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A Study of the Feasibility of Pneumatic Transport of Municipal Solid Waste and Recyclables in Manhattan Using Existing Transportation Infrastructure

Final Report

July 2013

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New York State Department of Transportation

University Transportation Research Center - Region 2

Final Report

A Study Of The Feasibility Of Pneumatic Transport Of Municipal Solid Waste And Recyclables In Manhattan Using Existing Transportation Infrastructure

Performing Organization: University Transportation Research Center (UTRC), CCNY/CUNY

July 2013

Sponsors:
New York State Energy Research and Development Authority (NYSERDA)
New York State Department of Transportation (NYSDOT)

University Transportation Research Center - Region 2

The Region 2 University Transportation Research Center (UTRC) is one of ten original University Transportation Centers established in 1987 by the U.S. Congress. These Centers were established with the recognition that transportation plays a key role in the nation's economy and the quality of life of its citizens. University faculty members provide a critical link in resolving our national and regional transportation problems while training the professionals who address our transportation systems and their customers on a daily basis.

The UTRC was established in order to support research, education and the transfer of technology in the field of transportation. The theme of the Center is "Planning and Managing Regional Transportation Systems in a Changing World." Presently, under the direction of Dr. Camille Kamga, the UTRC represents USDOT Region II, including New York, New Jersey, Puerto Rico and the U.S. Virgin Islands. Functioning as a consortium of twelve major Universities throughout the region, UTRC is located at the CUNY Institute for Transportation Systems at The City College of New York, the lead institution of the consortium. The Center, through its consortium, an Agency-Industry Council and its Director and Staff, supports research, education, and technology transfer under its theme. UTRC's three main goals are:

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A STUDY OF THE FEASIBILITY OF PNEUMATIC TRANSPORT OF MUNICIPAL SOLID WASTE AND RECYCLABLES IN MANHATTAN USING EXISTING TRANSPORTATION INFRASTRUCTURE

Final Report

Prepared for

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16. Abstract

This study explored possibilities for using existing transportation infrastructure for the cost-effective installation of pneumatic waste-collection technology in Manhattan. If shown to be economically and operationally feasible, reducing the number of trucks used on the island's densely encumbered streets could offer significant environmental, public-health, and quality-of-life benefits. Two cases were considered: 1) installing a pneumatic pipeline under the High Line Park (a retrofitted former elevated railroad) to collect waste from the Chelsea Market retail/office/hotel complex along with waste from the Park and adjacent buildings; and 2) installing pipelines in the space being excavated below Second Avenue for the construction of the Second Avenue Subway, in order to collect waste from residential, commercial, and hospital buildings, and from litter bins along a stretch of Second Avenue and in the subway station beneath it. Both design concepts were determined to be physically and operationally feasible and to offer significant quality-of-life benefits. Relative to conventional manual collection, the pneumatic systems would reduce energy use by 60% and greenhouse gas emissions by more than half. Direct operating costs for the proposed pneumatic installations, including the container dray from the pneumatic terminal to the transfer station, would be 30% less than those for conventional manual/truck collection in the two cases. But due to high initial capital costs, overall costs, including debt service, would be 55% higher in the High Line case and 30% higher in the Second Avenue Subway case. On a Net Present Value (NPV) basis, the cost of the pneumatic systems would be between 3.3 and 6.6 times greater than for conventional collection (for the Second Avenue Subway and High Line respectively). NPV costs would be equalized, however, if there were externality benefits on the order of $300,000 to $400,000 per year (respectively), using conservative assumptions. Given the space savings and other public-health and quality-of-life benefits associated with pneumatic systems--and the monetized value of decreased carbon emissions and energy use--externality benefits of this order of magnitude would appear to be likely.

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ABSTRACT

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The University Transportation Research Center, Region 2, gratefully acknowledge sponsorship of this project by the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Transportation (NYSDOT), under the direction of Joseph Tario of NYSERDA and Robert Ancar NYSDOT. The research team also acknowledges the very significant engineering support made to this study by Envac, A.B., the current corporate form of the Swedish firm that installed the world's first pneumatic waste collection system (still in operation today) at a hospital in Solleftea, Sweden in 1961, as well as the systems still in operation on Roosevelt Island, New York City (1975) and in Jersey City, New Jersey (1972), and which has since developed hundreds of other systems throughout Europe, Asia, and North America. We would particularly like to recognize the technical contribution made by Albert Mateu, P.E., former Envac sales vice-president for the Americas and South Europe. We acknowledge with appreciation the support provided this project by Robert E. Paaswell, Ph.D., Dist. M. ASCE, Distinguished Professor of Civil Engineering, Director, CUNY Institute for Urban Systems, and Director Emeritus of the University Transportation Research Center. We also acknowledge with appreciation the insightful review comments offered by Tammy Gamerman of the Citizens Budget Commission and Amy Marpman and Richard Fuller of Great Forest.

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EXECUTIVE SUMMARY

This study considered the physical and operational feasibility of retrofitting existing linear transportation infrastructure in densely populated areas with pneumatic tubes for the collection of multiple municipal solid waste (MSW)[1] fractions from a variety of public and private sources. The environmental and economic costs of these proposed systems were compared to those of conventional curbside collection by rear-loading compactor trucks or in containers loaded on to roll-on/roll-off ("RO-RO") trucks.[2] The two cases considered were an installation under the former railroad viaduct that forms the present High Line Park, which would also collect waste from the Chelsea Market complex through which the former rail line/current park runs, and an installation in a section of the Second Avenue Subway, which would also collect waste from the buildings and pedestrian litter bins lining a seven-block stretch on either side of Second Avenue.

The study found that both hypothetical installations would be physically and operationally practicable. In addition to the important benefit of significant reductions in heavy-duty truck miles travelled (nearly 25,000 miles a year in the Second Avenue Subway case, nearly 30,000 a year for the High Line facility), the pneumatic systems would offer a range of public- and worker-safety benefits (including reductions in fine-grained diesel-particulate emissions [PM10 and PM2.5], noise, and accidents), aesthetic and quality-of-life benefits (including increased reliability and service levels, reductions in odor, visual nuisances, and animal and insect pests), as well as potentially significant savings for waste-generators/building owners from reduced labor requirements and the recovery of space that would have been used for waste-storage or -staging in a conventional collection system. The pneumatic systems would also reduce energy use and greenhouse gas (GHG) emissions. In both cases, energy use would be about 60% less and GHG emissions would be cut by more than half.

As previous researchers have also reported, this study found that the relatively modest reductions in operating costs that may be associated with pneumatic collection are more than offset by significantly higher initial capital costs, producing Net Present Value costs between 3 and 7 times higher than those of conventional collection--*when only direct costs are compared*. However, when the potentially monetizable space savings, building-labor savings, and overall waste-management-system savings are included in the equation (such as those associated with reduced long-distance transport and disposal requirements, due to the use of the unit-pricing capability provided by pneumatic installations), the cost differential may be outweighed by the savings, as previous studies (summarized in Kogler, 2007)[3] have also found. In the case of these two proposed New York City installations, annual externality benefits on the order of $300,000 to $400,000 would make the overall costs of pneumatic collection comparable to those of conventional collection (for the Second Avenue Subway and High Line installations, respectively). In the case of the High Line installation, savings by building and park management in space, labor, and equipment would be just under $250,000/year. In the case of the Second Avenue Subway, these building-space, -labor, and -equipment savings could be as high as $4.9 million a year. With other forms of potentially achievable savings that might also be added to the equation, it would appear likely that the overall system costs of pneumatic collection could be less than those of conventional collection, while providing a range of environmental and quality-of-life benefits that are unobtainable with manual/truck-based systems.

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[1] "Garbage" is used here interchangeably with "municipal solid waste" (or MSW), the technical term. "Discarded materials" would be a better term than either, since it better suggests the multiplicity of waste fractions that are considered in this report. These include various recyclable and compostable materials as well as materials which it is only practicable under present circumstances to process for energy recovery or to landfill.

[2] The manual loading of rear-loading compactor trucks, or the manual handling of waste that is loaded into containers for removal by RO-RO trucks, is referred to throughout this report as "conventional" or "manual" collection.

[3] Thomas Kogler, "Waste Collection," 2007, p. 61, http://www.iswa.org/uploads/tx_iswaknowledgebase/ctt_2007_2.pdf, accessed 12-27-12.

Section 1

INTRODUCTION

THE PROBLEM

Manhattan is the most densely populated section of the most densely populated city in North America. Space is at a premium throughout the island; space for surface transport on its congested streets is in particularly short supply. Although relatively few in number compared to other types of vehicles on its streets, the thousands of garbage trucks that rumble through the city generate significant quantities of greenhouse gases, diesel particulates, noise, and other harmful emissions, cause accidents, and increase congestion--particularly as they idle in traffic lanes at each collection stop, running their power take-offs to pack in more waste with their compaction blades. Garbage collection thus represents a significant environmental--and economic--problem.

Unfortunately, this problem cannot be solved simply by eliminating its ultimate cause, garbage, since these materials are as inevitable a by-product of human civilization as are the other kinds of solid and liquid wastes that people produce.[4] And our technologies for removing waste and recyclables from the households, businesses, institutions, streets, parks, and subway stations where these discards are produced have seen scant improvement in the past century or so. Apart from one community in the middle of New York's East River (on Roosevelt Island), where less than two thousandths of a percent of the City's population live, New Yorkers have relied on early-20th-century technology that combines human brute strength[5] with that of heavy-duty trucks.

While our other solid and liquid wastes have long since been conveyed from our homes and places of business by sewer tubes (just as our water and gas and oil supplies have long been brought into the city by pipelines), our garbage has inertly remained in malodorous and unsightly heaps on our streets and sidewalks until, through the agency of human hands (and arms and legs and aching backs) it is slung into the rear-ends of trucks.[6] Yet in the last half-century other cities--and little Roosevelt Island in New York's East River--have used automated vacuum (AVAC) technology to collect and transport garbage via pneumatic tubes. Most of these installations--as in the case of the system that has operated on Roosevelt Island since it became a residential settlement in 1975--have been in new, greenfield developments. But it is also possible, as any number of venerable cities have demonstrated (Barcelona, Sevilla, and Paris among them), to retrofit existing neighborhoods with pneumatic installations.

The experience of these ancient cities demonstrates that it is practicable to tunnel by cut-and-covering or drilling or pipe-jacking through such difficult subterranean conditions as Roman graveyards. Indeed, if cost were no object, pneumatic waste-removal systems could be installed almost anywhere. But since cost generally *is* a concern, the question arises of how pneumatic installations might be retrofitted into existing urban centers most cost-effectively. Clearly a linear tube-system must have a linear right-of-way. In existing developments (or even in most planned ones), the most obvious option—since all transportation functions also require linear right-of-ways—would be to use the space below our most basic transportation infrastructures: our streets and sidewalks (just as our other utility systems do). But what if, in addition to

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[4] The *volume* of MSW can indeed be somewhat reduced, as studies of unitized waste-removal costs have demonstrated. And it is theoretically possible to recycle or compost most of the waste stream that remains after source-reduction measures have been used. But these materials still need to be collected for processing.

[5] It is for good reason that New York City's uniformed sanitation workers are proudly known as "New York's Strongest."

[6] One of this report's co-authors, in the course of writing this (on the morning of January 5, 2013), had to remove a chest-high wall of clear-bagged recyclables erected against the side of his car in order to get inside it. Since he had been among those responsible for the City's decision to collect recyclables in plastic bags in the first place, he blames himself.

piggybacking on their existing linearity, we were also able to avoid the expense of tunneling by taking advantage of available space in existing transportation infrastructure, such as the unused space within the vault of a subway tunnel, or the micro-air-rights in the no-man's land beneath elevated rail tracks?

Examining these possibilities was the object of the current study. We sought to determine whether, in the heavily-built-up city arguably in greatest need of advanced waste-collection technology, it would be feasible to reduce the number of garbage trucks by using existing transportation infrastructure to install pneumatic systems as cost-effectively as possible.

We tested this premise in two specific Manhattan locations:

- The High Line (HL), a 21st-century park created on a retrofitted elevated railroad viaduct built in the early 20th century using 19th-century technology, which runs directly through the second and third floors of a block-long complex, the Chelsea Market. Once the factory where Oreo cookies were first baked, the Chelsea Market--with its food-market complex on the ground floor of an office building that is being expanded to include a hotel and more office space--(like the High Line) has become one of the city's most popular tourist attractions. We considered waste generated within the Chelsea Market complex as well as waste produced by visitors to the High Line.

- The Second Avenue Subway (SAS), a line now moving toward completion nearly one hundred years after its construction first began in the early 20th century. At the request of the Metropolitan Transportation Authority (MTA), we considered the section of Second Avenue between 92nd and 99th Streets, and looked at residential, commercial, hospital, and litter-bin waste generated above ground, as well as waste that will be generated in the subway station now under construction below 96th Street.

BACKGROUND

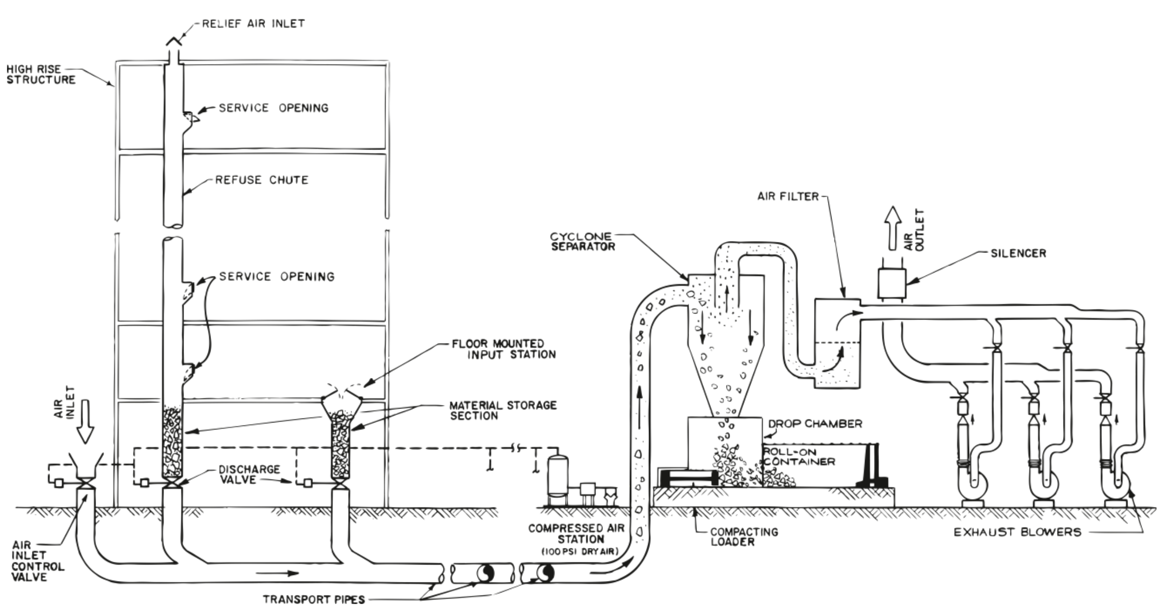
Pneumatic Tube Overview

Pneumatic collection systems use negative air pressure to pull solid waste through a network of pipes to a central collection point (terminal) where the waste is compacted and sealed into containers for transport to a processing or disposal facility.

Wastes are deposited into gravity-fed inlets (either indoor garbage chutes or outdoor litterbins) where they collect (inside the chute or in a reservoir beneath the litterbin) until the valves that connect the inlets to the tube transport network are opened.

When the material reaches the terminal, it enters a cyclone separator that sends the heavier-than-air waste spiraling down into a compactor, while the air in which the waste was entrained rises into a fabric filter. The fabric filter removes dust and impurities before the air is circulated through the exhausters and then out through the stacks.[7] The compacted waste is rammed into shipping containers. Figure 1-1, a diagram produced by the engineers who installed the system on Roosevelt Island, illustrates the basic concept.

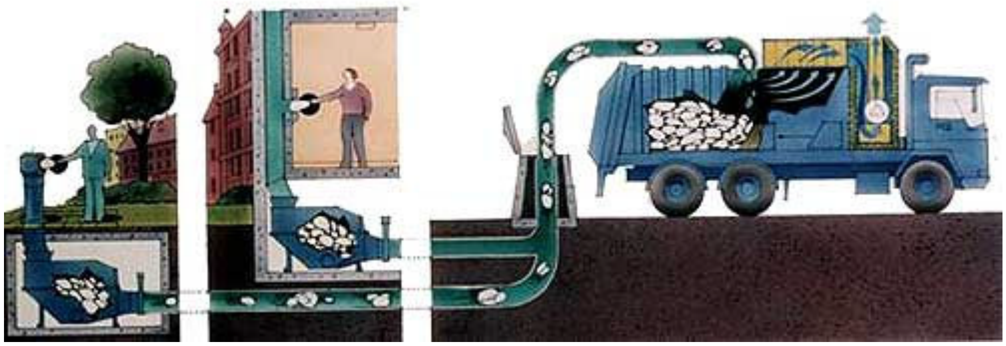
Figure 1-1. Roosevelt Island AVAC Operations Diagram
(Source: Gibbs and Hill Engineers, 1971)



There are two types of pneumatic networks: stationary systems with dedicated terminal facilities such as Roosevelt Island's, and mobile systems (Figure 1-2). Mobile installations require a specialized vacuum truck to suction waste via docking stations connected to the pipe network. The truck, which can serve several networks, compacts the waste and transports it for treatment or disposal.

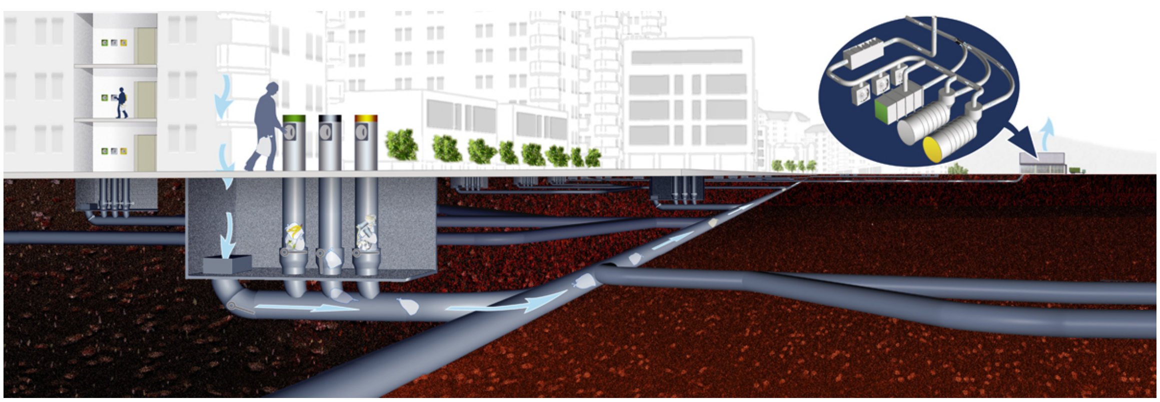
[7] This is pretty much the same principle by which any household vacuum cleaner operates, except that the common vacuum cleaner has no cyclone separator or trash compactor: the vacuum bags themselves are the fabric filters.

Figure 1-2. Mobile Pneumatic System,
(Source: Kogler, 2007)



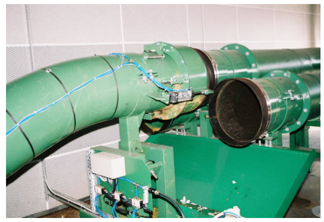
Both types of network can be used to collect multiple, source-separated waste streams or fractions. A single trunk pipe can transport these various fractions by pulling them at different times from their separate collection tanks (as shown in Figure 1-3). A dedicated cyclone-separator and compactor-container, or in the case of a mobile system, a dedicated truck run, allows for the separate collection of each fraction. In stationary systems, a switching valve connects the trunk line to the appropriate cyclone-separator before each new fraction is collected (as shown in Figure 1-4).

Figure 1-3. Schematic Stationary Pneumatic System Collecting 3 Fractions,
(Source: Envac, 2007)



Multi-fraction pneumatic systems require extra equipment and, since each separate pneumatic pull consumes additional energy, capital and operating costs are higher than for single-stream systems. The size of the terminal and the energy efficiency of the system depend on the length and geometry of the pipe network, the number of inlets connected to it, and the types and volume of waste to be handled.

Figure 1-4. Two-Way Diverter Valve
(Source: Kogler, 2007)



In installations built within the last decade or so, inlets are commonly equipped with key systems (magnetic cards with a unique identifier for each business or household) and with monitors that automatically register the volume of material introduced by the specific generator, or the number of times the generator accesses the inlet. This information can be used to automatically generate bills to be sent to each generator each month. In this way, at a relatively modest incremental cost, unit-based pricing systems can be integrated with pneumatic systems. Unit-pricing systems are often called "Pay-As-You-Throw" or "Save-As-You-Throw" programs. Since it is otherwise relatively difficult to charge individual households in high-rise buildings based on the volume of waste they dispose of, and since unit-based pricing has been widely demonstrated to produce significant reductions in the volumes of wastes set out for disposal,[8] such metered inlets can provide a significant system-wide benefit.

Figure 1-5. Save-As-You-Throw: Inlet Equipped with Magnetic Card-Reader
(Source: Envac, 2012)

<u>Literature Review</u>

Literature on pneumatic collection of municipal waste falls into several categories: engineering and waste-management-policy articles in academic journals; consultant or vendor reports and recommendations to potential system owners; and municipal plans and regulations written by system owners.

<u>The 1970s and the First Pneumatic Waste Systems</u>. Engineering articles from the early 1970s describe the context in which the first pneumatic systems for municipal waste in the US, including Roosevelt Island's system, were built.[9] Manufacturers targeted large-scale publicly-funded urban-renewal and housing programs similar in scale to the European new towns, the satellite developments where the strategy was first implemented. With the shift to disposable packaging and the banning of in-building incinerators, waste management was becoming increasingly cumbersome for municipalities such as New York City, where labor costs were rising and the tax base was eroding. We are aware of three systems in the U.S. that are still in operation: Disney World (1971),[10] Summit Plaza in Jersey City (1972)[11] and Roosevelt Island

[8] E.g., Kogler, 2007, p. 61.
[9] BT Kown/EA Kass of Gibbs and Hill Inc. 1973."Put refuse in a pipe; let air do the work," *American City*, June 1973.
[10] Bravo, Arthur C., "Environmental Systems at Walt Disney World." *Journal of the Environmental Engineering Division*, (December 1975): 887-95.

(1975). The strategy is also mentioned in reference to several other contemporary projects, the status of which the study team has not ascertained.[12] A 1974 article reported that over a dozen hospitals had incorporated pneumatic collection of waste or soiled linens.[13]

Recent General Literature on Pneumatic Tubes. Reports with recommendations for or against the installation of a pneumatic collection system by a developer or city agency highlight the importance of individual urban contexts in evaluating this technology. The 1972 report by Gibbs and Hill for Roosevelt Island recommended a pneumatic system to the Welfare Island Development Corporation as a means of avoiding the adverse environmental impacts associated with collection trucks.[14] Other reports focus on the administrative issues. For example, a 2008 report by Toronto's deputy city manager explained that the City could not support a pneumatic-collection proposal for a major waterfront renewal project without an implementation plan "where the City is not the owner/operator after the pilot project is completed."[15] A 2010 statement by the Traffic Administration in Stockholm, where the city's 400 pneumatic systems are owned by private developers, asked the City Council to retrofit the city center with a municipally owned system. In the Stockholm case, the primary motivation was worker safety in dense neighborhoods where storage areas in existing buildings did not meet current accessibility standards for waste handlers, and where making the modifications necessary to meet these standards was either impossible or costly.[16] In Saudi Arabia, engineers recommended a pneumatic network for the pedestrian plazas around the Grand Mosque in Mecca to handle high waste volumes and reduce congestion during pilgrimages.[17]

Administrative documents from cities that have publicly-owned pneumatic systems offer useful implementation models. For example, Barcelona developed criteria that it used to produce a master plan for pneumatic collection; this plan designated all of the areas within the city to be served by pneumatic collection.[18] City ordinances describe the responsibilities of property owners with respect to the portion of

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[11] U.S. Department of Housing and Urban Development, *Feedback: Operation Breakthrough Phase 1 Planning and Design*. Report prepared by HUD Office of Policy Development and Research with RTKL Associates Inc., Washington DC: U.S. Government Printing Office, 1976.
[12] Dellaire mentions two projects in development: a housing complex in East Harlem developed by the East Harlem Redevelopment Corporation (system designed by ECI Air-Flyte) and the Empire State Plaza office complex and meeting center in Albany New York (system designed by Trans-Vac). See Dellaire 1974: 83-4. *City Limits Magazine*, February 1979, Vol. 4, No. 2.
[13] Dellaire, Gene, "Pneumatic waste collection on the rise." *Civil Engineering ASCE*, (August 1974): 84
[14] Gibbs & Hill Inc. 1970. "Research Study on Refuse Collection for Welfare Island for New York State Urban Development Corporation," September, 1970.
[15] Deputy City Manager, City of Toronto. 2008. "Vacuum Waste Collection Systems." March 19, 2008. Unpublished staff report. www.toronto.ca/legdocs/mmis/2008/ex/.../backgroundfile-11780.pdf, accessed 7-18-12
[16] "Service Statement C. No. E2008-702-01621, C. No. T2008-702-02200, Authority for vacuum systems for waste. Response to commission from the City Development Committee and the Traffic and Waste Management Committee, dated October 2008," City Development Administration Traffic Administration, February 24, 2010. p.2.
[17] Al-Ghamdi, Abdullah Saeed and Abu-Rizaiza, Asad Seraj, "Report: Pipeline transport of solid waste in the Grand Holy Mosque in Makkah." *Waste Management & Research* 1, no. 5, (October 2003): 474-9. (This 600-ton-per-day pneumatic project, the largest in the world, is currently under construction. It is expected to open in 2013. The technology-provider is MariMatic.
http://www.finlandtimes.fi/business/2013/02/18/358/MariMatic-to-build-wastepipe-system-in-Mecca;
http://www.metrotaifun.com/automatic_solid_waste_collection_system/index.php/en/news-media/metrotaifun-news-and-media/8-news/26-marimatic-2011-11-08-marimatic-oy-delivers-to-saudi-arabia-world-s-largest-automatic-solid-waste-collection-system-awcs, accessed 6-5-13.)
[18] "Pla Tècnic 2006 de Recollida Pneumàtica de Residus: Avanç Econòmic," Clabsa and Ajuntament de Barcelona, 2006. http://fasttrash.org/library/archival-materials/ Reproduced by permission from Ajuntament de Barcelona, accessed 7-18-12.
http://w110.bcn.cat/portal/site/MediAmbient/menuitem.37ea1e76b6660e13e9c5e9c5a2ef8a0c/?vgnextoid=a94b25921cd1a210VgnVCM10000074fea8c0RCRD&vgnextchannel=a94b25921cd1a210VgnVCM10000074fea8c0RCRD&lang=en_GB, accessed 7-18-12.

the system that extends onto private property.[19] To ensure that networks built within the city meet technical standards and are properly documented, Barcelona developed its own design specifications for pneumatic collection.[20]

Recent Literature Comparing the Costs, Environmental Impacts, and Life Cycle Assessment of Pneumatic Tubes to Conventional Collection. Several recent studies compare pneumatic and conventional collection along a number of dimensions. These studies show a fair degree of similarity in their findings.

Jackson presents a variety of environmental, public-health, and quality-of-life arguments in favor of pneumatic vs. conventional collection. He acknowledges the high capital costs of pneumatic systems relative to truck-based collection, but finds that lower operating costs bring the Net Present Value break-even point to 7 years. Jackson's primary recommendation is for "[c]ontinued research into the development of low-cost, wear-resistant composite pipe materials…As improvements are achieved in the durability, workability, and manufacturing of various pipe materials, further reductions will in turn be realized in both the initial construction and long-term-maintenance costs for pneumatic waste collection systems; Thus [sic] making them less cost prohibitive and more attractive."[21] Other researchers comparing pneumatic systems to conventional collection also point to the role of the steel pipe in the overall economic and environmental costs of pneumatic systems.

Kogler focuses on the reductions in traffic congestion, worker accidents and exposure to pathogens and other sanitary hazards, noise (a one-quarter reduction in levels, a two-thirds reduction in duration), animal and insect pests, and odors, while documenting the relatively high capital costs of such systems ("nearly twice as high as traditional waste collection"). He notes, however, that these initial costs may be recovered: in addition to relatively modest operational savings (on the order of 20%), there could be savings of over 80% from renting out ground-floor space that conventional systems require for waste storage and handling, producing a net annual savings from pneumatic collection of over 25%.[22]

Three recent studies, a pair of parallel studies by Teerioja et al. and Punkkinen et al.,[23] and a study by Iriarte et al.,[24] compare the relative GHG emissions and other environmental impacts of hypothetical pneumatic collection systems with those of conventional collection, adding these factors to the analysis of direct capital and operating costs. The Teerioja and Punkkinen studies consider a four-fraction terminal-based pneumatic system, while Iriarte evaluates a mobile system using vacuum trucks. These studies use

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[19] "Ordenanza general del medio ambiente urbano de Barcelona (OMA)" Chapter 3 Article 63-6 "Recogida neumática," Chapter 4. Condiciones de los edificios y locales Article 64-2 "Edificios con sistema neumático" Ajuntament de Barcelona. http://w3.bcn.es/V04/Serveis/Ordenances/Controladors/V04CercaOrdenances_Ctl/0,3118,200713899_200726005_2_169473778,00.html?accio=detall, accessed 7-27-12.

[20] Ajuntament de Barcelona and Clabsa. "Plec d'Especificacions per a Installacions de Recollida Pneumàtica a l'Interior dels Edificis." http://www.clabsa.es/PDF/RECOLLIDA_PNEUMATICA/PLEC_ESPECIFICACIONS.pdf, accessed 7-27-12.

[21] Stephen B. Jackson, "An In-Depth Report on the Development, Advancement, and Implementation of Pneumatic Waste Collection Systems and A Proposed Program for the Practical Evaluation of such a System in Terms of Waste Disposal Parameters, Engineering Design, and Economic Costs," 2004, pp. 28, 30; http://www.dtic.mil/dtic/tr/fulltext/u2/a471879.pdf, accessed 12-27-12.

[22] Kogler, op. cit.

[23] Nea Teerioja, Katja Molia, Evelliina Kuvaja, Markku Ollikainen, Henna Punkkinen, Elina Merta, "Pneumatic vs. door-to-door waste collection systems in existing urban areas: a comparison of economic performance" *Waste Management*, Volume 32, Issue 10, October 2012, pp. 1782-1791; Henna Punkkinen, Elina Merta, Nea Teerioja, Katja Moliis, Evelliina Kuvaja, "Environmental sustainability comparison of a hypothetical pneumatic waste collection system and a door-to-door system," *Waste Management*, Volume 32, Issue 10, October 2012, pp. 1775-1781.

[24] Alfredo Iriarte, Xavier Gabarrell, Joan Rieradevall, "LCA of selective waste collection systems in dense urban areas," *Waste Management*, 29 (2009) 903-014.

Life Cycle Assessment (LCA) to compare total greenhouse emissions and other environmental impacts. Impacts associated with the manufacture and installation of all of system components (in the case of pneumatic collection: steel pipe, mechanical equipment, buildings) are added to those from operations (manufacture and consumption of fuels including electricity, maintenance, etc.) to assess the strategy's overall environmental impact.

In her base case--a pneumatic system handling just 5.3 tonnes/day, which is below the tonnage volume commonly thought to be economically practical--Teerioja found that capital expenditures for pneumatic collection were 10.4 times greater than those for conventional systems, and overall costs 5.6 times greater. But when the assumed tonnage was increased to 21.2 tonnes/day--since (unlike with conventional collection) fixed costs do not increase with additional tonnage--the overall cost differential decreased to 2.6 times more than conventional collection. Teerioja also found that "Environmental Costs" (these primarily reflect GHG emissions in the form of the costs of carbon dioxide equivalents [CO2-eq]) were 2.5 times higher for pneumatic than for conventional collection.

Teerioja notes that in addition to the unquantified (and undocumented, but probable) benefits due to "social aspects" ("Whether and how much the pneumatic system could reduce the possible negative amenity effects of the prevailing system, such as congestion, noise, and odor, and whether their economic value is crucial for the analysis, are questions that are left for future research."), the economic equation might well be reversed in situations where the value of land freed up by pneumatic collection from waste use can be taken advantage of, especially in high-land-value areas. Finally, Teerioja emphasizes that her findings pertain only to retrofit installations in existing developments. For pneumatic installations in new complexes, cost differences are likely to be less for three reasons: first (as is the case in New York City, due to the recent passage of Local Law 60 of 2012, which designates the minimum amount of space that must be set aside in residential buildings for waste and recyclable storage), because "in new residential areas, the costs of traditional waste collection increase due to modern requirements with regard to, for example, larger and more convenient waste sheds [i.e., waste rooms];" second, the cost of installation is lower in new construction; and third, "the saved space from waste collection activities can be easily put to alternative, more efficient uses."[25]

Teerioja does not mention other likely savings on the pneumatic side of the equation that could accrue from rationalization of the system design and operating conditions. For example, depending on the value of land in the neighborhood Teerioja analyzed, a subterranean terminal in one of the immediately adjacent parks (as have been installed in Stockholm, for example) could produce both real-estate savings and capital and operating savings associated with the hypothesized more-distant terminal location. Teerioja et al. might also have included a calculation of the economic and environmental benefits that could be expected from the volume-based pricing systems which "pneumatic systems enable" and which, they note, have been shown to be "efficient in reducing MSW generation."[26]

Punkkinen examined in greater detail the carbon dioxide-equivalent (CO2-eq) emissions from the same hypothetical stationary pneumatic installation in the same central-Helsinki already-developed neighborhood that Teerioja et al. had considered. She found that these per-tonne emissions, overall, were 3.2 times higher for pneumatic collection than for conventional collection. (Note that the results found in the present study of proposed facilities in Manhattan are quite different, with the pneumatic systems producing significantly lower GHG emissions than conventional collection; as will be explained below when these results are presented, this is due to the specific conditions associated with these proposed installations.) But while the relative emissions from the collection-and-transport component were only 2.2 times higher for the pneumatic system, the emissions from the manufacture of the fixed system components were 11.2 times higher than those for the "manufacture of waste containers"--the only conventional-system equipment component considered in her comparison. Given the major influence of the manufacture of the pneumatic system's long-lived steel (and cement) components, it is a striking omission on Punkkinen's part not to have included the GHG emissions associated with the manufacture and disposal of the major (primarily steel) components of the conventional system: short-lived (say 7 years) heavy-duty compactor trucks.

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[25] Teerioja et. al., 2012, p. 1790.
[26] Pp. 9-10.

Nonetheless, given the magnitude of the emissions associated with the steel pipes alone, it is unlikely that the parallel inclusion of the manufacturing and disposal impacts associated with conventional collection equipment would have significantly changed the relative magnitudes of the respective impacts.[27] Another infrastructural factor not included on the conventional side of the equation were the costs and emissions associated with the replacement of asphalt, concrete, and steel, due to the more-frequent reconstruction of roads and bridges due to the additional miles traveled by heavy-duty compactor trucks.

Iriarte et al. also found higher overall costs, GHG emissions, and BTU use when a mobile-pneumatic system was compared to conventional collection. In this study, however, a significant component of the relatively high BTU and GHG figures was the relatively low loading capacity of the mobile pneumatic equipment vs. the high load capacity of conventional trucks. Increased mobile loading capacity would significantly reduce the differential between the two types of systems.

Eisted et al. also compare GHG emissions associated with pneumatic collection to those from conventional systems. They find that emissions from different systems vary greatly, depending on material densities, compaction rates, and transport distances, but that pneumatic systems may produce emissions an order of magnitude higher than those from truck-based collection.[28]

Comparative findings from these studies are summarized in Tables 1-1 and 1-2.

Table 1-1: System Cost Including Space Savings
(Source: Kogler. 2007)

Cost Including Space Savings (Euros)			
Hammarby Sjostad	Manual	Pneumatic	**Ratio, P/M**
Capex	€ 2,949,835	€ 4,728,408	**1.6**
Opex	€ 271,696	€ 87,904	**0.3**
Total/Y	€ 486,031	€ 431,415	**0.89**
Sodra Station, Stockholm			
Capex Per Apartment	€ 1,259	€ 1,479	**1.17**
Opex Per Apartment	€ 64	€ 52	**0.81**
Space Cost/Y	€ 104	€ 18	**0.17**
Total/Y (Including Space Costs)	€ 207	€ 152	**0.73**

[27] Extrapolating from data published by the National Research Council of the National Academies (*Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use*) adding the impacts of truck production and disposal to the equation might increase CO2-equivalent GHG emissions of conventional collection by about a half, so that there would still be a disparity of nearly two to one in favor of the conventional system. Studies that have included GHG emissions associated with the production of trucks and other equipment and with the construction of infrastructure in the total GHG emissions associated with freight transport in general have found that these factors contribute between 5% and 30% to this total (M. Spielmann and R. W. Scholz, "Life cycle inventories of transport services--background data for freight transport, The EcoInvent Database," *International Journal on Life Cycle Assessment,* (2005), 10, 85-94; C. Facanha and A. Horvath, "Evaluation of life-cycle air emission factors of freight transportation," *Environmental Science & Technology*, (2007), 41, 7138-44; both cited in Rasmus Eisted, et al., "Collection, transfer and transport of waste: accounting of greenhouse gases and global warming contribution," *Waste Management & Research* (2009), 27: 738-45).

[28] Rasmus Eisted, Anna W. Larsen and Thomas H. Christensen, "Collection, transfer and transport of waste: accounting of greenhouse gases and global warming," *Waste Management & Research*, 2009: 27: 738-745.

Table 1-2. Life-Cycle GHG Emissions From Pneumatic and Conventional Systems
(Source: Punkkinen, 2012; Eisted, 2009)

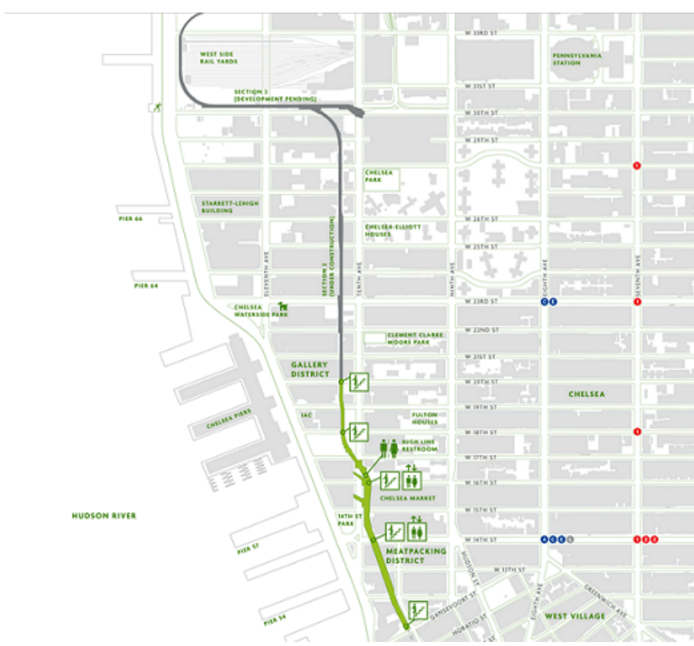
CO2-eq (kg/tonne)	Manual	Pneumatic	**Ratio, P/M**
Manufacture	1.86	20.74	**11.2**
Collection + Transport	16	35.66	**2.2**
Total (Helsinki)	17.86	56.4	**3.2**
Total (Copenhagen)	7.9	47.3	**6.0**

RESEARCH SETTING

High Line

The High Line was an elevated freight railroad built by the New York Central Railroad in 1932 to eliminate the tragedies that had plagued its West Side service for nearly a century: because of accidents that had produced an average of one mortality a week for decades, the street the company used to bring goods to and from the factories and warehouses that stretched inland from the Hudson River was called "Death Avenue." The Central's solution involved submerging what had been an at-grade line in an open cut north of 34th Street. South of 34th Street the line began to climb in a spiral that ran west to 12th Avenue then circled back east before turning south near 10th Avenue. At that point it was 23 feet in the air and plunged through the mid-block buildings in its path. It originally terminated at St. John's Park Terminal on Spring Street, but most of the portion south of Gansevoort Street was torn down in the 1960s; the last section was removed in 1991. In 2003 the City overturned its earlier decision to demolish the remaining 1.5 miles and agreed instead to turn over its management to a non-profit entity known as the Friends of the High Line for purposes of a park. The first section of the new park, a half-mile stretch between Gansevoort and 23rd Street, opened in 2009. The second half-mile section, between 23rd and 30th, opened in 2011. Construction on the third and final section, the half-mile spiral from 30th to 34th, began in 2012.

Figure 1-6. The High Line
(Source: Friends of the High Line)



To overcome the objections of adjacent land-owners who wanted this no-longer-used railroad torn down, the City passed a zoning amendment to create a "High Line District" that allowed them to realize revenues from the development of elevated structures built with the High Line's air-rights. At the same time, in order to spur development of the "Far West Side" in general, the City re-zoned the sixty-block area just north of the High Line, which straddles the below-grade continuation of the old Central route. The portion of this open-cut track immediately north of 34th Street, which runs in front of the Jacob Javits Convention Center (another site that is about to undergo reconstruction), will be developed into a new City park called "The Boulevard." Like Riverside Park farther uptown, the new park's surface will form a roof over the below-grade track. In order provide transit access to this former warehouse district, the MTA built an extension of its #7 subway, which formerly terminated at Times Square (Broadway and 42nd Street). The #7 now extends to 8th Avenue and then curves south to 34th Street; tunnel construction was substantially completed in 2012.

Figure 1-7. The Boulevard: A Planned Park Over the Sub-grade Northern Extension of the High Line

(Source: Michael Van Valkenburgh Associates Inc)[29]

Figure 1-8. The #7 Subway Line Extension (dotted purple line)

(Source: NYC MTA)

[29] http://www.mvvainc.com/project.php?id=56, accessed 4-1-12.

In combination, these recent planning decisions are expected to produce the greatest concentration of new construction ever developed in New York. Ground has already been broken on the largest property in this newly rezoned district. This 26-acre tract, now owned by the MTA, contains, at grade, the rail yard encoiled by the spiraling High Line where the Long Island Railroad stores its cars. The developer, The Related Companies, plans to build there, on an elevated deck, the equivalent of two downtown Seattles--12.7-million square feet of new residential, office, and retail towers. As it happens, The Related Companies, the City's largest developer, is also a partner in the development of the newest residential towers (three of which are yet to be constructed) on pneumatically-tubed Roosevelt Island. Thus equipped with direct experience of the benefits of automatic waste collection (space and labor savings and market-enhancing quality-of-life benefits), Related announced, in the spring of 2011, that it planned to install pneumatic-waste-collection facilities in its new mega-complex as well.[30]

Figure 1-9 Hudson Yards in 2017 and 2025: "As Big as Two Downtown Seattles"[31]
(Sources: The Related Companies, 2012)

Construction on an elevated deck over a railyard offers potential advantages for a pneumatic system, since it could not only facilitate the installation of below-grade pipes but provide a below-grade footprint for the terminal needed to receive the pneumatically conveyed materials. The West Side railyard offers a further important potential advantage. Manhattan, the densest generator of MSW in North America, currently has no facilities at which wastes can be deposited (for transfer or processing). A barge-loading facility for refuse is planned many congested blocks away, at East 91st Street (on the opposite side of the island), but this facility, if it is ever built, is not intended for material from the West Side of Manhattan.[32] The old Central Railroad line still wends its way north, below grade, up most of Manhattan's Hudson shorefront, and then above-ground to Albany and beyond. This track, the Empire Line, is currently owned (depending on the section in question) by Amtrak, MetroNorth (an MTA subsidiary), and CSX (whose portion is currently under Amtrak management). This line currently has the capacity and the potentially available right-of-way necessary for loading-sidings to remove railcars of containerized waste from Manhattan.[33] If

[30] http://www.cityrealty.com/new-york-city-real-estate/carters-view/related-posts-new-renderings-information-hudson-yards-project/carter-b-horsley/39962, accessed 10-11-11.
[31] http://www.nydailynews.com/new-york/huge-hudson-yards-project-break-ground-tuesday-article-1.1211363, accessed 10-11-11.
[32] Two other barge-loading facilities, one for recyclable paper and corrugated cardboard, the other for metals, glass, and plastic, are planned for West 59th Street and Gansevoort Street.
[33] As confirmed by representatives of these agencies to one of this report's co-authors. The concept of developing a waste-to-rail transfer facility at this point has been independently proposed and found to be conceptually feasible by a variety of engineering and rail-industry experts, including DMJM Harris (in reports commissioned by the Durst Organization, William Galligan (executive director of the East of Hudson Rail Freight Task Force), and Peter D. Cohen, a former railroad professional with decades of experience with the City of New York, Conrail, Canadian Pacific, and Amtrak.

this were done--as would be consistent with New York City's overall plans for rail export of its MSW,[34] as well as being operationally compatible with the City's current rail-export of waste from the Bronx up the Empire Line--the need for trucks for managing any aspect of refuse removal from that dense development would be entirely eliminated.

Figure 1-10. The Empire Line, the Northern Extension of the High Line
(Source: Henderson, 2010)[35]

Fourteen blocks from the southern terminus of the High Line Park is a 1.2 million-square-foot complex[36] known as the Chelsea Market. Although it appears, from the outside, to be one block-long brick complex, an examination of the interior reveals that it is actually a series of late-19th- and early-20th-century buildings that were fitted together to serve the purposes of then-revolutionary baking technology. Like a perpendicular parody of the High Line, which charged through the center of its building on a north-south axis at the third-floor level, the National Biscuit Company's (Nabisco's) wares (Oreos) were baked in a continuous tunnel of east-west-oriented ovens through which sprocketed a conveyor belt hundreds of feet long.[37] Would it not be fitting, we thought, to metaphorically combine these east-west and north-south transverse flows into one seamless pneumatic system, bringing waste materials out of the Chelsea Market complex (whose articulated joints [see Figure 3-1] seemed serendipitously adapted to an interior tube retrofit) and up the High Line toward the Related Company's own projected pneumatic-tube complex?

Adding to our initial interest in the possibilities offered by the Chelsea Market was the fact that the complex offered the highly unusual (for New York City) situation where the hundred companies in the complex all used the same private waste-carter. And that the building, with its restaurants and food markets, offered an unusually rich lode of high-quality organic materials which, if separately collected, might be processed via anaerobic digestion in a site adjacent to the pneumatic terminal (perhaps in conjunction with other organics from the Related Company's pneumatic collections?), thus avoiding the economic and environmental costs of long-distance transport and landfilling and offering the benefits of bio-gas, along with compost-additives that could be used in the High Line Park. The Chelsea Market complex offered one other potential opportunity: as this project began, the company that owns the Market announced plans to double its size by building vertical expansions at either end of its block.

In conjunction with the Related Company's announced pneumatic-collection plans for Hudson Yards, the vast waste-generating potential offered by the new developments expected along the High Line's axis, and

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[34] http://nytelecom.vo.llnwd.net/o15/agencies/planyc2030/pdf/planyc_2011_solid_waste.pdf, p. 136, accessed 1-16-13.
[35] http://en.wikipedia.org/wiki/File:Empire_Connection_fr_61_St_jeh.jpg, accessed 4-1-12.
[36] http://therealdeal.com/blog/2012/09/05/city-planning-gives-chelsea-market-expansion-the-go-ahead-mostly/, accessed 1-13-13.
[37] www.mbpo.org/uploads/ChelseaMarketULURP.pdf, accessed 2-05-13.

the global attention already focused on the High Line as one of New York City's preeminent tourist attractions, the proposed project appeared to offer truly transformative possibilities.

Second Avenue Subway

The Second Avenue Subway has been a glint in planners' eyes since the 1920's, when it was first conceived as the solution to the "Far East Side's" already-congested transit conditions. Originally envisioned as a line that would run from 129th Street in the north to Pine Street in the south, construction finally began in 1972 but continued for only three years, after which its partially-completed tunnels lay dormant until construction re-commenced in 2007.[38] One section currently under construction is the station-and-tunnel complex between 99th Street (from which a tunnel segment completed in the 1970's. stretches north) and 92nd Street. Since it began, the project has been a source of many neighborhood complaints due to noise and vibrations from underground blasting, dust and emissions from construction equipment, and the obstruction of streets and sidewalks. Among many other local grievances: the fact that it is difficult for municipal and private carters to collect MSW from storefronts and doorways that are blocked off from traffic by construction barricades, resulting in piles of bags that even-farther occlude narrow pedestrian and vehicular passageways.

Figure 1-11. The Second Avenue Subway, Area Under Construction for 96th St. Station
(Source: NYC MTA)

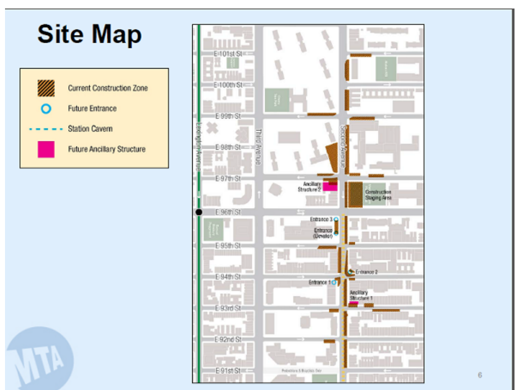


Figure 1-12. Second Avenue, on the Steel Plate Hanging Over a Cut-and-Cover Section
(Source: Miller, 2012)

[38] http://en.wikipedia.org/wiki/Second_Avenue_Subway, accessed 4-5-13.

In the meantime, below the streets, popular attention in 2011 and 2012 was once again focused on the Transit Authority's problems with a burgeoning population of garbage-engorged rats. Public and media attention also highlighted the MTA's apparent inability to keep the overflowing litter bins in its stations emptied or, via its expensive, work-train waste-collection system, its platforms free from leaning piles of pungent trash. And a high proportion of the labor time spent by MTA personnel "maintaining the track" was actually spent simply chipping away layers of muck encrusted between the rails.

Figure 1-13. Trash Is A Problem
(Source: NYC MTA, 2012; truenewsfromchangenyc.blogspot.com, 2012)

NEW YORK POST
Yuck! Subway's 'rat race' gets seriously ugly
By JENNIFER FERMINO and CHRISTINE PARKER
Last Updated: 7:54 AM, February 9, 2012

THE WALL STREET JOURNAL.
Nightmare Video: Rat on Subway Rider's Face

NYDailyNews.com
DAILY NEWS
MTA's idea to remove trash cans in hopes of cutting down on waste was a dirty - and unwise – move (April 1, 2012)

Would it be possible, we were asked by an MTA official, to take advantage of the opportunity offered by the temporary steel plate suspended over a stretch of Second Avenue between 92nd and 95th Street, under which other re-located utilities (water and sewer mains, gas lines, electricity and cable conduits) were already hanging, to strap a pneumatic waste tube--and thus offer the potential for alleviating the current problems with neighborhood waste collection, as well as the future problems of subway-waste removal?

Given the potential widespread applicability of such a retrofit elsewhere throughout the 722 miles of the subway system, and the unusual immediate opportunity offered by the ease of slinging a pipe beneath a suspended steel plate, we thought the analysis of the potential feasibility of this idea well worth the candle.

Section 2

RESEARCH METHOD

Both feasibility studies required data to answer three questions:

1. Would it be physically and operationally feasible to use the right-of-ways and structures associated with existing transportation infrastructure to install a pneumatic waste-collection system?

2. Are there sufficient waste volumes potentially accessible by a pneumatic system to meet customary economy-of-scale requirements (i.e., approximately 10 tons or more within a linear distance of about one mile)?

3. How would the operation of an automatic-pneumatic system compare to that of conventional manual/truck-based collection in terms of economic and environmental performance (particularly energy use and greenhouse emissions)?

Information to answer the first question was obtained from field observations, measurements from maps and plans, and engineering data and conceptual designs provided by Envac, the current form of the firm that built the first pneumatic waste collection system in Sweden in 1962, as well as the Roosevelt Island system in 1975, and which is now the leading global supplier of pneumatic waste-collection systems. (All technical and cost information pertaining to pneumatic systems, unless otherwise identified, is from Envac representatives.)

Information to answer the second was obtained through field observations, interviews, and a variety of public and private data sets that are specifically referenced in the Appendices.

Our answer to the third question is based on the calculations presented in the Appendices, which are based on various public, proprietary, and confidential data sources (as identified in the Appendix notes).

Section 3

FINDINGS: HIGH LINE/CHELSEA MARKET

PHYSICAL AND OPERATIONAL FEASIBILITY OF USING THE EXISTING INFRASTRUCTURE FOR INSTALLATION OF A PNEUMATIC WASTE-COLLECTION SYSTEM

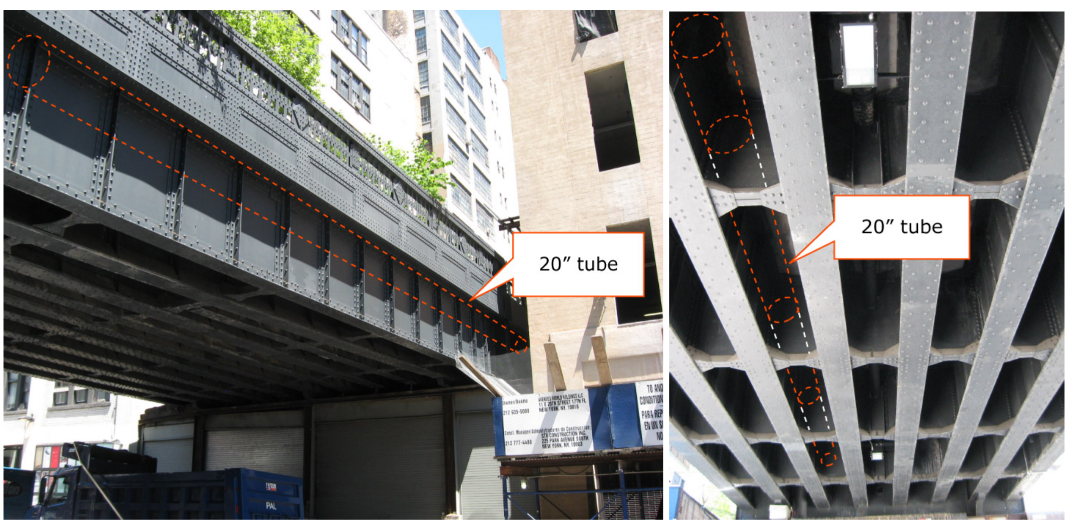
The High Line structure, though originally completed in 1932, was completely reconstructed prior to its opening as a park in 2009.[39] There is no question that the steel-and-concrete viaduct has sufficient load-bearing capacity to support the relatively modest weight of a 20” steel pipe and associated waste and air inlets. The Park’s current one-mile length is consistent with the standard maximum lengths associated with pneumatic installations.

From an aesthetic and public-education perspective, the preferred solution might be to install the trunk pipe on the top side of the viaduct platform, where it might snake through the shrubbery, half-buried but still-visible, providing the auditory impression of a brook as various waste fractions are, at intervals, pneumatically pulled through the system. It would be even better for the purposes of public-consciousness-raising if the pipe were transparent or translucent plexiglass, rather than the customary steel.

This design proposal, however, did not appeal to Friends of the High Line staff, who preferred a less-assertive, sub-platform placement, with the tube painted in the same green-black shade as the rest of the under-bearing steel structure. The simplest and most cost-effective way to accomplish this would be to strap the pipe against the side of the steel support structure. There are many segments of the High Line that cross streets or other non-built-up spaces where this solution could be used. (See Figure 3-1.)

Figure 3-1. High Line, View From Street Showing Tube Location Along Side Or Between Girders

(Source: Miller, 2011)



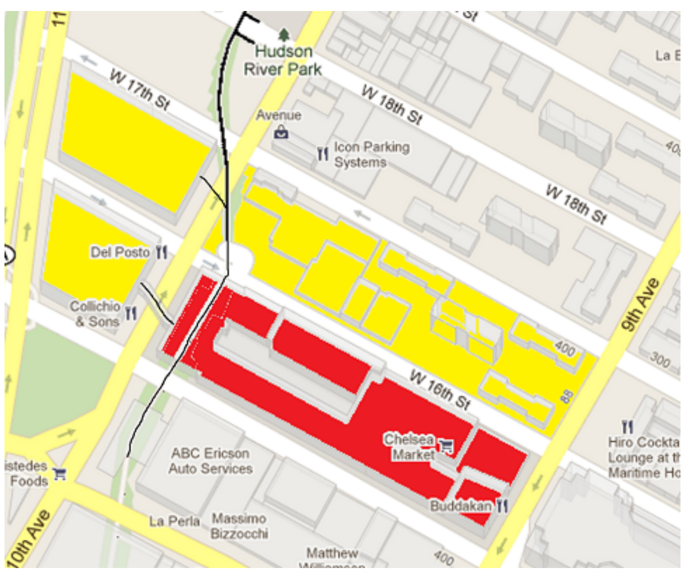
In other situations, however, buildings already abut the structure’s sides or can be expected to be erected against it in the foreseeable future. In such cases, since the exterior diameter of the pneumatic pipes is just over 20”, there would be space to place the pipe between its main girders. (See Figure 3-1.)

[39] A second reconstructed section opened in 2011. The third and final section is scheduled to open in 2014.

There are many potential waste sources that are located near-enough the High Line to be operationally practicable. Some of these are existing buildings. Others are already being planned, or are expected to be developed on adjacent "soft" or vacant parcels. With a higher degree of cost and difficulty, street-level litter bins and storefronts could also be accessed. But the easiest target of opportunity would be the Chelsea Market complex, which the High Line directly intersects. (See Figure 3-2) And if it were discovered that there were not enough wastes generated in the Market, there are three other block-long complexes also directly connected to the High Line, either directly or by spurs, which could be added to the flow. (See Figure 3-3.)

Figure 3-2. High Line, View From 16th Street, Where Park Intersects Chelsea Market
(Source: Miller, 2011)

Figure 3-3. Map of High Line Intersecting Chelsea Market (Red) and Adjacent Blocks (Yellow)
(Source: Google Maps, 2011)



The Chelsea Market is 800-feet long[40] and oriented in an east-west direction, perpendicular to the High Line. Material from throughout the length of the block would need to be moved to the High Line's

[40] http://www.nyc-architecture.com/CHE/CHE033.htm, accessed 1-5-13.

intersection at the building's western edge. The existing structure appears well-suited to the retrofit installation of the radial branch-pipe that would be required. (See Figure 3-4.) The design concept for this retrofit is that there would be one waste room located at High Line level somewhere in the middle of the block, to which all building tenants would bring their waste to be introduced into the system (as shown in Figure 3-5). This waste room would also have equipment for shredding old corrugated cardboard (OCC) boxes and densifying these shreds into blocks smaller than the tube's diameter so that they could be automatically ejected into the mixed-paper/OCC inlet, as shown in Figure 3-6.[41]

Figure 3-4. Chelsea Market Ground-Floor Retail Concourse, View of Potential Ceiling Tube Location
(Source: Miller, 2011)

Figure 3-5. Central Waste Room (Pneumatic Collection of Refuse and Organics) at the Sta Caterina Market, Barcelona
(Source: Envac, 2011)

[41] Building managers may prefer two or more inlet locations to reduce transport distance within the Chelsea Market.

Figure 3-6. An OCC Brick Machine Connected to a Pneumatic Network
(Source: Envac, 2011)

A pneumatic terminal capable of handling the waste volumes and fractions associated with the Chelsea Market and High Line would require a footprint of approximately 6,900 square feet (sf). As demonstrated by the experience of pneumatic terminal installations in many cities in Europe and Asia, this terminal footprint could be located as a free-standing structure at-grade, below-grade, or as an interior element of a building at any above- or below-ground elevation. (See Figure 3-7) There are any number of locations where a permanent terminal might be constructed in either existing or planned buildings, or below a small planned ground-level park adjacent to the High Line. Another possibility would be for a temporary "pop-up" terminal, enclosed in a low-cost, visually versatile shell, which could be erected and removed to another location along the High Line when a permanent location became available (see Figure 3-8). For purposes of the present feasibility analysis, we considered a location in the sub-basement of the future High Line Park Maintenance Building.[42]

The cost of the terminal building itself is not included in the capital expenditure and NPV calculation because the type of structure, if a structure is needed at all, is not known. The cost of retrofitting the Chelsea Market building with the tube and central waste room is not included either. This will require a detailed engineering and architectural analysis and the final cost will depend on whether the installation is coordinated with other construction projects such as the current Chelsea Market expansion. To test the sensitivity of the NPV to additional construction costs we added the estimated cost of a 6,900 sf terminal building based on average local construction costs and at a rate four times higher ($640,000 to $2.6M). Including these costs raised the baseline NPV for the pneumatic network between 8 and 33%.[43]

[42] In reality, the maintenance building is already under construction. Other potentially feasible sites would be the sub-basement of a new retail tower being built on the site of a recently closed gas station on the corner of 11th Avenue and 14th Street, and below the surface of a vest-pocket park that is planned for a vacant lot at 18th Street.
[43] For calculation and construction cost sources see Appendix Table B-1.01.

Figure 3-7. Terminal Installations Under a Bridge, Under a Park in Barcelona, and Under the Sub-Basement of the Santa Catarina Food Market in Barcelona
(Source: Envac, 2011)

Figure 3-8. Temporary Terminals in Vitoria, Spain and Hammarby Sjostad, Sweden
(Source: Envac, 2011)

The lay-out of such a system could be as shown in Figures 3-9 and 3-10.

Figure 3-9. Schematic High Line Pipe Network
(Source: Spertus, 2013; Data: Envac, 2011)

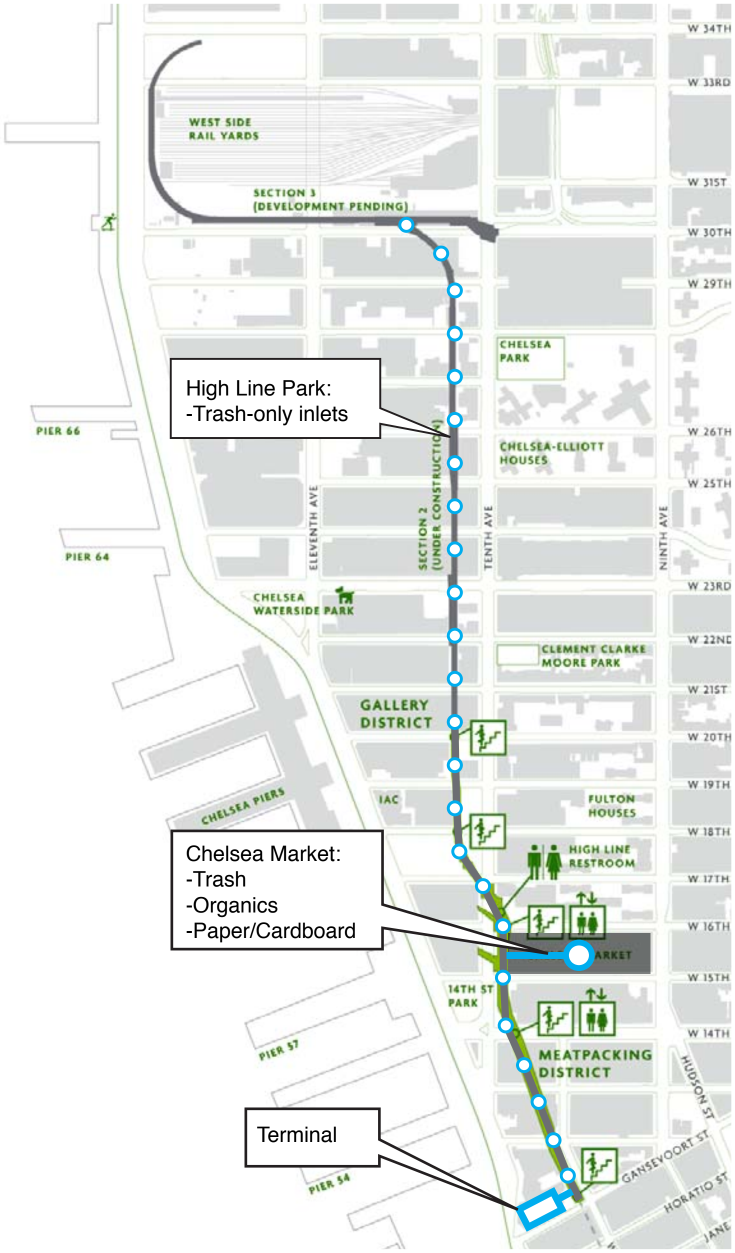
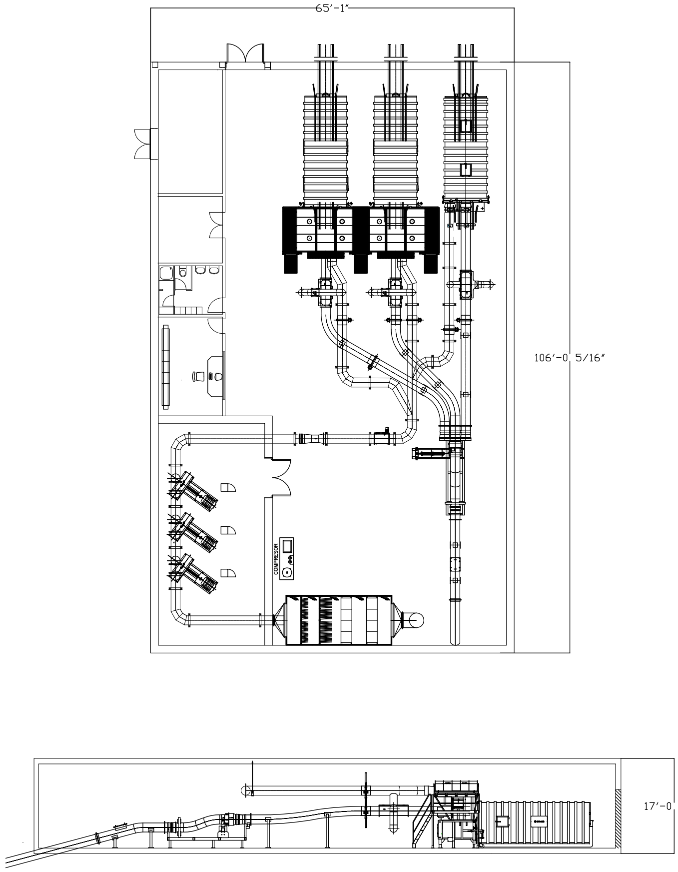


Figure 3-10. Terminal Floor Plan and Cross-Section
(Source: Envac, 2011)



The capital costs of such a system would be approximately $10.6 million.[44] Annual operating costs, without dray costs for moving the filled containers from the terminal to the disposal facility or debt service, would be approximately $467,000; total annual costs, including dray ($51,000) and debt service ($627,000), would be about $1.1 million. The capital and operating cost components are summarized in Table 3-1.

[44] Terminal costs do not include the building shell, the costs of which will vary significantly depending on location and material specifics. The sum of the dray components is the total cost of hauling containers from the AVAC terminal to what is traditionally considered "the end of the collection route" or "first dump": a transfer station for long-distance transport to a remote disposal facility, a recycling or organics processing center, or a local waste disposal (e.g., waste-to-energy) facility.

Table 3-1. High Line System Cost Components

		Units	Cost
	Tons/Y:	3,942	
Capital Components	Terminal SF	6,900	$2,892,362
	Trunk Pipe (meters)	1,729	$5,671,724
	High Line Inlets/Valves	24	$1,347,075
	Chelsea Market Waste Rm/Inlets		$658,659
	Total		**$10,569,820**
	Capital Cost Per Annual Ton		$2,681
	Debt Service (34yrs)/Y		$627,211
	Debt Service/T		$159
Expense Components	Labor (Facility) Employees	2	$301,231
	Electricity (kwh)	126,774	$63,352
	Minor Repairs+Spare Parts/Y		$19,332
	Employee Vehicle		$10,423
	Office Supplies		$2,170
	Telephone/Water		$3,510
	Component Replacement/Y		$66,671
	Total/Y (-Dray, Debt Service)		**$466,689**
	Cost/T (-Dray, Debt Service)		$118
Dray Components	Labor Shifts/Y	100	$36,085
	Diesel (Gals/Y)	1577	$5,281
	Vehicle Cost+Maintenance/Y		$7,776
	Tolls	74	$1,997
	Total Dray/Y		**$51,139**
	Total Dray/T		$13
Cost Summary	**Total/Y (Opex, Dray, Debt Service)**		**$1,145,039**
	Total/T		$290

WASTE VOLUMES AND FRACTIONS FROM THE CHELSEA MARKET AND THE HIGH LINE

The Chelsea Market, by itself, generates enough waste a day--some 10 tons--to fit the generally accepted profile of an economically and operationally viable pneumatic facility. Of particular interest, given the conceptual possibility of a future anaerobic digestion facility (perhaps in conjunction with Hudson Yard or some other future pneumatic installations along this Far West Side axis), is the volume of potentially accessible high-grade (high-BTU) food waste generated by the Market's businesses: 2.2 tons per day.

Although, on a square-foot basis, the High Line is perhaps the most heavily-visited park in the world, the daily volumes of waste it generates–1.2 tons--would not in themselves be sufficient to supply an economically-scaled stationary pneumatic facility. This volume, however, could easily be incorporated into a system designed to manage the material generated by the Chelsea Market.

Waste volumes and fractions from these two sources are summarized in Table 3-2.

Table 3-2. High Line System Waste Volumes and Fractions

Commercial Refuse Tons/Day	5.17
Commercial Organic Tons/Day	2.18
Commercial OCC & MGP Tons/Day	2.22
Subtotal Chelsea Mkt	**9.57**
High Line Refuse Tons/Day	1.23
Total/Day	**10.80**
Total/Year	3,942

Given the de minimis volume of recyclable metal, glass, and plastic generated by the Market, we did not find it economically practicable to include pneumatic inlets for that stream. Pneumatic inlets would be supplied only for the three highest-volume fractions: refuse, organics, and paper/OCC. The relatively small volumes of dry packaging material (the metal, glass, and plastic) could easily be stored for relatively long periods in a relatively small amount of space and collected by truck at cost- and volume-efficient intervals. The proposed scenario would collect only refuse from the High Line; Friends of the High Line staff would continue to collect, stage, and ferry bags of paper and metal/glass/plastic from park litter bins to the curb.[45]

FUTURE WASTE SOURCES

In addition to the current volumes noted above, Chelsea Market's plans for expanding its current 1.2 million sf by 330,000 sf will mean that waste volumes will increase by an amount that is expected to be somewhat less than the proportion of new square footage to the old square footage.[46]

The High Line, too, is being expanded by a third. Its waste volumes therefore would be expected to expand by at least that amount. (Further increases are expected over time due to the steadily increasing volume of traffic that the Park has attracted as it has expanded.)

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[45] Ideally all waste streams, or at least the same three fractions collected from Chelsea Market, would be collected from the High Line, but given the small volume of waste and the large number of inlets that would be required, we considered single-fraction collection more realistic. Although not examined here, if only one fraction is collected it is worth considering a focus on organic waste along the High Line (with refuse and recyclables collected manually) as a way to raise awareness of composting in a place where thousands of visitors come to picnic.

[46] Hotels and office spaces generate less waste per square foot than do retail businesses, especially food-retail establishments. The New York City Council approved the Market's expansion plans in 2012.

Section 4

FINDINGS: SECOND AVENUE SUBWAY/92ND TO 99TH STREETS

PHYSICAL AND OPERATIONAL FEASIBILITY OF USING THE EXISTING INFRASTRUCTURE FOR INSTALLATION OF A PNEUMATIC WASTE-COLLECTION SYSTEM

Unlike the relatively simple Chelsea Market-High Line installation, which requires only one trunk line to receive flows from both the Market and the High Line at one elevation, collecting waste at street level and at subway level will require two separate trunk lines because the 96th Street station is 50 feet below ground and the maximum vertical grade that the type of pneumatic system considered can accommodate is only 18%. Both trunk lines would be connected to one terminal as shown in Figure 4-1. The subway-level pipe, since it would handle only a relatively small volume of material, can be of 300mm polyvinyl chloride (PVC) rather than steel.

Another complicating factor in this situation is that, assuming that the subway installation may one day be extended between stations in order to take advantage of the available space in existing subway tunnels, the subway-level line must be able to accommodate differing station layouts. Express stations have platforms in the middle of the station (between tracks), while local stations have platforms on either side of the central tracks. There must therefore be two pneumatic pipes suspended between the north-south tracks between stations, one of which must swerve to opposite platform sides at local stations, and both of which must swerve to the central platforms at express stations. A conceptually feasible solution to this problem is presented in Figure 4-2.

Figure 4-1. Cross-Section of Second Avenue and Surface-Level and Subway Pipe Networks
(Source: Spertus, 2012)

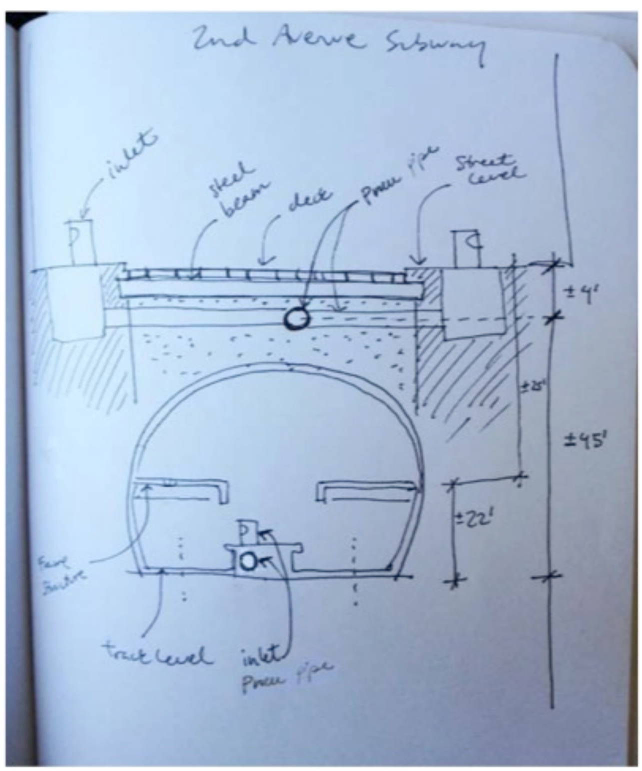

Figure 4-2. Pipe Layout for Single- and Double-Platform Configurations
(Source: Spertus 2012)

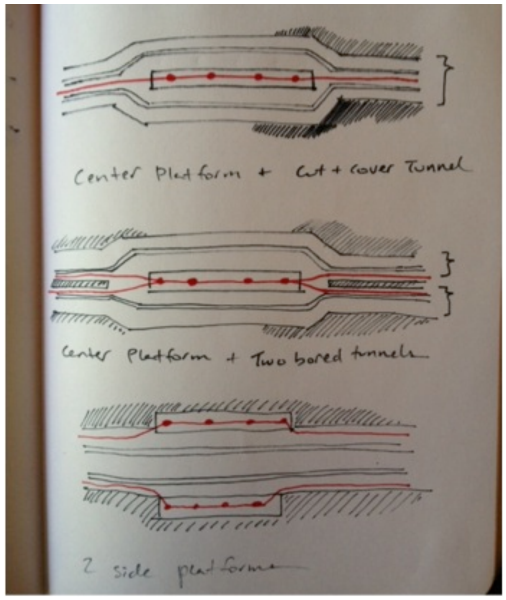

Figure 4-3. Schematic Second Avenue Pipe Network (Surface Level; Each Green Dot Represents 3 Inlets; Areas Served are Shaded Red)
(Source: Spertus, 2013; Data: Envac, NYCityMap)

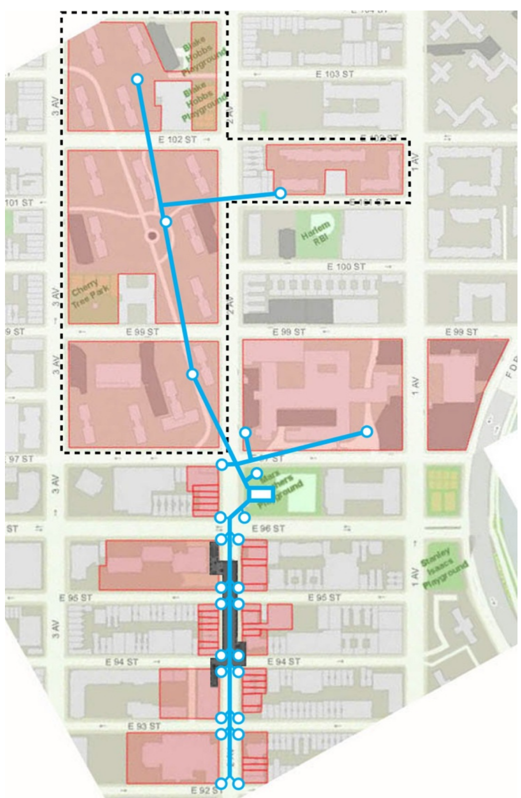

Figure 4-4. Plaza Lesseps, Barcelona, View of Terminal Stacks Which Double as Lighting for Park (Left); Plan and Section of Terminal (Right)

(Source: Envac, 2011)

As in the case of the conceptual terminal for the High Line/Chelsea Market situation, the terminal could be either free-standing or within another structure, at-grade or above- or below-ground as shown in Figure 4-4. In this case, the basic design decision would be whether the terminal would be at subway level (perhaps in a small side cavern bored from the bedrock in the course of tunneling for the subway itself) or somewhere above track level. Although containers of compacted materials from the terminal would then need to be lifted to street level for transport to transfer and/or processing facilities, a subway-level terminal might offer a number of advantages. One such potential advantage is that a small subterranean cavern drilled from bedrock might be the least-expensive real-estate in this area. Another is that a subterranean terminal would presumably require the least energy, since wastes from above-grade inlets could be flowed to the terminal with the assistance of gravity, while waste collected at subway level would not need to be pneumatically conveyed to the surface. (It is expected that it would be more efficient to elevate compacted containerized waste on a periodic basis than to pneumatically pull small volumes of separate fractions on a much more frequent basis.)

The 4,300 sf terminal could be located anywhere adjacent to the north-south pipeline, for example under a small section of the open space surrounding the four-block New York City Housing Authority (NYCHA) complex between 97th and 100th Streets. Fitting the terminal into an MTA structure being developed in conjunction with the subway construction would offer a number of logistical and institutional advantages. In addition to the possibility of a track-level side cavern, such a terminal could be incorporated into one of the stairway-elevator structures that will provide access to the 96th Street station, or into the street-level utility building on 97th Street. But the site that would appear to offer the least number of challenges is the one suggested by an MTA representative: the lot at the southeast corner of Second Avenue and 95th Street, where a slurry mill had been placed while tunneling was underway. The site, owned by the Parks Department, had not yet been returned to Parks's jurisdiction. The concept was that a temporary, grade-level terminal could be put there for near-term use while the subway system is still under construction (Figure 3-8), and a permanent terminal could be built there--below the grade of the park, as is commonly done in European pneumatic installations (Figure 4-4)--for long-term use. This terminal location is the small white rectangle shown in the network layout (Figure 4-3).

The capital costs of such a system would be approximately $10.8 million.[47] Annual operating costs, without dray costs for moving the filled containers from the terminal to the disposal facility or debt service,

[47] Terminal costs do not include the building shell, the costs of which will vary significantly depending on location and material specifics. The sum of the dray components is the total cost of hauling containers from the AVAC terminal to what is traditionally considered "the end of the collection route" or "first dump": a

would be approximately $557,000; total annual costs, including dray ($92,000) and debt service ($639,000), would be about $1.3 million. The capital and operating cost components are summarized in Table 4-1. As with the High Line network, all capital expenditures that can be estimated based on the information available are included: the cost of pipe, inlets and terminal equipment as well as their installation. As with the High Line network, the cost of constructing the terminal building is not included because the cost will depend on the type of terminal building designed. To test the sensitivity of the NPV to additional construction costs we added the cost of a 4,300 sf terminal building based on average local construction costs and at a rate four times higher ($400,000 to $1.6M). Including these costs raised the baseline NPV between 7 and 20%.[48]

Table 4-1: SAS Capital Cost Components

		Units	Cost
	Tons/Y:	7,239	
Capital Components	Terminal SF	4,300	$2,600,000
	Trunk Pipe (in 2nd Ave) (meters)	430	$860,000
	Trunk Pipe (in NYCHA) (meters)	455	$989,625
	Subway-Level (PVC) Pipe (meters)	300	$560,000
	Outdoor Inlets	180	$5,400,000
	Subway Inlets	12	$360,000
	Total		**$10,769,625**
	Capital Cost Per Annual Ton		$1,488
	Debt Service (34yrs)/Y		$639,068
	Debt Service/T		$88
Expense Components	Labor (Facility) Employees	2	$301,231
	Electricity (kwh)	302,330	$73,885
	Minor Repairs+Spare Parts/Y		$36,454
	Employee Vehicle		$10,423
	Office Supplies		$3,180
	Telephone/Water		$3,510
	Component Replacement/Y		$128,141
	Total/Y (-Dray, Debt Service)		**$556,824**
	Cost/T (-Dray, Debt Service)		$77
Dray Components	Labor Shifts/Y	121	$62,072
	Diesel (Gals/Y)	2,393	$8,017
	Vehicle Cost+Maintenance/Y		$12,346
	Tolls	338	$9,119
	Total Dray/Y		**$91,554**
	Total Dray/T		
Cost Summary	**Total/Y (Opex, Dray, Debt Service)**		**$1,287,446**
	Total/T		$178

transfer station for long-distance transport to a remote disposal facility, a recycling or organics processing center, or a local waste disposal (e.g., waste-to-energy) facility.

[48] For calculation and construction cost sources see Appendix Table B-1.01.

WASTE VOLUMES AND FRACTIONS FROM SECOND AVENUE, 92ND TO 99TH STREETS, ABOVE AND BELOW GROUND

In addition to waste generated by passengers, vendors, and employees in the 96th Street subway station, street-level wastes from five types of sources could be available along the stretch of Second Avenue between 92nd and 99th Streets: residential waste, commercial waste, waste from the NYCHA apartment buildings, non-hazardous wastes from Metropolitan Hospital, and pedestrian waste from street-level litter baskets. All of these waste streams with the exception of commercial waste and subway waste, are collected by the NYC Department of Sanitation (DSNY).

The waste volumes from these sources, by material type, are presented in Table 4-2.

Table 4-2. Second Avenue System Waste Volumes and Fractions (Tons/Day)

	Residential Refuse	4.37
	Residential Paper/OCC	0.76
Residential	Residential MGP	0.41
	NYCHA Refuse	4.25
	NYCHA Paper/OCC	0.73
NYCHA	NYCHA MGP	0.40
	Hospital (Non-Haz) Refuse	4.10
	Hospital Paper/OCC	0.71
Hospital	Hospital MGP	0.39
	Street Litter Bins Refuse	0.31
	Street Litter Bins Paper	0.19
Litter Bins	Street Litter Bins MGP	0.10
	Commercial Refuse	2.46
	Commercial Paper/OCC	0.32
Commercial	Commercial MGP	0.15
	Subway Refuse	0.10
	Subway Paper/OCC	0.06
Subway	Subway MGP	0.03
	Total Refuse	15.58
	Total Paper	2.77
	Total MGP	1.48
	Total/DAY	**19.83**
	Total/Year	**7,239**

Section 5

COMPARATIVE ECONOMIC AND ENVIRONMENTAL IMPACTS OF HANDLING WASTE IN MANHATTAN VIA RETROFIT PNEUMATIC INSTALLATIONS USING EXISTING TRANSPORTATION INFRASTRUCTURE VS. CONVENTIONAL MANUAL COLLECTION

CURRENT OPERATIONS

In the High Line/Chelsea Market case, only one private carter currently serves the hundred businesses in the complex. Given New York City's commercial-waste regulatory structure, which limits contract terms to two years,[49] there is no way to predict which carters, or how many, may be serving the complex in future years. At present, however, this carter sends four trucks to the market seven days a week to collect three waste fractions from the complex's loading docks: refuse, dry recyclables (paper, OCC, metal, glass), and compostable organics. Although, with a change of carter(s), or for many other reasons, the locations of garages and transfer or processing facilities can change, we think that our calculations of impacts based on truck-miles traveled to these current locations are representative of the order-of-magnitude differences between conventional and pneumatic collection. Since the cost-structures associated with private-carter collection are not publicly accessible, DSNY cost-structures were used to estimate costs. While private-carter costs may be somewhat less, these baseline costs nonetheless represent actual truck-based collection costs in New York City.

High Line wastes are deposited by park visitors in one of three types of litter-bins (refuse; paper; metal/glass/plastic). The filled plastic bags from these bins are loaded onto hand carts or bicycle carts by High Line staff and are taken for temporary storage to containers in a siding that extends off the High Line over 11th Avenue between 16th and 17th Streets. Three times a week--or on an as-needed basis--this material is loaded onto a passenger elevator at 18th Street to be taken to the street and piled at the curb. The bags are collected by the NYC Parks Department in rear-load compactors.[50] Refuse is driven to a rail-transfer yard in the South Bronx for transport to a landfill in Virginia.[51]

Figure 5-1. Current High Line Collection from Carts to Staging to Curbside (Via Elevator)
(Source: Miller 2011)

[49] http://www.nyc.gov/html/bic/html/trade_waste/customer_info_contracts.shtml, last accessed 2-6-13.

[50] Refuse collection operations are expected to change when the High Line's headquarters shifts to a dedicated building adjacent to the High Line in 2013.

[51] Recyclables are taken to processing facilities. The costs and impacts of recyclable-management are not considered here, because they would not be affected in this pneumatic installation scenario.

Figure 5-2. NYCHA Residents Protest Relocation of Central Compactor Containers and Truck Access to Picnic Area[52]

(Source: East Harlem Preservation, 2012)

In the Second Avenue case, both DSNY and the various private carters who collect commercial waste from the small-scale businesses on this stretch of Second Avenue use rear-load compactor trucks to collect residential waste from private buildings, recyclables from all buildings, business waste, and litter-basket waste. DSNY uses RO-ROs to collect containerized refuse from four exterior compactors at the NYCHA complexes and a private carter collects from two compactors at the municipal hospital. Subway waste is hauled by daily work trains to an open-air subway maintenance yard, where it is picked up by a private carter and taken to a private transfer station in Brooklyn.

The trucks for DSNY's RO-RO collections are based in a garage immediately adjacent to the NYCHA collection locations, on 99th Street between First and Second Avenues. This containerized refuse is taken to the Essex County Waste-to-Energy Facility in Newark. These were the origin, collection, and transfer locations assumed for purposes of calculating the DSNY RO-RO mileage for this analysis; RO-RO mileage for waste from the hospital was calculated using the current private carter's garage location (in New Jersey) and transfer station (in the Bronx). It was not possible to calculate actual rear-loader route miles, since the volumes of different types of materials from different types of generators that would be collected by municipal and private rear-loaders from this hypothetical project catchment area in each case would represent only a fraction of a typical truck load. Therefore, mileages were based on recent average data for this general region of Manhattan, and were apportioned based on the proportion of typical loads that the target volumes of refuse and recyclables would represent. (Again, there are differences between private routes and municipal routes, and between various private carters' routes, but we think that the data used are adequate for characterizing the differences in current Manhattan conditions between pneumatic and conventional collection.)

COMPARATIVE COSTS AND IMPACTS, THE PNEUMATIC ALTERNATIVE VS. CONVENTIONAL COLLECTION

Although direct operational costs for the automatic-pneumatic systems are less than those for the conventional-manual systems, the relatively high initial capital costs of the conceptual pneumatic systems compared to those imputed for the conventional systems (nearly $11 million for the pneumatic systems vs.

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[52] East Harlem Preservation Facebook Post, "NYCHA Tenants Protest Planned Transfer of Garbage Compactors," accessed 6-13-13.
tps://www.facebook.com/media/set/?set=a.342819339104195.95039.191628410889956&type=1, accessed 6-13-13. For management response see: http://www.nyc.gov/html/nycha/html/news/washington-garbage-compactors.shtml, accessed 6-13-13.

$1 to 2 million for manual collection)[53] mean that the Net Present Value costs of the pneumatic systems are about 3 to 7 times higher than those for conventional collection (for the Second Avenue Subway and Highline installations, respectively). However, if externality benefits on the order of $300,000 to $400,000/year can be realized with pneumatic collection--as appears likely given the associated space and generator-labor savings as well as public-health savings through reduced accidents, reduced diesel-particulate emissions, and other market-enhancing and/or potentially monetizable benefits--this negative cost differential would be erased. As figure 5-2 illustrates, residents protested the relocation of the community's garbage compactors from a relatively isolated location to a picnic area between two residential buildings. NYCHA managers studied other locations, but since they were unable to find a better one, they promised, as a compromise, to rebuild the picnic area elsewhere and to provide newer, quieter compacting equipment. The costs in time, energy, and quality of life that residents and management must make to accommodate manual collection are difficult to quantify. If these and other externality benefits were realized, the cost comparison would favor pneumatic collection.

Table 5-1. Comparative Costs of Pneumatic and Manual Systems

		HL Trucks	HL AVAC	SAS Trucks	SAS AVAC	HL A/T	SAS A/T
Waste Tons	Tons/Year	**Total TPY**	**3,942**	**7,239**	**7,239**		
Cost	CapEx	$1,224,323	10,569,820	$2,339,919	$10,769,625	8.63	4.60
	Annual OpEx+Replacement **w/o** Dray, DS	$667,814	$466,689	$834,452	$556,824	0.70	0.67
	Annual Debt Service	$72,651	$627,211	$138,413	$639,068	8.63	4.62
	Annual OpEx **w**/Dray + DEBT SERVICE	$740,505	$1,145,039	$972,865	$1,287,446	1.55	1.32
	Annual OpEx **w**/Dray + Debt Service/Ton	$188	$290	$134	$178	1.55	1.32
	NPV Ratio, P/M		6.6		3.3		
	Externality Benefits/Y to Balance NPV		$407,000		$310,000		

It will be noted from Table 5-1 that the economic performance of the two pneumatic installations differs somewhat in comparison with conventional collection. These differences reflect the quite different characteristics of the specific manual-truck systems against which the pneumatic concepts are being compared. The costs and efficiencies of conventional collection vary greatly depending on factors such as the degree of containerized (RO-RO) collection versus rear-loader collection (manually loaded bags or semi-automatic lifting of carts); the ratio of refuse to recyclables (refuse collection is less expensive than recyclables collection, in large part due to the relative volumes and densities of the respective waste streams); the waste-generation density of the collection route (how much waste is collected at each stop; how many stops and the length of the route needed to fill a truck); and the length of travel distances from the truck's garage of origin to the collection route and from the end of the collection route to the dump site. For a number of case-specific reasons, current conventional collection operations in these two locations are already--in comparison to typical New York City operations--highly efficient.

In the case of Chelsea Market and the High Line, almost 90% of the tonnage managed in the target catchment area is commercial waste (as shown in Table 3-2) which is collected from a one-block area,[54] consists primarily of relatively high-density materials (refuse, organics, OCC/paper), and it is collected by just one private carter whose garage of origin is relatively close to the collection site and whose dump site is not particularly far from the collection route. While it is true that, because of the different waste streams and the different collection times required by the waste-generators (customers), the material requires 4 daily truck trips (rather than the 1 trip that, from a strict capacity perspective, could accommodate that volume of material), this is still a quite-efficient collection situation by current New York City standards. Collection of materials from the High Line at the curb is also relatively efficient by New York City

[53] Imputed costs of conventional collection are derived from DSNY data, since adequate data on private carters' costs are not publicly available. Although private carters' costs would differ somewhat from DSNY costs, due to the differences between municipal and private operations, we think that using DSNY data to characterize all truck-based collections is adequate for the purposes of a general comparison of manual vs. pneumatic collection. The relative magnitude of these respective costs is generally consistent with the values reported in the literature sources previously cited. Details on how the costs of conventional (DSNY) collection were derived are in Appendix A, Table 1.1.

[54] Most of the material is collected from the loading docks on just one side of the building--i.e., one side of one block-long street.

standards, since the bagged volumes are aggregated at just one pick-up spot and are collected only when there is a significant accumulated volume.

The Second Avenue Subway case also offers relatively high manual-collection efficiencies (relative to the typical New York City situation) due to several unusual characteristics of the target catchment area. First, a high proportion of the waste (over 40%, as shown in Table 4-1) is collected by RO-RO from the NYCHA buildings and Metropolitan Hospital; for obvious reasons, RO-RO collection is much more cost-effective than manual rear-loader collection. In addition (as shown in Appendix B, Table B2.2), the haul distances in this particular catchment area are relatively small since the RO-RO garage is only a block away from the two container-generators.

With debt service included, the SAS pneumatic system's incremental opex costs over conventional collection are therefore somewhat less than the HL pneumatic system's incremental costs. The primary reason for this is that the SAS installation handles 85% more waste than does the HL plant, while overall capex is about the same (a difference of only 2%). This shows the importance of maximizing throughput to take advantage of a pneumatic installation's fixed capacity (as was also shown by Teerioja et al). With higher throughput through the HL system--where adjacent buildings offer plenty of potential opportunities for other easily-accessible waste--the per-ton costs (and incremental increase over conventional collection) would diminish significantly. Likewise, if SAS input volumes increased to the terminal's maximum effective capacity (which could be about 10 more tons a day), its already-modest incremental cost over that of conventional collection would further decrease.[55]

Note that the comparison of pneumatic to conventional collection costs in Table 5-1 pertains *only to the direct costs of the pneumatic system itself (including container dray and debt service) and the direct costs of conventional collection (including the pro-rated per-ton debt service of the equipment/facility capacity used) from the point where the waste is loaded onto a truck at curbside, loading dock, or compactor to the "first-dump" site.* This comparison does *not* include the waste-management and collection costs borne by the generator. These quantifiable costs associated with conventional collection, or potential savings due to pneumatic collection--lost revenue due to the use of space for waste storage and staging; labor hours--are shown in Table 5-8. (In addition to these clearly monetizable private-sector waste-generator factors, depending on the specifics of the situation there may be other potentially monetizable benefits associated with pneumatic systems--e.g., enhanced marketability of space or retail commodities.) Nor does the comparison in Table 5-1 include reduced drayage and handling costs due to the fact that the containerized waste removed from the terminals is ready to be loaded onto long-distance transport vehicles; savings due to reduced demand on transfer station or long-distance transport capacity; or potential reductions in disposal costs.

Note also, with regard to the capex and opex shown in Table 5-1, that the opex for the pneumatic systems includes ongoing replacement of all components after the initial construction/installation (the cost of which is represented by the capex figure and amortized over the presumed 34-year life of the bond). The steel trunk straight pipes are replaced every 20 years, for example, the exhaust fans every 15 years, and the compressors every 5 years.[56] For the pneumatic systems, then, after the capex debt service is paid off after 34 years, there are no more capital expenses or debt service over the system's remaining indefinite lifetime. For the manual system, this is not the case: capital costs and debt-service payments will continue indefinitely as trucks continue to be replaced on something like a 7-year cycle. After the pneumatic system's first 34 years, then, the all-in costs of the pneumatic systems will be significantly less expensive than those of truck-based collection.

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[55] This could be achieved by extending the street-level and/or subway-level trunk lines either north and/or south on Second Avenue, as would be technically feasible up to a total distance of about 20 blocks (approximately one mile). The current study considered only the section between 92nd and 102nd Streets simply because this is the area where the MTA currently has the street open and covered with a temporary metal plate, which would allow easy access for trunk-line installation.

[56] R. Rello, Envac, to Miller and Spertus, 2-20-13, "Update."

With regard to energy use and GHG emissions, there are also modest differences between the performance of the two pneumatic systems due to the specific circumstances associated with their target catchment areas. Three important factors are the number of truck miles travelled, the type of truck that does the traveling, and the nature of the collection route. As noted above, these factors are determined by local circumstances--the location of garages and dump sites relative to the collection routes, the length and density of the collection routes, whether the collection is by rear-loader or RO-RO, and whether the waste source is residential or commercial and the collector municipal or private. In the SAS case (with the unusually small distances for its RO-RO collections), the reduction in truck miles achieved by the pneumatic system is about 65%, while there would be about a 75% reduction for the HL, as shown in Table 5-2. Note that the decline in fuel use in both cases is not proportional with the relative decline in truck miles because of the different collection circumstances: the HL manual case involves essentially just two "stops"--90% of the waste is collected by a commercial carter from a single block-long commercial complex and the remainder is collected by municipal collectors from one curbside location where litter bags from High Line Park are piled. And because of the difference between commercial collection operations run by "Class A"-building carters (with large volumes coming from relatively few customers relatively closely spaced) and municipal collection operations (with many relatively smaller stops, more-frequent idling and compaction, and longer collection routes relative to dump routes), overall fuel efficiency in the HL case is higher.[57]

Table 5-2. Comparative Truck Miles and Fuel Use

		HL Trucks	HL AVAC	SAS Trucks	SAS AVAC	HL A/T	SAS A/T
Waste Tons	Tons/Year	**Total TPY**	**3,942**	**7,239**	**7,239**		
Electricity	Kwh/Y		126,774		302,330		
	Kwh/T		32		42		
Truck Miles	Total Truck Miles/Y	36,952	8,972	36,399	11,966	0.24	0.33
	Truck Miles/Y Saved v. Manual		27,980		24,433		
Fuel Use	Gals/Y	12,499	1,945	27,435	2,400	0.16	0.09
	Gals/T	3.17	0.49	3.79	0.33	0.16	0.09
	Gals Saved/Y v. Manual		10,554		25,035		

This diesel fuel use is reflected in overall energy (BTU) use and in GHG (CO2-eq) emissions, but for the pneumatic systems, these values also include the energy use and emissions associated with the electricity used to power the pneumatic systems. The per-ton difference in kWh between the two pneumatic systems is largely explained by the fact that the HL system would have many fewer inlets than are used in the SAS system and 90% of the waste would start from one location and travel a lesser distance (as shown in Table 5-3), thus requiring a significantly smaller expenditure of pipeline-transport energy. Envac's projected per-ton electricity consumption for both HL and SAS is relatively low compared to both the rate sited in Punkkinen, 2012 and to Envac's projections for Roosevelt Island upgrades. This is due to the specific circumstances of the proposed systems (number of inlets, length of pipes, waste volumes and source locations). But to test the effect of increased kWh use on overall energy use and GHG emissions, for the HL case we examined per-ton kWh increases of 20%, 50%, and 300% (which would be 96 kWh/ton, the rate used in Punkkinen, 2012). The rate of increase in overall energy use and CO2 emissions was about two thirds that of the increase in kWh increase. With 20% and 50% increases in kWhs, BTUs and GHG emissions are still lower than they would be with conventional collection. At 96 kWh per ton, or three times the projected consumption, the energy use and GHG emissions of the HL systems is about the same as for manual collection.

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[57] The relative energy efficiency of Manual collection in the SAS case, which include DSNY truck miles, may be slightly greater than is shown in this analysis. The emission factors used for heavy-duty trucks, as documented in the appendix, are those used in the latest PlaNYC for NYC-specific conditions. NYC DSNY trucks are likely to achieve greater fuel efficiency than the citywide fleet, due to the Department's aggressive use of the latest low-impact technology. http://www.nyc.gov/html/dsny/downloads/pdf/pubinfo/annual/Hybrid/LL38_2013_Final.pdf, accessed 6-3-13.

Table 5-3. Capital Cost Components of High Line and Second Avenue Subway Pneumatic Installations

HL Capital Costs			SAS Capital Costs		
Terminal SF	6,900	$2,892,362	Terminal SF	4,300	$2,600,000
Trunk Pipe (meters)	1,729	$5,671,724	Trunk Pipe, in 2nd Ave (m)	430	$860,000
			Trunk Pipe, NYCHA	455	$989,625
			Subway Pipe	300	$560,000
Outdoor Inlets	24	$1,347,075	Outdoor Inlets	180	$5,400,000
CM Waste Rm/Inlets		$658,659	Subway Inlets	12	$360,000
TOTAL		$10,569,820	TOTAL		$10,769,625

The story with relative GHG emissions is similar to that for BTU use. Both pneumatic cases emit about the same amount of GHG per ton, and both emit less than half the GHG of conventional collection, as shown in Table 5-4.[58]

Table 5-4. Comparative Energy Use and GHG Emissions

		HL Trucks	HL AVAC	SAS Trucks	SAS AVAC	HL A/T	SAS A/T
Waste Tons	Tons/Year	Total TPY	3,942	7,239	7,239		
Energy Use	BTUs/Y	1,736,082,548	702,718,358	3,810,753,767	1,364,923,741	0.40	0.36
	BTUs/T (wtd avg)	440,407	178,264	526,408	188,547	0.40	0.36
	BTUs/Y Saved v. Manual		1,033,364,190		2,445,830,026		
	Electric BTUs/T (wtd avg)		109,734		142,502		
	Diesel BTUs/T (wtd avg)	440,407	68,530	526,408	46,045	0.16	0.09
GHG	GHG T/Y	141	66	309	132	0.47	0.43
	Annual T GHG/Waste T (wt avg)	0.04	0.02	0.04	0.02	0.47	0.43
	GHG T/Y Saved v. Manual		75		177		

In addition to the benefits of reduced energy use and GHG emissions, there are the significant environmental advantages with both pneumatic systems due to the substitution of electricity for diesel fuel. Electric power not only produces lower levels of local emissions such as diesel particulate and sulfur and nitrogen dioxide (which are of particular public-health significance in a dense urban environment), but offers the potential (depending on the source of the electricity) for displacing non-renewable fossil fuels and reducing carbon emissions. (See Appendix A, Table A-2-3 for a breakdown of the current sources of New York City's electricity supply).

The comparative impacts of the two pneumatic cases relative to conventional collection for their target catchment areas are summarized in Figures 5-3 through 5-6.

[58] See footnote #53. For the same reason given there, GHG emissions for the DSNY fleet used in the SAS case are likely to be somewhat lower than those used in this analysis based on the citywide fleet.

Figure 5-3. Annual Truck Miles, Manual vs. Pneumatic

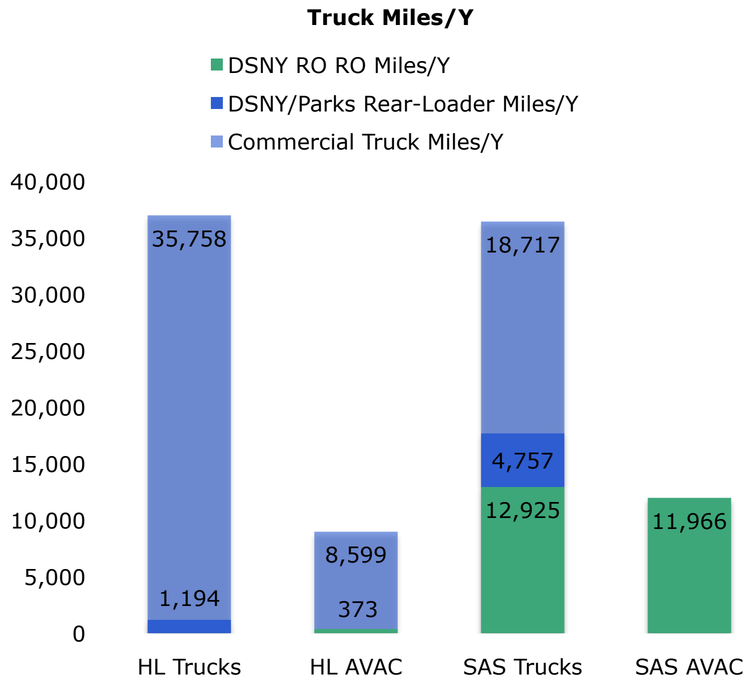


Figure 5-4. Annual Electric vs. Diesel Energy Use (BTUs), Manual vs. Pneumatic

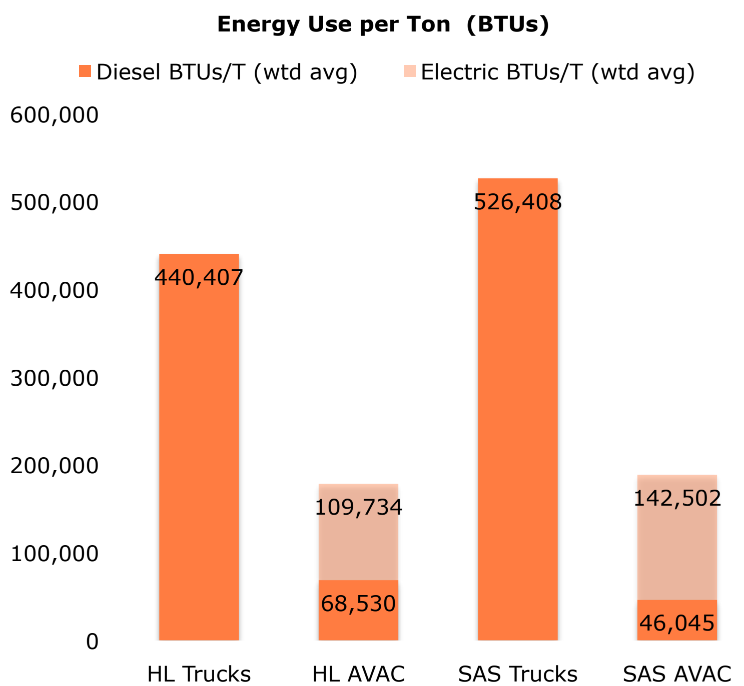


Figure 5-5. Annual GHG Emissions (tons CO2-eq), Manual vs. Electric

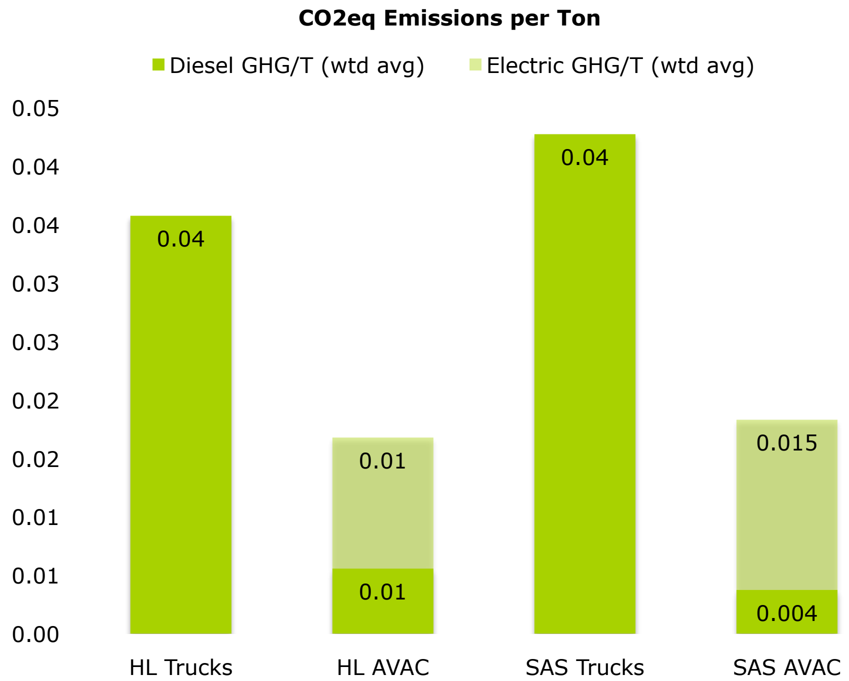
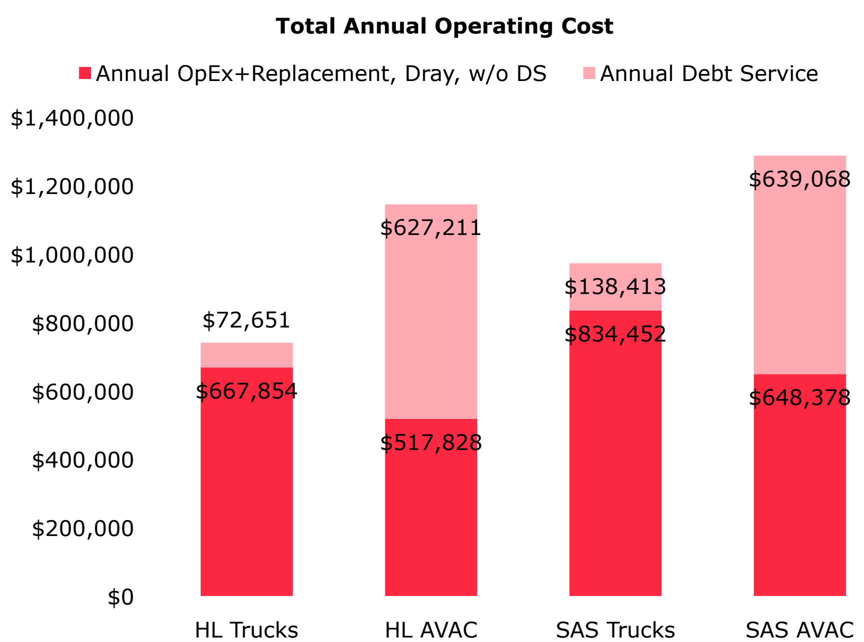


Figure 5-6. Annual Operating Costs, Including Ongoing Component Replacement and Debt Service, Manual vs. Pneumatic



In addition to the direct BTU-use and GHG-emission figures presented in Table 5-4 there are other upstream and downstream energy and emission impacts, the analysis of which is beyond the scope of the present study. A preliminary consideration of a broader range of such factors, however--such as the energy use and GHG emissions associated with the production and disposal of garbage trucks that have a 7-year life--suggests that the differentials shown in Tables 5-5 and 5-6 would be affected only marginally.

The factors likely to produce the most significant reductions in the BTU and GHG costs of pneumatic collection are those pertaining to the positive downstream effects on the larger waste-management system. To the extent that pneumatic installations allow or encourage waste-management practices that reduce the volumes of waste requiring long-distance transport to remote landfills (by reducing waste generation and/or shifting material from the refuse stream to the recyclable stream due to the economic incentives provided by metering, or by increasing the quality of the recyclable fraction, and hence reducing its residue rate), significant direct economic and environmental savings could be achieved not only from reduced transport and disposal requirements but also from the energy use and emissions avoided by producing fewer materials in the first place. (Each one-pound reduction in refuse produced avoids the generation of 61 pounds of upstream extraction, production and distribution waste.)[59] By allowing the metering of waste produced by residential buildings--something which would be possible, but more logistically difficult to do without pneumatic collection--long-distance transport and disposal needs could be reduced by an estimated 12%. Table 5-7 provides an illustration of the waste-volume reductions and economic and environmental savings that might be expected from such metering, using the case of Roosevelt Island's waste generation as an example.

Inlets for other waste sources--with the exception of pedestrian litter bins--could also be metered. Knowing the relative volumes introduced by each business, hospital, or NYCHA generator would be useful for managing financial accounts for the overall system and for apportioning costs between public and commercial generators. Waste-volume reductions from these other generator types would not be expected to be as large as those anticipated from residential generators, however, since business generators are already charged on a unit basis and the public-sector costs of collection from NYCHA and the hospital would not be expected to produce comparable economic incentives for these institutions or the individuals within them.[60]

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[59] Adam I. Davis, *Ecofables/Ecoscience* Vol. 1, No. 2, Summer 1998. An occasional publication of the Center for Conservation Biology, Stanford University.

[60] Metering for commercial waste generators would replace the current billing system used by private carters. It is presumed that the metered rates charged to these businesses would not be significantly higher than the maximum rates now established by NYC regulation, since the direct operating costs of the pneumatic system (not including debt service) are less than the operating costs for conventional collection, and since it is presumed that at least a significant portion of the capital costs for a system that collected waste from multiple residential and commercial sources would be provided by a public entity as a long-term investment in public infrastructure. If residential generators were also metered, the presumption is that they would receive a parallel reduction in property taxes (or a rent reduction commensurate with the landlord's reduction in property taxes) so that they would not incur an added expense due to this alternative method of charging for services that are currently paid for out of general tax revenues.

Table 5-5. Total System Impacts, Including Transport and Disposal, Upgraded Pneumatic (With Waste Volume Metering) vs. Conventional Collection (Roosevelt Island Example)[61]

	No-Action OR Manual	**Upgrade**
Residential Refuse TPD	7.33	6.45
Residential Paper TPD	1.96	2.20
Residential MGP TPD	1.27	1.48
Total	10.56	10.14
W/ Avg 6% Source Reduction		9.93
REFUSE		
Transport+Disposal Cost/Yr	$382,589	$336,679
Transport+Disposal Savings/Yr		$45,911
Transport Fuel/Gals Yr	6,827	6,008
Transport Fuel Savings/Gals Yr		819
Transport GHG/Yr	88	78
Transport GHG Savings/Yr		11
Disposal GHG/Yr	270	237
Disposal GHG Savings/Yr		32
Total Transport+Disposal GHG	358	315
Total Transport+Disposal GHG Savings		43
Transport BTUs/Yr	948,271,737	834,479,128
Transport BTU Savings/Yr		113,792,608
Transport Truck Miles/Yr	1,264	1,113
Transport Truck Mile Savings/Yr		152

Economic and environmental savings would also be realized due to reduced needs for additional handling, compaction, and containerization at transfer stations, since pneumatically collected waste would be compacted and containerized at the collection terminal. It is difficult to quantify the actual transfer-savings achieved because--unless all waste that would be handled in a particular transfer station serving a specific waste shed were collected pneumatically, which is not likely to be the case in the foreseeable future--the need for these transfer stations would not be eliminated. And the relative capacity savings produced by the specific pneumatic installation proposed would produce only a negligible reduction in overall facility demand. Nonetheless, New York City's planned barge-transfer facilities are hugely expensive,[62] particularly because they are merely an intermediate handling step before transport to yet-another transfer facility to lift containers out of barges and onto train cars. This very costly additional transport-transfer step could also be avoided with pneumatic collection, since the containers could avoid the barge facility and barge trip and move straight to rail.

In addition to the direct economic costs and benefits, and the direct comparison of relative BTU use and GHG emissions, there are other potentially quantifiable economic and environmental impacts as well as harder-to-quantify quality-of-life benefits (e.g., increased service frequency and reliability, reduced odors and aesthetic nuisances, reduced space competition for pedestrian and vehicular traffic, and reduced numbers of animal and insect pests--particularly rats).

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[61] C. Kamga, B. Miller, and J. Spertus, "Eliminating Trucks on Roosevelt Island for the Collection of Wastes," July, 2013. A feasibility study for the New York State Energy Research and Development Authority prepared by the University Transportation Research Center, Region 2.

[62] If a Net Present Value analysis of waste-system alternatives were conducted, the barge-transfer facilities being built or planned by DSNY might be expected to produce highly uncompetitive NPV values.

An exhaustive analysis of all potentially quantifiable impacts is beyond the scope of the present study. But other researchers have provided monetary estimates of the value of such related factors as:

- Reduced roadway maintenance costs due to pavement damage from heavy-duty trucks
- Travel-time savings to the public and to businesses from reduced traffic congestion
- Reduced accidents to sanitation workers (with associated reductions in disability payments) and civilians
- Reduced public-health costs due to reductions in emissions of public-health concern (e.g., cancer- and asthma-inducing particles of small soot from diesel exhaust [especially particulate matter 2.5 microns or less in size--PM-2.5])
- Enhanced property values due to quality of life improvements from the elimination of street-level staging of garbage containers and bags, and corresponding reductions in mess, odors, pests and noise pollution from truck idling and compactor equipment.

In a dense urban environment, one of the most significant private-sector savings associated with pneumatic collection is from the recovery of rentable or saleable space, both interior and exterior. These savings may not be applicable to existing buildings, where the space might not be recoverable, but could be a direct source of revenue from new developments.[63] Until recently, all building owners in New York City were allowed to make their own assessment of how much space was needed to store waste and recyclables for the 72-hour-period mandated by the Building Code. In 2011, the Department of City Planning added square footage requirements for residential buildings in districts included in the "Quality Housing Program." Local Law 60 of 2012 amended the city's Building Code to specify the space required in all new multi-family buildings for the storage of recyclables. Specifically exempted in the legislation are the pneumatic-system-served buildings on Roosevelt Island.[64] If pneumatic service were introduced in buildings elsewhere in the city, so that residents could place their waste and recyclables directly into pneumatic inlets, all of the space, equipment (compactors, bags, carts), and labor associated with in-building storage and removal of waste materials (other than bulky materials too large to be introduced into a pneumatic system) would be eliminated. In addition to the square footage thus recovered, the demands currently imposed on critical building infrastructure such as elevators and loading docks would be reduced, making them more available for other types of uses. The extent of the potential savings will depend on the number of inlets and fractions included in the system. In the case of the High Line, for example, labor would be reduced significantly because visitors would deposit refuse directly into the system, whereas Chelsea Market employees would have to store and ferry material to the central waste room. On the other hand, Chelsea Market businesses would control how often waste is deposited into the system and therefore what size storage containers they needed to use and how they needed to organize their utility space. An analysis of some of these potential savings for the High Line and the Second Avenue Subway installations case is presented in Tables 5-8 and 5-9.

[63] While some of this potentially recoverable space would be in hallways and ground-level areas that would be suitable for other high-value use, some of the recoverable space would be in less-desirable basement areas that would offer less economic value.

[64] The Quality Housing Program stipulates 12sf for each waste room and a storage and removal area of at least 2.9 cubic feet per dwelling unit. The new legislation orders that the Building Code be amended so that all new multifamily buildings must provide 5 sf of space in each waste room for recyclables and up to 350 sf for centralized storage and removal. (Local Law 60 of 2012)

Table 5-6. High Line Space, Labor & Equipment Comparison, Manual vs. Pneumatic

Annual Cost to Chelsea Market Owner for Refuse Handling Space, Labor & Equipment				
	Space	Labor	Equipment*	Total
Manual refuse, occ	$ 326,800.00	$ 152,820.94	$ 108,931.56	$ 588,552.50
AVAC refuse, occ	$ 154,500.00	$ 152,820.94	$ 111,480.71	$ 418,801.65
Savings, AVAC v. Manual	$ 172,300.00	$ -	$ (2,549.15)	$ 169,750.85
Annual Cost to Friends of the High Line for Refuse Handling Space, Labor & Equipment				
	Space	Labor	Equipment	Total
Manual refuse	$ 80,000.00	$ 90,234.38	$ 17,288.00	$ 187,522.38
AVAC refuse	$ 40,000.00	$ 45,117.19	$ 495.00	$ 85,612.19
Manual Sub-Totals by Category	$ 406,800.00	$ 243,055.31	$ 126,219.56	$ 776,074.88
AVAC Sub-Totals by Category	$ 194,500.00	$ 197,938.13	$ 111,975.71	$ 504,413.84
Savings, AVAC v. Manual	$ 40,000.00	$ 45,117.19	$ 16,793.00	$ 101,910.19
Cumulative Savings By Category	$ 212,300.00	$ 45,117.19	$ 14,243.85	
Cumulative Total, Manual				$ 776,074.88
Cumulative Total, AVAC				$ 504,413.84
Cumulative Savings, AVAC v. Manual				**$ 271,661.04**

Table 5-7. Second Avenue Subway, Labor & Equipment Comparison, Manual vs. Pneumatic[65]

Annual Cost to Residential Building Owners for Refuse Handling Space, Labor, Equip.					
		Space	Labor	Equipment	Total
Manual refuse, mgp, occ		$1,658,546	$231,282	NA	$1,889,829
AVAC refuse, mgp, occ		0	$192,575	NA	$192,575
Savings, AVAC v. Manual		$1,658,546	$38,707		$1,697,253
Annual Cost to NYCHA for Refuse Handling Space, Labor & Equipment					
		Space	Labor	Equipment	Total
Manual refuse		$1,391,100	$182,737	$35,422	$1,609,259
AVAC refuse		$81,900	$120,607	$0	$202,507
Savings, AVAC v. Manual		$1,309,200	$62,131	$35,422	$1,406,753
Annual Cost to Metropolitan Hospital for Refuse Handling Space, Labor & Equipment					
		Space	Labor	Equipment	Total
Manual refuse		$1,682,327	$110,483	$38,702	$1,831,513
AVAC refuse		$0	$72,919	$0	$72,919
Savings, AVAC v. Manual		$1,682,327	$37,564	$38,702	$1,758,594
Annual Cost to DSNY for Equipment					
		Equipment			
Manual refuse		$1,714			
Annual Cost for Subway Refuse Handling Space, Labor & Equipment					
		Space	Labor	Equipment	Total
Manual refuse		NA	$21,672	$373	$22,045
AVAC refuse		NA	$5,418	$0	$5,418
Savings, AVAC v. Manual			$16,254	$373	$16,627
Manual Sub-Totals by Category		$4,731,974	$546,175	$76,212	
AVAC Sub-Totals by Category		$81,900	$391,519	$0	
Cumulative Savings By Category		$4,650,074	$154,656	$76,212	
Cumulative Total, Manual			$5,354,360		
Cumulative Total, AVAC			$473,419		
Cumulative Savings, AVAC v. Manual			**$4,880,941**		

Based on these preliminary estimates, there would appear to be a reasonable likelihood of achieving at least the approximately $300,000 to $400,000/year benefit that would be required to equalize the costs of pneumatic and conventional collection--particularly for new buildings that are able to take advantage of the attendant space savings. If a significant proportion of existing buildings were able to capture the potential space savings associated with pneumatic collection, these preliminary estimates of potential space savings suggest that the savings could be an order of magnitude higher than those necessary to justify the capital investment in a pneumatic system.

[65] The terminal will require 4300 SF. The rent value will depend on where the terminal is located (basement, ground floor, upper floor). The space savings calculations here are meant to illustrate the savings that could be achieved. Refuse and recyclables tend to be staged in basement spaces rather than on the ground floor but for the purposes of comparison ground floor rents were applied. Existing spaces were not inventoried; instead the projected required SF based on 2012 recycling legislation and the Planning Department's "Quality Housing Program" (which currently only applies to certain districts) were used as the basis for estimating space requirements. In order to include bulky OCC in addition to paper, a baling machine would be needed. The space requirements and cost for the baling machines have not been included.

Security

An issue that merits consideration in the comparison of pneumatic and conventional waste collection systems is security. In the aftermath of 9/11, the Boston Marathon bombing, and other terrorist acts around the world in recent decades, the question naturally arises: What if someone dropped something like a pressure-cooker bomb into a pneumatic inlet? And what would happen if the pneumatic trunk line (as in the case of the proposed High Line or Second Avenue Subway installations) were suspended out in the open under a viaduct or inside a subway tunnel, rather than buried under the ground (as in the case of Roosevelt Island)?

The matter of security has faced all of the hundreds of pneumatic facilities built around the world over the past 50 years--particularly those built since 9/11/2001. As far as we are aware, no pneumatic installation has experienced any difficulties due to the introduction of explosive, incendiary, or toxic devices into the systems. On the other hand, the threats posed by conventional litter bins--which are ideally suited for the hidden placement of explosive materials, which offer metal surfaces that turn into sharp shrapnel in an explosion, and which are located at ground level where the explosive force may have a 360-degree lateral trajectory--are well-established. Litter bins were used as an effective shrapnel weapon by Irish Republican Army bombers in the 1970s, 1980s, and 1990s;[66] litter bins were therefore removed from subways and other crowded locations in British cities. Prior to the 2012 London Olympics, 100 custom-made bomb-proof litter bins were installed in London's financial district; they cost 25,000 pounds apiece.[67] Because of the dangers posed by the possibility of bombs in litter bins in crowded public spaces, they are removed from NYC's Times Square on New Year's Eve.[68] The most recent widely reported example of a bomb exploding in a litter bin--although no casualties were produced--was in Disneyland, in May, 2013.[69]

The largest pneumatic system in the world is at the Mosque, in Mecca.[70] It was built to serve the million pilgrims who descend on the tightly enclosed space on peak days,[71] in arguably the most violent region of the world. Security concerns therefore had to have played an important role in the choice between conventional and pneumatic collection. Apparently this analysis came out in favor of pneumatic tubes.

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[66] E.g., Record-Journal (Meriden, CT), 3-21-93 http://news.google.com/newspapers?id=o9hHAAAAIBAJ&sjid=DQANAAAAIBAJ&pg=4771,3402546&dq=child-4-dies-in-british-bombing&hl=en; http://en.wikipedia.org/wiki/List_of_terrorist_incidents_in_London; http://www.questia.com/library/1G1-61333492/bombers-strike-again-ira-litter-bin-blast-brings. All accessed 7-1-13.

[67] http://www.reuters.com/article/2012/02/03/uk-britain-bins-idUSLNE81203320120203, accessed 7-1-13.

[68] http://www.nydailynews.com/archives/news/times-square-safety-nypd-resolution-article-1.503111, accessed 7-1-13.

[69] E.g., http://alifestyleworthliving.com/employee-held-as-suspected-in-disneyland-bomb-scare/, accessed 7-1-13.

[70] E.g., http://www.metrotaifun.com/automatic_solid_waste_collection_system/index.php/en/news-media/metrotaifun-news-and-media/8-news/26-marimatic-2011-11-08-marimatic-oy-delivers-to-saudi-arabia-world-s-largest-automatic-solid-waste-collection-system-awcs, accessed 7-1-13.

[71] ISWSA, 2013 *Underground Solutions for Urban Waste Management*: http://www.iswa.org/en/525/knowledge_base.html?tx_iswaknowledgebase_searchbox%5Bsearchphrase%5D=Underground&cHash=30d970120a6a088fc022987f5e1b0666 accessed 7-1-13.

Figure 5-7: Pilgrims in the Al-Masjid al-Ḥarām Mosque, Mecca, Saudi Arabia
(Source: ISWA, 2013)

The professional judgment of security experts also favors pneumatic over conventional collection. Rather than causing an increased hazard, pneumatic tubes act as cannons that shoot the explosive charge out the end of the pipe into an enclosed centrifugal steel container in the terminal. It is likely, therefore, that the explosion would be contained and attenuated, rather than catastrophic, as it might be in a litter bin, garbage can, or plastic bag.

Section 6

IMPLEMENTATION

Developing either of the two facilities proposed in this report would require the coordination of a wide range of entities and the achievement of a number of preliminary objectives. In the case of the High Line/Chelsea Market concept, agreement to participate in the shared project would have to be obtained from:

- Friends of the High Line;
- the owner of the Chelsea Market complex;
- the private carter(s) currently serving Chelsea Market;
- the owner of the site in which the terminal would be placed.

In addition, construction financing would need to be obtained, perhaps from a consortium of public and private sources. Given the public-sector benefits associated with the facility, the project might qualify for City, State, or federal grant funds. Grants from non-profit foundations might also be available. It might qualify for operating-cost subsidies from public-sector entities--in recognition, for example, of the savings to the Parks Department and the Sanitation Department from reduced collection and disposal costs--which could provide revenue guarantees to facilitate private-sector financing. To the extent that the private carter(s) serving Chelsea Market would also experience reduced operating costs, some portion of these savings might also be assigned to paying interest on borrowed capital. Savings would also accrue to the owner of Chelsea Market through the recovery of dock space and interior space currently devoted at least part of the time to storing and staging refuse, recyclables, and source-separated kitchen waste, and through the enhanced marketability of its space. Businesses within the market would also enjoy greater control over waste staging and disposal, and perhaps increased revenues due to increased retail-customer satisfaction. Portions of these savings could also help to offset the costs of capital.

Another potential source of funding could be private sponsorships in return for the kind of global advertising benefits that an environmentally sustainable ("green") project might have. The city's recent experience with its expensive bikeshare program--known as "Citi Bikes" in recognition of a sponsorship agreement with Citibank--is illustrative of the significant financial resources that might be obtained in return for very substantial advertising benefits. Many major corporations might relish the prospect of being associated with a literally ground-breaking environmental initiative in the world's media capital. Google is one entity that comes to mind as having promoted innovative technological solutions to transportation problems (such as their driverless car initiative). It so happens that Google is located in the building which occupies the entire block immediately east of Chelsea Market--a building which might be connected to a Chelsea Market-High Line pneumatic installation.

In addition to acquiring routine permits from the Building Department and other relevant agencies for retrofitting the Chelsea Market and for building the terminal, it is possible that other administrative and/or environmental agencies (e.g., the New York City Business Integrity Commission) would also be required to conduct reviews and/or issue permits. Given that a pneumatic terminal's maximum capacity would be well under 12,500 tons a year, which is the threshold for a permit for a solid waste transfer station from the New York State Department of Environmental Conservation (DEC), the facility would not need a permit from the DEC.[72]

Under ideal circumstances, the terminal might be operated in coordination with any parallel pneumatic facility that might be constructed by the Related Companies at Hudson Yards (as the Related Company's

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[72]It would, however, need to be registered with the DEC. http://www.dec.ny.gov/chemical/23678.html, accessed 1-15-13.

Hudson Yards Web site has suggested may be a possibility).[73] Such coordination might involve the direct transfer of containerized materials onto railcars on the Amtrak-owned tracks adjacent to the Yard. Direct transfer, versions of which (based on conventional rather than pneumatic collection) have also been studied and found to be feasible by DMJM Harris on behalf of the Durst Organization, could also be carried out independently of any operations in which Related might be involved. Such direct rail transfer would require the cooperation of Amtrak, CSX, and MetroNorth.[74] Such a direct rail move, of course, would also need to be coordinated with the DSNY, under whose waste-transport and -disposal contracts these operations would have to take place.

This facility might also operate in coordination with a potential Hudson Yards pneumatic facility with regard to combined on-site management of source-separated organics, for example in an anaerobic-digestion facility that might be constructed under the Hudson Yards platform.

Further coordination with other building owners and developers along the High Line axis might allow additional waste from existing or future waste sources to be collected by the High Line pipe. This coordination might be extended northward, along the rapidly developing spine of the "Far West" re-zoned area above the planned Boulevard Park (over the below-grade northern extension of the old NY Central tracks) and above the #7 subway extension: a connecting pipe might be hung within the abandoned rail line under Boulevard Park and in the subway extension.

In the case of the Second Avenue Subway proposal, agreement to participate in the shared project would have to be obtained from:

- the MTA;
- DSNY;
- the uniformed sanitation workers' union
- NYCHA;
- the New York City Health and Hospitals Corporation (owner of Metropolitan Hospital);
- the private carters serving the businesses along that stretch of Second Avenue;
- the owner of the site in which the terminal would be placed (perhaps the Parks Department, which might provide a site below the ground-level surface of the Parks property at the corner of 95th Street).

Construction financing might be obtained from a combination of public and private sources, although (as argued below), in this multi-waste-generator case, ownership by a public entity is likely to be the most-desirable option. Given the public-sector benefits associated with the facility, the project might qualify for City, State, or federal grant funds (or from non-profit-foundation grants), or it might qualify for operating-cost subsidies from public-sector entities (in recognition, for example, of the reduced public-sector expenses to the Sanitation Department through reduced collection and disposal costs), which could provide revenue guarantees to facilitate private-sector financing. Insofar as the private carters serving businesses along the Avenue experienced reduced operating costs, some portion of these savings might also be assigned to paying interest on borrowed capital.

In addition to a building permit for the terminal, it is possible that other administrative agencies (e.g., New York City Business Integrity Commission) or environmental agencies would be required to conduct reviews and/or issue permits. Given that a pneumatic terminal's maximum capacity would be well under 12,500 tons a year, which is the threshold for a permit for a solid waste transfer station from the New York State DEC, the facility would not need a permit from the DEC, although it would need to be registered with them.

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[73] http://www.cityrealty.com/new-york-city-real-estate/carters-view/related-posts-new-renderings-information-hudson-yards-project/carter-b-horsley/39962, accessed 10-11-11.

[74] As noted above, representatives of all of these entities have previously indicated to one of this report's co-authors that such cooperation might well be feasible.

For both cases, the High Line and the Second Avenue Subway, the willingness of the sanitation workers' union to accept the introduction of pneumatic collection is an issue that deserves consideration since automated collection poses the potential for a reduction in union head count. (This issue also pertains to other potentially affected unions, such as those for building service staff.) Although a pneumatic installation requires fewer sanitation workers than does conventional collection (and possibly fewer building-staff hours), we do not think that from a citywide (or union-wide) perspective there would be an appreciable drop in head count due to the introduction of pneumatic collection: the limited rate at which it would be feasible to develop such systems across the city is likely to be outweighed by the increase over time in population and labor-demand. Moreover, given the ongoing demands for "clean streets" (a measure of municipal performance used in the annual *Mayor's Management Report*, as well as by the media[75]) there would be strong incentives, both from the labor and management sides, to use any labor savings produced by pneumatic collection for other sanitation services, e.g., street cleaning.

It is unlikely that unions would perceive the perforce incremental implementation of pneumatic collection as an entirely negative phenomena, since it would be accompanied by significant improvements in labor conditions. An historical precedent provides a basis for this prediction. The NYC sanitation union was a forceful supporter of the introduction of garbage bags in New York City, where garbage bags made their global debut in 1970 (with an accompanying national marketing campaign by Union Carbide, the maker of Glad® Bags).[76] The municipal government had to change its regulations, which required metal garbage cans, but in view of the significant labor and workers' compensation savings these plastic bags produced, the Lindsay administration was eager to do so. Despite the greater collection efficiency they entailed, the sanitation union was also eager to accept plastic bags because they made garbage collection easier and more pleasant, as well as helping to reduce worker injuries. A concern for worker safety is one of the primary reasons why Stockholm is considering the expansion of pneumatic collection in its historic central district.[77] On Roosevelt Island, in New York City, we were told by the superintendent of one residential building that a member of his building staff had requested a transfer to a building off the Island in order to reduce his commute. This porter quickly asked to return to the pneumatically-collected Roosevelt Island building because he was spending a significant part of his work day dealing with garbage bags--a distasteful task he had never before experienced.

There is also a precedent for the NYC sanitation union to share in productivity savings from a technological innovation. The most significant labor savings in DSNY's history came about with the introduction of the two-person truck. The standard collection truck, which had a driver and two collectors, was replaced by a new kind of truck equipped with steering wheels on both sides of the cab so that the driver could be eliminated: while the truck collected waste on one side of the street, the collector on the opposite side of the truck could jump into the cab to drive, with the allocation of roles reversed when the truck drove along the other side of the street. This citywide innovation produced an immediate 1/3 reduction in "posts." Since each post requires two workers to provide year-round coverage, the City immediately realized substantial savings. The union was also satisfied, because head count was reduced only through attrition, and the workers on two-person trucks received a significant "shift differential" which has continued to escalate over time. This productivity achievement is now taught in universities (e.g., Harvard's Kennedy School of Government and Columbia's School of Public Administration) as a shining example of effective municipal management.[78]

Another issue is the reaction of private carting companies to the introduction of a system that would combine the collection of residential and institutional waste (which is now collected by the municipality)

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[75] See for example, NYC's last-place rating for cleanliness among major U.S. cities in the 2012 *Travel and Leisure* http://www.travelandleisure.com/americas-favorite-cities/2011/category/quality-of-life-and-visitor-experience/cleanliness, accessed 7-8-13.
[76] E.g., "Paper and Plastic For Garbage Bags Will Get Test Here," New York Times, May 9, 1969, pg. 22; David Bird, "Cans That Go Clang in the Night May Yield to Paper and Plastic," New York Times, Dec 12, 1970, pg. 35.
[77] See footnote #16.
[78] Norman Steisel, Mayor Ed Koch's sanitation commissioner, carried out this initiative.

with the collection of commercial waste (which is now collected by private carters). While carters would be expected to oppose any system that reduced their customer levels, this need not necessarily be the case. One way of structuring the relationship between private and municipal collection would be to allow the carters to keep their current customers (or to maintain their ability to bid for collection contracts), while using the combined pneumatic collection system to achieve operational savings. Since the waste inputs of commercial customers would be metered so that the system's costs could be apportioned between the various waste generators, the generators could continue to make payments to the carters, and the carters could pay their pro-rated share of the overall system's costs, while (perhaps) maintaining their role in transporting and disposing of their pro-rated share of the material containerized at the terminal. All parties could thus share in the benefits of pneumatic collection.

To test the potential acceptability of this hypothetical scenario, we had several conversations with the head of a major carting company to explore the possibilities for participation in a joint municipal-commercial pneumatic installation. We were not rebuffed. On the contrary, we were encouraged to think that various mutually beneficial institutional arrangements might indeed be feasible.

POTENTIAL OWNERSHIP STRUCTURES

In the case of the SAS system, the most straightforward ownership arrangement would be to have a single public-sector owner. The MTA, which owns the vault space through which the subway-level trunk line would run, and whose waste-collection needs would thus be served, might be the most logical ownership entity. (In the context of the Second Avenue Subway's $17-billion capital budget,[79] $11 million to build a pneumatic system would be a rounding error.) In addition to serving its own waste needs--perhaps with extensions of the subway trunk-line north and/or south to additional stations in the system--the MTA could use the extra capacity of its pneumatic facility as a revenue source by charging the Housing Authority, the Health and Hospitals Corporation, the Department of Sanitation, and private carters and/or commercial waste generators for collection service.[80]

Other public-sector ownership candidates might be the NYC Department of Transportation, within whose street bed the main trunk tube would run (although this service would fall outside any of its normal functions); the NYCHA, which would be the largest-single waste generator in the system (again, it could charge other waste-generators for their use of system capacity not required for NYCHA's own needs), the Hospital Corporation, or the Department of Sanitation.

If a private-sector entity were involved in the ownership of the SAS installation, in the event that no public-sector entity chose to take on the responsibilities of financing and developing the proposed facility, the privately owned structure would presumably be financed on the basis of fixed-term contracts that would specify the payment rates to which the various waste-generators who chose to be connected to the system would be subject.

In the case of the HL installation, if Chelsea Market were the primary waste-generator, its owner might be a logical system owner, collecting the relatively small volume of waste from the High Line Park in return for permission to use the Park structure for running the trunk line between the Market and the pneumatic terminal, and collecting fees from any other adjacent property owners who chose to use the available capacity of the pneumatic system.

[79] https://en.wikipedia.org/wiki/Second_Avenue_Subway, accessed 6-7-13.

[80] It is our understanding, based on communications with MTA personnel, that the MTA derives revenues from other entities for providing space in its subway vaults for other sorts of utility lines.

CATALYZING THE DEVELOPMENT OF PNEUMATIC SYSTEMS IN NEW YORK CITY AND ELSEWHERE

As noted above, pneumatic collection is being considered by the Related Companies for their Hudson Yards project and it is also possible that Cornell-Technion may use pneumatic collection for their Roosevelt Island campus. Since these are the two largest current development projects in NYC, their use of pneumatic collection could provide a transformative push to the expansion of pneumatic systems in New York and beyond.

Yet these systems--if they are indeed built--would be typical of those that have been developed elsewhere in the world: installations in new complexes which are under the control of one developer. If pneumatic tube installations are to reach their true potential in a city such as New York that is already extensively developed (and where additional development sites on the scale of Hudson Yards and the new Cornell-Technion campus are all-but nonexistent), it will be because of more-difficult retrofit projects involving multiple property owners and a connecting pipeline network within publicly controlled right-of-ways. Projects of this degree of logistical and institutional complexity will require a significant degree of public-sector involvement. They are also likely to require the assistance of some entity that sees its mission as putting together all of the necessary pieces for such a project. Pneumatic system vendors typically provide equipment, install it, and operate it. They generally respond to bid requests from potential system owners, such as private developers or municipal governments. They do not typically engage in projects that involve more than a single public or private entity.

A group that took on this role--either a subsidiary of an existing development group[81] or a mission-focused start-up such as a pneumatic Kick-Starter--might use a combination of the latest social media and crowd-funding techniques, along with sophisticated engineering capabilities, to harness the interest and enthusiasm of multiple public or private waste generators to produce an integrated design for a retrofit installation using existing public right-of-ways for the connecting pipeline network. Such creative entrepreneurial vision could catalyze the kind of public-private partnership necessary to spread pneumatic installations across New York and other cities.

[81] Some major NYC developers have already demonstrated a commitment to sustainable waste-management practices: Forest City Ratner, for example, with its commitment to anaerobic digestion, and the Durst Organization, with its commitment to source-separated organics collection. E.g., http://ir.forestcity.net/phoenix.zhtml?c=88464&p=irol-newsArticle&ID=1712610&highlight=anaerobic; http://www.nyc.gov/html/dsny/html/pr2013/041813.shtml, both accessed 7-3-13;

Section 7

METRICS

Because of its population density and attendant waste volumes, as well as the severity of surface-transport congestion, the value of real estate, the amount of air and noise pollution, the negative aesthetic impacts of piles of waste bags and litter and rats and odors (and their economic consequences for tourism), most of New York City--and especially Manhattan--offers the kind of situation where pneumatic collection has been found to be desirable, practicable, and economically viable in other countries. However, since all areas of New York City--and again, especially Manhattan--are already highly developed, and since retrofitting existing developments with pneumatic equipment is generally more costly and logistically complicated than is installing pneumatic tubes during the construction phase of new developments, and since the economically important potential space-savings associated with pneumatic systems are less likely to be captured in existing developments, it is more likely that pneumatic systems will spread gradually in New York City as new developments are built than that a large proportion of already-built-up areas will be retrofitted with pneumatic installations. Indeed, this has been New York City's experience thus far. Its first pneumatic system was built in a planned new community, Roosevelt Island, where pneumatic connections have been extended to new buildings as they were built. The newly launched Hudson Yards development in Manhattan is the only other complex that thus far has mentioned plans for pneumatic collection.[82]

New York's rural and suburban areas are unlikely to meet the density criteria that would make them suitable candidates for pneumatic collection. To the extent that New York State's other large cities do offer areas where pneumatic collection, at least of the stationary-terminal sort, might be economically and operationally practicable, it is highly likely that this development pattern will hold true for them as well.

Given the relative logistical difficulties and economic hurdles associated with retrofitting existing developed areas, the relative ease of access and lower construction costs offered by the use of existing linear transportation infrastructure could facilitate the installation of pneumatic systems in certain opportune areas. The present feasibility analyses suggest the practicability of such retrofits in two specific Manhattan locations. Other potential opportunities with substantive similarity to the High Line and Second Avenue Subway cases could be the northward extension of the old High Line right-of-way below what is now planned as a public space (the Boulevard Park); the #7 subway extension from Times Square to Penn Station, along with other subways throughout the city; other highway/roadway and railway viaducts that are still in service; structures such as the Coney Island Boardwalk; proposed structures that would be similar to the High Line, including the currently abandoned "Low Line" subway tunnel in Lower Manhattan and--where it runs through areas with sufficient population density--the proposed QueensWay along the right-of-way of an abandoned rail line in Queens. Other opportunities for using existing subway facilities to provide pneumatic collection of above-grade waste from dense public spaces might include use of existing Times Square subway station facilities to collect waste from the new above-ground pedestrian mall around Times Square.

[82] http://www.cityrealty.com/new-york-city-real-estate/carters-view/related-posts-new-renderings-information-hudson-yards-project/carter-b-horsley/39962, accessed 10-11-11.

Figure 7-1. Other Elevated Transportation Structures in New York City For Which a High Line Pneumatic Installation Might Serve as a Model
(Sources: jesse3, 2008; Chang, 2008; Culhane, 2009; 12ozprophet.com, 2009.)

It is not possible to predict the degree to which such opportunistic pneumatic installations may actually be developed in New York City. But it is likely that any such installations will be relatively rare and that the pace at which they may be developed will be slow. It would seem unlikely that even as much as one percent of Manhattan's MSW would be collected via opportunistic installations using existing transportation infrastructure--as opposed to major new developments such as the 26-acre, 12.7-million-square-foot Hudson Yards development[83]--within the next several decades. Significant economic development benefits to New York from the development of new pneumatic-waste-collection facilities cannot be predicted for the near future.

Almost any pneumatic installation could be expected to produce safety and public-health benefits due to reduced particulate emissions, noise, accidents, and disease vectors. Quality-of-life benefits could be expected from reduced congestion, visual nuisances, and improved levels of service and reliability--particularly with regard to the disruptive threats posed by climate change to an estuarine urban agglomeration such as New York City. Economic benefits in the form of space and labor savings, as well as enhanced values of their space, can be expected for waste generators. And energetic and environmental benefits can be expected due to the substitution of electrical energy for fossil-derived transportation fuel. Overall reductions in BTU use and GHG emissions will depend on the specific characteristics of the given pneumatic installation in relation to conventional collection options, as will reductions in truck miles traveled. The two Manhattan projects considered here would produce significant reductions in overall BTU use (60% fewer) and GHG emissions (less than half as many as conventional collection).

The incremental annual operating cost of these pneumatic systems, including debt service and container-drayage--about a third to a half more than conventional collection--are relatively modest in proportion to

[83] http://en.wikipedia.org/wiki/Hudson_Yards_Redevelopment_Project, accessed 1-20-13

the benefits produced. Projected savings to waste generators (building owners and managers), in both cases, would either significantly outweigh (in the SAS case) or nearly equal (in the HL case) the externality benefits that would be required in order not to exceed the Net Present Value costs of conventional collection. Although beyond the scope of the present study, the inclusion of other potentially monetizable externality benefits for the general public (public health benefits, climate-change benefits, congestion benefits, quality-of-life improvements) could add substantially to the pneumatic side of the scale.

Section 8

CONCLUSIONS

This study assessed the feasibility of installing pneumatic MSW-collection equipment in already-developed dense urban areas by taking advantage of existing linear transportation infrastructures to reduce the costs and logistical difficulties associated with such a retrofit. It considered two specific potential opportunities, the High Line Park (with the Chelsea Market complex as a key waste source), and a stretch of the Second Avenue Subway (with the residential, commercial, and hospital buildings between 92nd and 99th Streets as the primary waste sources).

Both concepts were determined to be physically and operationally feasible.

The projected operating costs of both hypothetical systems--including the cost of draying containers from the terminal to the long-haul transfer station, but not including debt service--were found to be about 30% less expensive than those of conventional collection. When debt service is included, the overall annual costs are modestly higher (30% higher in the case of the SAS, 55% in the case of the HL, due to capital costs 5 to 9 times higher (respectively) than those for truck-based collection. This cost accounting does not include economic benefits recovered from space savings associated with pneumatic collection, or the value of labor savings by waste generators, which could significantly outweigh the total incremental collection costs of the pneumatic system (in the case of SAS), or substantially reduce these incremental costs (in the case of the HL). The negative Net Present Value costs associated with the pneumatic installations considered could be offset if annual monetizable externality benefits on the order of $300,000 to $400,000 a year could be captured. Given the range and significance of these positive externalities (for instance, those due to decreased long-distance transport and landfilling because of the unit-pricing capability associated with pneumatic inlets), this would appear to be likely. Savings of over $200,000 per year, for example, might be realized by the High Line/Chelsea installation, and of over $4.5 million per year for the Second Avenue Subway installation, just through the rental value of recovered space. (The actual space savings found for a pneumatic installation in Stockholm, as a ratio to the cost of space for conventional collection, fall between these two values, as shown in Table 8-1.)

Table 8-1. Space Costs of Conceptual Manhattan Pneumatic Installations Compared to Conventional Collection and Literature Values
(Stockholm Source: Kogler, 2007)

Relative Space Costs (Annual)	Conventional	Pneumatic	**Multiplier**
Sodra Station, Stockholm, Per Apartment	€ 104	€ 18	**0.17**
High Line/Chelsea Market, Total	$378,000	$194,500	**0.51**
SAS/Second Avenue 92nd-99th Streets	$4,731,974	$81,900	**0.02**

The fact that the overall costs of these conceptual Manhattan retrofit installations, relative to the costs of conventional collection, are somewhat less than those projected in another study of a conceptual urban retrofit installation (as shown in Table 8-2) may reflect savings in civil costs resulting from the use of existing linear transport structures for the installation of the pneumatic tubes. (Some of this cost difference between the Manhattan and Helsinki cases, however, is also due to the fact that civil costs for the Manhattan terminals are not included, for the reasons discussed above. But as noted above, these terminal costs would not be likely to produce a significant shift in the relative costs of collection.)

Table 8-2. Costs of Conceptual Manhattan Pneumatic Installations Compared to Conventional Collection and Literature Values
(Helsinki Source: Teerioja, 2012)

Cost (Euros/tonne)	Conventional	Pneumatic	**Multiplier**
Helsinki Capex	33	343	**10.4**
Helsinki Opex	40	71	**1.8**
Helsinki Enviro Cost (mainly CO2eq)	0.51	1.29	**2.5**
Total, Helsinki Base Case (5.3 tonnes/d)	74	415	**5.6**
Total, Helsinki Max Case (21.2 tonnes/d) Total	60	155	**2.6**
Cost ($/ton): Opex Including Debt Service and Dray (w/o Env Cost)			
High Line (11 tpd)	188	290	**1.5**
Second Avenue Subway (19 tpd)	134	178	**1.3**

Prior studies have found somewhat higher BTU use and GHG emissions for pneumatic collection than for conventional collection, whether or not complete Life Cycle Costs are included (upstream extraction, production, and distribution effects, and downstream transport, disposal, and avoided impacts). The present study has found that this would not be the case for the two Manhattan projects (as shown in Table 8-3, compared to the Helsinki case study). Because of the specific circumstances of the proposed Manhattan systems (number of inlets, length of pipes, waste volumes and source locations), BTU use and GHG emissions would be reduced by a significant margin. Envac's projected per ton electricity consumption for both HL and SAS is relatively low compared to the rate used by Punkkinen, 2012 as well as to Envac's own projections for potential upgrades to its existing Roosevelt Island system.[84] But as noted above, our sensitivity tests of higher kWh rates show that BTUs and GHG emissions increase at a lower rate than does kWh use, so that the comparison to manual collection would still be favorable even at significantly higher kWh rates.

Table 8-3. GHG Emissions from Conceptual Pneumatic Installations Compared to Conventional Collection and Literature Values
(Helsinki Source: Punkkinen, 2012)

	Conventional	Pneumatic	**Multiplier**
CO2-eq, Tons Per Waste Ton, Collection + Transport Only			
Helsinki	0.02	0.04	**2.2**
HL	0.04	0.02	**0.5**
SAS	0.04	0.02	**0.4**

Pneumatic systems would also offer local safety and public-health benefits due to reduced particulate emissions, noise emissions, accidents, disease vectors, and the substitution of electrical energy for fossil-derived transportation fuel. Additional benefits would be derived from effects on the overall waste-management system. Among these are a potential reduction in the volumes of waste requiring long-distance transport and landfill-disposal due to the unit-pricing capabilities associated with pneumatic collection.

[84] See Kamga, et al., op cit.

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Appendix A: High Line/Chelsea Market Data/Calculations

Table A-1.1. Imputed Costs of Conventional Collection for High Line-Chelsea Market

Derived From NYC DSNY Costs, Fiscal 2005(h)

	Refuse (+Recyclables)
Total cost/t (including disposal, debt service)(a)	267
Tons collected(b)	2,894,455
Tons/truck/shift	10.6
Total export costs for collected refuse/recyclables(b)©	$314,868,000
Debt service on garages/vehicles(d)	$44,890,165
Collection labor cost/t(e)	$99
Export/processing costs/t	$109
Debt service/t	$16
Debt service/t: 2011$	$18
Debt service/t: 2013$	$18
Collection only (-export/processing; debt service)	
2005 per ton collection only (-export/processing; debt service)	$143
2011 per ton collection costs w/o debt service	$164
2013 per ton collection costs w/o debt service	$169
Collection w/ debt service	
2005 per ton collection w/ debt service	$158
2011 per ton collection costs w/ debt service(g)	$182
2013 per ton collection costs w/o debt service	$188

Source:

http://docs.nrdc.org/cities/files/cit_08052801A.pdf, accessed 12-12-11

(a)p23, Table 4c without recycling revenues (with DSM adjustments, which do not include correcting for the fact that all enforcement costs are inappropriately assigned to the recycling budge and do not include parallel adjustments UTRC would recommend related to collection, e.g., not charging all Bureau of Waste Prevention, Reuse, and Recycling costs, which include a waste composition study and public education initiatives, along with processing costs for recyclables, to the cost of collecting recyclables, while not apportioning items that are related to collection, such as revenues from enforcement fines)

(b)p20, Table 2

(c)p21, Table 3a

(d)p23, Table 4b

(e)p25, Table 8a

(f)Collection costs apportioned using Roosevelt Island relative tonnages as identified in the Reconnaissance Report [Web link] (5.8tpd refuse; 2.62tpd recyclables)

(g) Inflated by BLS CPI index, 2005 to 2011, http://www.bls.gov/data/inflation_calculator.htm

(h) Only refuse collection costs are included in this analysis (not the higher per-ton recycling costs), on the theory that the collection of relatively large quantities of waste at a relatively few stops in each case (private carter collection at Chelsea Market, Parks Department collection at one curbside location from the High Line), would not impose the lower-volume cost effects associated with DSNY recycling collections. Even using refuse-only rates, the DSNY figure used here is considered likely to somewhat overestimate actual costs. This DSNY figure is used, however, as the best publicly available source.

	A	B	C	D	E	F
1	**Table A-1.2. Net Present Value Comparison: HL Pneumatic (AVAC) v. Manual (Truck)**					
2	3% Discount Rate			7% Discount Rate		
3			Externality benefit			Externality bene
4			$407,000			$407,000
5	Trucks	AVAC	AVACw/ext ben	Trucks	AVAC	AVACw/ext ben
6	3.000%	3.000%	3.000%	0.07	0.07	0.07
7	1,228,140	10,569,820	10,569,820	1,228,140	10,569,820	10,569,820
8	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
9	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
10	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
11	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
12	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
13	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
14	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
15	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
16	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
17	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
18	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
19	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
20	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
21	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
22	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
23	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
24	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
25	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
26	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
27	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
28	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
29	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
30	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
31	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
32	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
33	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
34	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
35	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
36	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
37	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
38	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
39	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
40	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
41	-72,651	-477,225	-70,225	-72,651	-477,225	-70,225
42	-1,535,250	-10,084,631	-1,483,973	-933,857	-6,134,249	-902,667
43	Differential	-8,549,381	51,277	Differential	-5,200,391	31,191
44	Multiplier	6.6	1.0	Multiplier	6.6	1.0
45						
46	Notes:					
47	Bond term and interest rate assumptions based on NYC Water Authority actuals:					
48	http://nycbonds.org/NYW/pdf/2013/NYW_2013_AA_Adj_Rate.pdf, accessed 12-19-12					
49	p1: term, latest nyc water authority bonds: 34 yrs					
50	pp181-2, interest rates for latest 3 years long-term fixed bonds (24 issues) (see "avg interest"					
51	worksheet for raw numbers): 4.725%					
52	Discount rate is 3% and 7%, as per current US DOT guidance for benefit-cost analyses required for					
53	transportation investments pursuant to its Transportation Investment Generating Economic Recovery					
54	(TIGER) grant program (TIGER Benefit-Cost Resource Guide, 2-1-2012,					
55	http://www.dot.gov/sites/dot.dev/files/docs/TIGER_BCA_RESOURCE_GUIDE.pdf, accessed 3-19-13.					

	I	J	K	L	M	N	O	P	Q
1	**Table A-1.2A. Sensitivity Analysis Energy efficiency, Terminal Building Cost & Labor Effect on Net Present Value AVAC v. Manua**								
2									
3								Externality benefit	
4		A 120%	A 150%	A +T Bldg	A 150%+Tl Bldg	A +4x T Bldg	A Labor x3	$1,007,000	
5	Trucks	AVAC	AVAC	AVAC	AVAC		AVAC	A labor x3 w/ext ben	
6	0.03	3.000%	3.000%	3.000%	3.000%	3.000%	3.000%	3.000%	
7	1228139.88	10,569,820	10,569,820	$11,214,481	$11,214,481	$13,167,739	10,569,820		
8	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
9	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
10	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
11	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
12	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
13	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
14	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
15	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
16	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
17	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
18	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
19	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
20	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
21	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
22	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
23	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
24	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
25	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
26	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
27	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
28	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
29	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
30	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
31	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
32	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
33	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
34	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
35	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
36	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
37	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
38	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
39	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
40	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
41	-72651.06	-478,746	-481,028	-513,382	-517,185	-628,923	-1,079,687	-72,687	
42	-1535250.334	-10,116,779	-10,165,000	-10,848,707	-10,929,076	-13,290,296	-22,815,770	-1,536,011	
43	Differential	-8,581,528	-8,629,750	-9,313,456	-9,393,825		-21,280,520	-760	
44	Multiplier	6.59	6.62	7.07	7.12	8.66	14.86	1.00	

	A	B	C	D	E	F	G
1	**Table A-1.3. Annual Cost of Ro-Ro Collection from HL/Chelsea Market**						
2	Pneumatic RORO Costs						
3		Carter Refuse	Paper	Organics(5)	Parks Refuse	TOTAL	
4	Truck Miles/Y(7,15)	3,543	2,480	1,487	373		
5	Fuel Cost/Y (1,7,8,9)	$2,374	$1,662	$996	$250	$5,281	
6	Cost of Ro-Ro Truck/Y (2)	$1,868	$1,236	$1,390	$300	$4,794	
7	Vehicle Maintenance/Y (2)	$1,162	$768	$865	$187	$2,982	
8	Tolls(5)	$1,997				$1,997	
9	Labor/Y (3,4)	$14,060	$9,300	$10,464	$2,260	$36,085	
10	Total Cost/Y	$21,460	$12,966	$13,715	$2,997	$51,139	
11						2013$	2011$
12	(1) #2 ULS B5 diesel fuel cost/gallon, for mileage see Table B-2.2:					$3.35	$3.25
13	(2) 2011 DSNY Roll-On/Roll-Off truck capex and opex, Brautigam to Miller 6-30 and 10-						
14	6-11. Cost annualized and apportioned based on number of shifts used assuming a 6-						
15	day work week.						
16		Truck capex				$205,461.73	$199,066
17		Truck life, yrs				5	5
18		Truck ann maintenance				$25,558.60	$24,763
19	DSNY working days/yr					301	301
20	Assumed number of shifts/day/truck					2	2
21	(3)Portion of shift/trip						
22	Carter Refuse	Based on DSNY FY2012 data, w/ comparable miles				0.37	0.37
23	Paper	Based on DSNY FY2012 data, w/ comparable miles				0.37	0.37
24	Organics	Based on Googlemaps drive time+1hr loading/unloading				0.66	0.66
25	DSNY Refuse	Based on DSNY FY2012 data, w/ comparable miles				0.25	0.25
26	(4) Avg salary plus fringe as of 6/1/2010(Brautigam to Miller 06/30/11)					$116,603.83	$109,517.18
27	2011 DSNY RO/RO Pickup Differential/day (ibid)					$98.83	$92.82
28	Shifts/yr, 301 DSNY working days, assume 20 vacation days					281	
29	Labor cost/shift					$514	$483
30	(5) The carter currently collecting CM pays tolls to cross the Hudson River inbound from its NJ garage						
31	and DSNY would pay Hudson River tolls to take refuse containers to the Essex Incinerator, so tolls						
32	(currently $27/ round-trip) would be involved, at least for refuse, no matter whether the dray were						
33	performed by a private carter or by DSNY.						27
34	(7) Mileage from HL Fuel Use.xlsx, Mileage Worksheet						
35	(8) RO/RO assumed mpg					5	
36	(9) Pneumatic trips/wk from Manhattan HL 3-5-13.xlsx, Containers					Trips/Y	Total Trips/Y
37		Carter Refuse			1.4	74.0	
38		Paper			0.9	48.9	
39		Organics			0.6	31.0	
40		DSNY Refuse			0.3	17.6	171.5
41	Avg Pneumatic tons/container						
42		Refuse				25.3	
43		Paper				16.9	
44		Organics				25.3	
45	(10)From Mileage worksheet, RORO miles/trip:						
46		Carter Refuse				47.9	
47		Paper				50.7	
48		Organic				47.9	
49		DSNY Refuse				21.2	

	A	B	C	D	E	F	G
1	**Table A-1.4. Pneumatic System Operating Cost Calculation**						
2	Annual Operating Costs: Proposed High Line Pneumatic System						
3	**PERSONNEL:**						
4			DESCRIPTION		NUMBER	COST	**TOTAL**
5		**DIRECT O&M PERSONNEL**					
6			OPERATOR O&M (a)		2	150,040	**300,079**
7		**UNIFORMS**					
8			UNIFORMS	Each	2	461	**922**
9		**MOBILE PHONE**					
10			TELEPHONE	Each	1	230	**230**
11		**TOTAL:**					**301,231**
12	**VEHICLES**						
13			DESCRIPTION	UNIT	NUMBER	COST	**TOTAL**
14		**MAINTENANCE CARS**					
15			OPERATOR VAN	Each	1	10,423	**10,423**
16		**TOTAL:**					**10,423**
17	**SPARE PARTS**						
18			DESCRIPTION	UNIT	NUMBER	COST	**TOTAL**
19		**SPARE PARTS**					
20		**TERMINAL**			1		
21			DIVERTER/TRIVERTER VALV	Each	1	1,249	**1,249**
22			EXHAUSTERS	Each	1	3,615	**3,615**
23			CONTAINER	Each	1	1,075	**1,075**
24			CYCLONE	Each	1	294	**294**
25			COMPACTOR	Each	1	1,808	**1,808**
26			CONTAINER MOVER	Each	1	868	**868**
27			CONTROL SYSTEM	Each	2	338	**676**
28			SECTION IN VALVE	Each	1	459	**459**
29			COMPRESSOR	Each	1	160	**160**
30		**FILTERS**			1		
31			DUST FILTERS	Each	1	2,931	**2,931**
32			CARBON	Each	1	4,838	**4,838**
33		**PIPE NETWORK**			1		
34			DUMP VALVES	Each	1	567	**567**
35			TRANSPORT VALVES	Each	1	457	**457**
36			SYSTEM DEVICE	Each	1	337	**337**
37		**TOTAL:**					**19,332**
38	**SUPPLIES**						

	A	B	C	D	E	F	G
39			DESCRIPTION	UNIT	NUMBER	COST	**TOTAL**
40		**MATERIAL**					
41			CLEANING GOODS	Each	1	853	**853**
42			TOOLS	Each	1	1,227	**1,227**
43			OFFICE SUPPLIES	Each	1	90	**90**
44		**TOTAL:**					**2,170**
45	**ELECTRIC POWER**						
46			DESCRIPTION	UNIT	NUMBER	COST	**TOTAL**
47		**ENERGY SUPPLY (b,c,d)**					
48			CONSUMPTION (Collection+	Kwh	126,774	0.06	**7,606**
49			Kw CONTRACT	Kw	199	$23.38	**55,745**
50		**TOTAL:**					**63,352**
51	**MISC**						
52			DESCRIPTION	UNIT	NUMBER	COST	**TOTAL**
53			TELEPHONE	Each	1	1,489	**1,489**
54			WATER	Each	1	2,021	**2,021**
55		**TOTAL:**					**3,510**
56	**ONGOING EQUIPMENT REPLACEMENT**						
57			DESCRIPTION	UNIT	NUMBER	COST	**TOTAL**
58		**REPLACEMENT COSTS**					
59			TERMINAL	Each	1	56,270	**56,270**
60			PIPE NETWORK	Each	1	10,401	**10,401**
61		**TOTAL:**					**66,671**
62	**PERSONNEL**	**301,231**	**RATIO**	**$**	**PER TON**		
63	**VEHICLES**	**10,423**	TONS			3,942	
64	**SUPPLIES**	**2,170**	**RATIO COST/TON**			**118**	
65	**SPARE PARTS**	**19,332**					
66	**ELECTRIC POWER**	**63,352**	**RATIO**	**Kwh**	**PER TON**		
67	**MISC**	**3,510**	TONS			3,942	
68	**EQUIP REPLACEMENT**	**66,671**	KWH			126,774	
69	**TOTAL**	**466,689**	**RATIO KWH/TON**			**32**	

(a) Steven Brautigam, DSNY to Miller 10/06/11. There are currently 8 full time employees, with the titles and pay rates shown in this note. Envac lists operator positions. The current DSNY titles used at AVAC are: Senior Stationary Engineer base salary $116,916, fringe @ 43% $50,274 = $167,191 total; Stationary Engineer base salary $102,356, fringe $43,013= $145,369; Machinist base salary $75,940, fringe $32,655 = $108,595. We assumed "Stationary Engineer" = "Operator."

(b)NYC DCAS, “Core Report, Facility-Level Energy Cost, Usage, and CO2e Emissions," 4-2011.

(c) Donald Porter, DSNY Bureau of Building Mgt, to Steven Brautigam, DSNY Asst. Comr., Environmental Affairs, 2-11-13

(d) Brautigam to Miller, 1-28-13

	L	M	N	O	P	Q
1	**Table A-1.4A Sensitivity Analysis, Pneumatic Operating Cost Calculation**					
2						
3						
4	**Labor (personnel requirements x3)**					
5		NUMBER	COST	TOTAL		
6						
7		6	150,039.52	900,237.12		
8						
9		6	460.88	2,765.29		
10						
11		3	230.44	691.32		
12			1.00	903,693.74		
13	Cost Increase v. projected:			**602,462.50**		
14	Total Opex w Replacement at 3x labor:			**1,069,151.27**		
15	Total Opex/t:			**271**		
16						
17						
18	**Electricity**					
19			120% KWH	150% KWH		
20	Kwh/y		152129	190161		
21	Cost per kwh		$0.06	$0.06		
22	Total cost kwh		$9,128	$11,410		
23	Total Cost KW (constant)		$55,745	$55,745		
24	Total		$64,873	$67,155		
25	Cost Increase v. projected:		**$1,521**	**$3,803**		
26	Total Opex w/ replacement		**$468,210**	**$470,492**		

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Table A-2.1. Pneumatic vs. Manual Energy Use and GHG Emissions**												
2		**Tons Per Day**	**Weight**	**KWH Per Day(5)**			**Gallons Per Day(2)**			**Tons CO2 Equivalent**			**BTUs**
3				**Manual**	**AVAC**		**Manual**	**AVAC**	Coeff t CO2e/unit (6)	**Manual**	**AVAC**	Coeff BTUs/unit (7)	**Manual**
4					347				0.0003		0.12103	3,412	NA
5	Commercial Refuse Tons/day (3)	5.17	0.48	NA			19.22	1.95	0.0113	0.22	0.022	138,900	2,670,075
6	Commercial Organic Tons/day (3)	2.18	0.20				6.5	0.8	0.0113	0.07	0.009	138,900	908,529
7	Commercial Paper/OCC T/day (3) (4)	2.22	0.21				7.0	2.4	0.0113	0.08	0.027	138,900	969,754
8	Subtotal Chelsea Mkt	**9.57**											
9	High Line Refuse Tons/day (1)	1.23	0.11				1.5	0.2	0.0113	0.02	0.002	138,900	208,033
10			1.00										
11	**Total/Day**	10.80			**347.3**		**34.2**	**5.3**		**0.39**	**0.18**		**4,756,391**
12	**Total/Year**	3942			**126,774**		**12,499**	**1,945**		**141**	**66**		**1,736,082,548**
13	**Weighted Average/Ton**				**32**								
14	**Electric Wtd Avg/Ton**												
15	**Diesel Wtd Avg/Ton**												
16	**Delta Multiple v. Manual Baseline**							**0.2**			**0.5**		
17	**Ann. Units Avoided v. Mbaseline**							**10,554**					**-**

Notes:

(1) Estimated average #90-gal bags/day: 35; Estimated avg lbs/bag 70; for 1.23 TPD. Based on brief interviews with HL maintenance personnel and on-site observations conducted 8-1-11.Waste quantities fluctuate seasonally. Note 03-22-12 meeting with FOHL staff mentioned 85 bags on 03-18-12.

(2) For fuel use see mileage worksheet.

(3) For tpd commercial refuse & recyclables, confidential industry sources

(4) Pneumatic system would not collect metal, glass and plastic. Trucks would still be required for MGP pick up, see mileage worksheet.

(5) 100 kwh/t is the average Envac considers an appropriate for this scenario, see R Rello to Miller 01/16/13

(6)NYC-specific emission factors for electricity and vehicle fuel from NYCPlan 2011 inventory, http://nytelecom.vo.llnwd.net/o15/agencies/planyc2030/pdf/greenhousegas_2011.pdf appendix H, I, (see 2011 Emissions Factors worksheet); coefficient for kg CO2e/unit based on weighted average of emissions from energy generation at power plants serving NYC for electricity and vehicle fuel based on type (see CO2e coefficient worksheet).

(7) http://www.onlineconversion.com/energy.htm

	N	O	P	Q	R	S	T
1							
2	/Day		Tons CO2Eq/Ton Waste			BTUs/Ton Waste	
3	AVAC		Manual	AVAC		Manual	AVAC
4	1,185,127			0.011			109,734
5	270,372		0.042	0.004		516,455	52,296
6	113,456		0.034	0.004		416,757	52,044
7	327,831		0.035	0.012		436,826	147,672
8							
9	28,469		0.014	0.002		169,132	23,146
10							
11	**1,925,256**						
12	**702,718,358**						
13			**0.036**	**0.017**		**440,407**	**178,264**
14				0.011			109,734
15			0.036	0.006		440,407	68,530
16	**0.405**			**0.5**			**0.405**
17	**0**						
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							

	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI
1	**Table A-2.1A Sensitivity Analysis, Effect of Electricity Consumption on Energy Efficiency and GHG Emissions**													
2		Tons Per Day		**KWH Per Day(5)**			**Gallons Per Day(2)**				**Tons CO2 Equivalent**			
3				AVAC 120%	AVAC 150%		AVAC 120%	AVAC 150%	Coeff t CO2e/unit (6)		AVAC 120%	AVAC 150%	Coeff BTUs/unit (7)	
4				417	520.99				0.0003		0.145	0.182	3,412	
5	Commercial Refuse Tons/day (3)	5.17					1.9	1.9	0.0113		0.022	0.022	138,900	
6	Commercial Organic Tons/day (3)	2.18					0.8	0.8	0.0113		0.009	0.009	138,900	
7	(4)	2.22					2.4	2.4	0.0113		0.027	0.027	138,900	
8	Subtotal Chelsea Mkt	9.57												
9	High Line Refuse Tons/day (1)	1.23					0.2	0.2	0.0113		0.002	0.002	138,900	
10														
11	**Total/Day**	10.8		**417**	**521**		**5.3**	**5.3**			**0.205**	**0.242**		
12	**Total/Year**	3942		**152,129**	**190,161**		**1,944.9**	**1,944.9**			**75**	**88**		
13	**Weighted Average/Ton**			**39**	**48**									
14														
15														
16	**Delta Multiple v. AVAC Baseline**													
17	**Ann. Units Added v. A Baseline**						**3.13**							

	AJ	AK	AL	AM	AN	AO	AP	AQ
1								
2	**BTUs/Day**			**Tons CO2Eq/Ton Waste**			**BTUs/Ton Waste**	
3	AVAC 120%	AVAC 150%		AVAC 120%	AVAC 150%		AVAC 120%	AVAC 150%
4	1,422,152	1,777,690		0.013	0.017		131,681	164,601
5	270,372	270,372		0.004	0.004		52,296	52,296
6	113,456	113,456		0.004	0.004		52,044	52,044
7	327,831	327,831		0.012	0.012		147,672	147,672
8								
9	28,469	28,469		0.002	0.002		23,146	23,146
10								
11	**2,162,281**	**2,517,819**						
12	**789,232,604**	**919,003,973**						
13				**0.019**	**0.022**		**200,211**	**233,131**
14								
15								
16				**1.134**	**1.334**		**1.123**	**1.308**
17				**0.002**	**0.006**		**21,947**	**54,867**

	A	B	C	D	E	F	G
1	**Table A-2.2. Pneumatic vs. Manual Mileage Factors**						
2	**Mileage**		Miles/Yr	Miles/Wk	Miles/Day	Gals/Day(10)	
3	**Current HL Curbside refuse pick-up 3.5 trips per week(2):**						
4	trips garage-HL: 3.5 trips per week (one way)			4.9			
5	trips HL-dump-garage: 3.5 trips per week (one way)			18.1			
6	*Subtotal*		1,194	23.0	3.3	1.5	
7							
8	**Current Private Carter Chelsea Market (CM) Collection)(1)(3)**						
9	*Commercial OCC/Paper 7 trips per week*						
10	Garage to CM: 7 trips per week (one way)			95.9			
11	Route around CM: 7 trips per week (one way)			2.8			
12	CM-MRF-garage: 7 trips per week (one way)			47.9			
13	*Subtotal*		7,624	146.6	20.9	7.0	
14							
15	*Commercial Refuse 14 trips a week (one way)*						
16	Garage to CM 14 trips per week (one way)			191.8			
17	Route around CM 14 trips per week (one way)			5.6			
18	CM-Dump-garage: 14 trips per week (one way)			206.3			
19	*Subtotal*		20,992	403.7	57.7	19.2	
20							
21	*Commercial organics 7 trips per week (one way)*						
22	Garage to CM 7 trips per week (one way)			95.9			
23	Route around CM 7 trips per week (one way)			2.8			
24	CM-compost facility-carter garage 7 trips per week (one way)(9)			38.7			
25	*Subtotal*		7,143	137.4	19.6	6.5	
26		**Total Miles/Y No-AVAC**	**36,952**				
27	**AVAC: Private Carter Chelsea Market (RO RO) (4)(5)**						
28	Paper/OCC (3)						
29	Carter garage to AVAC facility			12.9			
30	AVAC-MRF-garage			34.8			
31	*Subtotal*		2,480	47.7	6.8	1.4	
32							
33	Refuse						
34	Carter garage to AVAC facility			19.5			
35	AVAC-dump-garage(7)			48.6			
36	*Subtotal*		3,543	68.1	9.7	1.9	
37							
38	Organics						
39	Carter garage to AVAC facility			8.2			
40	AVAC-compost facility-garage			20.4			
41	*Subtotal*		1,487	28.6	4.1	0.8	
42							
43	MGP [NOT IN AVAC SYSTEM, REMAINS MANUAL REAR-LOAD COLLECTION] (3)						
44	Garage to CM: 1 trips per week (one way)						
45	Route around CM (1): 1 trips per week (one way)						
46	CM-MRF-garage: 1 trip per week (one way)						
47	*Subtotal*		1,089	20.9	3.0	1.0	
48							
49	**AVAC: HL refuse (RO RO) (8)**						
50	DSNY ro-ro garage to AVAC facility			1.0			
51	AVAC-roro dump-roro garage			6.2			
52	*Subtotal*		373	7.2	1.0	0.2	
53		**Total Miles/Y AVAC**	**8,972**				
54							

	A	B	C	D	E	F	G
55	**Commercial Carter locations**	**Address/miles**					
56	Hypothetical AVAC location:	Gansevoort St and Washington Ave. New York, NY 10014					
57	CM address:	10th Ave. & W16th St.					
58	Carter garage location:	451 Frelinghuysen Avenue, Newark, NJ					
59	Carter dump:	920 East 132nd Street, Bronx, NY 10454, or 941 Stanley Ave Brooklyn NY 11208					
60	Carter Paper/OCC (MRF):	1221 East Bay Ave Bronx NY 10474					
61	Carter compost facility (9)	[Assumed same distance as carter dump facility]					
62							
63	**Distance**						
64	Distance carter garage-Chelsea Market (CM):	13.7	via NJ truck route 1/9 to Holland Tunnel 13.7,				
65			http://goo.gl/maps/Zvk0Q				
66	Distance around CM:	0.4					
67	Distance CM-dump-carter garage:	34.2	CM to Bronx dump via 1st ave to Garage via G. Washington				
68			Br. To I-95, 34.2 http://goo.gl/maps/FaFca				
69	Distance CM-materials recovery facility (MRF)-carter garage:	37	CM to MRF to garage viaG. Washington Bridge to I-95, 37 http://goo.gl/maps/bLzjLl				
70	Distance CM-compost facility-garage(9):	34.2					
71	Distance carter garage-AVAC:	13.7					
72	Distance AVAC-carter dump-carter garage:	34.2					
73	Distance AVAC-MRF-carter garage:	37	See route above http://goo.gl/maps/f9cIy				
74	Distance AVAC-compost facility	34.2	See route above				
75							
76	**Parks Dept/DSNY Distances**						
77	Hypothetical AVAC location:	Gansevoort St and Washington Ave. New York, NY 10014					
78	Curbside pick up location:	W18th St. and 10th Avenue					
79	Parks rear-loader garage location:	Central Park					
80	Parks rear-loader dump location:	Harlem River Yard Transfer Station, used: Bronx Sanitation District Office, per Steve					
81		Simon, Chief of Staff, Parks Dept., Borough of Manhattan, to Miller, 12-19-12.					
82		720 East 132nd Street, Bronx, NY 10454					
83	HL pick-up only 2/5 of a truck, so miles used multiplied by	0.400					
84	DSNY RoRo garage location	Manhattan 3 Garage, South St., Pier 6, Montgomery & Jefferson St.					
85	RoRo dump location:	Covanta incinerator, 183 Raymond Blvd, Newark, NJ					
86	Distance Parks rear-loader garage-18th St.:	3.5					
87	Distance 18th St.-dump-rear-loader garage:	12.9					
88	Distance DSNY roro garage-AVAC	3.0					
89	Distance AVAC-roro dump-DSNY garage	18.2					
90							
91	**Notes:**						
92	(1) According to confidential industry sources, 4 trucks (2 refuse, 1 organic, 1 recyclables) pick up 7 days a week from loading docks on						
93	both 15th and 16th St. sides of block-long Chelsea Market building. According to google maps the distance is .4 mi from 10th Ave. and						
94	W16th to 9th Ave. and W16th and back along W15th. See google maps, http://goo.gl/maps/a4O6R						
95	(2) Parks collects HL refuse 3x week, 4x in summer assume 3.5 average; DSNY collects HL recycling 1x. See Meeting with Mike						
96	Lampariello and Judith Simon of FOHL 03/22/12.						
97	(3) According to confidential industry sources 90% of recyclables collected is OCC so pneumatic system would not collect metal glass and						
98	plastic. A cutting and baling machine located near the pneumatic inlets would pre-process OCC and insert it in the system. Trucks would						
99	still be required for MGP pick up, assumed to be 1x per week.						
100	(4) For number of 60cy containers for each fraction, see EnvCont worksheet. DSNY uses Mack roll-on trucks						
101	(http://www.flickr.com/photos/28535419@N03/4118397562/in/pool-1201958@N21/, accessed 10-5-12). The Mack Granite refuse						
102	series has a maximum rear-axle capacity (3 rear axles) of 69k lbs (34.5 tons)						
103	http://www.macktrucks.com/assets/MackMarketing/Specifications/GU7148x6GraniteAxleFwd.pdf, accessed 10-5-12. NYC truck						
104	regulations allow a total of 80k pounds on a truck with 3 or more axles. http://www.nyc.gov/html/dot/html/motorist/sizewt.shtml,						
105	accessed 10-5-12. With a tare weight of approximately 15 tons, container loads would not exceed weight limits.						
106			Refuse	Organics	Paper		
107		Carter+DSNY Trips/Wk	1.76	0.6	0.9		
108		Carter Trips/Wk	1.42				
109		DSNY Trips/Wk	0.34				
110		Tons/Container	25.3	25.3	16.9		

	A	B	C	D	E	F	G
111	Terminal has a minimum of 6 containers, 2 per fraction, so that service can continue without disruption when containers are removed for						
112	disposal.						
113	(5) Compost is delivered to processing facilities outside the city.						
114	(7) Since containers are rail-ready, and since normal dump site/transfer station is proximate to Harlem River Rail Yard (HRY), HRY is						
115	assumed dump site, but if current transfer station were used instead, mileage would be virtually the same. Other dump locations could						
116	be possible, but distances would not be significantly different.						
117	(8) Alternatively, 1 party--either the private carter or DSNY--could remove all containers, to the same locations. This would not however						
118	affect the total number of trips and would have only a minor influence on mileage. With metering, volumes and costs could in any event						
119	be allocated to the responsible party.						
120	(9) In real (but absurd) life, the current carter for CM hauls source-separated organics from CM a round-trip daily distance of 235 miles,						
121	since the nearest compost facility capable of accepting its overall volume of source-separated organics is in Wilmington, Delaware.						
122	(http://earth.columbia.edu/sitefiles/file/education/capstone/Capstone-Final-Report.pdf, accessed 1-10-13, p.17.) Since this situation						
123	should change as soon as the demand for nearby organics processing is met with a new facility, and since a haul of this irrational						
124	distance plays a disproportionate role in the comparison of Pneumatic and Manual costs (particularly given the magnitude of the tolls						
125	involved) and impacts, we are assuming for present comparative purposes that an organics processing facility is located at the same						
126	distance from CM as is the current refuse transfer station.						
127	Per cite above, average capacity (tons) of custom compost truck used:	13.5					
128	(10) Manhattan Rear-loader fuel economy from Multi-Fleet Demonstration of Hydraulic Regenerative Braking Technology In Refuse Truck						
129	Applications, Final Report prepared for NYSERDA, 2011, p44 Table 26. http://bit.ly/13b9Wd0, last accessed 02/21/13. Fuel economy for						
130	private carters assumed to be 3mpg because some collections use ro-ros and trips may involve fewer stops.						
131	DSNY rear-loader MPG						2.19
132	Assumed RORO MPG						5
133	Assumed private carter rear-loader MPG						3
134	(11) Assumed avg tons of refuse or OCC/office paper (some of which is baled, bundled, or pre-compacted) collected by "Class A-Building" private carters who typically have dense routes:						12

Table A-2.3. PlaNYC (New York City-Specific) GHG Emission Coefficients

NYC-specific emission factors for electricity and vehicle fuel from NYCPlan 2011 inventory, appendix H, I

http://nytelecom.vo.llnwd.net/o15/agencies/planyc2030/pdf/greenhousegas_2011.pdf

Appendix H

Electricity Emissions Coefficients

2005 ELECTRICITY EMISSIONS COEFFICENT											
	Generation (GJ)	CO_2 (Mg)	CO_2/GJ (kg)	CH_4 (Mg)	CH_4/GJ (kg)	N_2O (Mg)	N_2O/GJ (kg)	CO_2e (Mg)	CO_2e/GJ (kg)	Source energy (GJ)	Source GJ/GJ
In-city	88,618,432	13,939,008	157.292	274.78	0.00310	29.72	0.00034	13,953,992	157.462	233,463,499	2.634
Contract	63,154,249	2,045,234	32.385	38.57	0.00061	3.86	0.00006	2,047,240	32.417	221,522,697	3.508
NYISO Zone A	13,308,192	1,358,448	102.076	15.04	0.00113	21.85	0.00164	1,365,536	77.907	16,451,345	1.236
NYISO Zone D	5,613,408	170,458	30.366	3.22	0.00057	0.32	0.00006	170,625	102.609	3,849,636	0.686
Market procurement (Zone G, H, I)	23,730,919	3,753,034	158.150	84.58	0.00356	44.94	0.00189	3,768,740	30.396	68,670,819	2.894
Total	194,425,200	21,266,182	109.380	416.20	0.00214	100.68	0.00052	21,306,134	109.585	543,957,994	**2.798**
Total 2005 NYC consumption	185,030,541		Coefficient with transmission and distribution losses								
Transmission and distribution loss rate	-4.83%		114.665		0.00224		0.00054		115.149		

2006 ELECTRICITY EMISSIONS COEFFICENT											
	Generation (GJ)	CO_2 (Mg)	CO_2/GJ (kg)	CH_4 (Mg)	CH_4/GJ (kg)	N_2O (Mg)	N_2O/GJ (kg)	CO_2e (Mg)	CO_2e/GJ (kg)	Source energy (GJ)	Source GJ/GJ
Total	191,145,600	16,238,006	84.951	328.16	0.00172	84.47	0.00044	18,207,698	95.256	581,737,144	**3.043**
Total 2006 NYC consumption	181,779,844		Coefficient with transmission and distribution losses								
Transmission and distribution loss rate	-4.90%		89.113		0.00180		0.00046		100.163		

2007 ELECTRICITY EMISSIONS COEFFICENT											
	Generation (GJ)	CO_2 (Mg)	CO_2/GJ (kg)	CH_4 (Mg)	CH_4/GJ (kg)	N_2O (Mg)	N_2O/GJ (kg)	CO_2e (Mg)	CO_2e/GJ (kg)	Source energy (GJ)	Source GJ/GJ
Total	197,100,000	17,370,651	94.809	329.64	0.00175	69.212	0.00046	17,399,030	94.989	572,790,221	**2.906**
Total 2007 NYC consumption	188,202,200		Coefficient with transmission and distribution losses								
Transmission and distribution loss rate	-4.51%		99.090		0.00182		0.00048		99.480		

2008 ELECTRICITY EMISSIONS COEFFICENT											
	Generation (GJ)	CO_2 (Mg)	CO_2/GJ (kg)	CH_4 (Mg)	CH_4/GJ (kg)	N_2O (Mg)	N_2O/GJ (kg)	CO_2e (Mg)	CO_2e/GJ (kg)	Source energy (GJ)	Source GJ/GJ
Total	197,406,000	18,097,970	91.679	322.32	0.00163	91.96	0.00047	18,133,245	91.858	566,884,779	**2.872**
Total 2007 NYC consumption	186,150,634		Coefficient with transmission and distribution losses								
Transmission and distribution loss rate	-5.70%		96.906		0.00173		0.00049		97.412		

2009 ELECTRICITY EMISSIONS COEFFICENT											
	Generation (GJ)	CO_2 (Mg)	CO_2/GJ (kg)	CH_4 (Mg)	CH_4/GJ (kg)	N_2O (Mg)	N_2O/GJ (kg)	CO_2e (Mg)	CO_2e/GJ (kg)	Source energy (GJ)	Source GJ/GJ
In-city	83,690,030	10,784,766	128.866	204.98	0.00245	20.79	0.00025	10,795,517	128.994	214,179,004	2.559
Contract	51,125,157	1,630,338	31.889	30.75	0.00060	3.07	0.00006	1,631,937	31.920	215,435,675	4.214
NYISO Zone A	13,308,192	1,035,413	77.803	11.08	0.00083	17.35	0.00130	1,041,025	78.224	11,969,363	0.899
NYISO Zone D	5,613,408	102,679	18.292	1.94	0.00035	0.19	0.00003	102,780	18.310	2,043,149	0.364
Market procurement (Zone G, H, I)	34,899,058	2,481,293	71.099	38.66	0.00111	36.12	0.00104	2,493,303	71.443	97,101,617	2.782
Market procurement (ROS)	2,524,154	133,372	52.838	0.96	0.00038	0.90	0.00036	133,802	53.009	4,440,372	1.759
Total	191,160,000	16,167,861	84.578	288.37	0.00151	78.44	0.00041	16,198,364	84.737	545,169,181	**2.852**
Total 2009 NYC consumption	182,649,671		Coefficient with transmission and distribution losses								
Transmission and distribution loss rate	-4.45%		88.343		0.00158		0.00043		88.685		

2010 ELECTRICITY EMISSIONS COEFFICENT											
	Generation (GJ)	CO_2 (Mg)	CO_2/GJ (kg)	CH_4 (Mg)	CH_4/GJ (kg)	N_2O (Mg)	N_2O/GJ (kg)	CO_2e (Mg)	CO_2e/GJ (kg)	Source energy (GJ)	Source GJ/GJ
In-city	86,233,586	11,021,449	127.809	209.44	0.00243	21.24	0.00025	11,032,431	127.937	218,888,739	2.538
Contract	48,658,118	1,805,308	37.102	34.05	0.00070	3.40	0.00007	1,807,079	37.138	217,473,479	4.469
NYISO Zone A	13,308,192	1,149,229	86.355	12.37	0.00093	19.13	0.00144	1,155,420	86.820	13,169,352	0.990
NYISO Zone D	5,613,408	41,261	7.350	0.78	0.00014	0.08	0.00001	41,302	7.358	820,968	0.146
Market procurement (Zone G, H, I)	38,229,527	2,318,993	60.660	39.13	0.00102	31.53	0.00082	2,329,591	60.937	107,223,986	2.805
Market procurement (ROS)	6,367,569	375,193	58.922	2.35	0.00037	1.90	0.00030	376,333	59.102	11,365,231	1.785
Total	198,410,400	16,711,433	84.227	298.12	0.00150	77.29	0.00039	16,742,155	84.381	568,941,755	**2.867**
Total 2010 NYC consumption	190,667,806		Coefficient with transmission and distribution losses								
Transmission and distribution loss rate	-3.90%		87.647		0.00156		0.00041		87.808		

Table A-2.3. PlaNYC (New York City-Specific) GHG Emission Coefficients (continued)
NYC-specific emission factors for electricity and vehicle fuel from NYCPlan 2011 inventory, appendix H, I
http://nytelecom.vo.llnwd.net/o15/agencies/planyc2030/pdf/greenhousegas_2011.pdf

Appendix I

Fuel Emissions Coefficients

2010 FUEL EMISSIONS COEFFICIENTS							
	UNIT	GREENHOUSE GAS (Kg/UNIT)					FUEL EFFICIENCY (Km/UNIT)
		CO_2	CH_4	N_2O	CO_2e	GJ/UNIT	
Stationary source							
Natural gas (buildings)	GJ	50.25326	0.00474	0.00009	50.38216	0.99995	
Natural gas (industrials)	GJ	50.25326	0.00095	0.00009	50.30254	0.99995	
#2 fuel oil (buildings)	liter	2.69627	0.00040	0.00002	2.71147	0.03846	
#2 fuel oil (industrial)	liter	2.69627	0.00011	0.00002	2.70534	0.03846	
#4 fuel oil (buildings)	liter	2.89423	0.00042	0.00002	2.91031	0.04069	
#4 fuel oil (industrial)	liter	2.89423	0.00012	0.00002	2.90383	0.04069	
#6 residual fuel oil (buildings)	liter	2.97590	0.00044	0.00002	2.99242	0.04181	
#6 residual fuel oil (industrial)	liter	2.97590	0.00012	0.00002	2.98576	0.04181	
100% biodiesel*	liter	2.49683	0.00004	0.00000	2.49876	0.03567	
Propane (industrial)	liter	1.47748	0.00007	0.00001	1.48346	0.02536	
Kerosene (industrial)	liter	2.68187	0.00011	0.00002	2.69075	0.03762	
Mobile source							
On-road							
Diesel - buses	liter	2.69720	0.00002	0.00002	2.70253	0.03849	5.38
Diesel - light trucks	liter	2.69720	0.00000	0.00000	2.69851	0.03849	4.38
Diesel - heavy-duty vehicles	liter	2.69720	0.00001	0.00001	2.70082	0.03849	3.65
Diesel - passenger cars	liter	2.69720	0.00000	0.00000	2.69854	0.03849	6.73
Gasoline - light trucks	liter	2.31968	0.00012	0.00017	2.37403	0.03484	6.21
Gasoline - passenger cars	liter	2.31943	0.00015	0.00016	2.37200	0.03484	8.72
100% biodiesel (B100) - heavy trucks*	liter	2.49710	0.00004	0.00000	2.49903	0.03568	3.65
100% ethanol (E100) - passenger cars*	liter	1.51899	0.00022	0.00027	1.60857	0.02342	6.58
Compressed natural gas - bus	GJ	50.28833	0.10395	0.00925	55.33978	1.00000	0.37
Off-road							
Aviation gasoline	liter	2.19527	0.00186	0.00003	2.24333	0.03350	
Diesel, locomotives	liter	2.52840	0.00007	0.00008	2.55529	0.03763	
Diesel, ships and boats	liter	2.69720	0.00021	0.00007	2.72293	0.03866	
Jet fuel	liter	2.69749	0.00020	0.00007	2.72289	0.03866	

* Per the LGOP, CO_2 from biofuels is considered biogenic and is reported as a Scope 3 source
** Per the LGOP, building usage here is identified as residential, commerical, or institutional

Table A-2.4. PlaNYC (New York City-Specific) GHG Emission Coefficient Units

PlaNYC Factors	kg CO2e/GJ(1)	kwh per Giga Joule	kg CO2e/kwh	kg per ton (US)	t CO2e/kwh
electricity	87.808	277.77	0.316117651	907.18	0.000348462

	kg CO2e/liter (2)	liters per gallon	kg CO2e/gallon	kg per ton (US)	t CO2e/gallon
diesel hd truck	2.70	3.78541	10.22371104	907.18	0.011269771

Notes:
(1) See 2011 NYC Emissions Factors worksheet, Appendix H, Coefficient with transmission and distribution losses
(2) See 2011 NYC Emissions Factors worksheet, Appendix I

87.808 coefficient for kg CO2e/unit based on weighted average of emissions from energy generation at power plants serving NYC. To convert electricity to CO2e emissions per ton: 87.81 kg CO2e/GJ * electricity in Giga Joules (277.77GJ/kwh) = kg CO2e per day/1102.3 = tons C02e per day/tons collected per day = tons CO2e emissions per ton.
To convert diesel or gasoline to CO2e/l convert gallons to liters
NYC-specific emission factors for electricity and vehicle fuel from NYCPlan 2011 inventory, appendix H, I
http://nytelecom.vo.llnwd.net/o15/agencies/planyc2030/pdf/greenhousegas_2011.pdf

	A	B	C	D	E	F	G	H	I	J	K	L	P	Q
1	**Table A-2.5. Pneumatic System Container Calculation**													
2	FRACTIONS	% WEIGHT	FRACTION	REST	PACKING	ORGANIC	PAPER							
3	REST	0.52	1	0.52	0	0	0							
4	PACKINGS	0.07	0	0.07	0	0	0							
5	ORGANIC	0.2	1	0	0	0.2	0							
6	PAPER	0.21	1	0	0	0	0.21							
7		1		0.59	0	0.2	0.21							
8														
9														
10	DENSITY													
11		KG/L	DATA	CALC										
12	REST	0.13		0.13										
13	PACKING	0.08		0.08										
14	ORGANIC	0.2		0.2								factor(0,25-		
15	PAPER	0.05		0.05								1,00)		
16												0.75		
17														
18	CONTAINERS MOVE													
19		FRAC-CONT.	TRANSP	CONT	% Fraction	Tons/CONT	VOLUM	COMPACT.	DENSITY	RATIO VOL.	RATIO WEIGHT	MAX VALUE	Trips/Wk	Tons/Containe
20	REST C	0	1	0	0	12	30	0.29	0.13	0	0	0		
21	PACKING C	0	1	0	0	12	30	0.50	0.08	0	0	0		
22	ORGANIC C	0	1	0	0	12	30	0.77	0.2	0	0	0		
23	PAPER-CARDBOARD C	0	1	0	0	12	30	0.67	0.05	0	0	0		
24	REST C-CRANE	0	0	0	0	10	25	0.29	0.13	0	0	0		
25	PACKING C-CRANE	0	0	0	0	10	25	0.50	0.08	0	0	0		
26	ORGANIC C-CRANE	0	0	0	0	10	25	0.77	0.2	0	0	0		
27	PAPER-CARDBOARD C-CRANE	0	0	0	0	10	25	0.67	0.05	0	0	0		
28	REST G	1	1	1	0.59	19	45.6	0.29	0.13	0.31	0.34	0.25	1.8	25.3
29	PACKING G	0	1	0	0	19	45.6	0.50	0.08	0	0	0		
30	ORGANIC G	1	1	1	0.2	19	45.6	0.30	0.2	0.07	0.11	0.09	0.6	25.3
31	PAPER-CARDBOARD G	1	1	1	0.21	19	45.6	[redacted]					0.9	16.9
32	REST G-CRANE	1	0	0	0	10	25	0.29	0.13	0	0	0		
33	PACKING G-CRANE	0	0	0	0	10	25	0.50	0.08	0	0	0		
34	ORGANIC G-CRANE	1	0	0	0	10	25	0.77	0.2	0	0	0		
35	PAPER-CARDBOARD G-CRANE	1	0	0	0	10	25	0.67	0.05	0	0	0		
36	REST F	0	-	0	0	6	21	0.40	0.13	0	0	0		
37	**PACKING F**	**0**	**-**	**0**	**0**	**3.5**	**21**	**1.00**	**0.08**	**0**	**0**	**0**		
38	ORGANIC F	0	-	0	0	6	21	0.91	0.2	0	0	0		
39	**PAPER-CARDBOARD F**	**0**	**-**	**0**	**0**	**2**	**21**	**1.25**	**0.05**	**0**	**0**	**0**		
40	**TOTAL**				**1**			**22.50**				**0.71**		
41	REST G-CRANE	1	0	0	0	10	25	0.29	0.13	0	0	0		
42	PACKING G-CRANE	0	0	0	0	10	25	0.50	0.08	0	0	0		
43	ORGANIC G-CRANE	1	0	0	0	10	25	0.77	0.2	0	0	0		
44	PAPER-CARDBOARD G-CRANE	1	0	0	0	10	25	0.67	0.05	0	0	0		
45	REST F	0	-	0	0	6	21	0.40	0.13	0	0	0		
46	PACKING F	0	-	0	0	3.5	21	1.00	0.08	0	0	0		
47	ORGANIC F	0	-	0	0	6	21	0.91	0.2	0	0	0		
48	PAPER-CARDBOARD F	0	-	0	0	2	21	1.25	0.05	0	0	0		
49	TOTAL				1							0.83		
50	UTRC: assume 750 lbs compacted mixed office paper/OCC per cy													

Table A-3.1. Pneumatic vs. Manual Potentially Achievable Waste-Generator Savings

				staging SF			**Equivalent Annual Rent**		**Projected annual labor cost**		**Annual Equipment Cost (10)**	
	Tons/day	# of manual bins (5)	actual # manual bins (rounded to nearest)	$/Y 60-gal bags(14)	manual (5)	AVAC (3)(4)	Manual SF (2)	AVAC SF (2)	manual (8)	AVAC	manual	AVAC
									Time-guesstimation method			
Chelsea Market businesses												
compost	2.18	21.8	22	NA	176	44	$35,200	$8,800	$34,812	$34,812	$594	$149
occ	2.22	48.84	49	NA	882	220.5	$176,400	$44,100	$35,451	$35,451	$1,960	$490
refuse restaurant	3.46	3.46	4	$70,823	240	60	$48,000	$12,000	$55,252	$55,252	$71,223	$70,923
refuse other (11)	1.71	5.13	5	$35,002	336	84	$67,200	$16,800	$27,307	$27,307	$35,154	$35,040
central staging/OCC	NA				NA?	400		$80,000				$5,000
Total	9.57				1634	808.5	$326,800	$161,700	$152,821	$152,821	$108,932	$111,602
High Line Park												
central staging refuse (12)	1.25	1	1		400	200	$80,000	$40,000	$90,234	$45,117	$17,288	$495
Pneumatic Terminal (6)					NA	6890	NA					

Notes

(1) Chelsea Market includes 100,000 SF ground floor retail, and 1 million + SF commercial office space, Source: Jamestown Properties Chelsea Market Proposed Expansion, p3, http://bit.ly/VSKmSt, accessed 01/09/12

(2) For CM truck access, assume all refuse container staging is on ground floor at or near loading docks. Assume annual retail rent of $200/sf. Chelsea Market ground floor retail rent $200 to 300 SF, average commercial rent in Chelsea is 175 to 275 SF, Source: NYT, http://www.nytimes.com/2013/01/09/realestate/commercial/before-building-towers-chelsea-market-plans-to-add-vendors.html?pagewanted=all&_r=0, accessed 01/09/12; For HL assume same $200 SF rent. Since HL AVAC scenario only includes refuse, recyclable fractions would still be collected manually. Assume 50% recyclable.

(3) 4 inlets in a central waste collection space. The exact location and floor was not determined, but this scenario assumes the inlet room is at the same height as the trunk line, which in this case would be the second or third floor. Note: although this scenario assumes a central waste area, it is possible that 2 waste rooms, 1 at each end of the building would be preferable for tenant convenience. Assume that employees empty trash receptacles 4x every 24 hours, or at the beginning and end of each shift.

(4) A hydraulic briquetting machine is required in order to introduce occ into the system. Envac recommends the Brickman 900/1200, which is 15x15 (225 SF). Assume baler is located in central waste room with additional 10x15 (150SF) space for maneuvering 3x3 carts and accessing the 4 pneumatic inlets (no storage) , or approx 400 SF, for baler dimensions see http://www.orwak.com/Products_for_compaction/Brickman_briquette_presses.aspx, accessed 01/09/12

(5) CM refuse, occ and compost is collected every day. 1 ton of cardboard equals 22 cubic yards, or 22 1-cy containers occupying 9sf each, or 198sf; 1 ton of compostable food waste= approx 10 64-gallon totes occupying 4 sf ea. or 40 sf; 1 ton of mixed office waste = 25cy or 3 8-yd containers at 30sf ea. plus 1 1-cy container

at (9 sf@) for a total of 99 sf; 1 ton of restaurant wet waste = 1 8-cy container at 30 sf. It is assumed that an equivalent amount of space must be left for container maneuvering, so all container footprints are doubled for staging square footage. High Line stages waste in 1 10x20x8 (200sf) shipping container, it also has 2 10x20 (200sf) containers and 1 10x10 container (100sf), which are not currently in use but could be used when Sector 3 opens. These were not counted here. (Meeting with Mike Lampariello and Judith Simon of FOHL, 3-22-12.) Assume 50% of waste is recyclable, so in AVAC scenario assume 50% of area required for staging.

Supplies(7)	12,618	
Bins (2)	4,000	
container	sf	unit cost (10)
64 gal tote	4	270
1 cyd container	9	400
8 cyd container	30	1000

(6) It is assumed that the AVAC terminal will be located off-site adjacent to the High Line. The proposed terminal would be 6890 SF. See Envac: UA-O5-501.pdf Value in rent will depend on where the terminal is located (basement, ground floor, upper floor) .

(7) Restaurant and food service (combined max and min business waste) 3.46 tpd & office is 1.37, see Chelsea-preliminary draft.xlsx; according to confidential industry sources restaurants have 50% compost, 25% OCC, 25% refuse (rate of compost is higher for fresh food stores, but treated as restaurants here); office waste is 70% occ, 5% mgp, 25% refuse

(8) According to RI business survey, 9 hours of in-house labor are required per day to collect 8.7 tons of business waste on RI or approximately 1 hour per ton/waste, see Ref5-1, Reference docs 1016.pdf ; Assume $35,000 annual janitor salary or 17.5/hr http://www.indeed.com/salary/q-Custodian-l-New-York,-NY.html; OR use estimate based on actual time, using the FOHL estimate (note 12 below) for CM--however CM and types of refuse would have different volumes and frequencies and businesses will be different distances from AVAC OR Pure guesstimate based on converting tons to 60gal/40lb bags, 1 minute for each to load/tie, 2 mins for each to move 50 feet (round-trip), 2 minutes each to to take to elevator/loading dock, round-trip; AVAC=1/4 of this, since some carrying to inlets, management of OCC, cleaning

(9) Estimate a 25% reduction in labor in the AVAC scenario because waste must still be stored at each business and transported to inlets. Fewer containers would have to be maintained and less time would be spent processing OCC.

(10)64-gallon restauran-grade tote, http://www.foodservicewarehouse.com/rubbermaid/rcp-9w21-gra/p335640.aspx, accessed 01/09/12; 1 cyd container at $400 ea, (FOHL cost) and 8 cyd container at $1000, 10-yr life, annualized; According to Envac the Brickman 900/1200 hydrolic briquetting machine costs $50,000, assume 10-yr life, ann.

(11) office and non-food service retail refuse, assume office tonnages.

(12) HL labor: Assume that 25% of morning shift and 50% of afternoon shift used for waste handling or 37.5% average. Salary based on $35,000 average annual salary, http://www.indeed.com/salary/q-Custodian-l-New-York,-NY.html37.5% of 6 full-time and 3.5 summer custodians for waste handling, or 6.875 annual salaries. Assume summer to be June, July, August, (3.5 custodians *1/4 of the year).(Meeting with Mike Lampariello and Judith Simon of FOHL, 3-22-12.) Assume 50% of HL waste is recyclable, so 50% of labor needed in AVAC scenario.

(13) HL supplies: Trash bags 225 cases per year @ $56.08 per case of 50 (actual 2011 count); 35 bins for trash @ $800 ea., 7-year life annualized.

(14) For CM # of bags would be the same for AVAC scenario because waste has to be transported to inlets. Cost of bags is assumed to be the same as FOHL count, see note 13. Bags are eliminated in HL AVAC scenario.

Appendix B: Second Avenue Subway Data/Calculations

	A	B	C	D	E	F	G	H	I
	Table B-1.1. Capital Cost Components, High Line and Second Avenue Subway Pneumatic Installations								
	(b)			(a,c)					
	HL Capital Costs			**SAS Capital Costs**					
	Terminal SF	6,900	$2,892,362	Terminal SF	4,300	$2,600,000			
	Trunk Pipe (meters)	1,729	$5,671,724	Trunk Pipe, in 2nd Ave (m)	430	$860,000			
				Trunk Pipe, NYCHA	455	$989,625			
				Subway Pipe	300	$560,000			
	Outdoor Inlets	24	$1,347,075	Outdoor Inlets	180	$5,400,000			
	CM Waste Rm/Inlets		$658,659	Subway Inlets	12	$360,000			
	TOTAL		$10,569,820	TOTAL		$10,769,625			
				w/o subway					
				terminal SF	4,300	$2,600,000			
				street pipe	800m	$860,000			
				street inlets	180	$5,400,000			
				TOTAL		$8,860,000			
				w/o street level					
				terminal, "3F"	2,000sf	$1,200,000			
				13" 330mm polyethylene pip	600m	$200,000			
				litter bin inlets	12@20,000	$240,000			
				TOTAL		$1,640,000			
	Notes:								
	(a) Based on Mateu to Miller/Spertus, 7-12-12; civil cost of pipe for trenching under NYCHA blocks, $475/m, from Mateu to Miller/Spertus, 2-15-12; equipment								
	cost of pipe, $1,700/m, from Mateu 7-12-12; installed cost of pipe in opened Second Avenue, $2,000/m (including equipment cost), Rello to Tornblom, 2-20-13.								
	(b) Mateu to Miller and Spertus, 9-29-11; HL pipe length, Google maps								
	© Trunk Pipe, in NYCHA Blocks		455						
	pipe cost/m		$1,700						
	civil cost/m		$475						
	Installed Cost		$989,625						
	Sensitivity Analysis: SAS Capital Costs with estimated cost for terminal building								
	Estimated cost of 4300 SF terminal building:			$401,746					
	Estimated cost of 6900 SF terminal building:			$644,661				2011$	2013$
	Per SF Construction cost for a manufacturing facilit in New York City in 2011, 1 floor, metal exterior, metal roof,							$69.10	$71.32
	5,000-25,000 sf. See http://www.dcd.com/pdf_files/1107analysis.pdf, accessed 04-08-13:						Constractor fee	25%	$17.83
	This Per SF construction cost does not include fees. Including fees as outlined in						Architectural fee	6%	$4.28

	A	B	C	D	E	F	G	H	I
38	http://www.reedconstructiondata.com/rsmeans/models/warehouse/new-york/new-york/						Total		$93.43
39	Estimated cost of 4300 SF terminal building at projected RI construction cost rate:						$1,618,993		
40	Estimated cost of 6900 SF terminal building at projected RI construction cost rate:						$2,597,919		
41								2012$	2013$
42			Cost per SF estimated by Envac, see Rello to Miller 01/18/13:					$372	$377
43			multiple Capital Costs RI Rate v. NYC Estimate:			4			

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
2	**Table B-1.2. Potential Space, Labor, And Equipment Savings With Pneumatic Collection**														
3					**staging SF**			**Equiv. Ann. Rent (2)**			**Proj. Ann. Labor Cost (1)**			**Ann. Equip. Cost (1)**	
4			tpd	40 or 60 lb (60 or 90 gal) bags	manual	AVAC		Manual SF (2)	AVAC SF (2)		manual (8)	AVAC		manual	AVAC
5											Time-guesstimation method				
6		Residential Refuse Tons/day	4.37	145.67	8494.1	0		$1,274,115	0		$231,282	$152,646		NA	NA
7	**Residential**	Residential Paper/OCC Tons/day	0.76	38		0					$39,298	$25,937		NA	NA
8	**(3)(4)(5)(6)**	Residential MGP Tons/day	0.41	20.5	2563	0		$384,431	0		$21,200	$13,992		NA	NA
9		NYCHA Refuse Tons/day	3.39	113	8000	0		$1,200,000	0		$116,861	$77,128		NA	NA
10		NYCHA Paper/OCC Tons/day	0.59	29.5	826	0		$123,900	$53,100		$42,711	$28,189		NA	NA
11	**NYCHA (3)(7)(8)(9)(10)**	NYCHA MGP Tons/day	0.32	16	448	0		$67,200	$28,800		$23,165	$15,289		$35,422	0
12		Hospital (Non-Haz) Refuse Tons/day	4.1	137	9676	0		$1,451,327	0		$70,668	$46,641		$38,702	0
13		Hospital Paper/OCC Tons/day	0.71	35.5	994	0		$149,100	0		$25,699	$16,961		NA	NA
14	**Hospital (11)**	Hospital MGP Tons/day	0.39	19.5	546	0		$81,900	0		$14,116	$9,317		NA	NA
15		Street Litter Bins Refuse Tons/day	0.47	23.5	NA	NA		NA	NA		NA	NA		$1,714	NA
16		Street Litter Bins Paper Tons/day	0.08	4	NA	NA		NA	NA		NA	NA		NA	NA
17	**Litter Bins (12)(13)**	Street Litter Bins MGP Tons/day	0.04	2	NA	NA		NA	NA		NA	NA		NA	NA
18		Commercial Refuse Tons/day	2.31	115.5	462	462		NA	NA		NA	NA		NA	NA
19		Commercial Paper/OCC Tons/day	0.4	20	80	80		NA	NA		NA	NA		NA	NA
20	**Commercial (14)**	Commercial MGP Tons/day	0.22	11	44	44		NA	NA		NA	NA		NA	NA
21		Subway Refuse Tons/day	0.15												
22		Subway Paper/OCC Tons/day	0.03												
23	**Subway (15)(16)(17)**	Subway MGP Tons/day	0.01	9.5	266			NA	NA		$21,672	$5,418		$373	0
24	**Total**							$4,731,974	$81,900		$606,674	$391,519		$74,498	0
25	Notes														

(1) **ALL WASTE SOURCES**: Not included are any labor or supply costs (bags) for getting refuse or recyclables to the exterior compactors or curbside, since it is assumed that building interiors would not be retrofitted with pipes; inlets would be located near the curb, with handling, as usual, by porters. There may be time savings due to reduced exterior transport distances, but these would be expected to be relatively modest. Assume all residential compacting equipment is interior and would continue to be used, and therefore not counted. Assume NYCHA compactors would not be used and are counted. Assume each 60 gal bag occupies same area as one 64 gallon tote, or 29" x 23" or approx 4 sf. See: http://www.usplastic.com/catalog/item.aspx?itemid=27384. Assume that pneumatic collection would require about a third less labor than manual collection in NYCHA, Residential Buildings and Hospital contexts. Employees still have to maneuver waste to outdoor inlets but no longer maintain equipment and distances may be reduced.

(2) SF, Annual rent per square foot on 2nd Avenue between 72nd and 96th Sts. Estimated at $150 for ground floor retail after subway is completed. See The Real Deal August 6, 2012 http://therealdeal.com/blog/2012/08/06/amid-construction-low-retail-rents-on-second-avenue/ (Accessed 01/19/13).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
34	**Residential Buildings**														
35–37	(3) Total Residential Units in study area: 2929, See SAS-waste Sources_0119, 92-9!K50; Apply 2.9 sf per unit and 350 sf per 400 units or .875 sf to total units to estimate staging area required according to regulations above. Assume staging is on ground floor. AVAC scenario, assume all waste and recycling taken directly to curb as required so no sf necessary for staging.														
38–41	(4) Space, Residential Refuse:"storage and removal locations shall be provided at the rate of 2.9 cubic feet per #dwelling unit#" NYC Dept. of City Planning, Article II: Residence District Regulations Chapter 8 - The Quality Housing Program, 28-23; Refuse Storage and Disposal, (2/2/11); Recycling: Resident waste room refers to the space where residents deposit their trash. A new bill proposes to amend the building code so new multifamily buildings must provide 5 sf of space in each waste room for recyclables and up to 350 sf for staging. Estimated 350 sf per 400 units. (beginning in 2014) http://www.crainsnewyork.com/article/20121211/REAL_ESTATE/121219978														
42–45	(5) Labor, Residential Recycling: (Buildings vary see previous) Taking bags of recyclables dropped off by tenants in waste rooms on each floor to basement storage room, 5 minutes per floor including elevator wait, putting them into 60-gal clear or blue bags, bringing to curb 1x week, guesstimating 60-gal clear and blue bags, 40 lbs/bag, 2 minutes to fill and tie each bag, 2 minutes for each bag, round-trip, to ferry to storage room, 1 minute for each bag to place and remove from storage room, 4 minutes for each bag to place on cart to take to curb, round-trip, =7 minutes/bag *320 bags/wk. See "wastevol" worksheet.														
46–49	(6) Labor, Residential Refuse: Residential buildings in study area vary from 5-story walk ups to high rises. Treat all tonnage as high rise for purposes of study: Assume waste is collected in 60 gal bags, 40 lbs/bag, 2 minutes to fill and tie each bag, 2 minutes for each bag, round-trip, to ferry to storage room, 1 minute for each bag to place and remove from storage room, 4 minutes for each bag to place on cart to take to curb, round-trip, =9 minutes/bag. Assumes an annual salary of 60,000 (with fringe), or $29 per hour, for property manager based on average listed on http://www.indeed.com/salary?q1=property+manager&l1=New+York%2C+NY (accessed 01/19/13)														
50	**NYCHA**														
51–52	gallon bag (the sf of a 64-gallong tote)*bags/day*7; assume that in pneumatic scenario recyclables could be collected 3x a week (or as often as necessary) so 3/7 of the staging area needed.														
53–57	(8) Equipment, NYCHA Refuse: 3 self-contained exterior compactor installations@100k with 15-year life-expectancy, Gentile to Miller 1-3-13, see also: http://www.nyc.gov/html/nycha/html/news/washington-garbage-compactors.shtml(06-13-13), These are treated as an annualized operating cost rather than capex to be consistent with other opex cost factors which provide for ongoing replacement. These costs are annualized over their 15-year life-expectancy. $2,000 in compactor maintenance costs 6x per year, 2 Ford F150 pick up trucks, (only one for bulk items would be necessary in pneumatic scenario) mtg w Gentile 5-15-13. Ford F150 XL cost $23,955 (http://www.ford.com/trucks/f150/ (accessed 06-12-13) annualized over 7 years.														
58	Compactor annual cost:	$20,000	Ford F150 annual cost:					$3,422	Compactor annual maintena			$12,000			
59–61	(9) Labor, NYCHA Recycling: Taking bags of recyclables dropped off in or next to ground-floor receptacles, putting them into 60-gal clear or blue bags, bringing to curb 1x week, guesstimating 60-gal clear and blue bags, 40 lbs/bag, 2 minutes to fill and tie each bag, 2 minutes for each bag, round-trip, to ferry to storage room, 1 minute for each bag to place and remove from storage room, 4 minutes for each bag to place on cart to take to curb, round-trip, =7 minutes/bag * 320 bags/wk. (See "wastevol" worksheet.)														
62–63	(10) Labor, NYCHA Refuse: 90-gal bags loaded into compactor: 5 minutes per bag to tie, transport to compactor, insert into compactor, guesstimate; see "wastevol" worksheet, assume Resident Building Superintendent, salary $70,000, 2011, http://seethroughny.net/payrolls/cities/ (accessed 011913) Hourly rate 70,000/52*40 is $34.														
64	**Hospital**														
65–66	truck. For SF use compactor sf for refuse & 4 sf per 60 gal bag for recyclables. Apply NYCHA labor time to hospital volume. Custodian salary $35,000, or $17/hour, see http://seethroughny.net/payrolls/cities/ (NYC Dept of Health_ (accessed 011913).														
67	**Litter Bins**														
68	(12) Equipment, Litter bins. Guess 2 sets of 3 (1 for each fraction) litter bins per block (5 blocks) at $400 each, with a 7-year life. Litter bins for AVAC scenario are included in Capex														
69–70	(13) Labor, Litter bins. is included in DSNY opex. No space savings because AVAC will require litter-bin size inlets. Equipment cost should be included in DSNY operating costs as inlets are included in AVAC opex.														
71	**2nd Avenue Businesses**														
72	(14) Labor businesses, guess that employees will spend roughly the same amount of time staging waste in both scenarios.														
73	**Subway**														
74	(15) Space, Subway platform sf estimated, guessing collection 1x week, but not monetized as ground floor space.														
75	(16) Equipment, Subway, Guess (3) locations for waste receptacles on platform with: (3) 64 gallon steel receptacles for refuse, (3) for paper and (3) for m/g/p and(1) 4cyd custom														

	A B C D E F G H I J K L M N O
76	steel lockers for storage.Guess $400 ea for receptacles and $2000 ea for lockers. Assume 15-year life.
77	(17) Labor, Subway Refuse, Assume 15 minutes per bag to install in bin, remove from bin and tie, stage in storage locker, get onto waste train, haul on waste train, remove from
78	train to carter truck. $25 per hour transit labor class cleaner. http://seethroughny.net/payrolls/cities/ MTA (accessed 011913) Assume Subway employees would not handle bagged
79	waste but would still clean around inlets or about 25% of manual labor.
80	Note: Terminal will require 4300 SF, Mateu to Miller and Spertus, 7/12/12. Value in rent will depend on where the terminal is located (basement, ground floor, upper floor) .
81	Note: The space savings calculations here are meant to illustrate the savings that could be achieved. Refuse and recyclables tend to be staged in basement spaces rather than on
82	the ground floor but for the purposes of comparison ground floor rents were applied. Existing spaces were not invantoried, instead the projected required SF based on 2012
83	recycling legislation and the Planning Department's "Quality Housing Program" (which currently only applies to certain districts) were used.
84	*Note, in order to include bulky OCC in addition to paper, a baling machine will need to be provided. The space requirements and cost for the baling machines that would be
85	required have not been included.

	A	B	C	D	E	F	G	H
1	**Table B-1.3 Waste Tonnages By Source, Fractions, Current Collection Method**							
2	**Source**	**TPD Total**						
3	NYCHA(1)	5.38						
4	Residences 92-5	3.04						
5	Businesses 92-5	1.73						
6	Litter Bins 92-5	0.3						
7	Sub Sta 96th St	0.19						
8	Hospital	5.19						
9	Residences 95-99	2.5						
10	Businesses 95-9	1.2						
11	Litter Bins 95-9	0.3						
12	**Total**	**19.83**						
13								
14	**Source**	**TPD Total**						
15	**DSNY**							
16	Residences 92-5	3.04	Residential	Refuse	Paper	MGP	Total	
17	Residences 95-99	2.5	5.54	4.37253	0.75555	0.41472	5.5428	
18	Litter Bins 92-5	0.3	Bins					
19	Litter Bins 95-9	0.3	0.6					
20	NYCHA(1)	5.38						
21								
22	**Private Carters**							
23	Hospital	5.19						
24	Businesses 92-5	1.73	Business(2)	2.46	0.32	0.15	2.93	
25	Businesses 95-9	1.2	2.93					
26	Sub Sta 96th St	0.19						
27	**Total**	**19.83**						
28								
29	(1)DSNY SCAN, Collection Route Data, FY 2012, Washington Houses refuse; assume additional recyclable tonnage is negligible							
30	(2)Confidential industry source: recycling ratio OCC/paper to metal/glass/plastic							
31		paper	MGP					
32		[redacted]						
33		0.68	0.32					

	A	B	C	D	E	F	G
1	**Table B-1.3.1 Second Avenue Subway Cost Summary, Pneumatic v Manual**						
2		**Manual**	**AVAC**	**AVAC 120%**	**AVAC 150%**	**AVAC+T Bldg Cost (3)**	**AVAC 150%+T Bldg Cost**
3	TPD Rear-Loader	**10.9**					
4	TPD Ro-Ro	**8.9**					
5	TPY Rear-Loader	**3,983**					
6	TPY Ro-Ro	**3,256**					
7	Total TPY	**7,239**	**7,239**				
8	Capex(1)	$2,339,919	$10,769,625			$11,171,371	
9	Capex/T	$719	$1,488			$1,543	
10	Opex w/ Replacement w/o Dray or Debt Service	$834,452	$556,824	$560,452	$565,894		$565,894
11	Opex/T w/ Replacement w/o Dray or Debt Service(1)	$115	$77	$77	$78	$77	
12	RORO Dray Costs(2)		$91,554				
13	Opex w/Replacement + Dray w/o Debt Service	$834,452	$648,378	$652,006	$657,448	$648,378	$657,448
14	Annual Debt Service(1)	$138,413	$639,068			$660,819	$660,819
15	Opex w/ Replacement + Dray + Debt Service	$972,865	$1,287,446	$1,291,074	$1,296,516	$1,309,197	$1,318,267
16	Opex w/ Replacement, Dray, Debt Service/T(1)	$134	$178	$178	$179	$181	$182
17	Delta Opex w/Replacement + Dray w/o DS, AVAC v. Manual		-$186,074	-$182,446	-$177,004	-$186,074	-$177,004
18	Delta Opex w/ Replacement + Dray w/o DS Delta %, A v. M		78%	78%	79%	78%	79%
19	Delta Opex w/Replacement + Dray + DS, A v. M		$314,581	$318,209	$323,651	$336,332	$345,402
20	Delta Opex w/ Replacement + Dray + DS Delta %, A v. M		132%	133%	133%	135%	136%
21	NPV Multiple, A v. M		3.3	3.3	3.3	3.4	3.5
22	Annual Externality Benefits Required to Equalize NPV Costs		$310,000				
23	NPV Multiple, AVAC v. AVAC Sensitivity			1.01	1.02	1.05	1.07
24	(1)DSNY Cost Structure worksheet: Manual Capex back-calculated from per-ton debt service, weighted average based on the specific ratios of refuse and						
25	recyclables in the specific sections of Manhattan Districts 8 and 11, as shown in "DSNY" and "wastevol"						
26	(2)RORO costs from RORO Worksheet. Manual based on actual trips, shifts, miles, truck capex and maintenance costs and average labor costs. Does not						
27	include garage costs, administrative overhead and other costs included in total rear-loader per/ton costs based on citywide averages prorated by waste						
28	fractions, and therefore significantly understates RORO costs, but allows for a direct comparison with Pneumatic costs based on the same actual data with						
29	the number of Pneumatic trips based on the Container worksheet. Opex for both the Manual and Pneumatic cases will therefore be somewhat understated.						
30	http://bretwhissel.net/cgi-bin/amortize	Manual	Pneumatic		Pneu +T Bldg Cost	Pneu +T Bldg Cost RI Rate	
31	Interest (see NPV worksheet)	4.725	4.725		4.725	4.725	
32	Bond Term (""), 34 yrs=408 mos	408	408		408	408	
33	Monthly Debt Service(1)	$11,534	$53,256		$55,068	$61,069	
34	Principal (back-calculated based on monthly debt service,						
35	bond term, interest rate)	$2,339,919			$11,171,371	$12,388,618	
36	(3) See capex for rough building cost estimate based on New York City per sf construction cost factors.						
37	Multiple NPV AVAC +T Bldg v. AVAC +T Bldg RI Rate:	1.15					

	H	I
1		
2	**AVAC +T Bldg RI Rate**	**AVAC Labor x3**
3		
4		
5		
6		
7		
8	$12,388,618	
9	$1,711.33	
10		$1,159,287
11	$77	$160
12		
13	$648,378	$1,250,841
14	$732,822.36	$639,068
15	$1,381,200.68	$1,889,908
16	$191	$261
17	-$186,074	$416,389
18	78%	150%
19	$408,335.58	$917,043.40
20	142%	194%
21	4.0	7.6
22		$915,000
23	1.21	2.33
24		
25		
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	A	B	C	D	E	F	G	H
1	**Table B-1.4. Net Present Value Comparison, Pneumatic vs. Manual**							
2	Manual	AVAC	AVACw/externality benefit	Externality Benefit	Manual	AVAC	AVACw/externality benefit	Externality Benefit
3	3.0%	3.0%	3.0%	310,000	7.0%	7.0%	7.0%	310,000
4	2,340,647	10,769,625	10,769,625		2,340,647	10,769,625	10,769,625	
5	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
6	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
7	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
8	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
9	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
10	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
11	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
12	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
13	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
14	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
15	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
16	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
17	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
18	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
19	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
20	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
21	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
22	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
23	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
24	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
25	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
26	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
27	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
28	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
29	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
30	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
31	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
32	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
33	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
34	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
35	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
36	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
37	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
38	-138,413	-452,994	-142,994		-138,413	-452,994	-142,994	
39	-2,924,919	-9,572,592	-3,021,722		-1,779,161	-5,822,787	-1,838,044	
40	Differential	-6,647,672	-96,803		Differential			
41	Multiplier	3.3	1.0		Multiplier	3.3	1.0	
42	Bond term and interest rate assumptions based on NYC Water Authority actuals:							
43	http://nycbonds.org/NYW/pdf/2013/NYW_2013_AA_Adj_Rate.pdf, accessed 12-19-12							
44	p1: term, latest nyc water authority bonds: 34 yrs							
45–46	pp181-2, interest rates for latest 3 years long-term fixed bonds (24 issues) (see "avg interest" worksheet for raw numbers): 4.725%							
47–49	Discount rate is 3% and 7%, as per current US DOT guidance for benefit-cost analyses required for transportation investments pursuant to its Transportation Investment Generating Economic Recovery (TIGER) grant program TIGER Benefit-Cost Resource Guide, 2-1-2012, http://www.dot.gov/sites/dot.dev/files/docs/TIGER_BCA_RESOURCE_GUIDE.pdf,							

	J	K	L	M	N	O	P	Q	R
1	**Table B-1.4A Sensitivity Analysis Effect of Electricity Consumption, Terminal Building & Labor Cost on Net Present Value**								
2	Manual	A 120%	A 150%	A +T Bldg	A 150%+Tl Bldg	A +T Bldg RI Rate	A labor x3	A labor x3 w/ext	Externality B
3	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	915,000
4	2,340,647	10,769,625	10,769,625	11,171,371	11,171,371	12,388,618	10,769,625	10,769,625	
5	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
6	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
7	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
8	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
9	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
10	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
11	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
12	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
13	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
14	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
15	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
16	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
17	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
18	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
19	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
20	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
21	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
22	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
23	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
24	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
25	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
26	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
27	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
28	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
29	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
30	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
31	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
32	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
33	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
34	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
35	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
36	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
37	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
38	-138,413	-456,622	-462,064	-474,745	-483,815	-546,749	-1,055,456	-140,456	
39	-2,924,919	-9,649,257	-9,764,255	-10,032,229	-10,223,893	-11,553,800	-22,303,731	-2,968,100	
40	Differential	-6,724,338	-6,839,336	-7,107,310	-7,298,974	-8,628,881	-19,378,811	-43,181	
41	Multiplier	3.3	3.3	3.4	3.5	4.0	7.6	1.0	

	A	B	C	D	E	F	G	H	I
1	**Table B-1.5. Litter Basket Waste Tonnage Calculation**								
2	**Material Grp**	**Mat Subgrp**	**Mat Cat/Subcat**	**Rcy Indic**	**%**	**Refuse**	**Paper**	**MGP**	**Compo**
3	paper	ONP	newspaper	r paper	15.63				
4	paper	OCC	OCC/Kraft	r paper	3.77				
5	paper	Mx P	high grade	r paper	0.35				
6	paper	Mx P	mxd low grade	r paper	8.54				
7	paper	Mx P	phone bks/paperbacks	r paper	1.09				
8	paper	Mx P	bags	r paper	1.43				
9	paper	Bev Cartons	polycoated containers	r bev cartons	0.34		31.15		
10	paper	compostable P	compostable/soiled/waxed/OCC/kraft	c orgs	4.57				6.46
11	paper	compostable P	single use paper plates, cups	c orgs	1.89				
12	paper	other p	other nonrecy	nr paper	0.66	0.66			
13	plastic	PET bottles	PET bottles	r plastics	2.28			2.71	
14	plastic	HDPE bottles	HDPE bottles: natural	r plastics	0.25				
15	plastic	HDPE bottles	HDPE bottles: colored	r plastics	0.18				
16	plastic	Injection molded tubs	#1-#2 tubs/trays/other containers: #1 PET	pr plastics	0	10.68			
17	plastic	Injection molded tubs	#1-#2 tubs/trays/other containers: #2 HDPE	pr plastics	0.03				
18	plastic	#3-#7 bottles	#3-#7 bottles: #3 PVC	pr plastics	0.01				
19	plastic	#3-#7 bottles	#3-#7 bottles: #4 LDPE	pr plastics	0				
20	plastic	#3-#7 bottles	#3-#7 bottles: #5 PP	pr plastics	0				
21	plastic	#3-#7 bottles	#3-#7 bottles: #7 other	pr plastics	0.04				
22	plastic	Injection molded tubs	#3-#7 tubs: #3 PVC	pr plastics	0				
23	plastic	Injection molded tubs	#3-#7 tubs: #4 LDPE	pr plastics	0				
24	plastic	Injection molded tubs	#3-#7 tubs: #5 PP	pr plastics	0.18				
25	plastic	Injection molded tubs	#3-#7 tubs: #7 Other	pr plastics	0.04				
26	plastic	other rigid containers/pkging	soda crates and bottle carriers	pr plastics	0.06				
27	plastic	other plastic products	other PVC	nr plastics	0.04				
28	plastic	other rigid containers/pkging	rigid polystyrene containers and pkging	pr plastics	0.34				
29	plastic	other rigid containers/pkging	expanded polystyrene containers and pkging	pr plastics	0.41				
30	plastic	other rigid containers/pkging	other rigid containers/pkging	pr plastics	0.6				
31	plastic	film	bags	pr plastics	2.3				
32	plastic	film	other film	pr plastics	4.28				
33	plastic	other plastic products	single use plastic plates, cubs, cutlery, etc.	nr plastics	1.21				
34	plastic	other plastic products	other plastic materials	nr plastics	1.14				
35	glass	container	clear container	r glass	4.43			7.25	
36	glass	container	green container	r glass	1.03				
37	glass	container	brown container	r glass	0.75				
38	glass	mxd cullet	mxd cullet	r glass	1.02				
39	glass	container	other container	r glass	0.02				
40	glass	other glass	other glass	pr glass	0.17	0.17			
41	metal	al	cans	r metal	0.51			4.86	
42	metal	al	foil/containers	r metal	0.49				
43	metal	al	other al	r metal	0.04				
44	metal	non-ferrous	other non-ferrous	r metal	0.17				
45	metal	ferrous	tin food cans	r metal	0.51				
46	metal	ferrous	empty aerosol cans	r metal	0.07				
47	metal	ferrous	other ferrous	r metal	2.61				
48	metal	other metal	mxd metals	r metal	0.46				
49	organics	yard	leaves and grass	c orgs	1.23				1.53
50	organics	yard	prunings	c orgs	0.3				
51	organics	wood	stumps/limbs	nr other	0.07	0.07			
52	organics	food	food	c orgs	13.53				13.53
53	organics	wood	furniture/furniture pieces	nr other	0.47	13.28			
54	organics	wood	non-C&D untreated wood	nr other	0.4				
55	organics	textiles	non-clothing textiles	nr other	1.02				
56	organics	textiles	clothing	nr other	1.35				
57	organics	textiles	carpet/upholstery	nr other	0.07				
58	organics	diapers/hygiene	disposable diapers and sanitary products	nr other	0.85				
59	organics	misc organic	animal by-products	nr other	1.74				
60	organics	misc organic	rubber products	nr other	0.15				
61	organics	textiles	shoes	nr other	0.38				
62	organics	textiles	other leather products	nr other	0.08				
63	organics	misc organic	fines	nr other	5.26				
64	organics	textiles	upholstered or other organic-type furniture	nr other	0.18				
65	organics	misc organic	misc organics	nr other	1.33				
66	appliance/electronics	ferrous	appliances: ferrous	r metal	1.13			1.17	
67	appliance/electronics	non-ferrous	appliances: non-ferrous	r metal	0.04				
68	appliance/electronics	household appliance-plastic	appliances: plastic	nr other	0.09	5.67			
69	appliance/electronics	electronic/av/computer	audio/visual equip: cell phones	nr other	0				
70	appliance/electronics	electronic/av/computer	audio/visual equip: other	nr other	0.17				
71	appliance/electronics	electronic/av/computer	computer monitors	nr other	0.01				
72	appliance/electronics	electronic/av/computer	televisions	nr other	0.06				
73	appliance/electronics	electronic/av/computer	other computer equip	nr other	0.18				
74	C&D Debris	wood	untreated dimension lumber, pallets, crates	nr other	0.8				
75	C&D Debris	wood	treated/contaminated wood	nr other	0.74				
76	C&D Debris	inorganic C&D	gypsum scrap	nr other	1.04				
77	C&D Debris	inorganic C&D	roci/concrete/bricks	nr other	1.73				
78	misc inorganics	misc organic	misc organics	nr other	0.09				
79	misc inorganics	misc organic	ceramics	nr other	0.26				

	A	B	C	D	E	F	G	H	I
80	HHW	hhw	oil filters	nr other	0				
81	HHW	hhw	antifreeze	nr other	0				
82	HHW	hhw	wet-cell batteries	nr other	0				
83	HHW	hhw	gasoline/kerosene/motor oil/diesel fuel	nr other	0.05				
84	HHW	hhw	latex paints/water-based adhesives/glues	nr other	0.1				
85	HHW	hhw	oil-based paints/solvent-based adhesives/glue	nr other	0.08				
86	HHW	hhw	pesticides/herbicides/rodenticides	nr other	0.01				
87	HHW	hhw	dry-cell batteries	nr other	0.15				
88	HHW	hhw	fluorescent tubes	nr other	0				
89	HHW	hhw	mercury-laden waste	nr other	0				
90	HHW	hhw	compressed gas cylinders, fire extinguishers	nr other	0				
91	HHW	hhw	home medical products	nr other	0.02				
92	HHW	hhw	other potentially harmful wastes	nr other	0.09				
93	Source: DSNY				TOTALS	30.53	31.15	15.99	21.52
94	Annual, fall 2004-summer 2005								
95	http://www.nyc.gov/html/nycwasteless/downloads/pdf/wastecharreports/wcsfinal/report/wcs_08_V1_5_WCSstreetbasketresults.pdf, t1-133, p.2, accessed								
96	8-11-11, table 1-133, p. 2, annual by recycling indicator								
97									
98			**Tons A Day**						
99	**Refuse**	**Paper**	**MGP**	**Compostable**	Total				
100	**0.31**	**0.19**	**0.10**		0.5952				
101	0.18	0.19	0.10	0.13					
102	0.305	0.312	0.16	0.215	0.992				
103	30.53	31.15	15.99	21.52					

Table B-1.6. Imputed Costs of Conventional Collection for Second Avenue-92nd-99th Sts

NYC DSNY Costs, Fiscal 2005

	Refuse	**Recyclables**	**Wtd. Avg.**
Total cost/t (including disposal, debt service)(a)	$267	$294	
Tons collected(b)	2894455	629796	
Tons/truck/shift	10.6	6.2	
Total export costs for collected refuse/recyclables(b)©	$314,868,000	$12,683,000	
Debt service on garages/vehicles(d)	$44,890,165	$16,056,326	
Collection labor cost/t(e)	$99	$152	
Export/processing costs/t	$109	$20	
Debt service/t	$16	$25	$16.08
Debt service/t: 2011$	$18	$29	$18.52
Debt service/t: 2013$			$19.12
Collection only (-export/processing; debt service)	$143	$248	
M8/11 wtd avg collection costs (2005)(f)	0.943	0.057	$148.72
M8/11 wtd avg collection costs w/o debt service 2011			$171.29
M8/11 wtd avg collection costs w/o debt service 2013			$176.79
Collection w/ debt service	$158	$274	
M8/11 wtd avg collection costs w/ debt service (2005)			$164.80
M8/11 wtd avg collection costs w/ debt service 2011 (g)	$182	$316	$189.81
M8/11 wtd avg collection costs w/ debt service 2013 (g)			$195.91

Source:
http://docs.nrdc.org/cities/files/cit_08052801A.pdf, accessed 12-12-11

(a)p23, Table 4c without recycling revenues (with DSM adjustments, which do not include correcting for the fact that all enforcement costs are inappropriately assigned to the recycling budge and do not include parallel adjustments UTRC would recommend related to collection, e.g., not charging all Bureau of Waste Prevention, Reuse, and Recycling costs, which include a waste composition study and public education initiatives, along with processing costs for recyclables, to the cost of collecting recyclables, while not apportioning items that are related to collection, such as revenues from enforcement fines)

(b)p20, Table 2

(c)p21, Table 3a

(d)p23, Table 4b

(e)p25, Table 8a

(f)Collection costs apportioned using the project-specific sections of Manhattan Districts 8 and 11, based on DSNY 2004 waste composition study, calculations in SAS-waste-sources.xlsx

(g) Inflated by BLS CPI index, 2005 to 2013, http://www.bls.gov/data/inflation_calculator.htm

Table B-1.7. DSNY RO RO Collection Factors

Roosevelt Island Costs to Convert to 25 Yard Truck Pick-up

Roosevelt Island Containerized Tonnage for Calendar Year 2009

Commodity	Refuse (24)	Bulk (25)	Paper (27)	MGP (29)
Totals	2069.81	835.73	391.61	295.52

Roosevelt Island Containerized Tonnage for Calendar Year 2008
(January 1 2008 through December 31 2008)

Commodity	Refuse (24)	Bulk (25)	Paper (27)	MGP (29)
Totals	2129.18	780.36	423.59	240.82

Roosevelt Island Containerized Tonnage for Calendar Year 2007:
(January 1 2007 through December 31 2007)

Commodity	Refuse (24)	Bulk (25)	Paper (27)	MGP (29)
Totals	2113.76	832.21	390.69	241.78

CY 2007-2009 Average Tonnage

Commodity	**Refuse (24)**	**Bulk (25)**	**Paper (27)**	**MGP (29)**
Totals	**2104.3**	**816.1**	**402.0**	**259.4**

Weekly Amount

Commodity	**Refuse (24)**	**Bulk (25)**	**Paper (27)**	**MGP (29)**
Totals	**40.5**	**15.7**	**7.7**	**5.0**

Costs of adding a Truckshift per year.

FTE due to the absence factor

Posts	FTE
2	3

2) The average Sanworker costs calculation as of 6/1/2010

Average Cost	Benefits Costs @ 67.12%	Total Costs per Sanworker
$65,532.00	$43,985.08	$109,517.08

3) Additional Costs

25 Cubic Yard Differential @ $43.44 per Day for 300 day year per post
$13,032.00
$12.72 for 300 day year per post
$3,816.00

4) Dump on Shift $5.80 per load

Costs of 45 Cubic Yard Container

45 Cubic Yard Container Pick-up		
Amount	Posts	FTE
4 Times per we	4	1

Additional Costs

RO/RO Pickup Differential @ $92.82 per Day for 208 day year
$19,306.56

Convert to Start Trucks	Tons ZWA	Trucks ZWA	Daily Posts (2 Posts Per Truck)	FTE	Costs @ $109,517.08 per SW	Differentials per post	Dump on shift costs QW01	Total Costs
Refuse	40.5	4	1.3	2.0	$219,034	$17,376	$58.00	$236,468
			{'=8/6	{1.5 factor for absences				

Costs @ $109,517.08 per SW	Differentials per post @ $92.82	Dump on shift costs QW01	Total Costs
$109,517.08	$19,307	0	$128,823.64

Cost Benefit Analysis Conclusion using 6/10/2010		{ratio
Regular House Hold Pick-up	**$236,468**	0.544782
RO/RO Pick-up	**$128,824**	
Saving for using EZ-Pack	**$107,645**	

Note:
The above data was extracted from the recorded scale weights at the location via hand written 202's
In Calendar year 2007, 128.9 tons of refuse was collected by rear loader, allocated to material type 84 in section QW016, total refuse tonnage would have been 2242.66, had it been collected via containerization.
There are no such findings for calendar year 2008 or 2009.
#'s in () next to commodity name are the SCAN material code numbers
Truck Conversions uses the targeted TPTS amount and divided it into the ZWA tonnage.
Dump on shift FY2010 Average used for QW01 are 4.8% Refuse
Source: Brautigam to Miller, 6-22-11

	A	B	C	D	E	F	G
1	**Table B-1.8. Annual Cost of Ro-Ro Collection, Pneumatic v Manual**						
2				Residential, Commercial, NYCHA, Hospital, Street-Level Litter Bins and			
3		Current NYCHA Refuse		Subway Refuse and Recyclables			
4			**Manual**	**Pneumatic**			
5	Tons Drayed by Ro-Ro(9)		1,964	7,239			
6	Truck Miles(7,15)		12,925	11,966			
7	Fuel Cost (1,7,8,10)		$8,660	$8,017			
8	Cost of Ro-Ro Truck, Ann (2)		$6,844	$7,612			
9	Vehicle Maintenance (2)		$4,257	$4,734			
10	Tolls (5,6)		$7,301	$9,119			
11	Labor (3,4)		$51,518	$62,072			
12	Total Cost:		$78,580	$91,554			
13	Cost per ton(9):		$40	$13			
14						2013$	2011$
15	(1) #2 ULS B5 diesel fuel cost/gallon 2011$, for mileage see Table B-2.2:					$3.35	$3.25
16	(2) 2011 DSNY Roll-On/Roll-Off truck capex and opex, Brautigam to Miller 6-30 and 10-6-11. Cost annualized and						
17	apportioned based on number of shifts used assuming a 6-day work week:						
18		Truck capex				$205,461.73	$199,066
19		Truck life, yrs				5	5
20		Truck ann maintenance				$25,558.60	$24,763
21	FY2012 DSNY SCAN Collection Data						
22		Number of pickups/yr				271	271
23		Avg % of shift				0.37	0.37
24	DSNY working days/yr					301	301
25	Assumed number of shifts/day/truck					2	2
26	(3)Portion of shift/trip (see Washington Hses.xls):					0.37	0.37
27	(4) Avg salary plus fringe as of 6/1/2010(Brautigam to Miller 06/30/11)[2013$ from 2010$]					$116,603.83	$109,517.18
28	2010 (FY2011) DSNY RO/RO Pickup Differential/day (ibid) [2013$ from 2010$]					$98.83	$92.82
29	Shifts/yr, 301 DSNY working days, assume 20 vacation days					281	281
30	Labor cost/shift					$514	$483
31	(5) Toll: EZ-Pass off-peak rate for 3-axle trucks per roundtrip (tolls collected eastbound only).					$27.00	
32	http://www.panynj.gov/about/new-toll-fare-2011.html?tabnum=1, accessed 02-19-13.						
33	(6) Manual trips/wk from SAS Fuel Use.xlsx, Mileage Worksheet, based on actual FY2012 data (for NYCHA only):					5.2	

	A	B	C	D	E	F	G
34	(7) Mileage from SAS Fuel Use.xlsx, Mileage Worksheet						
35	(8) RO/RO assumed mpg					5	
36	(9) NYCHA Refuse tons/yr (SAS Fuel Use.xlsx, Waste Summary						
37	SCAN value, FY2012, NYCHA					1,964	
38							
39	Future NYCHA recyclable fractions based on M11 avgs, using DSNY waste comp data, but current recycling, based on interviews of operating						
40	personnel presumed to be negligible. Current NYCHA refuse tons therefore are based on actual data, while pneumatic RORO refuse tons based on M11 average on the theory that a pneumatic system for both NYCHA and private residences would level the playing field.						
41							
42							
43				Refuse fraction	0.79	1,550	
44				Paper fraction	0.14	268	
45				MGP fraction	0.07	147	
46	(10) Pneumatic trips/wk from Manhattan SAS 3-5-13.xlsx, Containers						
47		Refuse				4.34	
48		Paper				1.15	
49		MGP				1.00	
50		Refuse trips/yr				226	
51		Paper+MGP trips/yr				112	
52	(11) Portion of shift/trip assumed for MGP and Paper					0.25	
53	(12) Trips at .37 shift						
54	Trips at .25 shift						
55	(13) Wtd avg of pneumatic shifts for Refuse, Paper, MGP					0.36	
56	(14) Avg Manual tons/container (refuse only, NYCHA only, based on FY2012 actual):					7.2	
57	Avg Pneumatic tons/container						
58		Refuse				25.40	
59		Paper				9.75	
60		MGP				16.88	
61		Wtd Avg container				22.64	
62	(15)Mileage worksheet:						
63		Refuse RORO miles/trip (same for Pneumatic and Manual)				47.8	
64		Paper RORO miles/trip				8.3	
65		MGP RORO miles/trip				14.4	

Table B-1.9. Electricity Cost Calculation

AVAC Actual Electricity Use(1)(3)

	BTUs	kw	kwh	$
FY2011	3,318		972,000	$499,186
FY2010	3,345		980,000	$487,221
Avg(1)	**3,332**	**1,087**	**976,000**	**$493,204**

Cost Factors	DSNY Actual, Rate (2)	2013$
kwh@	$0.06	$0.06
kw@	$23.12	$23.38

Electricity Use for Alternative Scenarios (4)				Total Annual Elec Cost, Actual Rates (5)		
	Upgrade	Upg+Rcy	URCL	Upg	UR	URCL
KWH/year	193,974	548,935	837,017	12,010	33,988	51,825
kw	331	331	662	$91,876	$91,876	$183,751
Total Electricity Cost				$103,886	$125,864	$235,577

(1)NYC DCAS, "Core Report, Facility-Level Energy Cost, Usage, and CO2e Emissions," 4-2011.

(2) DSNY actual rate as of April, 2012, Donald Porter, DSNY Bureau of Building Management, to Steven Brautigam, DSNY Asst. Comr., Environmental Affairs, 2-11-13

(3) Brautigam to Miller, 1-28-13

(4) Ricardo Rello, Envac, to Spertus and Miller, 1-29-13

(5) Customers whose maximum monthly demand is below 1,500 kw are not eligible for Time of Day service.
http://www.coned.com/documents/PSC12-PASNY/PASNYPSC12.pdf, accessed 2-13-13.

	A	B	C	D	E	F	G
2	**Table B-1.10. Pneumatic System Operating Cost Calculation**						
3	**PROJECT NAME**			MANHATTAN SAS			
4	**PLACEMENT:**			NEW YORK			
5	**DATE:**	3/7/13		UTRC DATE:	3/8/13	**$**	
6	**PERSONNEL:**						
7			DESCRIPTION		Quant.	COST	**TOTAL**
8	**DIRECT O&M PERSONNEL**						
9			OPERATOR O&M (a)		2.00	150,039.52	**300,079.04**
10		**UNIFORMS**					
11			**UNIFORMS**	Ea.	2.00	460.88	**921.76**
12		**MOBILE PHONE**					
13			TELEPHONE	Ea.	1.00	230.44	**230.44**
14		**TOTAL:**					**301,231.24**
15	**VEHICLES**						
16			DESCRIPTION	UNIT	Quant.	COST	**TOTAL**
17	**MAINTENANCE CARS**						
18			OPERATOR VAN	Ea.	1.00	10,423.03	**10,423.03**
19		**TOTAL:**					**10,423.03**
20	**SPARE PARTS**						
21			DESCRIPTION	UNIT	Quant.	COST	**TOTAL**
22		**SPARE PARTS**					
23		**TERMINAL**				1.00	
24			DIVERTER/TRIVERTER VALVE	Ea.	1.00	1,248.94	**1,248.94**
25			EXHAUSTERS	Ea.	1.00	4,131.78	**4,131.78**
26			CONTAINER	Ea.	1.00	1,474.28	**1,474.28**
27			CYCLONE	Ea.	1.00	566.63	**566.63**
28			COMPACTOR	Ea.	1.00	3,254.76	**3,254.76**
29			CONTAINER MOVER	Ea.	1.00	982.07	**982.07**
30			CONTROL SYSTEM	Ea.	2.00	337.76	**675.53**
31			SECTION IN VALVE	Ea.	1.00	458.60	**458.60**
32			COMPRESSOR	Ea.	1.00	340.70	**340.70**
33		**FILTERS**				1.00	
34			DUST FILTERS	Ea.	1.00	2,930.94	**2,930.94**
35			CARBON	Ea.	1.00	10,895.10	**10,895.10**
36		**PIPE NETWORK**				1.00	
37			DUMP VALVES	Ea.	1.00	5,644.70	**5,644.70**
38			TRANSPORT VALVES	Ea.	1.00	1,516.77	**1,516.77**
39			SYSTEM DEVICE	Ea.	1.00	2,333.49	**2,333.49**
40		**TOTAL:**					**36,454.29**
41	**SUPPLIES**						
42			DESCRIPTION	UNIT	Quant.	COST	**TOTAL**
43		**MATERIAL**					
44			CLEANING GOODS	Ea.	1.00	1,569.14	**1,569.14**
45			TOOLS	Ea.	1.00	1,445.02	**1,445.02**
46			OFFICE SUPPLIES	Ea.	1.00	165.45	**165.45**
47		**TOTAL:**					**3,179.61**
48	**ENERGY SUPPLY**						
49			DESCRIPTION	UNIT	Quant.	COST	**TOTAL**
50	**ENERGY SUPPLY (b,c,d)**						
51			CONSUMPTION (Collection+Aux)	Kwh	302,330.03	0.06	**18,139.80**
52			Kw CONTRACT	Kw	198.69	23.38	**55,745.31**
53		**TOTAL:**					**73,885.11**
54	**MISC**						
55			DESCRIPTION	UNIT	Quant.	COST	**TOTAL**
56			TELEPHONE	Ea.	1.00	1,489.00	**1,489.00**
57			WATER	Ea.	1.00	2,020.79	**2,020.79**

	A	B	C	D	E	F	G
58		**TOTAL:**					**3,509.79**
59	**EQUIPMENT REPLACEMENT**						
60			DESCRIPTION	UNIT	Quant.	COST	**TOTAL**
61							
62	**COMPONENT REPLACEMENT**						
63							
64			TERMINAL	Ea.	1.00	54,724.55	**54,724.55**
65			PIPE NETWORK	Ea.	1.00	73,416.61	**73,416.61**
66							
67		**TOTAL:**					**128,141.16**
68	**PERSONNEL**			**301,231.24**	**RATIO**		**$PER TON**
69	**VEHICLES**			**10,423.03**	TONS		7,256
70	**SUPPLIES**			**3,179.61**	**RATIO COST/TON**		**76.74**
71	**SPARE PARTS**			**36,454.29**			
72	**ELECTRIC POWER**			**73,885.11**	**RATIO**	**Kwh**	**PER TON**
73	**OTHERS**			**3,509.79**	TONS		7,256
74	**EQUIPMENT UPDATING**			**128,141.16**	KWH		302,330
75	**TOTAL**			**556,824.23**	**RATIO KWH/TON**		**41.67**
76	Notes:						
77							
78	(a) Steven Brautigam, DSNY to Miller 10/06/11. There are currently 8 full time employees, with the titles and pay rates shown in this note. Envac lists operator positions. The current DSNY titles used at AVAC are: Senior Stationary Engineer base salary $116,916, fringe @ 43% $50,274 = $167,191 total; Stationary Engineer base salary $102,356, fringe $43,013= $145,369; Machinist base salary $75,940, fringe $32,655 = $108,595. We assumed "Stationary Engineer" = "Operator."						
79							
80							
81	(b)NYC DCAS, "Core Report, Facility-Level Energy Cost, Usage, and CO2e Emissions," 4-2011.						
82	(c) Donald Porter, DSNY Bureau of Building Management, to Steven Brautigam, DSNY Asst. Comr., Environmental Affairs, 2-11-13						
83	(d) Brautigam to Miller, 1-28-13						

	A	B	C	D	E	F	G	H	I	J	K	L	P	Q
13	**Table B-1.11. Pneumatic System Container Calculation**													
14	FRACTIONS								T/day					
15		% WEIGHT	FRACTION	REST	PACKING	ORGANIC	PAPER		dwellings	6,212				
16	REST	0.30	1	0.30	0.00	0.00	0.00		kg/dwelling	3.20				
17	PACKINGS	0.07	1	0.00	0.07	0.00	0.00		kg/Dwellin data					
18	ORGANIC	0.49	0	0.49	0.00	0.00	0.00		total	19.88				
19	PAPER	0.14	1	0.00	0.00	0.00	0.14		short/ton					
20		1.00		0.79	0.07	0.00	0.14							
21														
22														
23	DENSITY													
24		KG/L	DATA	CALC										
25	REST	0.13	150.00	150.00										
26	PACKING	0.08		0.08										
27	ORGANIC	0.20		0.20										
28	PAPER	0.05		0.05							Correc. factor(0,25-1,00)			
29												0.75		
30														
31	CONTAINERS MOVE													
32		FRAC-CONT	TRANSP	CONT	% Fraction	Tons/CONT	VOLUM	COMPACT.	DENSITY	RATIO VOL.	RATIO WEIGHT	MAX VALUE	Trips/Wk	Tons/Cont
33	REST C	0	1	0	0.00	12.00	30.00	0.29	150.00	0.00	0.00	0.00		
34	PACKING C	0	1	0	0.00	12.00	30.00	0.50	0.08	0.00	0.00	0.00		
35	ORGANIC C	0	1	0	0.00	12.00	30.00	0.77	0.20	0.00	0.00	0.00		
36	PAPER-CARDBOARD C	0	1	0	0.00	12.00	30.00	0.67	0.05	0.00	0.00	0.00		
37	REST C-CRANE	0	0	0	0.00	10.00	25.00	0.29	150.00	0.00	0.00	0.00		
38	PACKING C-CRANE	0	0	0	0.00	10.00	25.00	0.50	0.08	0.00	0.00	0.00		
39	ORGANIC C-CRANE	0	0	0	0.00	10.00	25.00	0.77	0.20	0.00	0.00	0.00		
40	PAPER-CARDBOARD C-CRANE	0	0	0	0.00	10.00	25.00	0.67	0.05	0.00	0.00	0.00		
41	REST G	1	1	1	0.79	19.00	45.60	0.29	150.00	0.00	0.83	0.62	4.34	25.40
42	PACKING G	1	1	1	0.07	19.00	45.60	0.50	0.08	0.19	0.07	0.14	1.00	9.75
43	ORGANIC G	0	1	0	0.00	19.00	45.60	0.30	0.20	0.00	0.00	0.00		
44	PAPER-CARDBOARD G	1	1	1	0.14	19.00	45.60	[redacted]					1.15	16.88
45	REST G-CRANE	1	0	0	0.00	10.00	25.00	0.29	150.00	0.00	0.00	0.00		
46	PACKING G-CRANE	1	0	0	0.00	10.00	25.00	0.50	0.08	0.00	0.00	0.00		
47	ORGANIC G-CRANE	0	0	0	0.00	10.00	25.00	0.77	0.20	0.00	0.00	0.00		
48	PAPER-CARDBOARD G-CRANE	1	0	0	0.00	10.00	25.00	0.67	0.05	0.00	0.00	0.00		
49	REST F	0	-	0	0.00	6.00	21.00	0.40	150.00	0.00	0.00	0.00		
50	PACKING F	0	-	0	0.00	3.50	21.00	1.00	0.08	0.00	0.00	0.00		
51	ORGANIC F	0	-	0	0.00	6.00	21.00	0.91	0.20	0.00	0.00	0.00		
52	PAPER-CARDBOARD F	0	-	0	0.00	2.00	21.00	1.25	0.05	0.00	0.00	0.00		
53	TOTAL				1.00							1.22		
54	Note: UTRC: assume 750 lbs compacted mixed office paper/OCC per cy													

	A	B	C	D	E	F	G	H	I	J	K	L	M
2	**Table B-2.1. Energy and GHG Comparison by Waste Source**												
3		**Tons Per Day(1)**			**KWH Per Day(5)**		**Gallons Per Day(2)**			**Tons CO2 Equivalent/Day**			**BTU**
4			**Sub-totals**	**Weight**	**Manual**	**AVAC**	**Manual**	**AVAC**	Coeff t CO2e/ unit (3)	**Manual**	**AVAC**	Coeff BTUs/ unit (4)	**Manual**
5						828			0.0003		0.28863	3,412	
6	Residential Refuse t/day	4.37		0.220			34.3		0.0113	0.387		138,900	4,770,577
7	Residential Paper/OCC t/day	0.76		0.038			0.4		0.0113	0.004		138,900	49,097
8	Residential MGP t/day	0.41	**5.54**	0.021			0.4		0.0113	0.004		138,900	49,097
9	NYCHA Refuse t/day	4.25		0.214			7.1		0.0113	0.080		138,900	986,428
10	NYCHA Paper/OCC t/day	0.73		0.037			0.1		0.0113	0.001		138,900	16,281
11	NYCHA MGP t/day	0.40	**5.38**	0.020			0.1		0.0113	0.001		138,900	16,281
12	Hospital (Non-Haz) Refuse t/day	4.10											
13	Hospital Paper/OCC t/day	0.71											
14	Hospital MGP t/day	0.39	**5.19**	0.262			6.6		0.0113	0.074		138,900	911,184
15	Street Litter Bins Refuse t/day	0.31											
16	Street Litter Bins Paper t/day	0.19											
17	Street Litter Bins MGP t/day	0.10	**0.60**	0.030			19.5		0.0113	0.219		138,900	2,701,780
18	Commercial Refuse t/day	2.46		0.124			5.6		0.0113	0.063		138,900	781,396
19	Commercial Paper/OCC t/day	0.32		0.016			0.5		0.0113	0.006		138,900	74,419
20	Commercial MGP t/day	0.15	**2.93**	0.007			0.5		0.0113	0.006		138,900	74,419
21	Subway Refuse t/day	0.095											
22	Subway Paper/OCC t/day	0.065											
23	Subway MGP t/day	0.030	**0.19**	0.010			0.1		0.0113	0.001		138,900	9,462
24				1.00									
25	**Total Refuse/Day**	15.58		0.79				5.9			0.293		
26	**Total Paper/Day**	2.77		0.14				0.3			0.043		
27	**Total MGP/Day**	1.48		0.07				0.4			0.026		
28	**Total/Day**	**19.83**		1.00		**828**	**75.2**	**6.6**		**0.85**	**0.36**		**10,440,421**
29	**Total/Year**	**7,239**				**302,330**	**27,435**	**2,400**		**309**	**132**		**3,810,753,767**
30	**Weighted Average/Ton**					**42**							
31	**Weighted Average Electric/Ton**												
32	**Weighted Average Diesel/Ton**												
33	**Multiple vs. Manual Baseline**							**0.1**			**0.4**		
34	**Baseline**							**25,035**			**177**		
35	Notes:	Not Recycled											

36 (1) SAS Waste Sources.xlsx (summarized in Waste Summary worksheet); subway fractions per Mileage worksheet, note 20; commercial fractions per Waste Summary Worksheet, note 2;
37 litter basket fractions per Basfrac Worksheet.
38 (2) For fuel use see mileage worksheet.
39 (3)NYC-specific emission factors for electricity and vehicle fuel from NYCPlan 2011 inventory, http://nytelecom.vo.llnwd.net/o15/agencies/planyc2030/pdf/greenhousegas_2011.pdf
40 appendix H, I (see 2011 Emissions Factors worksheet); coefficient for kg CO2e/unit based on wtd ave of emissions from energy gen. at power plants serving NYC for electricity & vehicle
41 fuel based on type (see CO2e coeff worksheet).
42 (4) http://www.onlineconversion.com/energy.htm
43 (5) 100 kwh/t is the average Envac considers appropriate for this scenario, see R Rello to Miller 01/16/13
44 *Post-Collection Recycling entails the removal and recycling of materials from the 468 subway stations in the transit system. In 2011, NYC Transit's subway stations yielded 7,275 tons of recyclables-approximately*
45 *50 percent of all refuse removed from the system-and one of the highest recycling rates in the United States.*

	N	O	P	Q	R
2					
3	s/Day	Tons CO2Eq/ Ton Waste		BTUs/Ton Waste	
4	**AVAC**	**Manual**	**AVAC**	**Manual**	**AVAC**
5	2,826,281		0.0146		142,502
6		0.09		1,091,034	
7		0.01		64,982	
8		0.01		118,386	
9		0.02		232,306	
10		0.00		22,190	
11		0.00		40,426	
12					
13					
14		0.01		175,477	
15				-	
16				-	
17		0.37		4,539,281	
18		0.03		317,486	
19		0.02		231,763	
20		0.04		503,844	
21					
22				-	
23		0.00		49,802	
24					
25	3,040,340		0.0188		195,103
26	431,838		0.0156		155,898
27	267,340		0.0176		180,625
28	**3,739,517**				
29	**1,364,923,741**				
30		**0.0427**	**0.0183**	**526,408**	**188,547**
31			0.0146		142,502
32		0.0427	0.0037	**526,408**	46,045
33	**0.36**		**0.428**		**0.36**
34	**2,445,830,026**				
35					
36					
37					
38					
39					
40					
41					
42					
43					
44					
45					

	S	T	U	V	W	X	Y	Z	AA	AB
2	**Table B-2.1.A. Sensitivity Analysis, Effet of Electricity Consumption on Pneumatic System Energy Efficiency**									
3		**Tons Per Day(1)**		**KWH Per Day(5)**		**Gallons Per Day(2)**		**Tons CO2 Equivalent/Day**		
4			**Sub-totals**	**120% KWH**	**150% KWH**	**AVAC**	**Coeff t CO2e/ unit (3)**	**120% KWH**	**150% KWH**	**Coeff BTUs/ unit (4)**
5				993.96	1,242.45		0.0003	0.3464	0.432947222	3,412
6	Residential Refuse t/day	4.37					0.0113			138,900
7	Residential Paper/OCC t/day	0.76					0.0113			138,900
8	Residential MGP t/day	0.41	**5.54**				0.0113			138,900
9	NYCHA Refuse t/day	4.25					0.0113			138,900
10	NYCHA Paper/OCC t/day	0.73					0.0113			138,900
11	NYCHA MGP t/day	0.40	**5.38**				0.0113			138,900
12	Hospital (Non-Haz) Refuse t/day	4.10								
13	Hospital Paper/OCC t/day	0.71								
14	Hospital MGP t/day	0.39	**5.19**				0.0113			138,900
15	Street Litter Bins Refuse t/day	0.31								
16	Street Litter Bins Paper t/day	0.19								
17	Street Litter Bins MGP t/day	0.10	**0.60**				0.0113			138,900
18	Commercial Refuse t/day	2.46					0.0113			138,900
19	Commercial Paper/OCC t/day	0.32					0.0113			138,900
20	Commercial MGP t/day	0.15	**2.93**				0.0113			138,900
21	Subway Refuse t/day	0.10								
22	Subway Paper/OCC t/day	0.06								
23	Subway MGP t/day	0.03	**0.19**				0.0113			138,900
24										
25	**Total Refuse/Day**	15.58				5.9		0.33864	0.40668	
26	**Total Paper/Day**	2.77				0.3		0.05138	0.06348	
27	**Total MGP/Day**	1.48				0.4		0.03043	0.03689	
28	**Total/Day**	19.83		**993.96**	**1,242.45**	**6.6**		**0.42045**	**0.50704**	
29	**Total/Year**	7239.17		**362,796.03**	**453,495.04**	**2,399.8**		**153**	**185**	
30	Weighted Average/Ton			**50.12**	**62.64**					
31										
32										
33	Multiple vs. AVAC baseline			**1.2**	**1.5**			**1.16**	**1.40**	
34	baseline			**166**	**414**			**21**	**53**	

	AC	AD	AE	AF	AG	AH
2						
3	**BTUs/Day**		**Tons CO2Eq/ Ton Waste**		**BTUs/Ton Waste**	
4	**120% KWH**	**150% KWH**	**120% KWH**	**150% KWH**	**120% KWH**	**150% KWH**
5	3,391,538	4,239,422	0.01746341	0.02182926	171001.818	213752.2725
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25	3,484,467	4,150,659	0.0217	0.0261	223,603	266,354
26	510,783	629,202	0.0186	0.0229	184,399	227,149
27	309,523	372,797	0.0206	0.0249	209,125	251,876
28	**4,304,773**	**5,152,658**				
29	**1,571,242,277**	**1,880,720,081**				
30			**0.0212**	**0.0256**	**217,047**	**259,798**
31						
32						
33	**1.2**	**1.4**	**1.16**	**1.40**	**1.15**	**1.38**
34	**206,318,536**	**515,796,340**				

	A	B	C	D	E	F
1	**Table B-2.2. Mileage Factors, Pneumatic vs. Manual**					
2	**Total Mileage: Collection to "First Dump"**		Miles/Yr	Miles/Wk	Miles/Day	) (4)
3						
4	**Current**					
5	Residential Refuse, 3x wk(1, 11)		3,063	58.9	8.4	34.3
6	Residential Paper, 1x wk(1, 12)		73	1.4	0.2	0.4
7	Residential MGP, 1x wk(1,13)		37	0.7	0.1	0.3
8	NYCHA Refuse (compacted containers/Ro-Ro)(2)		12,925	248.6	35.5	7.1
9	NYCHA Paper, 1x wk(3)		71	1.4	0.2	0.1
10	NYCHA MGP, 1x wk(3)		36	0.7	0.1	0.1
11	Hospital Refuse (non-haz) (compacted containers/Ro-Ro, 4 RT trips wk)(5)		11,939	229.6	32.8	6.6
12	[No Hospital MGP, Paper, just minor amount of shredded paper]		0.0	0.0	0.0	0.0
13	Street-Level Litter Bins(14,15,16)		1,476	28.4	4.1	19.5
14	Commercial Refuse 6x week(6,7,21)		6,143	118.1	16.9	5.6
15	Commercial MGP, Paper 3x wk(18,7,21)		585	11.3	1.6	0.5
16	Subway Commingled Refuse, Paper, MGP, 7x wk(6,7,19,20,22,23)		50	1.0	0.14	0.07
17	Total Miles/Y Manual (No-AVAC)		36,399			
18	**AVAC (4)**					
19	Refuse (8)		10,741	206.5	29.5	5.9
20	Paper (9)		486	9.4	1.3	0.3
21	MGP (10)		739	14.2	2.0	0.4
22	Total Miles/Y AVAC		11,966		AVAC	6.6
23						
24	Multiple, Pneumatic Miles/Manual Miles	*0.329*				
25						
26	**Locations/Distances**	**es**				
27	Hypothetical AVAC location:	2nd Ave and 97th St, SE corner				
28	2nd Ave Street-Level Zone (not including NYCHA/Metropolitan Hospital):	92nd to 96th Sts				
29	NYCHA Buildings(17)	230 E 102 St				
30	Metropolitan Hospital	1880 2nd Ave (98th St)				
31	DSNY garage location (24):	343 East 99th St, New York, NY				
32						
33						
34						
35						
36						
37	DSNY M11 refuse dump (Essex incinerator) (25):	183 Raymond Blvd, Newark, NJ				
38						
39	DSNY M11 paper (26)	59th St and West Side Hwy				
40	DSNY M11 MGP (27)	Gansevoort St and West Side Hwy				
41	Carter garage location (28):	451 Frelinghuysen Ave, Newark, NJ				
42						
43	Carter dump (28):	920 East 132nd St, Bronx, NY 10454				
44	Carter OCC/MGP (+Subway Commingled Refuse/Recyclables) (MRF) (28):	1221 East Bay Ave Bronx NY 10474				
45	Subway refuse pick-up location(20)	3961 10th Ave, NY NY				
46	Distance DSNY Upper Manhattan collection route(4)	12.30	All other distances from Google maps.			

	A	B	C	D	E	F
47	Round-trip distance DSNY Upper Manhattan collection route to refuse dump	46.2	Manhattan			
48	Distance ro-ro garage-NYCHA	0.4				
49	Distance carter garage-hospital:	27.6				
50	Distance NYCHA-refuse incinerator:	23.1				
51	Distance incinerator-roro garage	24.3				
52	Distance subway-carter MRF (all commingled refuse/recyclable fractions)(19)	7.4				
53	Distance hospital-transfer:	3.2				
54	Distance transfer-carter garage	26.6				
55	Distance carter garage to subway pickup location	24.1				
56	Distance carter MRF-carter garage	27				
57	Distance Ro-Ro-garage-AVAC	0.2				
58	Distance AVAC-refuse incinerator (29):	23.1				
59	Distance AVAC-Paper	4				
60	Distance AVAC-MGP	5.5				
61	Distance Paper-garage	3.9				
62	Distance MGP-garage	8.5				
63						
64	**Notes:**					
65	(1) New West Technologies, LLC, 12-2011, http://www.stacenergy.org/projects/05-STAC-01/06-Final_Report.pdf, accessed 3-27-13:					
66	Table 24: Average Collection Route Driving Distance, including in-Manhattan dump			12.3		
67	UTRC-imputed average collection route, not including in-Manhattan dump			6		
68	Table 25: Average mpg [collection route]			1.34		
69	includes PTO and idling), mpg			2.19		
70	Brautigam to Miller, 6-11-11)			3		
71	(2) Pickups/wk, Washington Houses, FY2012 (DSNY Collection Data)			5.2		
72	Tons/container, FY2012			7.2		
73	(3) David Salomon, NYCHA Recycling Director, telecon w/ Miller, 1-3-13.					
74	(4) Ro-Ro MPG:			5.0		
75	(5) Hospital containers/wk			3.584		
76	(6) Assumed private carter refuse tons/25cy truck:			12		
77	(7) Average daily private carter miles/ton are greater than the DSNY average for many reasons, including					
78	the facts that there are (a) no garages in Manhattan, (b) no dumps in Manhattan, © generators are not					
79	continuous but intermittently dispersed, (d) collection route distances are significantly increased in order to					
80	synchronize collection with customers' collective set-outs in a given area, and (e) average travel speeds are					
81	significantly higher. Assumed miles/ton (confidential industry source):			8		
82	(8) AVAC refuse container pickups/wk, Manhattan SAS 3-5-13.xlsx, Containers worksheet			4.34		
83	(9) AVAC paper container pickups/wk, Manhattan SAS 3-5-13.xlsx, Containers worksheet			1.15		
84	(10) AVAC MGP container pickups/wk, Manhattan SAS 3-5-13.xlsx, Containers worksheet			1.00		
85	(11)Avg tons refuse collected per truck shift, Manhattan 8 Section 5 & M11 Section 1, FY2012 (DSNY SCAN)			11.6		
86	(12) Avg tons paper/OCC, ""			6.6		
87	(13) Avg tons MGP, ""			7.1		
88	(14) Avg tons litter baskets ""			2.9		
89	(15) Avg tons in litter basket truck, "", when dumped ("")			8.1		
90	(16) Ratio of hours to collect ton of basket litter v. ton of res. refuse (CBC to Miller, 12-12)			3.0		
91	(17) http://www.nydailynews.com/new-york/uptown/tenants-fume-nycha-plan-replace-picnic-area-trash-					
92	compactors-george-washington-houses-article-1.1052430					

	A	B	C	D	E	F
93	(18) Assumed private carter recyclable tons/truck (primarily OCC/paper, including some pre-					
94	bundled/baled/compacted) (750 lbs/cy after compaction in truck)			9		
95	(19) NYC TA, Addendum #4, Contract #RFQ 33134, Refuse Removal, Disposal and Recycling Services, 1-18-					
96	13, #4http://www.mta.info/nyct/procure/addenda/33134add4.pdf, accessed 3-27-13					
97	p18: "The Contractor shall process approximately forty-four tons of Subway Refuse from NYC Transit's					
98	Refuse Platforms and Authority-owned and -operated Rear Packer Trucks on a postcollection separation					
99	basis, daily, by means of a mechanized sorting and baling process. Approximately 50% (22 tons) of the					
100	forty-four tons is recyclable material in the following proportions: 59% is recyclable newspaper (13 tons),					
101	3% is cardboard (1 ton), 32% metal, glass, plastic (7 tons), and 6% other recyclables (1 tons).					
102	Approximately 50% of these forty-four tons is refuse (22 tons) as indicated by the Authority's analysis of					
103	the waste composition."					
104	p20: "The 207th St. Refuse Platform receives three full trains daily, each with one hundred and eight (108)					
105	three-quarter cubic yard containers/inserts. The three trains require service 7 days per week…"					
106	p36: "Uncompacted Subway Refuse - Refuse Platforms. Location: 207 St. Refuse Platform - Train 4					
107	[assumption is that 2nd Avenue Subway waste will run north], 3961 10th Ave., NYC, 108 3/4cy containers,					
108	daily, 567 total weekly uncompacted cubic yards					
109	p48: [for Items 1 & 2: required to use 31 or 32 cy rear-loaders to remove from 3/4cy, 1cy, 1 1/2cy 2 cy, 8					
110	cy and 10 cy containers					
111	(20) Action Environmental Carting is low-bidder for 5-year TA-wide refuse/recycling contract, bid opened 2-					
112	16-13:					
113	http://enterprise.mtanyct.info/bidresult/BidResultsReport.asp?bidNumber=0000033134&queryType=bidNu					
114	mber, accessed 3-28-13					
115	(21) Assumed private carter 25cy rear-loader mpg			3.0		
116	(22) Assumed private carter rear-loader tons/32cy rear-loader			15.5		
117	(23) Assumed private carter 32cy rear-loader mpg			2.0		
118	per Peter G. McKeon, DSNY Chief of Collection/Recycling Operations, personal					
119	(25) While Construction bids are in for the E 91st Street Marine Transfer Ramp, and it is expected to be in					
120	operation when construction completed, we are using the current dump site.					
121	(26) Marine transfer station to barge to Visy plant on Staten Island.					
122	(27) (Planned marine transfer station to barge to Sims plant in Brooklyn. Legislative approval but not yet					
123	constructed.)					
124	(28) (Hypothetical carter; this could be any carter; hypothetical location is for largest carter in NYC.)					
125	(29) For the purposes of comparison, Newark location is used for both manual and pneumatic collection.					

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A Study of the Feasibility of Pneumatic Transport of Municipal Solid Waste and Recyclables in Manhattan Using Existing Transportation Infrastructure

Final Report
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