45 and Section 24-163.11 of the New York State administrative code, BART is technology verified by the USEPA or the California Air Resources Board for reducing the emissions of pollutants that achieves reductions in particulate matter emissions at the highest classification level for diesel emission control strategies that is applicable for a particular engine and application that has been approved for use by the NYC Department of Environmental Protection (NYCDEP) commissioner.

In addition, the City promulgated a rule under *New York City Administrative Code, Title 24, Chapter 1, Subchapter 7, Section 24-163*, limiting idling to three minutes while parking, standing or stopping. In 2009, through promulgation of Local Law Number 5, the administrative code was amended to reduce the engine idling time to one minute adjacent to any school, pre-K to 12th grade, public or private.

NEW YORK CITY AIR QUALITY STATUS

Each criteria pollutant presented in Table 1 is monitored on a continuous basis throughout the State of New York by the NYSDEC. Ambient air quality data reported in Table 2 details maximum values documented amongst all available monitoring stations within the five counties of New York City.

Table 2: Representative Monitored Ambient Air Quality Data – All New York City Counties

Pollutant	Monitoring Station	Averaging Period	Concentration
Carbon Monoxide[1]	Botanical Gardens (Pfizer Lab), Bronx County	1 hour 8 hour	2.2 ppm 1.3 ppm
Ozone[2]	Susan Wagner, Richmond County	8 hour	0.073 ppm
Nitrogen Dioxide[3]	IS 52, Bronx County Botanical Gardens (Pfizer Lab), Bronx County	Annual 1 hour	.020 ppm .058 ppm
Lead	IS 52, Bronx County	3 months	.004 µg/m³
Sulfur Dioxide	Botanical Gardens (Pfizer Lab), Bronx County	1 hour	22.2 ppb
Inhalable Particulates (PM_{10})	Division Street, New York County	24 hour	60 µg/m³
Fine Particulates ($PM_{2.5}$)[4]	Botanical Gardens (Pfizer Lab), Bronx County PS 19, New York County	24 hour Annual	25.7 µg/m³ 11.2 µg/m³

Notes:

1. CO data corresponds to the 2nd highest maximum value.
2. Ozone data corresponds to the 3-year average value of the fourth highest maximum 8-hour concentration, consistent with the statistical form in the NAAQS. The 3-year average is based on the last 3 years of monitored data (i.e. 2012, 2013, 2014).
3. The monitored 1-hour value is based on a 3-year average (2012-2014) of the 98th percentile of daily maximum 1-hour average concentrations.
4. 24-hour $PM_{2.5}$ data is representative of the 98th percentile 24-hour concentration averaged over three year, consistent with the statistical form in the NAAQS. The annual $PM_{2.5}$ data is representative of the average of three consecutive annual means (i.e. 2012, 2013, 2014 based on available data), consistent with the statistical form in the NAAQS.

Source: NYSDEC, New York Ambient Air Quality Report (2014).

An area which does not meet a standard is referred to as a nonattainment area. All New York City counties are in O_3 nonattainment. Ground-level O_3 is created when NO_x and volatile organic compounds (VOC) react in the presence of sunlight and heat. In addition, New York County (Manhattan) is in PM_{10} nonattainment. The USEPA re-designated all New York City counties from nonattainment to maintenance for CO and $PM_{2.5}$, and they are subject to a strict maintenance plan to ensure continued attainment[xv].

Major objectives of monitoring air quality are to provide an early warning system for pollutant concentrations, assess air quality in light of public health and welfare standards, as well as track trends or changes in these pollutant levels. NYSDEC monitored data is available in an annual report entitled *New York State Ambient Air Quality Report*.

ASSESSED AIR EMISSIONS

Emissions related to a number of air pollutants were chosen to be assessed and grouped into two main categories: a) Criteria Pollutants and b) Tracked Greenhouse Gases/Climate Forcers/Other Pollutants. Table 3 presents the air pollutants chosen for the study, organized by category. The rationale for selection of these pollutants is included within. In addition, fossil fuel consumption, in gallons, was quantified for 2016 existing and future 2020 scenarios.

Table 3: Assessed Pollutants

Criteria Pollutants	Particulate Matter < 10 micrometers (PM_{10})
	Ozone (Volatile Organic Compounds (VOC) + Nitrogen Oxides (NO_x))
	Carbon Monoxide (CO)
	Particulate Matter < 2.5 micrometers ($PM_{2.5}$)
Tracked Greenhouse Gases/Climate Forcers/Other Pollutants	Carbon Dioxide Equivalent (CO_2e) [Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O)]
	Elemental Carbon (EC)
	Total Gaseous Hydrocarbons (THC)

Criteria Pollutants – Emissions related to criteria pollutants were assessed, as they represent pollutants for which the USEPA has developed NAAQS, as required by the CAAA. The assessment focused on New York City nonattainment and maintenance criteria pollutants. Specifically, only New York County is in non-attainment for PM_{10}. All five New York City counties are in O_3 non-attainment; therefore both PM_{10} and O_3 emissions were estimated. While ozone cannot be modeled directly, VOCs and NO_x emissions were estimated, as these pollutants are precursors to the formation of ground level ozone (i.e. VOCs and NO_x react chemically in the atmosphere in presence of sunlight to form ground level ozone). In addition, CO and $PM_{2.5}$ are in maintenance within all New York City counties and was therefore additionally estimated.

Tracked greenhouse gases/Climate forcers/Other Pollutants – Tracked greenhouse gases are those which trap heat in the atmosphere by absorbing energy and slowing the rate at which that energy escapes into space, thereby leading to global warming. While there are several greenhouse gases, those which are byproducts of fossil fuel combustion were selected, as they would be most pertinent to a mobile emissions analysis.

Three primary tracked greenhouses gases that result from fossil fuel combustion include CO_2, CH_4 and N_2O. According to the USEPA, each one of these gases has a different effect on the earth's atmosphere because they absorb energy differently and have differing lifetimes (i.e. some stay in the atmosphere longer than others). In order to compare global warming impacts of different gases and quantify total greenhouse gas emissions, a factor called

Global Warming Potential (GWP) was created. The GWP is a measure of how much energy the emissions of one ton of a gas will absorb over a given period of time, relative to the emissions of one ton of CO_2. By definition, CO_2 has a GWP of 1 because it is the reference gas. Multiplying each pollutant by its GWP factor yields the CO_2 equivalent. The USEPA's most updated motor vehicle emission simulator (MOVES2014a) utilizes CO_2 equivalence factors (i.e. GWP values) of 1, 21 and 310 for CO_2, CH_4, and N_2O, respectively, and provides the total CO_2 equivalent (CO_2e) of these gases based on provided factors[xvi].

According to the USEPA, 'climate forcing' is an indicator that measures the heating effect caused by greenhouse gases in the atmosphere. Elemental Carbon, formed by the incomplete combustion of fossil fuels, absorbs both incoming and outgoing radiation, thereby contributing to warming of the atmosphere. Climate scientists believe that elemental carbon plays a significant role in 'climate forcing'[xvii]. According to the USEPA's *Report to Congress on Black Carbon, Department of the Interior, Environment, and Related Agencies Appropriations Act, 2010, March 2012,* elemental carbon has a short atmospheric lifetime, and therefore, reductions in elemental carbon emissions can be expected to provide more immediate climate benefits.

In addition to the primary tracked greenhouse gases, total gaseous hydrocarbon emissions were quantified. Hydrocarbon is an organic compound comprised of hydrogen and carbon atoms. Hydrocarbons are found in crude oil and typically included with SIPs addressing areas of ozone nonattainment, such as the five counties of New York City.

ASSESSMENT METHODOLOGY

In order to estimate carting fleet emissions, the assessment was based on the following major components in order to compare emissions related to the existing carting system with a potential zone based system (random and clustered approaches) for recyclable and putrescible waste. Air emissions directly related to refuse trucks were quantified for existing 2016 and future 2020 scenarios with, and without a zone based system.

Fleet Characteristics – The New York City Business Integrity Commission (BIC) provided a Vehicle Identification Number (VIN) database which included active vehicles listed by carter. Starting in 1981, VINs were standardized into a 17-character series of letters and numbers. By decoding each VIN[xviii], key information was obtained for 98.6% of VINs provided such as engine year, fuel type, manufacturer, make and model. Passenger vehicles, small trucks and vans, and potential managerial or utility vehicles were assumed not to be utilized for carting activities and were removed from the fleet analysis.

The truck fleet consists of vehicles manufactured by Autocar, Crane Carrier Co., Ford, GMC, Hino, International, Isuzu, Kenworth, Mack, Mitsubishi Fuso, Nissan, Peterbilt, Sterling, Volvo, Western Star and WhiteGMC. The overwhelming fuel type of the fleet was determined to be diesel.

The VIN database details that 60% of the current carting fleet are between 7 and 17 years old. Engine year obtained from the VIN database identifies the engine emission standard. Engine model years 2006 and older are not subject to the emissions standards set forth within the aforementioned USEPA's "2007 Highway Rule," as those standards are applicable to engine model years 2007 and newer. Currently, there are no federal regulations requiring retrofits of engine model year 2006 or older for refuse trucks, and NYC LL 145 is not effective until January 1, 2020. Further, since VIN data does not provide any retrofit information, the existing 2016 analysis assumes that no aftermarket strategy or retrofit has been installed on any vehicle within the fleet.

Based on the VIN database, 38% of the fleet's engines currently meet the "2007 Highway Rule" and approximately 22% meet the NO_X and NMHC standard. Assuming no changes to the fleet occur over the next four years, approximately 62% of the fleet will be required to meet NYC Local Law 145 of 2013. Both analyses performed for 2020 assumed full compliance with NYC LL 145 of 2013.

As aforementioned, the law requires model year 2006 and older vehicles to either install BART or replace older model engines with model year 2007 or newer. Since engine replacement would reduce emissions from multiple other pollutants, including NOx, the analysis conservatively assumed that all carters with model year 2006 engines or older would install BART, such as a diesel particulate filter (DPFs), in lieu of replacing engines. Diesel particulate filters provide, at a minimum, an 85% reduction in particulate matter, as well as reductions in hydrocarbons and carbon monoxide. Although there are currently no DPFs on USEPA's or CARB's list of verified technologies for model years older than 1990, the analysis assumed that by the effective date of LL 145 (i.e. January 1, 2020), DPFs fitting these older model years will be added to the list of verified technologies.

Emission Factors – The USEPA's most updated motor vehicle emission simulator, MOVES2014a[xix], was utilized to estimate existing 2016 and future 2020 emission rates in units of grams-per-vehicle-mile (g/veh-mi). Modeling assumed two specified vehicle types (refuse trucks and single unit short haul trucks) over a custom domain area which covered the five New York City counties (Bronx, New York, Queens, Kings, and Richmond). Temperature profiles for all five counties were averaged over this custom domain. New York fuel supply and fuel formulations[1] data was provided by New York State Department of Environmental

[1] Year 2017 MOVES2014a input files supplied by NYSDEC include a diesel fuel formulation with a sulfur content of 11 ppm. The fuel supply input includes a market share value of 1, thereby indicating fuel with this sulfur content is supplied to and sold within New York City. According to NYSDEC, a sulfur content of 11 ppm is a default value representative of the average sulfur content of diesel fuel meeting the 15 ppm standard, as fuels meeting this standard are produced with a compliance margin to account for differences in testing and contamination downstream. A sulfur content value of 11 ppm is consistently utilized by NYSDEC in MOVES modeling.

Conservation (NYSDEC). A project-specific vehicular age distribution was developed from the decoded VIN database provide by NYCBIC.

A large database of emission factors was developed for each of the sixteen (16) speed bins, weekdays and weekends, for all months of the year. Emission factors were, in some cases, a product of several emission processes. The analysis evaluated emissions associated with refuse and single-unit short haul trucks under operating conditions, without assessing start, evaporative, refueling, extended idle, well-to-pump or auxiliary power exhaust. Table 4 provides the emission processes evaluated based on each pollutant.

Table 4: Pollutants Processes Assessed

Running + Crankcase Exhaust	Carbon Monoxide (CO), Elemental Carbon (EC), Methane (CH_4), Nitrogen Oxides (NO_x), and Volatile Organic Compounds (VOC)
Running Exhaust	Carbon Dioxide (CO_2), Nitrous Oxide (N_2O), Total Gaseous Hydrocarbons (THC), and Fuel
Running + Crankcase+ Brakewear+ Tirewear Exhaust	Particulate Matter < 10 micrometers (PM_{10}) and Particulate Matter < 2.5 micrometers ($PM_{2.5}$)

Existing route data provided by individual carters were utilized by traffic engineers to identify 2016 current system VMTs. Due to the number of accounts related to each route, emission factors associated with refuse trucks traveling on urban unrestricted roadways were utilized for this study. Conservatively, the highest emission rate within operating hours (10:00 PM to 6:00 AM) was utilized for this vehicle type.

Fuel consumption is reported by MOVES2014a in terms of energy use (units of kilojoules [KJ]). Utilizing Table 6-1 of the USEPA's *Greenhouse Gas and Energy Consumption rates for On-Road Vehicles: Updates for MOVES2014*, EPA-420-R-15-003, *October 2015* document, fuel consumption output data was converted to volume of fuel consumption in units of gallons per year. The calculation accounts for the fuel density (grams/gallon) of the fuel type (conventional diesel fuel) and the energy content of that fuel type (KJ/grams).

VMT Factors – Project vehicle-miles-traveled (VMT) were obtained by Sam Schwartz Engineering (SSE) for a Wednesday in September. Based on factors provided by SSE, VMTs were adjusted for each day of the week.

Table 5: Daily VMT Factors

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0.772	1.021	1.000	1.033	1.053	0.747	0.198

Speeds – Traffic engineers provided speed data based on GIS modeling. Thirty-four (34) seconds per account for service (based on DSNY assumption) was added to the travel time provided by GIS. Overall travel time was divided by the route distance to yield travel speed over the entire route. The speed data was assumed to represent the average speed over the entire route. Therefore, excess emissions due to idling or acceleration has not been included within this study.

2016 ASSESSMENT RESULTS

Pollutant emissions were estimated utilizing MOVES2014a 2016 emission factors for this project-specific fleet. The highest emission factor during operating hours applied for the specific estimated speed for each route was multiplied by daily VMT and estimated per carter. Emission estimates for all carters were summed to provide 2016 yearly emissions in tons per year.

Table 6 details 2016 emission totals for each studied pollutant related to the existing carting system. Based on the analysis, it is estimated that approximately 5.5M gallons of diesel fuel is consumed by the existing carting system on a yearly bases. Table 7 details 2016 emission totals for each studied pollutants related to the optimized existing carting system. Based on the analysis, it is estimated that approximately 1.6M gallons of diesel fuel would be consumed by the optimized existing carting system on a yearly bases.

Table 6: 2016 Existing System Annual Emissions

<table>
<tr><th colspan="3" rowspan="2">Pollutants</th><th>2016 Annual Emissions</th></tr>
<tr><th>Total (tons)</th></tr>
<tr><td rowspan="5">Criteria Pollutants</td><td colspan="2">Carbon Monoxide (CO)</td><td>95.3</td></tr>
<tr><td colspan="2">Particulate Matter < 10 micrometers (PM_{10})</td><td>34.8</td></tr>
<tr><td colspan="2">Particulate Matter < 2.5 micrometers ($PM_{2.5}$)</td><td>20.0</td></tr>
<tr><td rowspan="2">Ozone</td><td>Nitrogen Oxides (NO_x)</td><td>301.7</td></tr>
<tr><td>Volatile Organic Compounds (VOC)</td><td>21.9</td></tr>
<tr><td rowspan="3">Greenhouse Gases/Climate Forcers/Other Pollutants</td><td colspan="2">Carbon Dioxide Equivalent (CO_2e) (metric tons)</td><td>56,327</td></tr>
<tr><td colspan="2">Elemental Carbon (EC)</td><td>9.7</td></tr>
<tr><td colspan="2">Total Hydrocarbons (THC)</td><td>20.4</td></tr>
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Table 7: 2016 Optimized Existing System Annual Emissions

Pollutants			2016 Annual Emissions Total (tons)
Criteria Pollutants	Carbon Monoxide (CO)		**30.7**
	Particulate Matter < 10 micrometers (PM_{10})		**11.7**
	Particulate Matter < 2.5 micrometers ($PM_{2.5}$)		**6.3**
	Ozone	Nitrogen Oxides (NO_x)	**93.6**
		Volatile Organic Compounds (VOC)	**7.9**
Greenhouse Gases/Climate Forcers/Other Pollutants	Carbon Dioxide Equivalent (CO_2e) (metric tons)		**16,634**
	Elemental Carbon (EC)		**2.5**
	Total Hydrocarbons (THC)		**7.4**

2020 ASSESSMENT RESULTS

Pollutant emissions were estimated utilizing MOVES2014a 2020 emission factors for the project-specific fleet, assuming 100% compliance with NYC LL145. Current fleet characteristics (engine year, fuel type, manufacturer, make and model) provided by BIC were utilized for 2020 MOVES2014a inputs. As detailed within, assuming no changes to the fleet between 2016 and 2020, approximately 62% of the fleet will be required to meet NYC LL 145. Other than full compliance with NYC LL145, no other aftermarket strategy, retrofit technology or fleet turnover has been assumed for the 2020 analysis.

Four analyses were performed; 2020 emissions based on the existing carting system and optimized existing carting system (VMTs and speeds) as well as zone based systems; random and clustered approaches (VMTs and speeds).

2020 Existing System Emissions – Assuming no changes to the existing carting system collection routes (VMT, daily VMT factors or vehicular speeds) except full compliance of LL145 of the existing fleet, 2020 existing system emissions were estimated. A similar methodology as evaluated for the 2016 analysis was employed, including utilizing the highest refuse truck 2020 emission factor during operating hours applied for the specific estimated speed for each route. Emission estimates per carter were evaluated and summed to provide total 2020 yearly emissions in tons per year. Table 8 provides annual emission estimates for criteria pollutants, greenhouse gas, climate forcers, and other pollutants chosen for the analysis. In addition, it is estimated that approximately 5.5M gallons of diesel fuel would be consumed in 2020 with the existing carting system.

Table 8: 2020 Existing System Annual Emissions

Pollutants			2020 Annual Emissions Total (tons)
Criteria Pollutants	Carbon Monoxide (CO)		**88.4**
	Particulate Matter < 10 micrometers (PM_{10})		**21.8**
	Particulate Matter < 2.5 micrometers ($PM_{2.5}$)		**8.0**
	Ozone	Nitrogen Oxides (NO_x)	**282.5**
		Volatile Organic Compounds (VOC)	**20.1**
Greenhouse Gases/Climate Forcers/Other Pollutants	Carbon Dioxide Equivalent (CO_2e) (metric tons)		**56,298**
	Elemental Carbon (EC)		**1.4**
	Total Hydrocarbons (THC)		**19.1**

2020 Optimized Existing System Emissions – Traffic engineers evaluated an optimized existing conditions scenario, where the stops in a route are reordered to generate the lowest possible VMT, while other considerations of developing a route are ignored. Specific information pertaining to the optimized conditions scenario is presented within the *Private Carting VMT Analysis, performed by Sam Schwartz Engineering, D.P.C., dated June 2, 2016.*

This analysis also was performed based on utilizing the highest refuse truck 2020 emission factors during operating hours applied for the specific estimated speed for each route. Emission estimates per carter were evaluated and summed to provide total 2020 yearly emissions in tons per year. Table 9 provides annual emission estimates for criteria pollutants, greenhouse gas, climate forcers, and other pollutants chosen for the analysis. In addition, it is estimated that approximately 1.6M gallons of diesel fuel would be consumed in 2020 with the optimized existing carting system.

Table 9: 2020 Optimized Existing System Annual Emissions

<table>
<tr><th colspan="3" rowspan="2">Pollutants</th><th>2020 Annual Emissions</th></tr>
<tr><th>Total (tons)</th></tr>
<tr><td rowspan="5">Criteria Pollutants</td><td colspan="2">Carbon Monoxide (CO)</td><td>28.5</td></tr>
<tr><td colspan="2">Particulate Matter < 10 micrometers (PM_{10})</td><td>7.8</td></tr>
<tr><td colspan="2">Particulate Matter < 2.5 micrometers ($PM_{2.5}$)</td><td>2.8</td></tr>
<tr><td rowspan="2">Ozone</td><td>Nitrogen Oxides (NO_x)</td><td>87.8</td></tr>
<tr><td>Volatile Organic Compounds (VOC)</td><td>7.3</td></tr>
<tr><td rowspan="3">Greenhouse Gases/Climate Forcers/Other Pollutants</td><td colspan="2">Carbon Dioxide Equivalent (CO_2e) (metric tons)</td><td>16,627</td></tr>
<tr><td colspan="2">Elemental Carbon (EC)</td><td>0.4</td></tr>
<tr><td colspan="2">Total Hydrocarbons (THC)</td><td>6.9</td></tr>
</table>

2020 Zone Based System Emissions (Random Approach) – As described within the traffic analysis report, all routes were separated into eleven (11) zones. VMTs and associated speeds were provided for a typical Wednesday. Factors, detailed in Table 5, were applied to achieve daily VMTs to account for the other days of the week. VMTs and speeds associated with a zone based system (random approach) were utilized to estimate 2020 emissions. Conservatively, the highest MOVES2014a refuse truck emission factors during operating hours related to the estimated speed for each route within a zone was multiplied by daily VMT estimates. Emission estimates for all zones were summed to provide 2020 yearly emissions in tons per year. Table 10 provides emission estimates for criteria pollutants, greenhouse gas, climate forcers, and other pollutants chosen for the assessment. In addition, it is estimated that approximately 2.0M gallons of diesel fuel would be consumed in 2020 with implementation of the zone based system (random approach).

Table 10: 2020 Carting Emission Based on Zoned System (Random Approach)

Pollutants			2020 Annual Emissions Zone Based System (Random Approach) Total (tons)
Criteria Pollutants	CO		**36.0**
	PM10		**10.8**
	PM2.5		**3.6**
	Ozone	NO_x	**107.8**
		VOC	**9.3**
Greenhouse Gases/Climate Forcers/Other Pollutants	CO_2e		**20,374**
	EC		**0.4**
	THC		**8.8**

2020 Zone Based System Emissions (Clustered Approach) – As described within the traffic analysis report, all routes were separated into eleven (11) zones. VMTs and associated speeds were provided for a typical Wednesday. Factors, detailed in Table 5, were applied to achieve daily VMTs to account for the other days of the week. Conservatively, the highest MOVES2014a refuse truck emission factors during operating hours related to the estimated speed for each route within a zone was multiplied by daily VMT estimates.

Emission estimates for all zones were summed to provide 2020 yearly emissions in tons per year assuming the zone based system (clustered approach). Table 11 provides emission estimates for criteria pollutants, greenhouse gas, climate forcers, and other pollutants chosen for the assessment. In addition, it is estimated that approximately 0.9M gallons of diesel fuel would be consumed in 2020 with implementation of the zone based system (clustered approach).

Table 11: 2020 Carting Emission Based on Zoned System (Clustered Approach)

Pollutants			2020 Annual Emissions Zone Based System (Random Approach) Total (tons)
Criteria Pollutants	CO		**17.8**
	PM_{10}		**5.2**
	$PM_{2.5}$		**1.9**
	Ozone	NO_x	**53.6**
		VOC	**5.0**
Greenhouse Gases/Climate Forcers/Other Pollutants	CO_2e		**9,661**
	EC		**0.2**
	THC		**4.7**

SUMMARY

Based on the analysis detailed within this technical memorandum, emission reductions were determined with implementation of either of the two analyzed zone based systems (random or clustered approach). Using USEPA's most updated motor vehicle emission simulator (MOVES2014a) and VMT values for each scenario, significant air emission reductions have been estimated. In comparing the 2020 existing system with the 2020 zone based system (randomized approach), emission reduction estimates ranged from 51 to 70%. Emission reduction estimates ranged from 32 to 49% in comparing the 2020 optimized existing system with the 2020 zone based system (optimized approach). Emission reductions comparing the 2020 existing system with the 2020 zone based system (random approach) and the 2020 optimized existing system to the 2020 zone based system (clustered approach) is presented within Table 12.

Table 12: Zone Based System Estimated Emission Reductions

Pollutants			% Reduction 2020 Existing System to 2020 Zone Based System (Random Approach)	% Reduction 2020 Optimized Existing System to Zone Based System (Clustered Approach)
Criteria Pollutants	CO		**59.3%**	**37.6%**
	PM_{10}		**50.8%**	**34.0%**
	PM2.5		**55.5%**	**33.6%**
	Ozone	NO_x	**61.8%**	**39.0%**
		VOC	**53.9%**	**31.8%**
Greenhouse Gases/Climate Forcers/Other Pollutants	CO_2e		**63.8%**	**41.9%**
	EC		**69.6%**	**49.3%**
	THC		**53.8%**	**31.9%**

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[i] USEPA Final Rule publication in the US Federal Register on January 18, 2001
[ii] 40 CFR Part 80 Subpart I
[iii] *White House Council on Environmental Quality* (CEQ) *Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions, February 18, 2010*
[iv] *USEPA Health Assessment Document for Diesel Engine Exhaust EPA/600/8-90/057F, May 2002*
[v] *EPA-HQ-2005-0036*
[vi] *NYCRR Part 225-4*
[vii] *6 CRR-NY Subpart 217-5*
[viii] *6 CRR-NY Subpart 217-5*
[ix] *6 CRR-NY 217-3.3*
[x] *2015 New York State Energy Plan, New York State Energy Planning Board, June 25, 2015*
[xi] *Assessing Energy Use and Greenhouse Gas Emissions in Environmental Impact Statements, July 15, 2009*
[xii] *PlaNYC A Greener, Greater New York, Mayor's Office of Sustainability and Resiliency and Recovery*
[xiii] *Title 24, Chapter 1, Subchapter 7, Section 24- 163.11*
[xiv] *Emission Standards and Supplemental Requirements for 2007 and Later Model Year Diesel Heavy-Duty Engines and Vehicles*
[xv] *New York State Implementation Plan, New York Metropolitan Area Carbon Monoxide Limited Maintenance Plan For 2012 – 2022, dated December 2012 and Redesignation Request and Maintenance Plan For the 1997 Annual and 2006 24-Hour PM2.5 NAAQS: New York-Northern New Jersey-Long Island, NY-NJ-CT Nonattainment Area, February 2013*
[xvi] *Using MOVES for Estimating State and Local Inventories of On-Road Greenhouse Gas Emissions and Energy Consumption, USEPA Transportation and Climate Division, Office of Transportation and Air Quality, EPA-420-B-12-068, November 2012*
[xvii] *Spatial and Temporal Trends in PM2.5 Organic and Elemental Carbon across the United States, Advances in Meteorology, Volume 2013, Article ID 367674*
[xviii] TrustVin.com
[xix] USEPA, MOVES2014a, Motor Vehicle Emission Simulator, EPA-420-B-15-095, November 2015