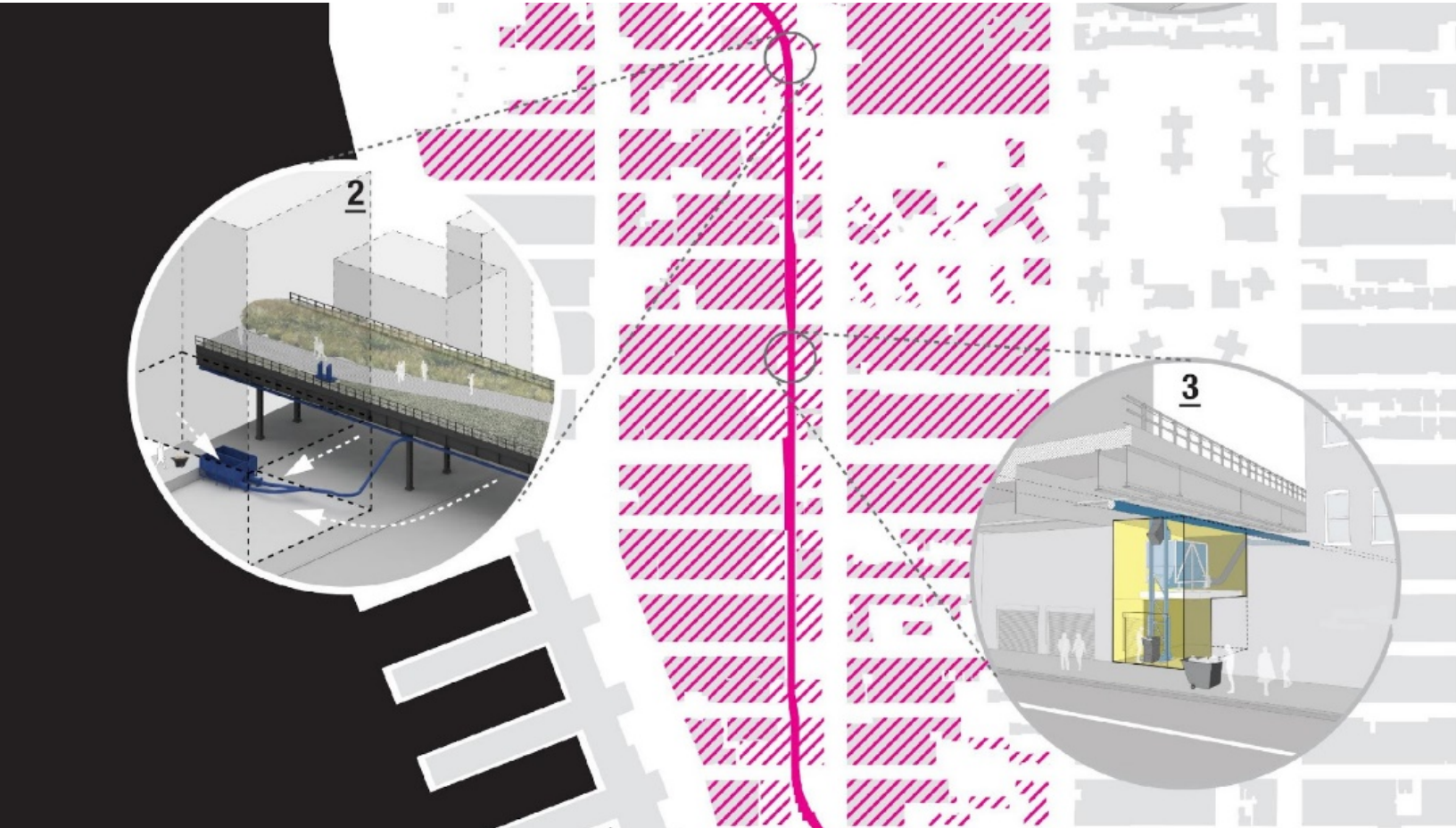


High Line Corridor Pneumatic Waste-Management Initiative: Pre-implementation Planning Study



Final Report | Report Number 18-28 | January 2019



NYSERDA

**Department of
Transportation**

High Line Corridor Pneumatic Waste-Management Initiative: Pre-implementation Planning Study

Final Report

Prepared for:

New York State Energy Research and Development Authority

Albany, NY

Robyn Marquis, Ph.D., Project Manager

Joseph D. Tario, P.E., Sr. Project Manager

New York State Department of Transportation

Albany, NY

Mark Grainer and Robert Ancar, Project Managers

Prepared by:

ClosedLoops LLC

New York, NY

Benjamin Miller and Juliette Spertus, Co-Principal Investigators

with

Albert Mateu, P.E., Green Bending

Christina Grace, Foodprint Group

Stephen Lynch, A.I.A., Caliper Studio

James Lima, James Lima Planning + Development

Thomas Erickson, Rail Cents

Niclas Tylli, Ph.D., P.E., MariMatic Oy

Jan Allen, P.E., Impact BioEnergy

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Preferred Citation

New York State Energy Research and Development Authority (NYSERDA). 2018. “High Line Corridor Pneumatic Waste-Management Initiative,” NYSERDA Report Number 18-28. Prepared by ClosedLoops LLC. [nyserdera.ny.gov/publications:Pre-implimentation Planning Study](https://nyserdera.ny.gov/publications:Pre-implimentation%20Planning%20Study)

Technical Report Documentation Page

1. Report No. C-15-11	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle High Line Corridor Pneumatic Waste-Management Initiative: Pre-implementation Planning Study		5. Report Date October 2018	
		6. Performing Organization Code:	
7. Author(s) Benjamin Miller, Juliette Spertus, Albert Mateu, Christina Grace, Stephen Lynch, James Lima, Thomas Erickson, Niclas Tylli, Jan Allen		8. Performing Organization Report No.	
9. Performing Organization Name and Address ClosedLoops LLC 156 Mountain Road Stanfordville, NY 12581		10. Work Unit No.	
		11. Contract or Grant No. NYSERDA Contract 81377	
12. Sponsoring Agency Name and Address New York State Department of Transportation (NYSDOT), 50 Wolf Road, Albany, NY 12232		13. Type of Report and Period Final Report (2016 to 2018)	
		14. Sponsoring Agency Code	
15. Supplementary Notes Joseph D. Tario and Robyn Marquis of NYSERDA and Robert Ancar and Mark Grainer of NYSDOT served as Project Managers. This project was funded in part with funds from the Federal Highway Administration.			
16. Abstract This study was conducted to advance the High Line Corridor Pneumatic Waste-Management Initiative toward the implementation stage. The High Line is a 1.5-mile viaduct, once used to provide rail-freight service for a manufacturing district in Manhattan, which is now a park. The project would attach a pneumatic tube to this viaduct to transport three waste fractions (refuse, recyclables, and organics) from adjacent buildings, as well as from litter bins in the park and the local Business Improvement District, to a collection terminal. There, these materials would be compacted into sealed containers and loaded directly onto railcars to be hauled to processing and disposal facilities for each waste type. The proposal includes a separate, small-diameter pneumatic tube that would collect kitchen waste from adjacent food businesses to be processed in an anaerobic digester located near the High Line. A prior phase of this project established its economic and operational feasibility, as well as its potential to provide environmental and quality-of-life benefits. The purpose of this project phase was to examine issues that need to be addressed if the project is to be implemented. These included advancing discussions with the stakeholders whose support for and participation in the project would be needed for its realization; developing more-detailed physical and operational analyses needed for the detailed design and engineering plans required for budgeting; and devising a potential financing, business, and ownership model for project development and operation.			
17. Key Words Pneumatic waste collection; municipal solid waste; urban freight transport; urban goods movement; solid waste management; low-emission freight transport; energy efficiency; district-scale utilities; small-scale anaerobic digestion; micro-freight hub; urban rail freight		18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161. http://www.ntis.gov	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 92	22. Price NA

Abstract

This study was conducted to advance the High Line Corridor Pneumatic Waste-Management Initiative toward the implementation stage. The High Line is a 1.5-mile viaduct, once used to provide rail-freight service to and through a busy manufacturing district on Manhattan's Far West Side, which is now a heavily used Park that runs through one of the nation's most densely developing districts. The project proposed would attach a pneumatic trunk line to this viaduct to transport three waste fractions (refuse, recyclables, and organics) from adjacent buildings, as well as from litter bins in the park and the local Business Improvement District, to a collection terminal at its northern end. There, these source-separated materials would be compacted into sealed containers and loaded directly onto railcars to be hauled to processing and disposal facilities for each waste type. The proposal also includes a separate, small-diameter pneumatic tube that would collect kitchen waste from adjacent food businesses to be processed in an anaerobic digester located near the High Line. A prior phase of this project established its conceptual economic and operational feasibility, as well as its potential to provide environmental and quality-of-life benefits to the neighborhood and beyond. The purpose of this project phase was to examine issues that would need to be addressed if the project is to be implemented. Issues included advancing discussions with the stakeholders whose support for and participation in the project would be needed for its realization; developing more-detailed physical and operational analyses needed for the detailed design and engineering plans required for budgeting; and devising a potential financing, business, and ownership model for project development and operation.

Keywords

Pneumatic waste collection; municipal solid waste; urban freight transport; urban goods movement; solid waste management; low-emission freight transport; energy efficiency; district-scale utilities; small-scale anaerobic digestion; micro-freight hub; urban rail freight; eco-district

Acknowledgments

This report would not have been written if Robert Ancar and Joseph D. Tario, P.E., the NYSDOT and NYSERDA contract managers for a project that began in 2010, had not challenged us, on completion of its first phase in 2013, to “make it happen.” Without them and their ongoing encouragement and support, the concept for using the High Line viaduct to reduce the number of trash trucks and trash bags on New York City’s streets would have remained an academic exercise. The study team also gratefully acknowledges the thoughtful support of our current NYSERDA and NYSDOT contract managers, Robyn Marquis, Ph.D., Mark Grainer, and Deborah Mooney.

The project would not have reached its present stage without the critical contributions of ClosedLoops’ valued partners and collaborators, whose fundamental roles are reflected in their place on the title page as co-authors. Other collaborators whose ideas, enthusiasm, and expansive-yet-exacting understanding of the range of practicable possibilities infused this project are Andrew Manshel, J.D. and Clare Mifflin, AIA. Other mentors on whose valued advice we depended are Norman Steisel and Brendan Sexton. Andrew Bennett of SourceOne played an instrumental role in assessing a potential anaerobic digestion site. The NYC officials who have played the most important part in this effort as members of our interagency steering committee are Elizabeth Balkan (formerly DSNY), Kristen Bell (EDC), Kate Mikuliak (NYC DOT), Alan Price (DOB), Namshik Yoon (Parks & Recreation/retired), and Kate Gouin (Mayor’s Office of Sustainability) for her leadership in driving the project forward. The team sincerely thanks the members of our advisory committee for their thoughtful participation in a process that gave the project its present shape: Sarah Currie-Halpern (Manhattan Solid Waste Advisory Board), Martin de Kadt (Observer, Manhattan Community Board 4), Gardner Dunnan (Avenues School), Dan Egan (Vornado), Adam Ganser (Friends of the High Line), Chris Garvin (formerly Terra Bright Green), Kim Goodger (Jamestown), Mitchell Grant (RXR Realty), Lakshan Gunaratne (Standard Hotel), Kevin Hussey (Jamestown), Emily Kildow (Taconic Management/Google), Alyssa Zucker (Vornado)—and in keystone roles: Jeffrey LeFrancois and Lauren Danziger (Meatpacking BID).

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Acronyms and Abbreviations

AD	anaerobic digestion
AD	Americans with Disability Act
BIC	Business Integrity Commission
BID	Business Improvement District
CHP	Combined Heat and Power
DEP	Department of Environmental Protection
DOB	Department of Buildings
DOT	NYC Department of Transportation
DSNY	NYC Department of Sanitation
FotHL	Friends of the High Line
ft	feet
kWh	kilowatt-hours
MOS	Mayor's Office of Sustainability
MSW	municipal solid waste
NFPA	National Fire Protection Association
NYC	New York City
NYCEDC	New York City Economic Development Corporation
NYCHA	New York City Housing Authority
NYSDOT	New York State Department of Transportation
OTCR	Office of Technical Certification and Research
tpd	tons per day
UTRC2	University Transportation Research Center, Region 2

Executive Summary

The High Line Corridor is the densely developed—and intensively developing—stretch of Manhattan’s Far West Side that wraps around the High Line, a viaduct that was once a railroad and is now a park. The area, once home to the world’s greatest agglomeration of urban industry, is now a mixed-use neighborhood filled with high-rise apartments, luxury retail, restaurants and galleries, mammoth construction cranes, and millions of visitors.

The High Line Corridor Pneumatic Waste-Management Initiative is an attempt to demonstrate the role that an ensemble of innovative waste-management techniques could play in producing significant environmental, economic, and quality-of-life benefits in this neighborhood and beyond. Though its component elements are all based on well-established technologies, they have never before been used in the combination proposed, nor in the specific fashion envisioned. As importantly, the initiative represents an innovative approach to developing district-scale utility infrastructure—an approach that does not rely, as is typically the case, on top-down governmental planning or on the development of a new complex by a private owner who controls all the parcels within its structures. Like the High Line Park itself, which grew from a vision of what an iconic piece of legacy infrastructure might become if it were repurposed to support local needs, the initiative began with the premise that this strategically located asset, on an elevated right-of-way running through the middle of blocks and buildings, might be leveraged to do more than provide an exquisitely landscaped public promenade. The project’s objective was to provide the means by which the High Line can serve critical urban functions that go well beyond bearing pedestrian traffic, and by so doing, not only improve the quality of life for the residents, workers, and visitors in the corridor, but provide a model from which components could be widely replicated elsewhere.

The High Line railroad once served as the major freight conduit for bringing goods to Manhattan by land, and for shipping manufactured and imported wares from this dense industrial corridor to the City’s hinterland. Today freight neither enters nor leaves Manhattan by rail or by water. Like most of the other 8.5 million New Yorkers, Manhattanites are entirely dependent on trucks for delivering everything they consume and for removing everything they discard. Their discards wrapped in blue and

clear and black bags heaped in front of each building to be picked up by human hands every day or multiple times a week, require a special kind of truck—one that uses more fuel, emits more greenhouse gases and more noise, creates more congestion and roadway wear, and causes more injuries and fatalities than any other on the road.¹

The idea behind the High Line Corridor Initiative is that the number of plastic bags on the street and the number of trucks that come to pick them up could be significantly reduced if the use of this former freight viaduct could be expanded to include its former transport function—if a pneumatic tube could be attached to it to carry separate fractions of waste (recyclables, organics, refuse) from their points of origin to a central collection terminal where these three types of materials could be separately compacted into sealed containers, loaded onto railcars, and taken directly to processing or disposal facilities. A separate, smaller-diameter pneumatic tube could carry pre-consumer food waste straight from commercial kitchens and food-preparation businesses to a small-scale anaerobic digester to produce electricity and heat for local use. This network of facilities could be cooperatively owned by its users, including major buildings along the corridor, with government agencies and foundations—in recognition of the public benefits it would provide and the services it would offer in collecting public waste—contributing to the users’ capital investment. The Meatpacking BID, the local business improvement district, is one of the potential entities that might manage this facility.

The idea began with an academic study conducted under the auspices of City College’s Urban Transportation Research Center (UTRC2), with funding from NYSERDA and New York State Department of Transportation (NYSDOT). The objective was to determine whether it would be feasible and beneficial to reduce heavy-truck trips—and the energy consumed, greenhouse gas emitted, and roadway congestion produced—by using existing linear transportation infrastructure (such as subway tunnels or railway viaducts). This would support the retrofit of existing neighborhoods with a waste-transport technology that (despite decades of successful experience on Roosevelt Island in New York City and hundreds of similar installations developed over the past half-century in Europe and Asia) has rarely been used in New York or the rest of the U.S. The initial report, published in 2013,² found that attaching a tube to the High Line to automatically collect recyclables, organics, and refuse from the Park and buildings closest to it would be physically and operationally practicable, would produce significant environmental and quality-of-life benefits, and could repay the capital investment required to build it through long-term savings in operational costs.

The initial funders' (the study's NYSERDA and NYSDOT contract managers) response to the completed report was to challenge the study team to advance the vision beyond the feasibility/cost-benefit stage: "Make it happen. Catalyze it." The study team formed ClosedLoops LLC as the organizational vehicle that would try to meet this challenge.

After receiving a subsequent round of research funding from the Volvo Research and Education Foundation (again under the auspices of UTRC2), the concept evolved to include direct transfer of waste containers between the pneumatic terminal and rail cars, so that they could be transported to processing or disposal facilities without trucks, and the study team expanded to include experts in pneumatic engineering, rail facilities and operations, and food- and commercial-waste management. After the report for this phase of work was published in 2015,³ NYSERDA and NYSDOT awarded ClosedLoops funding for the present phase of this project, which was designed to carry the initiative forward from the feasibility/cost-benefit stage toward pre-implementation planning.

The report documents the work completed during this phase of effort. The study team expanded to include an architect and an economic-development expert, and manufacturers of pneumatic and anaerobic digestion equipment contributed their pro bono support. The team also benefited from the pro bono participation of a lawyer with wide experience with business improvement districts and public-space design.

The original concept evolved, as described below, as the study team engaged with a growing universe of private and public-sector stakeholders. The discussion below provides an overview of the individual components of the project, a report on the current status of each of these elements and outlines the next steps in the road ahead.

1 Introduction

The problems associated with truck-hauled freight in dense urban areas, especially since online purchasing has led to a dramatic expansion of package deliveries, are widely appreciated even if their solutions are not yet well-understood. In New York City, the problems due to street and roadway congestion, particularly those caused by truck traffic and door-to-door deliveries, are apparent to anyone who has tried to move by any means on the surface of its streets or sidewalks, or breathed its air, or heard its sounds. Anyone concerned with global warming and sustainable energy, or with the health effects of diesel-particulate emissions, or with the risks of death or injury due to vehicular crashes, is aware of the problems associated with trucks in City streets.

Less appreciated are the ramped-up adverse environmental, economic, and quality-of-life impacts due to a sub-category of these trucks—those that stop in front of every building in the City multiple times a week or a day so that workers can manually load refuse, recyclables, or organics into the hydraulic compactors. These trucks are heavier, noisier, less fuel-efficient, and more dangerous than any other vehicles on the streets, and they usually come with a special added ingredient—garbage bags. These sacks are in themselves an environmental nuisance since they emit odors and litter, impede traffic, and attract rodents and other pests.

1.1 The High Line Corridor Pneumatic Waste-Management Concept

There are many means by which this status quo situation might be improved upon.⁴ Cities around the world have devised various ways to minimize the truck trips and impacts associated with waste removal. Often these in some way involve a reduction in the reliance on door-to-door pickups and on the use of human muscles for hoisting plastic bags stuffed with refuse or recyclables. Of these, pneumatic collection—the most expensive of these solutions to install—is the gold standard for those situations where, due to density and other geographic circumstances, it provides the highest level of social and environmental advantages.⁵

Pneumatic waste systems, like sewers, use a common trunk line to convey waste from individual buildings to a central terminal, but use vacuum-pulled air rather than gravity-propelled water as the conveyance medium.⁶

Like sewer trunks, pneumatic trunk lines are connected to individual inlets in buildings via branch pipes, as shown in Figure 1. Pneumatic systems can provide segregated inlets for defined waste fractions such as refuse, recyclables, and organics.⁷ Valves at the bottom of each inlet separate it from the branch pipe, so that the space between the inlet opening and the valve functions as a storage reservoir when the valve is closed. The separate fractions can be pulsed through the common trunk tube at different times so that the waste fraction can be separately conveyed to the terminal and sealed in a dedicated container.

Figure 1. Typical Pneumatic Network.

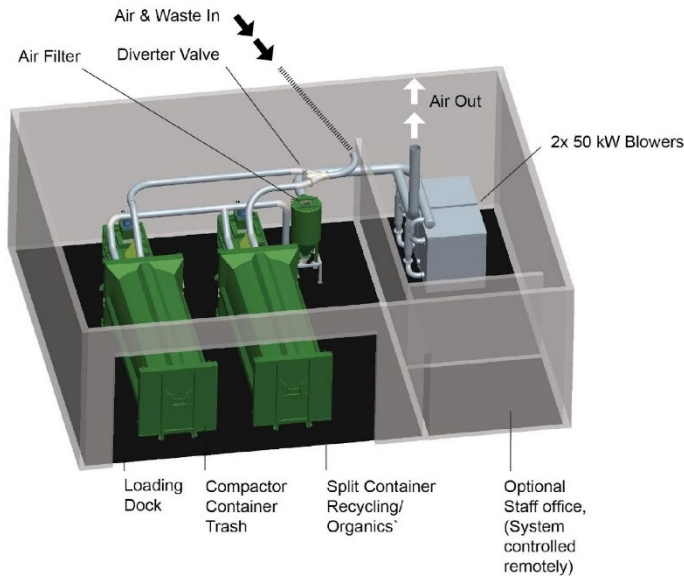
Source: MariMatic Oy, annotated by ClosedLoops



1 Exterior Inlets 2 Interior Inlets 3 Pipeline 4 Collection Terminal

Figure 2. Typical Pneumatic Collection Terminal.

Source: MariMatic Oy, annotated by ClosedLoops



Pneumatic systems have been used for over half a century to provide sanitation service that minimizes environmental impacts and maximizes quality-of-life benefits by eliminating manual door-to-door collection into trucks. Since 1962 hundreds of pneumatic networks have been installed in Europe and Asia, including hundreds in Stockholm where the technology was first applied, nine in Barcelona (the first of which was built for the 1992 Olympic Village), and in the last decade, five in and around Paris and one in London.⁸ Within the past two decades, as recycling programs have added truck routes to increasingly congested city centers, the ability to transport source-separated waste through a single pipe has magnified the relative benefits of pneumatic technology. Yet, despite a few examples (among them the legacy pre-digital network on Roosevelt Island in New York City, which has been in operation since 1975), the technology has not yet achieved widespread adoption in the U.S.⁹

Prior studies conducted by the research team, with funding from NYSERDA, NYSDOT, and the Volvo Research Foundation,¹⁰ have established the conceptual economic and operational feasibility of installing tubes within existing linear transportation infrastructure as a way of providing pneumatic collection networks in existing neighborhoods while avoiding the economic and logistical hurdles of tunneling. These studies have also shown the potential for such retrofit installations to provide environmental and quality-of-life benefits for the neighborhood and beyond. The present study was designed to advance this concept toward implementation by covering some of the distance between establishing conceptual feasibility and developing a project plan that could be used as a basis for financing, final design, procurement, and installation.

The High Line is a 1.5-mile viaduct that was once used to provide rail-freight service to and through a busy manufacturing district on Manhattan's Far West Side. It is now a heavily used Park that runs through one of the nation's most densely-developing districts. The High Line Corridor Pneumatic Waste-Management Initiative calls for attaching a pneumatic trunk line to this viaduct to transport three waste fractions (refuse, recyclables, and organics)¹¹ from adjacent buildings—as well as from litter bins in the Park and the adjacent Business Improvement District—to a collection terminal at its northern end. There, these source-separated materials would be compacted into sealed containers and loaded directly onto rail to be hauled to processing and disposal facilities for each waste type. The proposal also includes a separate, small-diameter pneumatic tube that would collect kitchen waste from adjacent food businesses for processing in a small-scale anaerobic digester located near the High Line.

Figure 3. Cross-Section of the High Line Showing Trunk Tube (Early Iteration)

Source: Image, Colin Curley



The High Line Pneumatic Initiative offers several innovations over past practice by combining existing technologies in new ways. Pneumatic networks have been retrofitted into existing neighborhoods using abandoned traffic tunnels (Plaza Lesseps, Barcelona), space inside a sewer tunnel (Clichy-Batignolles, Paris), or the underside of a pier (Expo, Portugal), but as far as the project team is aware, no installation has focused exclusively on existing above-ground infrastructure to avoid the need for tunneling. Nor is the team aware of a project initiated not by top-down governmental planning or by a single owner developing a large-scale greenfield complex, but as a district-scale, ground-up enterprise involving the coordination of multiple owners of multiple parcels. And only a couple of pneumatic facilities have completely eliminated the use of trucks by using a direct rail connection to a processing facility.¹²

1.2 Its Evolution

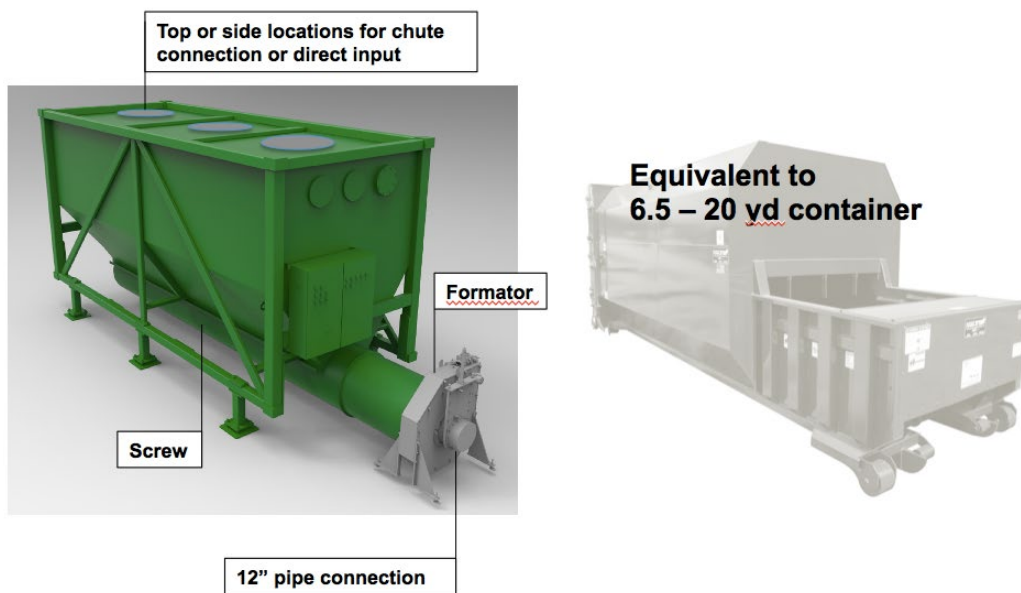
As originally conceived (in the feasibility/cost-benefit analysis completed in 2013),¹³ the High Line Corridor project focused on the High Line viaduct as a means to leverage a pre-existing right-of-way between immediately adjacent buildings in which interior inlets would be installed to provide direct connections to the trunk line. The program targeted the “lowest-hanging fruit”—the buildings that actually touched the viaduct as well as the litter-bin waste collected from the Park on top of the viaduct. For simplicity, the team proposed collecting waste from a single block-long building, the Chelsea Market, whose estimated daily volume of 10 tons the team determined was the minimum economically viable demand load. During the course of a second round of study, completed in 2015,¹⁴ the scope expanded to capture waste from a half-dozen large buildings directly adjacent to the

High Line; together these buildings would supply as much waste as a typical pneumatic facility could handle (about 20 tons). This use of available capacity increased the efficiency both of the pneumatic network itself and of the rail-transfer facility that was added to the project concept at this stage. Transferring containers from the pneumatic terminal directly to railcars would allow them to be shipped directly to processing facilities without the use of trucks.

Another change introduced at this stage involved the means by which material would be introduced into the pneumatic system. The original plan assumed several waste rooms with chutes at Chelsea Market, similar to the chute room provided at the Santa Catarina Market in Barcelona, and individual inlets along the High Line to replace its litter baskets. But the team’s conversations with building owners revealed that they would prefer not to retrofit their buildings with chutes or to have multiple waste rooms, but rather to continue with their present reliance on loading docks, where large-scale inlets—tanks—would take the place of existing compactors. The modified design thus involved sealed inlet tanks. Depending on the building’s size and the waste fraction for which it is intended, the tanks would store between 6.5 and 20 cubic yards of waste.¹⁵

Figure 4. Inlet Concept

Source: Marimatic Oy, modified by ClosedLoops



At 20 tons per day, the system could only capture a portion of the waste along the High Line Corridor—and only from buildings directly adjacent to the High Line, many of which, like the Chelsea Market, already consolidate their waste in compactor-containers within loading docks. Bags of waste from sidewalk litter bins, or from buildings (without loading docks) that were too far away to justify a direct connection to the trunk line, would still be piled on the sidewalk. Stakeholders asked: Could it be possible to use the pneumatic tube not only to handle their buildings' waste but also to provide neighborhood benefits by in addition removing these bags (and truck trips) from local streets? Instead of asking how many buildings could be connected to the trunk tube, the question became: How much waste could a High Line Corridor system capture with a fixed set of input points?

The answer was inspired by the team's parallel work with Kiss & Cathcart Architects on the Zero Waste Design Guidelines for the Center for Architecture/AIANY. One of the best-practice case studies presented in the guidelines is the aggregated waste-collection system used in Battery Park City in lower Manhattan, where multiple buildings share the use of compactors in loading docks.^{16,17} The team modified the system design to minimize the number of inlets—which would mean not providing small post-style inlets in the Park to replace existing litter bins¹⁸—and to increase the size of the inlets—by providing large-scale sealed tanks into which carts of material from multiple locations (within a building or within a convenient walking distance) would be tipped.

Figure 5. Battery Park City Shared Compactor Model

Building staff loading cart of refuse into tipper at shared compactor in a loading bay in a residential building in Battery Park City.

Source: Nick Sbordone, Battery Park City Authority



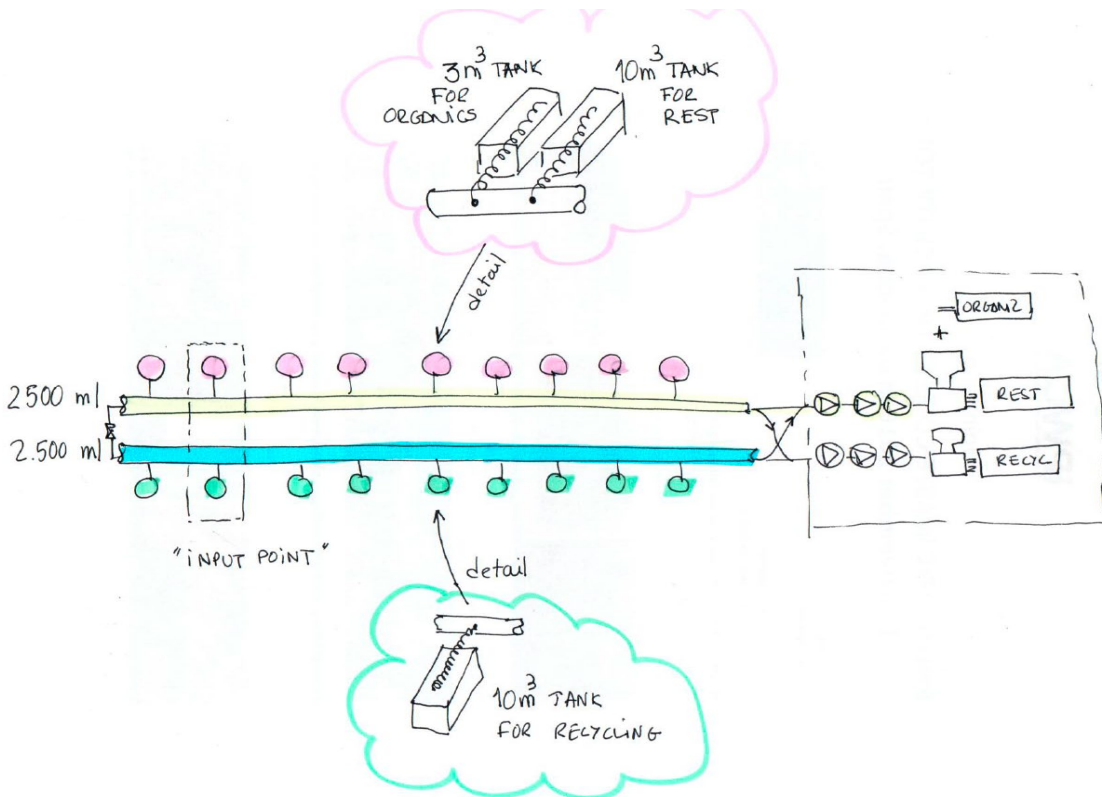
The decrease in the number of inlets reduces capital costs while increasing system efficiency, since the larger reservoirs located at fewer locations reduce the number of times that valves between the inlet reservoirs and the connections to the trunk tube would need to be opened, and correspondingly reduce the amount of energy required to pull material through the trunk line to the terminal. This increase in efficiency permits a tripling of the equipment's effective capacity, raising it from 20 to 60 tons a day. This change not only makes the system more flexible by providing potential access to any building within a few blocks but expands the network's geographic footprint and magnifies the community benefits (the reduction in truck trips and numbers of bags on the streets). Dissociating the transport pipe from buildings means that the system could continue to serve the neighborhood even as buildings are built or modified or demolished and as land uses and activity patterns change.

This capacity increase required adding a second trunk line to provide system robustness and redundancy, and to avoid the need for scheduling collection pulls for specific fractions at specific times. One of the parallel tubes would generally be used for two of the fractions (refuse and organics), while the other would generally be attached to a compactor for recyclables. But in order to accommodate planned maintenance or to respond to unplanned events, either tube could be attached to any of the container lines (there would be two container lines for each fraction¹⁹) to handle any of the three fractions. The incremental capital cost of the second tube would be relatively modest (under \$2 million) while not significantly increasing operating costs.²⁰

Figure 6. Design for High-Capacity High Line Network

This diagram shows the nine sets of input points that are connected to the two trunk pipes. The blue pipe is for recyclables and the yellow one for organics and refuse. Arrows indicate how the diverter valve could shift the flow between compactors to provide redundancy in the event that one pipe is down.

Source: Green Bending



Because of the reconceived inlet points or hubs—which allow waste to be delivered to the shared buffer tanks from a distance of several blocks and allow the network to accommodate three times as much material—it became possible to consider the possibility of accepting not only pedestrian litter from the Park but also material collected from street-level litter bins in the neighboring Meatpacking Business Improvement District (BID). Rather than emptying bagged waste from the bins and staging the bags in piles alongside the bins or at nearby locations until New York City Department of Sanitation (DSNY) trucks come each day to collect them, BID staff could roll them in wheeled carts directly to the buffer-tank inlets so that the piles of bags would not remain on the street all day.

Figure 7. Map of Litter Bins in the Meatpacking BID and Bags Staged for DSNY Collection

Source: ClosedLoops



Because piles of bagged litter bin waste on streets in the Meatpacking District pose adverse quality-of-life and economic impacts for residents, workers, visitors, and businesses in the District, the executive staff of the BID expressed interest in the possibility of using the proposed pneumatic system to avoid the need for staging bags of waste in their public space. And because managing this waste is one of the BID's core operational functions, they also expressed a willingness to consider the possibility of performing an administrative role in managing the proposed system.

Just as the project has evolved during its trajectory from the germ of an idea, through the feasibility-analysis phase, through the current phase, it will doubtless continue to evolve as new opportunities arise, new barriers emerge, and new strategies are devised to overcome them. The present report represents a snapshot in time: The State of the Initiative as of July 2018—one moment in an ongoing trajectory toward the goal of project implementation. It is possible in this report only to summarize its status and to outline the currently proposed configuration of its components. By the time you read this, it is likely that various conditions and proposals described below will have changed. Visit the project page at ClosedLoops.net to find out the latest developments related to the project.

2 The Components

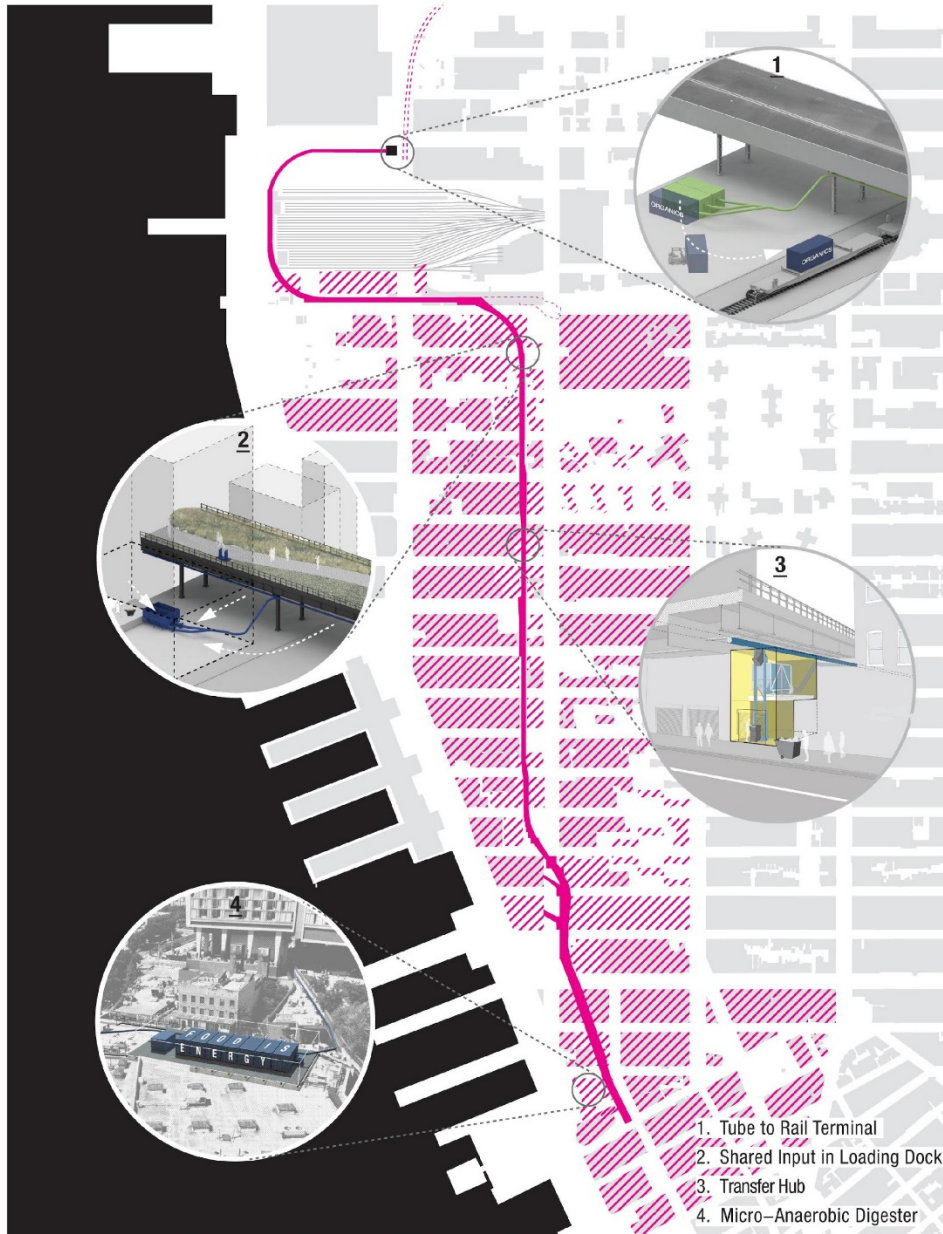
The High Line Corridor Pneumatic Initiative includes three independent components:

- A pneumatic waste-collection network that consists of the following:
 - Inlet tanks in sets of three for three waste fractions (refuse, recyclables, post-consumer organics) that would receive waste tipped from rolling carts.
 - A double-trunk line attached to the length of the High Line viaduct, which would be connected by branch pipes to the sets of inlets, and to a collection terminal at the northern end of the High Line.
 - A collection terminal housing the vacuum pumps, separators, compactors, containers, and control equipment needed to pull source-separated waste fractions at different time intervals from the inlet tanks to the terminal to be compacted into sealed shipping containers.
- A tube-to-rail transfer facility that would allow for the direct transfer of sealed containers of segregated waste fractions directly onto rail cars, on which they would be hauled to processing or disposal facilities for the respective waste types.
- An organics-processing system with a pneumatic-collection tube directly connected to a small-scale anaerobic digestion (AD) facility.

Figure 8. Components of the High Line Pneumatic Initiative

(1) Pneumatic terminal, (2-3) Inlet options and pneumatic trunk line, and (4) AD facility in illustrative location. The pink line is the High Line viaduct; the pneumatic trunk line would run along its length. The shaded area represents the potential waste-catchment area for shared inlets.

Source: Caliper Architecture



2.1 Pneumatic System

The system would be capable of handling 60 tons per day (tpd) of material and would be available 24 hours a day, 365 days a year. It would receive waste from specific buildings immediately along the viaduct as well as material from the Park, from litter bins in the Meatpacking BID, and potentially from other buildings within a few blocks of the viaduct (the practicable transport distance of a rolling cart that is either moved manually or by a small electric tractor or cargo bike). The system would run automatically, with digital sensors and controls. Individual waste fractions would be pulled through the common trunk line from individual inlets when sensors indicate that the reservoir of one or more inlets for a given material type is nearing capacity. The terminal vacuum pumps would operate only when one of the three fractions is being collected, for a maximum total duration of about 12 hours a day. (It would take 2.5 to 4.5 hours to empty all the tanks for each fraction type, depending on the fraction, or about 15 to 30 minutes per tank, depending on the fraction.) Each fraction might be pulled a couple of times within a 24-hour period, but the number of pulls, and the duration of each, would vary based on the volume and density of the waste that needed to be transported (up to an average total of 60 tpd).

The base waste volume includes waste from the potential system users who participated in this phase of the project, whose buildings are directly connected to the High Line; the High Line Park; litter bins from the Meatpacking BID; and NYCHA's Fulton and Chelsea-Elliot Houses.

Table 1. Pneumatic Tube-to-Rail System Base-Waste Volume

Source: ClosedLoops

Source	Type	Floor Area (sf)	Refuse ^a (tpd)	Recycling ^b (tpd)	Post-Consumer Organics (tpd)	Pre-Consumer Organics (tpd)	Total (tpd)
Park	Litter bin		0.8	0.5	0.03	-	1.3
BID	Litter bin		2.5	-	-	-	2.5
Building A	Food Processing	78,000	1.4	-	-	0.6	2.0
Building B	Hotel	219,000	2.2	0.2	-	1.0	3.3
Building C	Office	325,000	1.1	0.9	-	-	2.0
Building D	Office, Retail, Food	1,100,500	1.1	4.1	0.75	0.8	6.7
Building E	Office, Food	540,300	2.0	1.5	-	1.5	5.0
Building F	School	101,000	0.3	0.2	-	0.5	1.0
Building G	Residential		1.4	1.4	1.7	-	4.4
Total		2,363,800.0	12.7	8.7	2.5	4.3	28.2
Total Minus Pre-consum organics							23.9
Remaining Capacity ^c							36.1

^a Most participating buildings provided hauler bills. Most bills do not include waste volumes. Unquantified volumes were estimated based on building size and occupancy, and known volumes for similar-size buildings.

^b Metal, glass, plastic, paper; cardboard and other bulk material is not included because it will continue to be collected manually.

^c The potential catchment area indicated in red shading in Figure 6 is based on proximity to the High Line. It is assumed that any generator within this area would have potential access to the system. Based on the size and occupancy of the buildings in the shaded area, aggregate generation would significantly exceed 36.2tpd.

The technical specifications for the type of pneumatic installation described below are based on those of the team’s pro bono industry partner for this study, MariMatic Oy.^{21,22}

2.1.1 Inlets and Branch Pipe

A standard approach for depositing material for collection by a pneumatic network is to install interior chutes, as shown in Figure 9. While chutes would typically be considered in a new-build situation when they can be integrated with the rest of the building’s infrastructure, it is also possible to retrofit chutes into existing buildings (just as elevators and other equipment can be added to existing structures). When the potential users along the corridor considered this option (as illustrated in Figure 8), they expressed a preference for isolating the retrofit installation within existing loading areas. This alternative, while

it would not achieve the full-labor savings that more-decentralized inputs could provide, would avoid interfering with intricate existing spatial arrangements. The inlet design that the potential users preferred is shown in Figure 9. This design would rely on the same waste-handling operations that these owners currently use within their buildings, as well as the same consolidation/storage/collection space that they use, as shown in Figures 11, 12, 13, and 14. And it would provide buffer-storage capacity that would reduce the frequency with which the inlets would need to be emptied.

Figure 9. Staff Using Input Chute for Pneumatic Collection, Santa Catarina Market, Barcelona

Source: Envac



Figure 10. Dispersed-Input Scenarios

Building owners were asked to consider adding a gravity chute (center image), installing branch pipe (left image), or adding multiple input points (right image) to reduce manual waste-consolidation.

Source: Image, Caliper Architecture

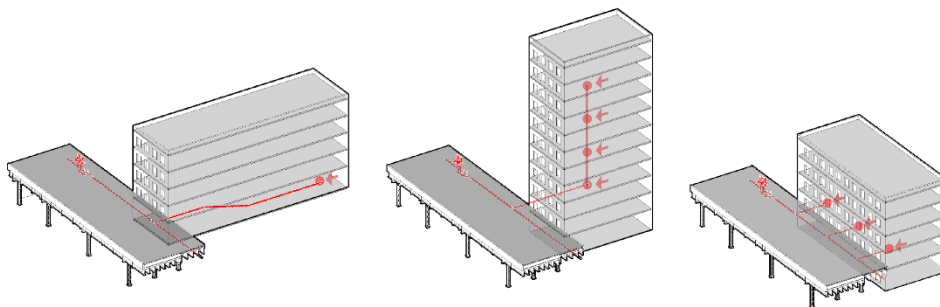
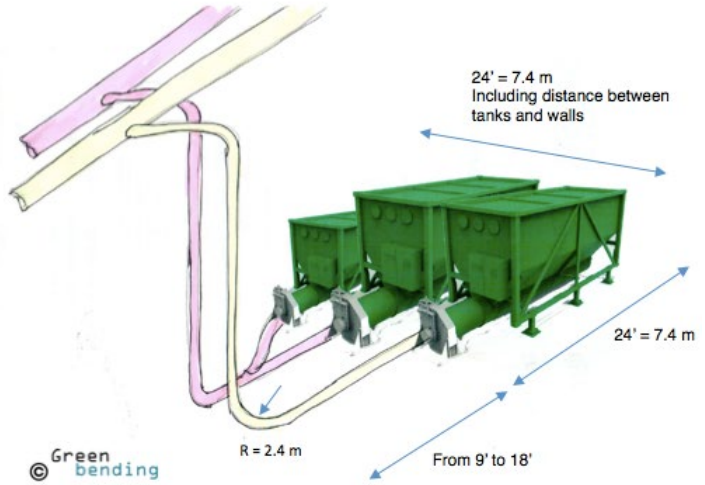


Figure 11. Inlet Design, Typical Inlet Location

Source: Diagram, Green Bending, Photo ClosedLoops



Conditions under the viaduct vary



Minimum Footprint (3 tanks side by side): 24' x 33' or 792 SF

Figure 12. Section Diagram of Typical Loading Area Adjacent to the High Line

A typical loading area used for waste-staging and inbound deliveries. This image shows staff arriving with a tilt truck empty waste into a typical 30-cubic-yard compactor container.

Source: Caliper Architecture

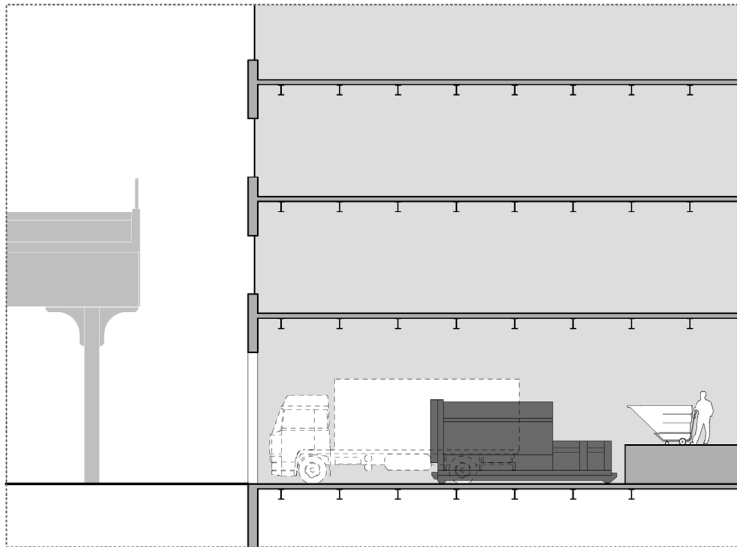


Figure 13. Containers in a Typical Loading Area

Source: ClosedLoops

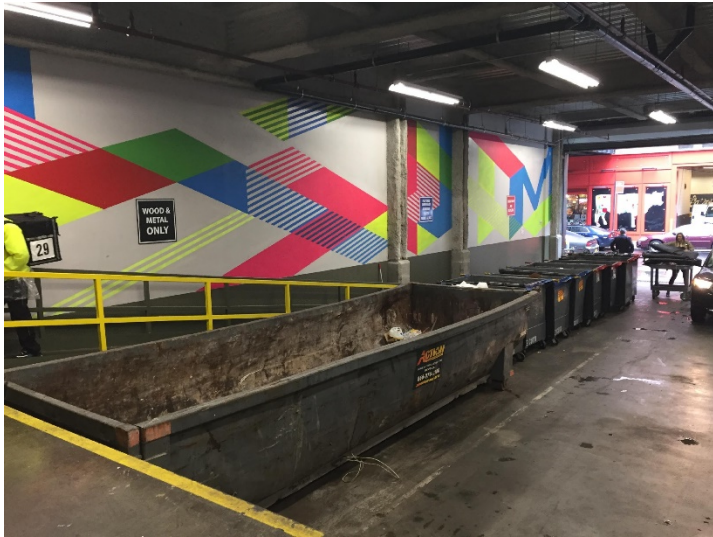
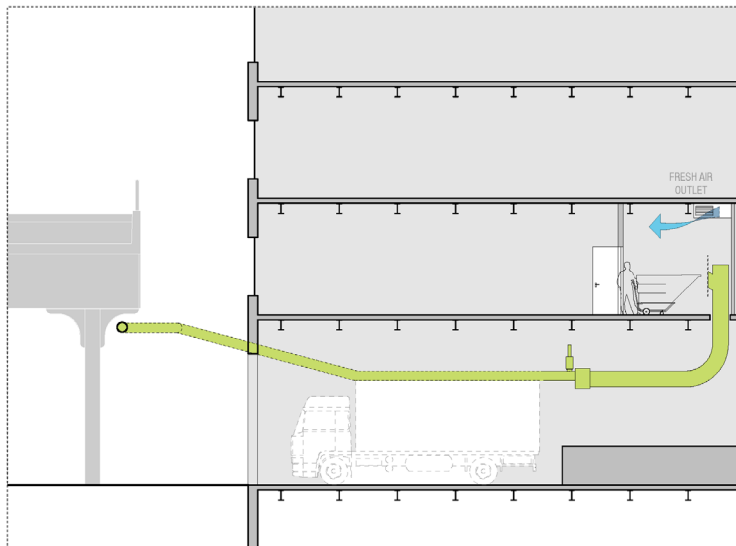


Figure 14. Section Diagram of Building Adjacent to the High Line with Input Point on Second Floor

Smaller buildings were asked to consider input points without buffer tanks. This option maximizes space savings, but the inlet can only accept about 2 cubic yards of material before its reservoir has to be emptied.

Source: Image, Caliper Architecture



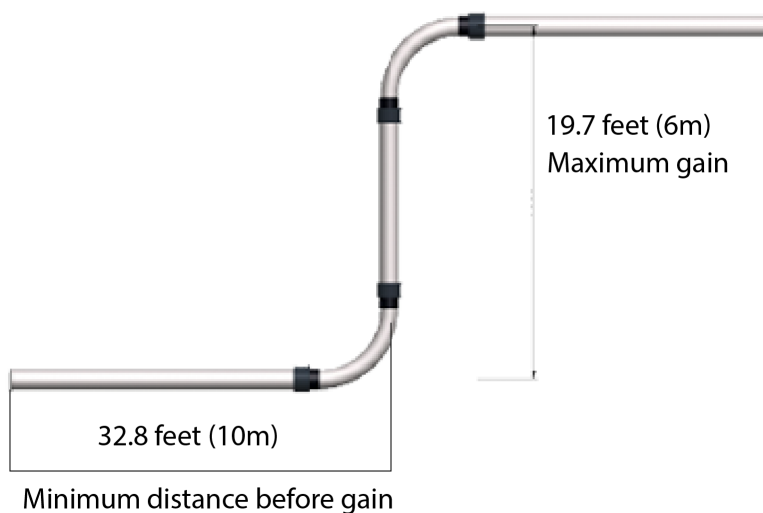
Inlets would be located in sets of three, with an inlet for each waste fraction. There would be nine inlet locations. Potential locations might include loading-dock areas or other ground-floor or street-level spaces in or adjacent to the Chelsea Market, the Milk Studio, the Standard Hotel, 85 10th Avenue, 832 Washington Street, and the Avenues School. Other inlet sites might be on publicly owned space under or adjacent to the viaduct. The overall footprint required for each set of three tanks, including space between tanks and enclosure, would be approximately 800 square feet. The tanks could be located at grade or above grade. If it were necessary to elevate the tilt carts above the tank to permit tipping at a given location, this elevation could be achieved by means of a ramp, by an adjacent platform at a higher elevation (of the sort commonly found in truck docks), or with a mechanical tipping device that raises the cart above the tank, as are commonly used for such applications (for example at the shared compactors at Battery Park City).

The design of input points must take into account the geometry of the pipe. For example, a length of horizontal pipe is needed to accelerate material before a vertical bend. A 33-foot horizontal pipe run prior to a vertical bend would allow buffer tanks at street-level to connect with a transport pipe attached to the bottom of the High Line.

Figure 15. Pipe-Geometry Parameters

Conditions for maximum vertical gain for 12-inch interior diameter pipe (not drawn to scale).

Source: Green Bending



Branch pipe must meet the transport pipe at a specific angle to maintain smooth airflow. For this reason, the final path of the transport pipe will have to be coordinated with the input points and branch pipe, as well as with the viaduct structure.

Figure 16. Maximum Branch-Pipe Angle

Maximum angle at which branch pipe must connect to transport pipe.

Source: Image, Caliper Architecture

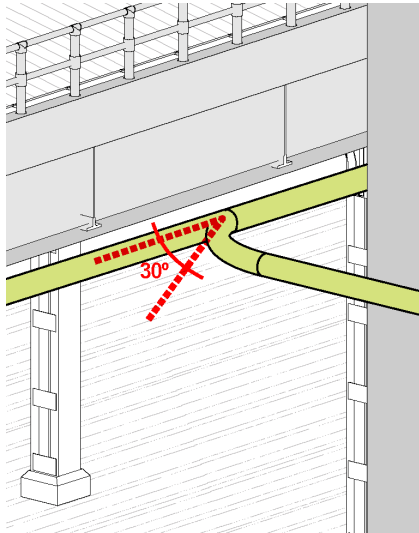
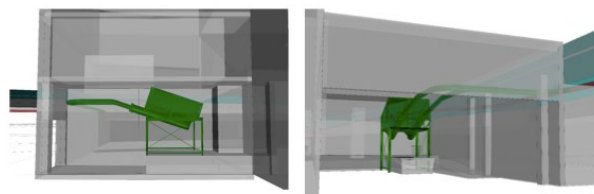


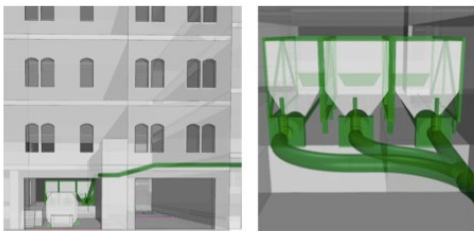
Figure 17. Buffer Tanks at Grade or Raised Above Loading Area

Buffer tanks as they might be installed inside three actual loading docks.

Source: Image, Caliper Architecture



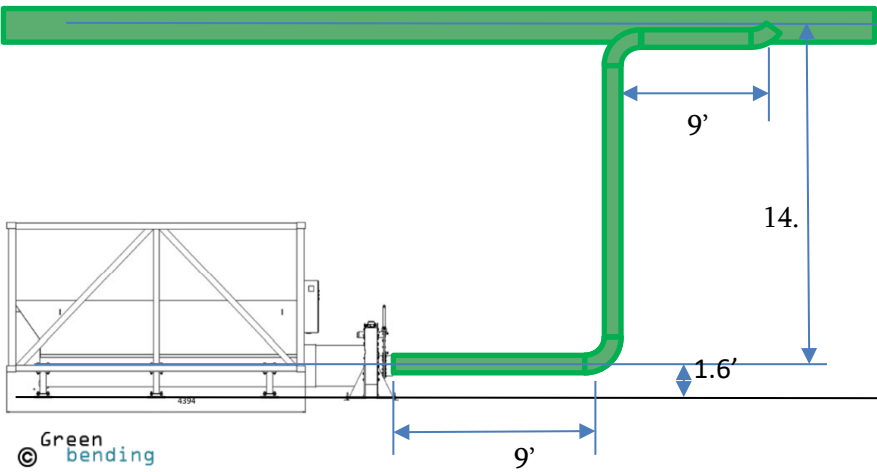
Tank raised, carts emptied by tipper



Tank on loading dock floor, carts emptied directly

Figure 18. Buffer Tank

Buffer tank at grade with a vertical connection to the transport pipe.



If the shared inlet tank were elevated toward the underside of the viaduct, the space under it could be used for a complementary purpose, such as serving as a micro-distribution hub for packages. Staff from adjacent buildings delivering inbound waste could pick up and deliver packages for their buildings in the same trip. Alternatively, this underside space could be used for baling cardboard and staging it for collection.

Figure 19: Pneumatic Inlets Combined with Micro Freight-Distribution Hub

This shared inlet-tank is elevated. Rolling carts are lifted with tipper equipment to dump into the tank. The space below could be used to stage inbound deliveries or cardboard-baling equipment.

Source: Caliper Architecture



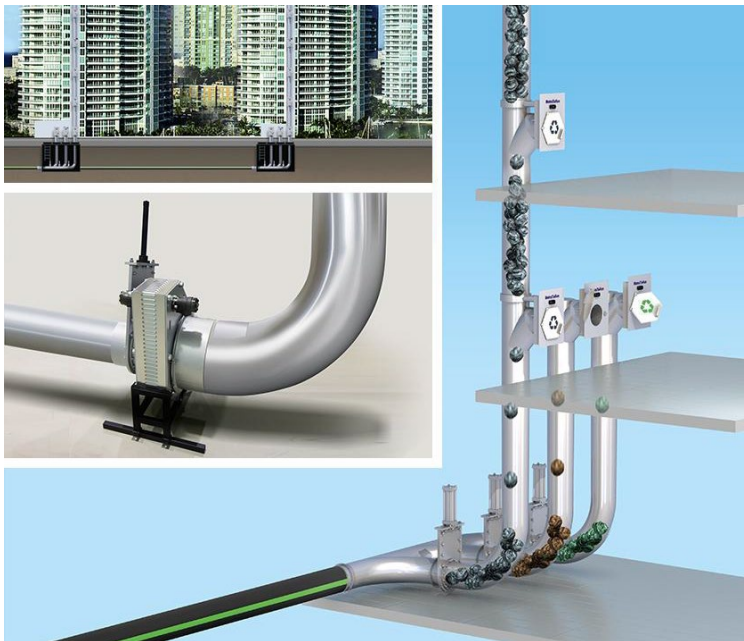
2.1.1.1 Formators

Pneumatic pipe is typically 20 inches in diameter and waste is typically introduced into it via a gravity chute of the same size. MariMatic’s design for a 12-inch pipe provides a two-thirds’ reduction in the volume of air needed to transport the waste, which in turn produces a significant reduction in energy requirements. This design also allows the pipe to be installed with a steeper grade, and with tighter turning radii, both of which are advantageous in the case of an elevated trunk line receiving inputs from below. In order for bags of waste to fit into a 12-inch interior diameter tube, the material must be densified into a shape that will fit into an opening the size of a dinner plate. A device called a “formator” accomplishes this task with a proprietary design that twists incoming material to break it up and squeeze it into the branch pipe that is connected to the trunk line.

Figure 20. Formators in Typical Gravity-Chute Inlets

Gravity chutes in building cores are connected via valves to a below-grade transport pipe. The formator device shown in the center left panel, and at the junction of the vertical and horizontal pipes shown on the right, is where the 24-inch diameter chute meets the 12-inch diameter pneumatic transport pipe.

Source: Marimatic Oy



2.1.2 Trunk Line

2.1.2.1 Material

The trunk pipe (as well as the branch-line connections to it) has a 12-inch interior diameter and a thickness of 0.9 inches, to produce an overall diameter of 13.8 inches. It is made of a composite plastic that offers a variety of advantages over mild or carbon steel, including reduced cost and weight, a lower friction coefficient (which reduces energy use), a lower noise-production capacity, and a greater ability to absorb vibrations. Composite pipes do not have external or internal corrosion problems (as steel pipes sometimes do). The composite plastic is made of an outer structural layer of high-density polyethylene (HDPE) and an inner wear-resistant layer made of a combination of flexible and semi-rigid thermoplastic. It weighs 16 pounds per linear foot so that it can easily be carried by hand. It comes in lengths of up to 72 feet and is flexible for easy bending in the field to adjust to site conditions. The lengths of pipe are joined by thermo-electrically fused coupling, a process that can be carried out by one worker in approximately 30 minutes.²³

Figure 21. Flexible Composite Pipe

Source: MariMatic Oy

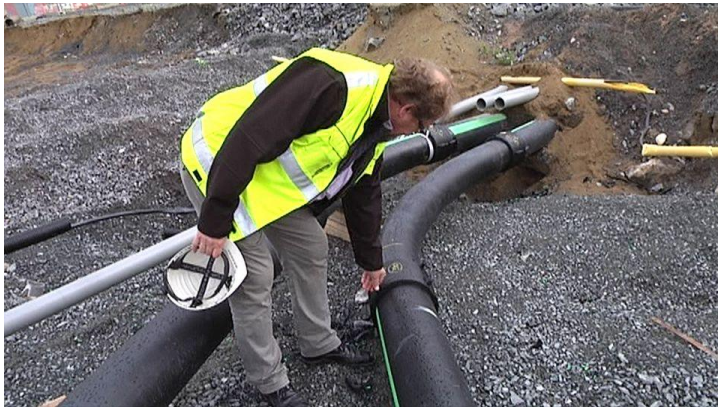


Figure 22. Thermal-Electric Fusion Used to Install Couplings

Source: MariMatic Oy



If necessary in interior spaces for code reasons, or if desired for any location for any other reason, steel pipe can be used and can be connected to composite pipe.

Inspection points at intervals of approximately 80 feet can be opened for inspections or to clear blockages. While blockages at discharge valves are relatively common and easy to remove, blockages within the trunk pipe are very rare. (Systems installed over the past decade have experienced blockages at the rate of about one per year.)²⁴ When they occur, the location of the blockage is identified remotely by pressure-monitoring sensors. They can be cleared—usually remotely—by closing off the pipeline section behind the blockage and increasing the vacuum pressure in front of it. The High Line network design would allow more-severe blockages to be cleared by using a “push-pull” technique. The double main trunk is designed to allow the two trunks to be connected in a way that would allow a simultaneous vacuum pull in front of the blockage and a pressurized-air push behind the blockage, so that the two trunks would function as a “ring line.” As a last resort, blockages can be cleared by opening the nearest inspection points and using air or water jets.

A fire-rated wrap assembly can be applied to the exterior of trunk and branch tubes to comply with fire-protection requirements. For details, see the discussion of building-code issues below. If it were necessary, additional sound-attenuation measures can be taken to dampen the noise of material flowing through the pipe, though this is rarely necessary due to the sound- and vibration-absorptive properties of the composite pipe itself.

2.1.2.2 Attachments

Pipe is hung from horizontal or vertical surfaces using standard steel brackets as shown in Figure 23. The brackets are typically installed every ten feet.

Figure 23. Brackets

Pipe hung from ceiling with brackets.

Source: MariMatic Oy



2.1.2.3 Path

There is a five-foot easement around the High Line viaduct (as represented by the shaded area in Figure 24). The default condition would be to attach the pipe within this area, to the side of the viaduct, as shown in the top-left photo in Figure 25. A more-complicated condition, shown in the photo for Condition E (also in Figure 25), is when the viaduct passes through buildings, which would require opening parapet walls to gain access for installing and maintaining the tube. If for any reason this access were not available, the pipe would need to be installed within the viaduct structure (on the underside, between the beams).

Figure 24. Typical Pipe Location for High Line Installation

Area shaded in orange represents the five-foot easement around the viaduct structure.

Source: 2003 High Line Competition Base Drawing modified by ClosedLoops

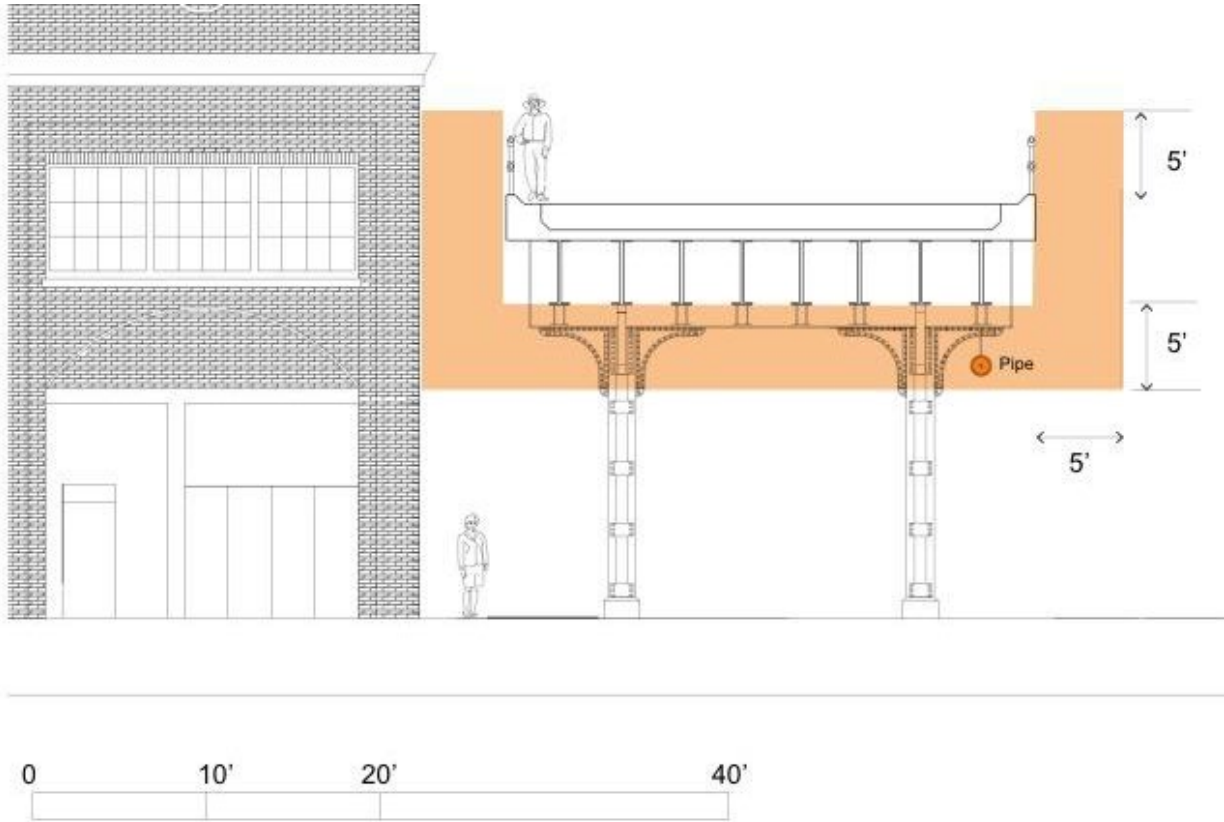
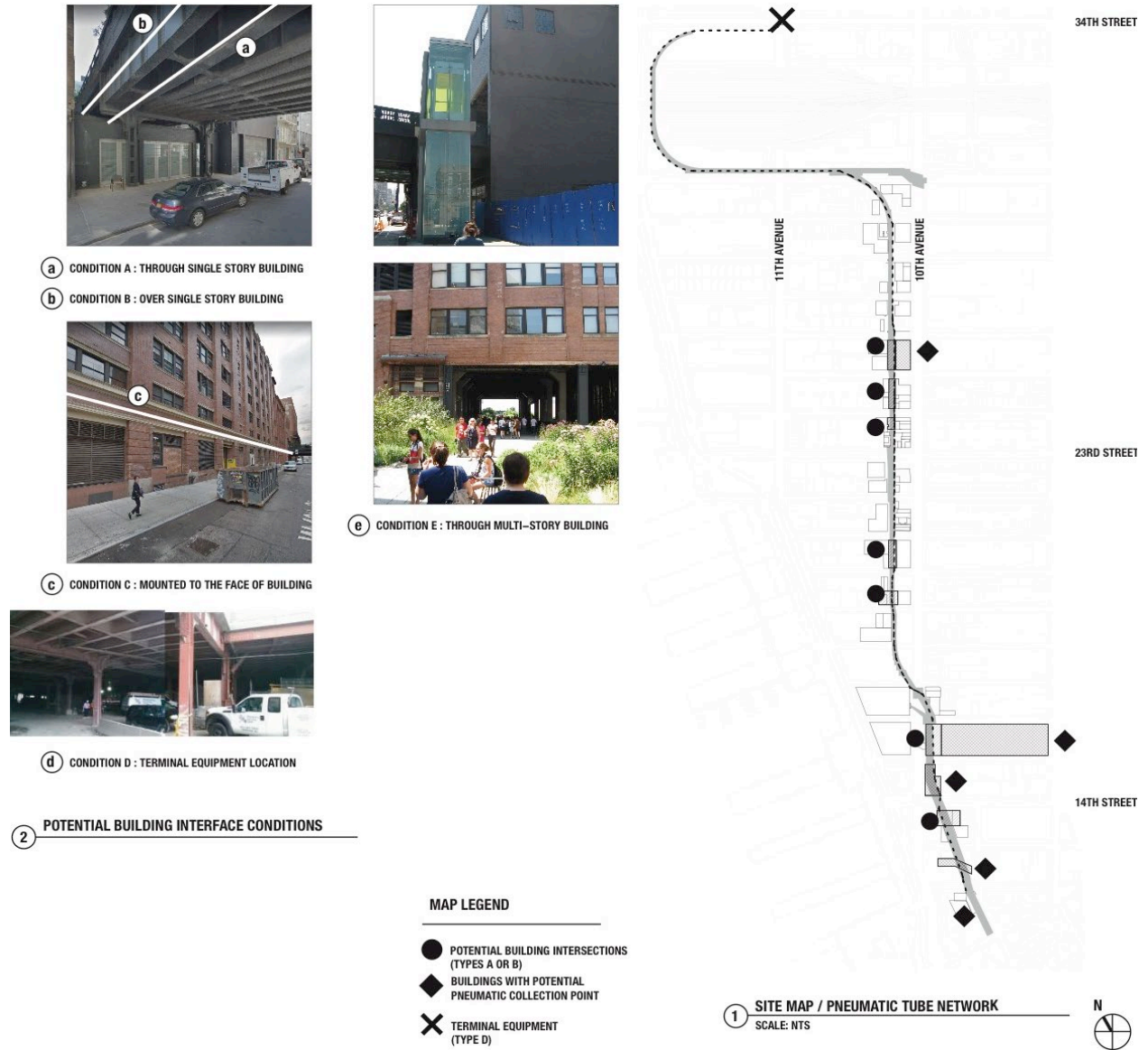


Figure 25: Building Conditions Map Prepared for NYC Department of Buildings Office of Technical Review

Source: Caliper Architecture

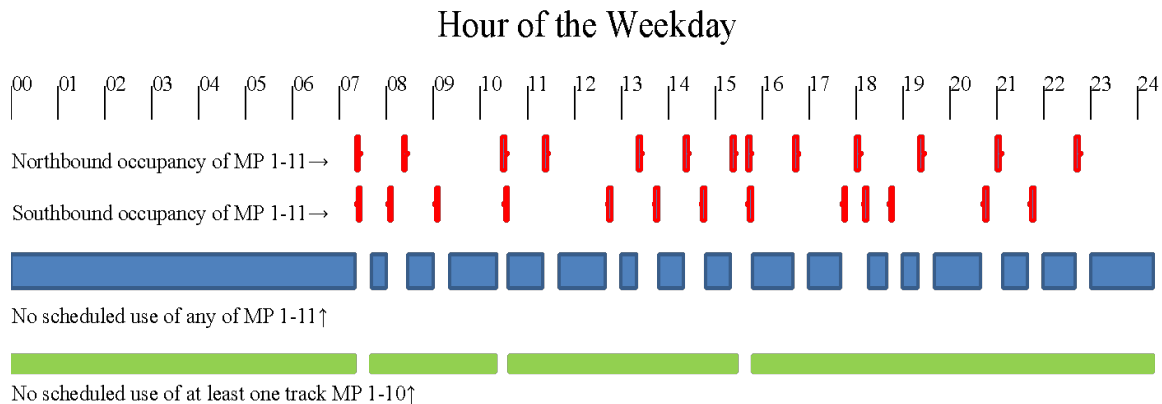


2.2 Tube-to-Rail Terminal

Though relatively few people are aware of it, Manhattan’s western shore is graced by a rail asset of great strategic significance with regard to possibilities for economically efficient and environmentally sustainable movement of freight. It is the former New York Central line, which provided the City’s only unbroken connection to the rest of the continental rail-freight network. This was the route to and through the densest agglomeration of manufacturing industries in the world, which once terminated in the High Line viaduct that ran through the middle of blocks and buildings. Built with the capacity to handle hundreds of trains a day, it snaked down the West Side, under Riverside Park, through the rail yards beneath what was once known as “Trump City,” and under what is now the Javits Center, to the railroad’s freight headquarters on Spring Street. Today it carries only 26 Amtrak passenger trains a day (13 in each direction). It thus offers, as the graph in Figure 26 suggests, the substantial opportunity of its untapped capacity.

Figure 26. Capacity of Manhattan’s Empire Line

Source: Rail Cents



Comments:

- Above track occupancy data does not show potential capacity from using five existing wayside signal blocks.
- Above track occupancy data does not show potential capacity from using virtual blocks with PTC technology.
- Upshot: less than 10% of the capacity of the Empire Connection is utilized in the most congested area in the US.

The proposed location for the pneumatic terminal, which would provide direct access to rail transfer, is under the roadway viaduct near the corner of 11th Avenue and West 34th Street. The viaduct and area beneath it are owned by the City of New York and controlled by NYC DOT, which is responsible for maintaining it. The thousand feet of track that once linked the High Line (immediately to the south and west) to the Empire Line (immediately to the north and east), which provides a rail connection northward to the regional and national railway system, is now missing. The New York Central's successor railroad (Amtrak, which now connects to Penn Station via a tunnel south of 34th Street) retains a subterranean easement through the east side of 11th Avenue between 35th and 33rd Streets. Developing the rail terminal will require replacing these 1,000 feet of track and adding two or three sidings adjacent to the terminal for railcar storage and switching.

Figure 27. Equipment Layout for Pneumatic Terminal with Capacity of 60 Tons per Day

The terminal is actually two individual and independent terminals that are linked, one for refuse and organics with four containers and one for recycling with two containers. The two terminals share air pumps and other equipment and can be connected. If the containers are arranged as shown, the footprint for the "double terminal" is 60 feet x 90 feet, or about 5,400 square feet and requires about 14 feet floor-to-ceiling clearance. (Compactors are shown on the refuse and recyclables lines; a fifth compactor, shown on one organics line, would only be used as a spare for the refuse or recyclables lines.)

Source: Green Bending

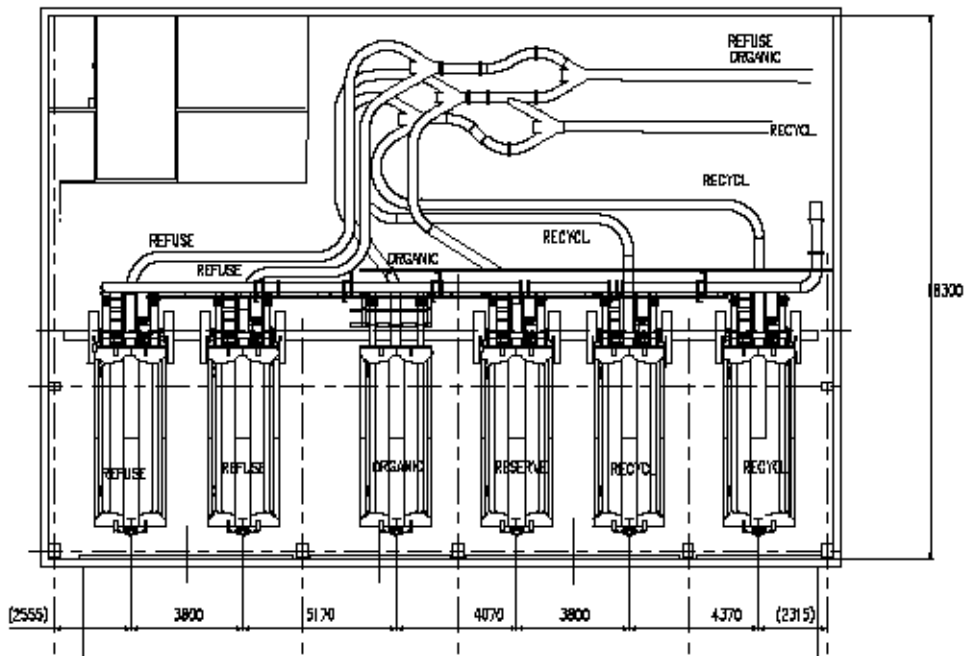
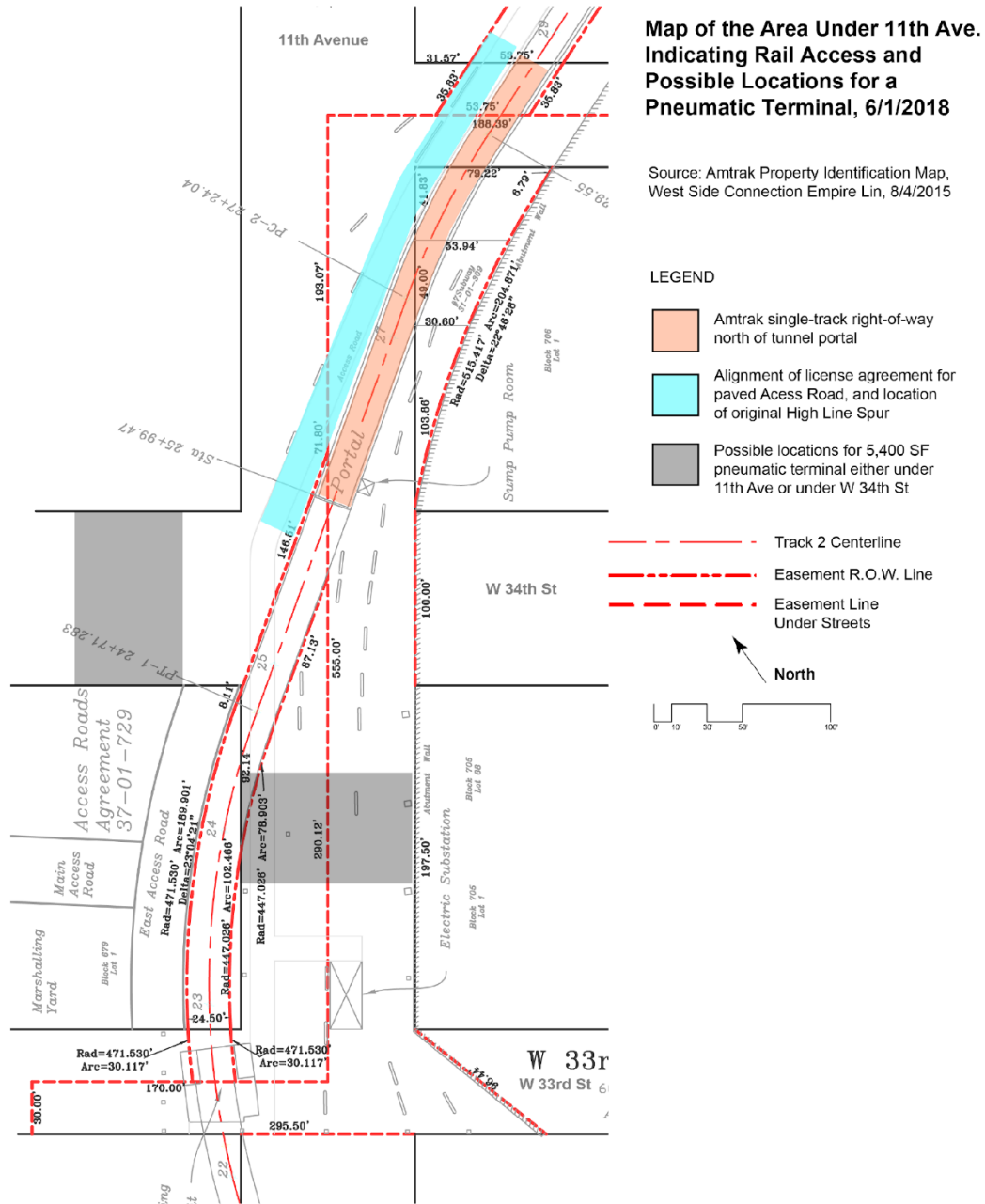


Figure 28. Hypothetical New Tracks for Loading Containers Under West 34th Street and 11th Avenue

Railcars enter along alignment of original High Line Spur (blue). Containers are shifted from railcars onto bogies. The bogies are pulled over rails into position, the containers are connected to the pneumatic network and filled, possibly in one of the areas shown in grey. The terminal design and a detailed design for transferring containers to and from railcars are dependent on field verification of horizontal and vertical clearances.

Source: Amtrak Property Identification Map, West Side Connection Empire Line, annotated by ClosedLoops



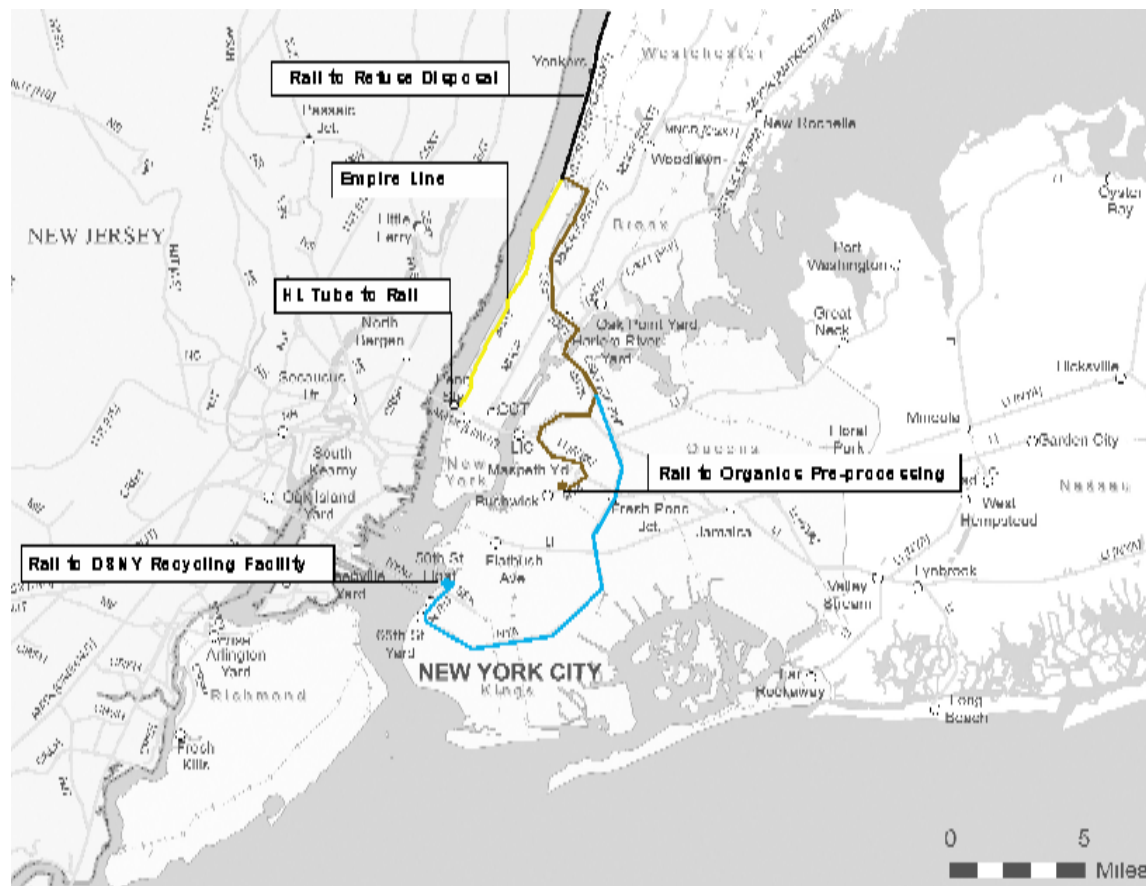
The design of the system for moving shipping containers from their filling position at the end of the pneumatic trunk tube onto rail cars would be developed in coordination with NYC DOT engineers to ensure that the proposed arrangement is compatible with the department's plans and ongoing needs. The current concept is to have six short spurs off a fixed guideway, each leading to one of the six container lines that would be connected (via a diverter valve) to the trunk tube at one end. The other end would then be connected to the containers for the three types of waste (refuse, recyclables, organics). (As shown in Figure 25, there would be two lines for each fraction, so that there would always be a spare in place when one container switches out.) The waste containers connected to the tube lines would rest on light, rail-wheeled undercarriages (referred to as "bogies" for purposes of this discussion), which would be pulled along the guideway with one of the various types of small-scale car-moving equipment used in rail yards. The guideway, which would be of the same gauge as rail tracks, would be connected, via the lead track, to the two or three rail sidings on which flatcars for the three waste fractions would be staged. Because the guideway would serve only short bogies carrying single containers, the turning radii between the sections under the tube-lines and the connection to the lead track could be sharp enough to meet the conditions imposed by the support columns under the viaduct and the short distance between the tube-lines and the lead track. A filled container would move down the siding where the flatcar for the waste-type it contains is staged. A bridge crane located at the abutting ends of the flatcars would lift the container onto the car. (Since the flatcars would hold four containers each, the loading and unloading between flatcar and bogie would take place one container at a time, with the container at the non-abutting end always the first one on the car and the last one off.) The empty containers on an inbound car would be unloaded (using the bridge crane and bogies) to be placed in a storage location adjacent to the guideway until needed (using a type of lifting equipment capable of lifting empty 20-foot containers). A freight operator would pick up separate rail cars for each type of waste on an as-needed basis, generally removing a car for each fraction on each trip, once or twice a week.

After picking up cars from the pneumatic terminal, the freight operator would drop them off on an interchange track that would be constructed near Spuyten Duyvil Creek. CSX trains pass this vicinity in both directions six days a week, bringing containers of waste on flatcars north from Long Island, Queens, Brooklyn, and the Bronx to the nearest Hudson River crossing at Castleton-on-Hudson (just south of Albany) and from there to landfills in Virginia or elsewhere, and bringing empty containers back to NYC and Long Island for refilling. These CSX trains could pick up the refuse cars at the interchange track to take them, along with their other cars, to one of these landfill destinations. Alternatively—an environmentally and economically preferable solution—the cars could be handed off (after they have crossed the Hudson at Castleton) to another CSX train, coming north from New

Jersey, to join other Manhattan waste headed to a waste-to-energy facility in Niagara Falls. Southbound CSX trains could pick up cars of recyclables and organics from the interchange track and drop them at Fresh Pond Junction in Queens, where they pick up and drop off other cars every day. From there, the recycling and organics cars could be hauled by the New York & Atlantic, the short-line freight railroad that has exclusive freight rights over the Long Island Railroad's tracks, to the Waste Management facility on Varick Avenue in Brooklyn, which preprocesses the City's separately collected organics waste for anaerobic co-digestion at the nearby Newtown Creek Wastewater Treatment Plant, and to the Sims recycling facility at 29th Street on the Sunset Park waterfront, where the City's recyclables are processed.²⁵

Figure 29. High Line Tube Connection to Existing Rail Freight Network

Source: NYS Rail Map, 2013 modified by ClosedLoops



In the event that the pneumatic terminal is ready to start operation before arrangements for rail service are in place, the terminal could be serviced by roll-on/roll-off truck, as are almost all other pneumatic terminals.

2.3 Anaerobic Digestion System

2.3.1 Tube

There is enough high-quality pre-consumer food waste generated by the restaurant kitchens and other food businesses along the corridor (e.g., in the Chelsea Market, 85 Tenth Avenue, the Standard Hotel, and the Meatpacking Co-op) that would not require pre-processing prior to treatment in an anaerobic digester. Since this situation supports an economically viable AD facility,²⁶ rather than mixing the high-quality waste material with the lower-quality post-consumer organics generated by visitors and office workers, the initiative proposes the creation of a separate pneumatic system to collect food-prep material directly from restaurant kitchens and food suppliers. Hundreds of such food-service pneumatic systems are in operation around the world, typically in applications such as cruise ships, slaughterhouses, and commissary kitchens.²⁷ The energy produced by processing this material in a micro-AD facility could offset energy consumed by the main pneumatic network.

Figure 30. Pneumatic Inlet at a Dishwashing Station in a Central Kitchen in Finland

Source: ClosedLoops



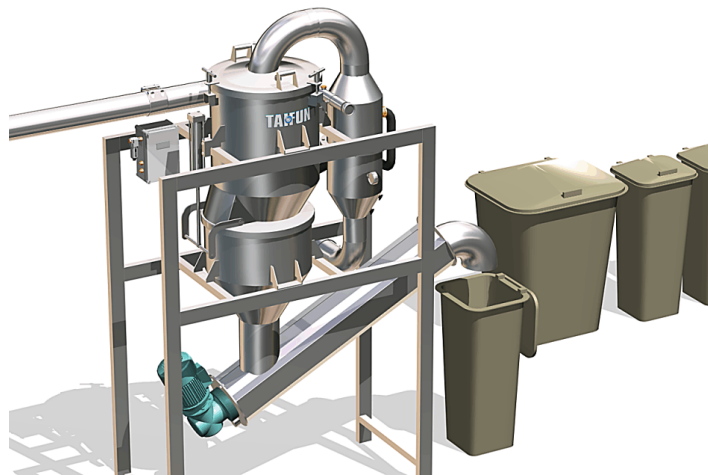
The material would be transported in a small-diameter tube (2 inch to 8 inch) made of PVC pipe or stainless steel, depending on the manufacturer. If the AD facility were in place prior to the installation of the pneumatic-collection network, material from nearby businesses could be delivered manually by tilt carts tipped into an inlet tank (as in the case of the inlet tanks for the central pneumatic system). Using a pneumatic system to send material directly from kitchens to the AD facility offers many operational benefits over manual delivery, including eliminating the space, labor and equipment required for storage and staging of organics, as well as the need for maintaining and cleaning storage

and transport equipment and storage space. If all of the material is delivered pneumatically, the AD facility would not need to provide a “mouth” at ground level, which would also reduce space and labor requirements. Given the complexity of a multiparcel installation akin to that of the main pneumatic network for municipal solid waste (MSW) and the uncertainty of the AD facility’s location, the current project phase did not include the design of the pipe network to the AD facility. Since the AD facility’s viability does not depend on the proposed separate pneumatic-to-AD network, its development is not contingent on whether or not a separate pneumatic system is built.

Figure 31. Vacuum Pump and Pneumatic Pipe Discharging Organics into Bins

This equipment pumps food waste through the tube network and discharges the material into toters. In the High Line system, the tube would instead feed directly into a buffer tank connected to the anaerobic digester.

Source: MariMatic Oy



2.3.2 Anaerobic Digester

Small-scale AD facilities using equipment offered by a range of manufacturers are coming into operation in a number of countries. The technology is based on specifications described below and was developed by pro bono project partner Impact Bioenergy.²⁸ It is a wet-process system with a digestion time in continuous stirred-tank reactors of approximately 30 days. With 912.5 tons/year of input material, it would produce 280,000 to 520,000 kilowatt-hours (kWh) of electricity. (The lower rate assumes an electrical efficiency of 30% with a calorie content for food waste that is 70% of the maximum and an availability rate of 95%; the higher rate assumes an electrical efficiency of 37%, a calorie content for food waste that is 100% of the maximum, and 100% availability.) The biogas could be used in various forms (converted to a natural-gas or compressed-natural-gas fuel or burned to generate electricity and/or

heat) and/or stored on site (if such storage were approved by the relevant authorities) to provide a local emergency-backup energy supply. The current concept assumes—given the local demand for electricity for such purposes as refrigeration by the Meatpacking Co-op (an electricity demand that would roughly match the energy-generation capacity of the proposed facility)—that electricity would be the primary energy product from the biogas, with recovered heat also used for local purposes. Although only one AD site was evaluated in this study, the goal would be a network of micro-anaerobic digestors that could convert all of the thousands of pounds of pre-consumer food waste generated along the High Line Corridor every day into energy for local use. Two micro-AD facilities (managing a combined 10,000 pounds of food waste per day) sited with the pneumatic terminal could generate 70% of the electricity needed to run the 1.5-mile-long pneumatic system. If the combined heat and power (CHP) system were larger, and fed in part by grid gas, the facility could provide all of the electricity for the pneumatic system.

The proposed 5,000-pound/day facility would produce a nominal 15,330 cubic feet of biogas per day. It would also produce 575 gallons of liquid emulsion (digestate) containing 3–6% total solids, which could be used for fertilizer, either as an emulsion or separated into a grey-water liquid that could be sent to a drain and a thickened liquid for land application. If the digestate were dehydrated, it could be distributed as a solid plant-food powder. But in order to avoid the cost and complexity of dehydration, the current proposal for this facility is to pipe the digestate into one-cubic yard tanks that would be loaded onto a truck and driven a short distance for application as fertilizer at local parks and urban farms. If the quality is high enough, the parks and farms might absorb the cost of transport and application.

The pneumatically transported organics would enter a buffer tank from which material would be discharged at periodic intervals into the digester. (If input material is instead manually tipped into an inlet tank, this tank would serve as the buffer tank, and material would be charged into the digester via a screw feeder, grinder pump, or screw pump.)

The functional digestion equipment for handling 5,000 pounds a day (excluding space that might be required for biogas upgrading or storage) would occupy an area of about 22 feet by 88 feet at a height of 12 feet.²⁹

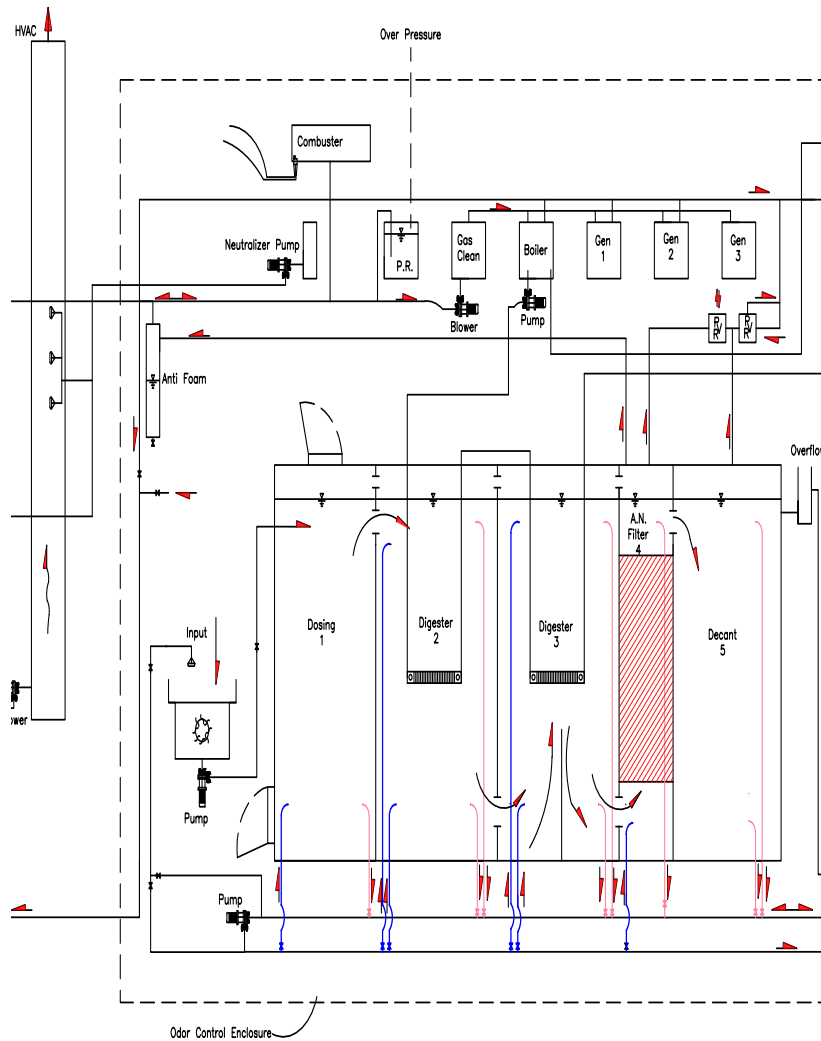
Since the practicable transport distance for pneumatic systems for food waste is on the order of 1,200 feet, and there are upwards of 5,000 pounds a day of such organics potentially available from the sources mentioned above, it would be logical to place a small-scale AD plant in the area. The sources are located

within a short distance of each other at the southern end of the High Line, a location along the southern end of the corridor, such as the City-owned property at 832 Washington Street.

Figure 33 illustrates how the type of facility proposed might look if it were sited on a potentially viable location along the High Line.³⁰

Figure 32. Process Diagram for a Micro-Anaerobic Digester

Source: Impact Bioenergy



<p>Jan Allen, P.E. CMQ/OE, President Distributed Bioenergy Solutions 1001 NW 167th St Shoreline, WA 98177 USA 206.250.3242 impactbioenergy.com</p>	<p>Anaerobic Digest 185 Process Flow Schematic</p> <p>This document and its contents are the exclusive property of IMPACT BIOENERGY. It is proprietary and protected. No part of this document may be reproduced or transmitted in any form by any means without the express written permission of IMPACT BIOENERGY</p>	
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Figure 33. Concept for a Rooftop Micro-Anaerobic Digester at 832 Washington Street

Source: Caliper Architecture



3 The Costs

As previously noted, the proposed initiative consists of three complementary but independent components: a pneumatic collection system for refuse, recyclables, and post-consumer organics; a direct tube-to-rail transfer facility; and a small-diameter pneumatic system for pre-consumer food waste connected to a small-scale anaerobic-digestion facility. Either of the two pneumatic systems could be developed without the other, the anaerobic digestion facility could be developed without a pneumatic-collection system, and the main pneumatic system could be developed without the rail-transfer facility. (If there were no rail facility—or until the development of the rail facility—the containerized waste would be removed by roll-on/roll-off truck, as is done in most pneumatic facilities, and the costs would remain the responsibility of those who currently provide truck-based collection at the City’s transfer facilities.) This means that the costs below should be seen as independent—or as potentially sequential rather than simultaneous expenditures. Capital costs for the main pneumatic system, with or without the rail-transfer facility (since the capital component of the rail-transfer primarily involves a modest amount of rail track), is about \$15 million. The operating expenses of this system, however, are very much dependent on the rail component, which (at some \$700,000 a year) outweighs those of the pneumatic-collection component (at some \$660,000 a year).

The capital cost for the AD system is about \$2.7 million. Its operating costs are on the order of \$150,000/year. Its projected revenues include the value of its energy products (biogas/electricity and waste heat) as well as processing (“tipping”) fees that are currently paid to private haulers. These costs do not include the direct connections via a smaller food waste-only pneumatic-tube network. Depending on the configuration and the number of input points, this would add around \$1 million for equipment and installation and \$30,000 in annual operating costs.³¹

Note that while the AD section below includes a table on revenues, since it would produce energy products as well as receive the tipping fees, the main pneumatic section does not include revenues. This is because its only source of revenues is tipping fees, and the structure for these fees is more complex than that for the AD facility (which simply involves a direct transfer to the AD system of fees currently paid to carters). (The currently envisioned fee structure for the main pneumatic system is discussed in Section 5.)

Supporting details and assumptions for the tables below can be found in the Appendix B.

3.1 Summary: Pneumatic Tube-to-Rail System Capital Cost

Estimating equipment costs is a relatively straight-forward exercise. Estimating the costs of installation and the soft costs associated with implementation involves many more unknowns at this point in the project. This explains the overall contingency line of about 25% of overall estimated costs (on top of additional contingency allocations for terminal-site prep and enclosure construction and for the pneumatic system installation). The reserve fund (somewhat over half of projected annual operating costs for both the main pneumatic system and the rail-transfer/transport operation) is provided to protect against potential risks to the projected administrative entity, as discussed in Section 5 below.

It is important to note that these numbers do not reflect several additional costs because it is impossible to know what they might be without the level of study proposed in the following sections that cover next steps. For instance, in relation to cost of leasing land, should stand-alone input points be installed on private property not owned by a system user?; how would the time and complexity of coordinating access to sites under the viaduct affect cost?; and would the cost of preparing the terminal site and leasing land add significantly to total costs?.

Table 2. Pneumatic Tube-to-Rail System Capital Cost Summary

Components	Cost
Pneumatic Network	\$15,140,000
Rail Facility	\$400,000
Total	\$15,540,000
Contingency	\$4,000,000
Reserve Fund	\$750,000

3.2 Pneumatic System Costs

3.2.1 Capital Cost

Table 3. Pneumatic Network Capital Cost

Components	Units	Cost
Pneumatic pipe, linear meters	5,000	\$3,440,000
Pneumatic terminal	1	\$2,890,000
Buffer tanks	27	\$3,120,000
Misc. ^a	15% total equip cost	\$1,420,000
Terminal enclosure/site prep contingency	100% terminal cost	\$2,890,000
Pneumatic system contingency	10% of total	\$1,380,000
Total		\$15,140,000

^a On-site storage, car-shifting, bogie movers, site security, on-demand services.

3.2.2 Operating Cost

The operating costs shown below cover only the services provided by the proposed system itself: collection and transport to the pneumatic terminal; compaction into sealed containers; loading onto railcars; and rail transport to in-City processing facilities (for recyclables and post-consumer organics) and to an interchange site for refuse transport and disposal outside the City. Costs that are not included—but which are currently paid by the projected system users to private carters (or are paid by the City for the management of waste removed from the High Line Park and BID litter bins and the adjacent NYCHA complexes)—are those associated with rail transport to processing or disposal facilities beyond the City limits and the tip fees associated with processing or disposal (either inside or outside the City). Costs of administering the system—e.g., billing users and administering the operating contract or managing operating personnel—are discussed in Section 5. Just as the capital costs shown above will be refined as more-detailed information becomes available in the next phase of planning, final operating costs will depend on a level of information that is not yet available, such as, for example, the location and organization of input points, and the cost of staffing inlet points is not included, nor is the cost of leasing space.

There are three conceptual options for how the costs for these services beyond the scope of the proposed High Line Corridor system could be managed. The first is that these costs paid to processing- or disposal-facility operators would continue to be paid by an entity that currently pays for these services (whether or not they currently pay these fees to the specific facilities to which the project waste would be delivered). Private carters currently pay the fees for these services

on behalf of their commercial customers, from a portion of the fees they charge these customers for their overall service for waste collection and management. The City currently pays the fees for these services for the waste it collects from the Park, the BID, and NYCHA. Under this option, the existing carter who has a contract for managing a given system user's waste would continue to charge the user—on a unit basis for the material they put into the system—for the downstream costs of processing or disposal.

The second option is that the project administrator would charge commercial system users (including residential buildings other than NYCHA facilities that might choose to join the system) for the full costs of waste management and pay the downstream fees for receiving the system's waste. A third option may become available in the future (as described in Section 5): if/when a franchise system for commercial waste is implemented in the City, a private carter would be the natural entity for providing one-stop administrative management for all of the system's needs.

For all options, it is assumed the processing and disposal fees would be apportioned on the basis of commercial or non-commercial volumes handled, so that the system's commercial users, who would pay the system's *direct operating costs* for *all waste* handled by the system, are not also responsible for *processing/disposal costs* for *non-commercial* waste. While there are no precedents for the City to pay ongoing costs to replace *collection services* it currently provides, there are precedents for the City to pay ongoing costs for the *processing/disposal services* it requires. For present purposes it is assumed that the proportion of the system's waste that is received from non-commercial sources would fall under the City's processing/disposal contracts (as it does now), so that an additional charge for these materials would not be levied on the pneumatic system by the City's processing/disposal contractors.

For all options, it may be desirable to have the City—which pays to provide these services for City-managed waste—continue to make the direct payments to these processing/disposal entities so that the project could benefit from paying the rates negotiated for the City's much-larger contract and fall under the City's existing contractual umbrella, rather than having to negotiate separate agreements with each entity on its own. In this case the project would reimburse the City for the cost of the commercial waste processed.

Table 4. Pneumatic Network Annual Operating Cost

Category	Units	Unit Cost	Cost
Electricity, kWh ^a	1,314,000	\$0.06	\$78,840
Electricity Capacity, kW	330	\$24	\$7,920
Electricity, auxiliary	Variable		\$60,000
Labor, hours, weighted	5,674	\$63	\$357,462
Component replacement, supplies,	Variable		\$155,000
Total			\$659,222

^a 60 kWh/T *60Tpd*365 days/Y.

3.3 Rail Costs

3.3.1 Capital Cost

Table 5. Rail Capital Cost

Category	Units	Unit Cost	Cost
Track installation, feet ^a	1,500	\$200	\$300,000
Turnouts, each	2	\$50,000	\$100,000

^a Includes sidings for staging railcars.

3.3.2 Operating Cost

Table 6. Rail Operating Cost

Category	Units	Unit Cost	Cost
Car haul cost/yr	469	Variable	\$570,000
Car lease/yr	7	\$5,000	\$34,000
Container annualized cost	27	\$3,000	\$80,000
Fuel cost	3452	\$3.15	\$11,000
Track maintenance	1000	\$2.00	\$2,000
Total			\$700,000

Table 7. Combined Pneumatic-Rail System Annual Operating Cost

Category	Cost
Pneumatic System Operations ^a	\$657,716
Rail Operations	\$700,484
Administration	\$150,000
Total	\$1,508,200

^a Assumes no tip fee for processing/disposal (DSNY and carters responsible for pro-rated share).

3.4 Anaerobic Digestion Facility Costs

The estimated \$1.6 million equipment cost includes a 50-kilowatt (kW) CHP system, gas storage and upgrading or cleaning biogas. The equipment cost is based on a similar system installed in Washington State in 2018.³² Costs for CHP systems, interconnection, biogas storage and upgrading may be higher in New York City.

3.4.1 Capital

Table 8. Micro-Anaerobic Digester Capital Cost

Components	Cost
AD and CHP equipment	\$1,600,000
Installation and site prep	\$1,000,000
Engineering costs, including permitting ^a	\$50,000
Total	\$2,650,000

^a Soft costs include engineering and architectural services to design the platform and visible enclosure and a waste characterization study and operations protocol for a facility receiving waste from multiple buildings.

3.4.2 Operating Cost

Table 9. Micro-Anaerobic Digester Operating Cost

Category	Units	Unit Cost	Cost
Labor hours	2,190	\$63	\$138,000
Liquid digestate removal, per 1 cubic yard container ^a	382	Covered by end-user	0
Consumables and repairs, per ton	912.5	\$10	\$9,000
TOTAL			\$148,000

^a If possible, containers would be picked up by end-users for land application in local parks. If not, transport cost would be added.

3.4.3 Potential Revenue

Table 10. Potential Revenue, Micro-Anaerobic Digester

Category	Units	Unit Price	Revenue
Tipping fees, per 64-gallon toter ^a	5,500	\$18	\$100,000
Heat, therms	48,600	??	
Electricity, kWh ^b	512,500	\$0.18	\$90,000
TOTAL			\$190,000+heat value

^a Tipping fee currently charged by private haulers. (Foodprint Group, personal communication, 6-15-2016).

^b The parasitic load, 10-15% of energy generated, has not been deducted.

4 Cost-Benefit Analysis

Pneumatic-collection systems justify their relatively high-upfront investment with reduced congestion, improved working conditions, reliability and most importantly, public safety. These systems, particularly in new-build situations, also hold the potential for a variety of savings on the generator side. These include labor savings due to the elimination of multiple waste handlings and the reduction of waste-movement distances.³³ Space savings due to the elimination of waste storage rooms³⁴ and savings due to reductions in worker injuries and workers' compensation insurance costs add to its economic value.³⁵ But in the case of the retrofit installation proposed for the High Line Corridor, direct generator-side benefits are limited to loading areas because waste handling inside the building is not expected to change significantly.

Although it would be possible to retrofit at least some of the existing buildings along the corridor with chutes, the potential system users prefer that they retain their current waste-handling arrangements (porters collecting waste on each floor in rolling carts, moving it to the ground floor via elevator, and rolling it to the loading dock to be tipped into a compactor-container). The only operational change is that the compactor-container would be swapped to a pneumatic-inlet tank that would use roughly the same footprint. But potential users think that this relatively minor shift could nonetheless offer them significant benefits. Truck collection, though scheduled daily (six or seven times a week)—one potential user reported—is relatively unreliable, with missed collections due to holidays, adverse weather, and other factors. On-call, backup service trips are also required when peak waste levels exceed the volumes that can be accommodated in the regularly scheduled trips. Securing a backup collector for a missed collection costs about \$600 per trip, collectively costing the user tens of thousands of dollars a year for auxiliary service. Additional costs accrue each day because, during the hours that the compactor container is removed from the loading dock for a trip to the dump site and a return with the empty container. Furthermore, building staff need to stage the waste in a temporary storage area near the loading dock, and then move it again into the compactor. For smaller buildings, advantages include not having to pile bags on the street or clean up the curb after pickup. The benefits to building owners along the corridor could be summarized as improvements in waste collection as follows:

- reliability of service
- frequency of service
- continuity of service without interruption
- enhanced tracking and transparency of waste volumes and processing

In addition to these benefits for their own operations, the use of a pneumatic tank-inlet, which can be emptied as often as needed during the course of a day, while requiring no more space than a compactor, allows the user to provide community benefits to the neighborhood (the elimination of waste bags on the street and the avoidance of bin-to-bin or door-to-door truck trips) by offering shared access to its inlet. As members of the community themselves, the users would also benefit from these reductions in street bags and truck trips.

From the perspective of the High Line Park, there would be significant efficiencies from eliminating the need to temporarily store each day's accumulation of waste bags in the headquarters building until they can be taken to the street for pickup, and from eliminating the need to take this material, via elevator, to the street (with refuse and organics taken to one location and recyclables to another).

From the BID's perspective, the benefit would be an increase in member satisfaction due to the elimination of litter bags staged at the curb throughout the course of the day (for example, in front of retail and restaurant windows, or in front of commercial or residential doorways), and a reduction in daily truck trips with stops for idling and compaction at every litter bin in the district.

From NYCHA's perspective (should the financial model determined by the user cooperative include the subsidized inclusion of NYCHA waste in the system), daily use of the system would eliminate the storage of waste on the campus grounds for the days prior to collection, eliminate truck trips to the two building complexes multiple times a week, and permit the street-facing space where the facilities' compactors are currently located to be used for a higher, more-desirable purpose.

However, the most significant benefits of the proposed system would be improvements in public safety and quality of life in the community. Avoided truck trips translate directly into energy savings and greenhouse gas emissions avoided, as well as into reductions in truck-crash fatalities and injuries, in the adverse health impacts due to diesel particulates and other air emissions, and in congestion delays and roadway wear. These effects can be quantified.

To compare the environmental and public-health impacts produced by collecting 60 tons per day of waste by truck or by the proposed system, the team calculated the effects of collection by truck on a per-ton basis for both municipal and private routes. They did this because the exact sources of waste, the number of generators of each type (commercial or public-sector/residential), and the origin and destination points for the commercial haulers who would be involved are not known at this point.

These annual avoided impacts from the system as proposed—with a 60 tons/day pneumatic-to-rail network and a 2.5 ton/day pneumatic-to-anaerobic-digester network, accepting waste from commercial generators and “municipal” waste from the Park, BID litter bins, and two NYCHA complexes—would include the following:

- 150,000 truck miles
- 32,000 gallons of diesel fuel
- 316 metric tons of greenhouse gas emissions
- 0.4 tons of particulate emissions (PM_{2.5}+PM₁₀)
- 0.3 pedestrian/bicyclist fatalities

The basis for these calculations, and others, are presented in Appendix C.

It is difficult to quantify many of the more-general community benefits the initiative could provide. But the issues listed below clearly would entail economic, environmental, public-health, or quality-of-life benefits:

- Rodents. Reducing the number of waste bags on the street and the number of hours that they remain there would reduce rat populations. The correlation between rat populations and the availability of food, such as that provided by waste in plastic bags, is well documented.³⁶ Reducing rodent populations by reducing access to garbage is a major City policy priority.³⁷
- Litter and leaking liquids. Major potential users such as Chelsea Market and the Standard Hotel, whose interior loading docks provide access for roll-on/roll-off trucks to collect compactor-containers, already use waste-collection techniques that avoid the generation of litter produced by waste set out and collection in plastic bags. But some potential system users, including the BID and the park, currently rely on a collection method that involves daily stacked bags on the street.
- Noise. The noise of collection trucks on late night routes are a major source of noise complaints in commercial areas and the number one source of 311 (a non-emergency call system for information about city programs) complaints.³⁸
- Odors. Waste bags on the street may release unpleasant odors, especially during the summer months.
- Visual nuisance. Heaps of waste bags are unattractive obstacles that obstruct views.
- Pedestrian congestion. Waste bags occluding crowded, narrow sidewalks and impede foot traffic.
- Inbound deliveries. The ability to provide off-hour deliveries, which are a demonstrated means to reduce congestion, is impeded by the use of loading docks for off-hour waste collection.³⁹
- Resilience. Pneumatic systems are less subject to interruption due to storms than manual collection. (The pneumatically collected waste on Roosevelt Island was the only waste in NYC collected during Super Storm Sandy or the Blizzard of 2012, for example.)

- Emergency power. If the AD facility is allowed to store a supply of biogas on site for emergency purposes, it could provide a means of powering critical local equipment, such as the central refrigeration units of the Meatpacking Co-op, during storm events or other disruptions.
- Real estate value. Waste bags piled in front of retail windows (building managers and officials in multiple BIDs have told the study team) are a primary source of complaints from retailers. This suggests that waste bags adversely affect the value of retail space. A parallel argument could be made for the effect of street bags and collection-truck pickups on the rental or sales value of other kinds of space, and on the attractiveness of public space from the perspective of visitors, customers, workers, and residents.

Other project-specific benefits include the following:

- creating at least one administration and four permanent technician jobs
- catalyzing use of 10 miles of urban freight rail in Manhattan
- potentially recovering about 8,000 square feet of space from two compactor yards at NYCHA complexes

5 Development Model

There are two standard models for developing pneumatic installations.⁴⁰ One is government-sponsorship, with a governmental entity providing the initial financing and a governmental entity paying the ongoing costs of operation, and perhaps actually operating the system—as in the case of the pneumatic system on Roosevelt Island. The other is ownership and operation by a private developer, generally in conjunction with the construction of the developer’s large-scale residential, commercial, or mixed-use complex—as in the case of the pneumatic facility built at Wembley City in London or the one considered for residential waste at Hudson Yards. Although there are dozens of retrofit pneumatic installations in Europe, in every case they have been developed by governmental agencies as a result of large-scale neighborhood redevelopment projects. Nowhere has a district-scale installation involving multiple owners of multiple parcels been developed through an initiative in which a government agency did not take the lead role in ownership, planning, financing, and operation.

In the case of this initiative, the City of New York and various State agencies have played a highly supportive role, providing seed funding for feasibility study and pre-implementation planning and coordinating agency involvement in this planning. As of yet, however, no government agency has expressed interest in taking a lead role in financing or developing the project.

There are few pre-existing institutional mechanisms to foster ground-up coordination between multiple property owners that could be used as a template for multi-owner private sponsorship, but none specifically focused on waste.⁴¹ Innovative approaches are therefore needed if this type of project, which would provide benefits that potential stakeholders readily agree would be desirable, is to be built.

An alternative model presents itself for consideration: sponsorship by a private waste-collection company. Because private collection companies often play a major role in a city’s waste-management system, they have been involved in pneumatic-system operations in various European countries, sometimes in system-development as well as in operation, sometimes in partnership with governmental entities.⁴² In the case of New York City, however, given the current regulatory framework governing private collection, it would not be practicable—nor desirable from a public-policy perspective—for a private carter to be the owner of long-term waste-utility assets for a defined swath of waste generators. Currently New York City allows an open competition between carters for customers on any block or within any building and limits carter-customer contracts to two-year terms.

The existing institutional structure governing waste collection in New York City may however be modified in the coming years. In 2017 the City engaged consultants to design a program that would replace the current open competition between private carters with a system that would involve franchise zones awarded on a 10-year basis.⁴³ Such a framework (which is not expected to be implemented for a number of years) would form a natural basis for a private carter to play a central role in a future pneumatic system. Such a relatively long-term contract affecting a relatively large volume of waste would provide a means for financing a capital-intensive facility within a defined franchise zone, since the carter would have a defined cash flow for guaranteeing the payment of capital and operating costs. And the carter would already have operational responsibility for collections from the area, so that company (or a subcontractor) would be the natural entity for managing the system. If or when the franchise rights passed to another collection company, the successor company could assume the predecessor's financial and operational responsibilities for owning and operating the pneumatic system as a condition of the franchise agreement. Or, better, the guaranteed income stream that a private carter with a franchise agreement could offer to a pneumatic system could facilitate the development and ownership of the pneumatic infrastructure by a public entity. In either case, the design of the franchise program could make the provision of such types of specified, high-level service as pneumatic collection a criterion for awarding franchises as well as for defining the boundaries of franchise zones.⁴⁴

Since this option is not available at present to provide a means for financing, owning, and operating the High Line Corridor system, an alternative business model is required. Business Improvement Districts (there are now 75 in New York City⁴⁵) are entities created through local legislation that under State statute are provided the ability to assess charges on businesses in order to provide a defined set of services supplemental to those provided by the City. Sanitation services are generally one of their core missions. With regard to their potential role in filling various business functions associated with a pneumatic system, they offer a variety of advantageous possibilities. BIDs that have been incorporated as local development corporations under State statute are empowered to enter into agreements with the City regarding City-owned property on a sole-source basis. BIDs have in past practice served as grant recipients from City agencies. Their assessments are secured by the City's power to assess taxes against real property, which has in the past been used as security for borrowings. Of crucial importance is the fact that they often have a productive working relationship with property owners and tenants who are their members within the district.

The Meatpacking District is the BID most directly connected to the High Line Corridor. Providing sanitation services—specifically, providing staff to empty the hundred plus⁴⁶ continuously filling litter bins on its narrow, busy streets and sidewalks and staging them alongside the bins or at some nearby location until the daily DSNY pickup—is one of their key functions. Sanitation-related issues are also their largest source of complaints from their member businesses. The redesign of the High Line Corridor Initiative to allow it to accommodate material delivered from nearby blocks made it possible to consider the possibility of accepting litter-bin material from the entire Meatpacking district. This possibility provided an extremely important benefit—the interest of the top BID staff—and with it, their gracious support in helping to assess the potential interest of their major members who could be the project’s anchor users.

The executive staff of the BID have expressed a willingness to consider the possibility—subject to Board approval of the concept—that the BID might play a central management role if the project is implemented. Specifically, if the project is granted approval to site its pneumatic terminal on the City-owned at-grade site below the elevated intersection of 11th Avenue and West 34th Street, the BID might be one of the entities that could lease the site for use by the pneumatic terminal. The BID might also serve as the lessee of other publicly owned sites that might be used for the AD facility or for inlet tanks for the pneumatic and/or AD facility. The BID (or another public or semipublic entity) might also serve as the pneumatic facility’s ongoing manager of operations, collecting user fees from its member-users and contracting for technical operating services for the pneumatic system.

The currently proposed financing structure calls for capital investments in ownership of the facility’s assets from its major private users, supplemented by government and foundation grants made in recognition of the public benefits it offers (e.g., due to reduced truck trips and waste bags on the street) and in exchange for the City’s future avoided costs for collecting material from the Park and the BID bins.⁴⁷ The system assets could be owned by a cooperative of the user-investors, with the BID serving as the managing agent. If a building owner transferred ownership of the building to a new entity, the owner’s share of the co-op’s facility assets would transfer along with the building’s ownership.

If in the future the City were to develop a franchise-zone system for the collection of commercial waste along with a parallel system in which some public entity would undertake to develop and own infrastructural assets (e.g., pneumatic systems or other types of collection and processing infrastructure such as submerged containers or anaerobic digestors), the co-op could choose to transfer its assets in the system to this public entity.

The commercial system users would continue to pay a collection fee, as they currently do to private carters. This fee would presumably have an established minimum floor-rate in order to ensure that the system received enough revenue to cover its costs and might be based on the building's occupancy level or square footage. The fee might well also include a unit-based component⁴⁸ to incentivize waste-reduction and recycling.⁴⁹ And it is likely that the fee structure would provide a lower rate for users who were also system owners than that for non-owning users.

The user fees charged to the system's commercial users would cover the costs of operation, including the costs of handling material from the Park and the BID. Depending on the final cost-structure and the decisions of the users' co-op board, these operating subsidies might also allow the system to accommodate waste from the two adjacent NYCHA complexes, Clinton and Fulton. (Again, it is anticipated that the City's contribution to the system for these avoided costs, and for the other public benefits [of reduced truck traffic, waste bags on the street, etc.], would be in the form of up-front capital grants that would reduce financing costs and hence the system's ongoing operating costs.)⁵⁰

Since capital investments in the system would produce long-term public benefits, while user fees would cover ongoing costs, the system users' investment in the system would, in effect, be equivalent (from the perspective of providing community benefits) to a one-time investment in a public park that did not require ongoing fundraising for ongoing maintenance since it would have a self-sustaining source of income.

As noted above, there are three options for how downstream services not provided by the system (long-distance transport of refuse, processing and disposal of all three fractions) could be covered: paid by the existing private carter, by the pneumatic-system manager, or (as a potential future alternative) by the private carter franchisee(s).

The operating costs of automated pneumatic collection, as established in the prior analyses by this team as well as by other researchers, are generally less than those of conventional labor-intensive, truck-based collection.⁵¹ The up-front capital costs, however, as also established in the literature cited, are significantly greater, so that there is only a long-term return on investment.⁵² The currently proposed development model assumes that system users would jointly invest in and own the system assets, and that capital grants from public agencies and foundations would reduce the level of investment required from users. It would therefore be possible to structure the operating costs at a level comparable to the users' current waste-hauling costs, while also covering the costs of managing public-sector waste from

the Park and BID litter bins. Depending on the actual project budget and operating costs,⁵³ user fees (at least for system owners) could be set at a level that is somewhat less than current costs. Or, depending on decisions the user board might make about subsidizing public benefits for potential waste generators such as the NYCHA complexes, the fees might be about the same as current costs.

Bottom line is that the primary benefits of pneumatic systems are not significant reductions in overall costs, but the provision of significant benefits in improved service (increased frequency and reliability, reduced adverse environmental and quality-of-life impacts) which translate not only into benefits for the user buildings (such as enhanced real estate values and retail marketability) but into appreciable community benefits associated with reductions in truck traffic and the number of waste bags on the street. (Public awareness of the businesses' leadership in promoting such environmentally sustainable community benefits, in turn, could be expected to produce public relations benefits for the system's owners.)

If, as projected, overall waste costs for system users remain roughly comparable to current rates, the system would offer the benefit of price stability, while rates for conventional collection are expected to increase due to anticipated changes affecting commercial carting. The franchise system envisioned by the City is expected to produce a relatively level-cost structure for all businesses within a given zone, so that prices would go up for those who are paying the lowest rates (typically large waste-generators with significant negotiating leverage), while those who are paying the highest rates (typically small-scale generators, such as restaurants and bodegas) would pay less.⁵⁴ Since the major buildings along the corridor that are potential users of the system are currently paying most-favored rates, it is very likely that their costs would go up under franchising. Another reason to expect increases over baseline rates for conventional collection is that the City has announced its intention to expand requirements for businesses to source-separate organic wastes. Since this impending separation requirement would add another truck trip, it would be likely to increase hauling charges, while organic collection via the pneumatic system would not produce incremental costs.⁵⁵

Table 11. Annual Operating Costs/User Fees for Pneumatic-Rail Network

Pneumatic network	\$660,000
Rail System	\$700,000
Administration	\$150,000
Total	\$1,500,000
Total Operating Cost/Ton	\$70
Scenario 1 including High Line, BID Litter Bins and NYCHA	
User Fees/Ton	\$90
Commercial, Annual Tons	19,000
DSNY, Annual Tons (Collected free)	3,000
Total Annual Revenue	\$1,700,000
Scenario 2 Including High Line and BID Litter Bins Only	
User Fees/Ton	\$80
Commercial, Annual Tons	20,500
DSNY, Annual Tons (Collected free)	1,400
Total Annual Revenue	\$1,640,000

(Numbers do not total due to rounding.)

The anticipated cost structure for the independent AD facility would be similar: user fees would be comparable to current private carter fees (\$50/ton for meatpacker waste; \$150/ton for kitchen waste), but the users could have the benefits of greater collection frequency and reliability and a potential reduction in storage and handling costs, while providing a range of community benefits (including reduced truck trips and sustainably produced energy for local use). If the facility were located on the roof of 832 Washington, visible from the High Line and other institutions, and made accessible for educational tours and community outreach, it would provide an opportunity to showcase an organics processing facility. Since the City currently has an acute deficiency of organics-processing capacity, the development of such local facilities will have a decisive effect on whether or not the City is able to reach its 80 x 50 GHG-reduction goals.⁵⁶ The community benefits for their neighbors could also provide economic value to the user buildings themselves in terms of real estate prices and retail sales. And the companies' demonstration of leadership in environmentally sustainable practices could also produce public-relations benefits.

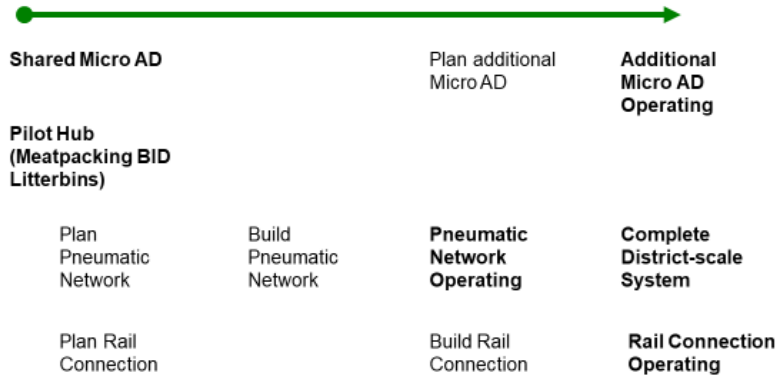
The financing, ownership, and management structure of the AD network could parallel that of the main pneumatic system. A cooperative of system users could own the system assets, which could be financed in part by capital grants from public and private sources, user fees could cover ongoing operating costs, and the Meatpacking BID (or another public or private entity) could serve as system administrator. (Or, instead of using a parallel ownership and administrative structure, the system could be structured as a

component of the larger pneumatic-facility system.) There are other alternatives—such as ownership by a single major user, who would offer access to the system to neighboring businesses (as in the case of the Brewery Blocks cooling system in Portland, OR).⁵⁷ Or a government agency (such as EDC) could sponsor the facility, but no individual entity or agency has thus far indicated interest in this type of role. It is unlikely that such a facility would be of interest to a private AD-facility developer—unless it were part of a larger network of facilities along the corridor (which would magnify the complexity and hurdles to development)—since the scale of this single facility would not generate sufficient revenue to justify it as an entrepreneurial venture. If commercial-waste franchise zones are implemented, such a system (perhaps owned by an independent authority, as discussed above) could be managed by a carter (or carters) with operating privileges for that zone. In such a case, the facility could be financed on the strength of that carter's or carters' contracts with users. As in the case of the proposed cooperative for the large pneumatic system, the co-op's ownership interest in the system could be transferred to such an entity should a franchise system be developed.⁵⁸

6 Phasing

Since the components of the initiative are, to varying degrees, independent, its implementation can be considered in phases—some of which may be deferred indefinitely if circumstances warrant.

Figure 34. Possible Implementation Sequence



The anaerobic digestion facility is independent of the larger pneumatic network and could be developed and operated by itself whether or not the pneumatic facility is built. Since its implementation cost is considerably lower than that of the pneumatic facility, and its space needs smaller, it could be developed more quickly than the parallel pneumatic network. Since it could be operated with material manually delivered to a shared buffer tank (as is the plan for the larger pneumatic facility, which would rely on shared buffer-tank inlets), it could begin operations before the dedicated small-diameter pneumatic network is installed and could function without it indefinitely.

In order to begin removing the BID’s and the park’s litter-bin bags from the street as quickly as possible, and to begin “test-driving” the shared-inlet concept, refuse, recyclables, and post-consumer organics from the park and BID litter bins⁵⁹ could be co-collected in a shared “inlet” system prior to the installation of the pneumatic network—using compactor containers that would be collected by roll-on/roll-off trucks (as in the case of the Battery Park City aggregated collection model). The compactors could be switched for pneumatic buffer tanks when the pneumatic system is installed.

If the contractual arrangements required for implementing the rail operation have not been completed by the time the pneumatic facility is ready to begin operation, the containers of pneumatically collected material from the terminal could be removed by roll-on/roll-off truck until such time as the rail operation can begin.

7 Replicability

Assessing the degree to which the ensemble of components proposed by the initiative can be replicated across New York City, New York State, and elsewhere requires an examination of its various interrelated elements.

The initiative's core objectives can be succinctly summarized:

- Reducing truck trips and miles, along with their attendant adverse economic, environmental, public-safety, and quality-of-life impacts.
- Reducing the number of plastic waste bags in the public realm, with their attendant adverse quality-of-life, public-safety, environmental, and economic impacts.
- Facilitating the diversion of waste from disposal to reduce the adverse environmental impacts and costs of long-distance transport and landfilling.

Its secondary goals can also be summarized briefly:

- Repurposing existing infrastructure for renewed or expanded use.
- Recovering sustainable energy from locally generated waste in order to avoid the long-distance transport of outbound waste for disposal and of inbound energy for local needs, and to provide local energy reserves for use in emergencies.
- Developing strategies to facilitate first-and-last-mile management of waste collection and freight distribution with facilities such as micro-collection/distribution hubs that can serve both purposes in the same space with single trips.

The means by which the initiative proposes to advance the achievement of these objectives, briefly, are the following:

- Moving away from the use of plastic bags in the public realm toward rigid sealed containers that are thoughtfully designed to be installed or placed in private or public space and are compatible with some form of automated collection rather than requiring manual lifting.
- Moving away from frequent door-to-door collection that requires multiple handlings and interior storage prior to taking out on the street toward aggregated collection of larger units of compacted material through the use of equipment shared between buildings.
- Use of small-scale, on-site processing of waste materials, using local labor, to produce energy and material products for local use and to serve local needs in the event of emergencies.
- Re-thinking and reconfiguring existing infrastructure and facilities and public space to provide high value use for 21st century needs (e.g., low-impact diversion from landfills,⁶⁰ wireless-information facilities, seating on streets and other public-space amenities, greening and run-off controls, traffic calming, pedestrian and bicyclist mobility) rather than low-value use for 20th century needs (e.g., parking spaces for individually owned automobiles).

This listing of the initiative’s intended ends and means suggests the degree to which the various physical and institutional components of the initiative could be used in varying combinations elsewhere. To the extent that all of its objectives are relevant to any densely developed area, one or more of its component-means (broadly conceived) could be used almost anywhere.

At its most specific—the use of pneumatic collection in retrofit situations without the use of tunneling—the scope of possibly applicable locations narrows, but still remains substantial. In New York City—as this study team’s prior work has established—opportunities for pneumatic-retrofit installations exist in large expanses of every borough. The initial feasibility-study phase of the team’s work for the current project sponsors established the viability of pneumatic installations in subway tunnels.⁶¹ More recently, in consultation with a potential sponsor, the team has devised practicable concepts for retrofit installations for elevated subway structures. Other existing rights-of-way that would allow the retrofit installation of a pneumatic trunk line include the northbound extension of the railroad that once served the High Line (the at-grade submerged tunnel under the Boulevard Park that the City is currently developing); the proposed “Low Line” park that would transform an unused tunnel in Lower Manhattan into an inviting public space;⁶² the Coney Island boardwalk; and roadway viaducts.

Figure 35. Concept for Pneumatic Network Along #7 Line Viaduct Between Court Square and Flushing, Queens.

Source: Image, Caliper Architecture

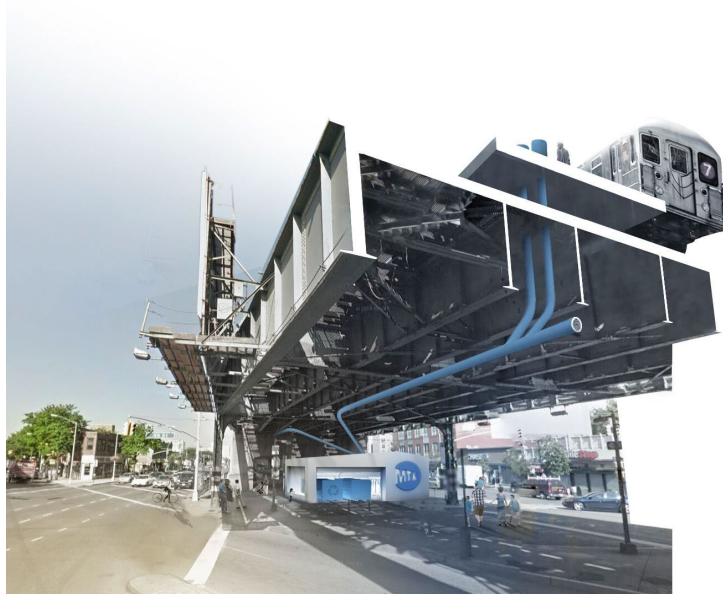
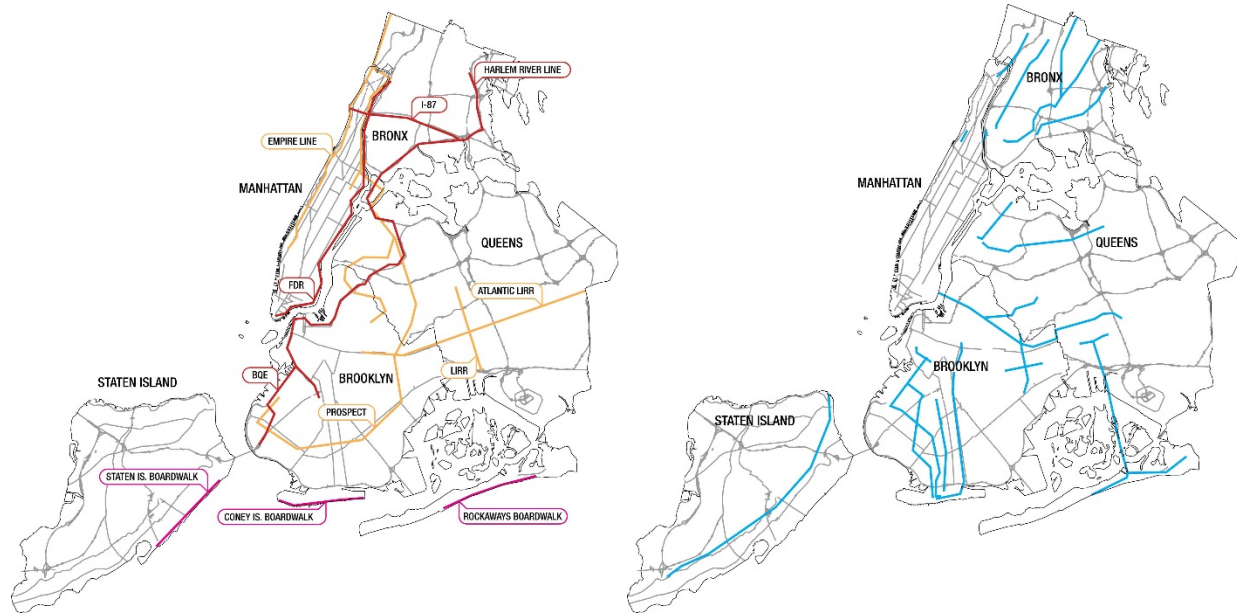


Figure 36. At-Grade and Elevated Transportation Infrastructure

Linear rights-of-way in New York City (subways, expressways and railways)

Source: Image, Caliper Architecture



Opportunities for transferring sealed containers of waste directly from other pneumatic terminals will be more limited, but there is nonetheless a significant set of such options. The opportunity for pneumatic transfer to Manhattan’s Empire Line would also be available to any other pneumatic installation installed north of the High Line. Likewise, there could be opportunities anywhere along the existing freight lines that run through the other four boroughs.

Opportunities for aggregated/shared collection using some form of container compatible with automated collection by truck abound; for example, systems using equipment for compacted or non-compacted at-grade or submerged containers, or drop-off kiosks for small-volume waste fractions such as textiles or e-wastes, could be found in every area of the City. In many cases, means could also be devised to permit a double use of space—and a two-way use of local trips by manually pushed carts or small-scale electric equipment—by developing micro-hub collection/distribution centers for both dropping off wastes and picking up packages.

An innovative institutional component considered here could also be broadly replicated elsewhere in New York City and beyond; for example, the use of Business Improvement Districts to provide an administrative structure for developing and operating sustainable waste-management services that offer advantages over existing methods. As in the case of the Meatpacking District, many of the City's BIDs are ideally situated to perform this function, given their key position between City government and their local members, their core focus on sanitation services, and the capacities and capabilities provided by their staff and legal status.

BIDs' roles in initiating and organizing improved waste-management services could be enhanced should NYC implement franchise zones for commercial waste collection. As noted above, the existence of these zones could significantly diminish the hurdles to financing and administering waste-management infrastructure that costs more to develop than conventional systems but offer more-efficient operation and greater environmental and community benefits. BIDs could play a key role in catalyzing such systemic improvements for their districts by helping to identify local needs and opportunities and by participating in the design of location-specific options for meeting them.

8 Developments to Date

The following section discusses the current status of major project elements and the issues remaining to be addressed by component.

8.1 Stakeholders

Moving from feasibility analyses toward the goal of project implementation requires, above all, the possibility of support from the entities that the project's realization would depend. This support in turn depends on an understanding—shared between the private companies along the corridor and the public agencies with management responsibilities over it—of current waste-management conditions and of the practicability of the alternatives proposed for addressing them. A central element of this phase of the project, therefore, has been engagement with the public and private stakeholders.

The initiative was fortunate to encounter a group of building owners who, as conscientious corporate citizens, were aware of the impacts of their operations on the neighborhood and were eager to consider the possibility of providing community and environmental benefits by playing a leadership role in developing a sustainable waste-management system that other cities could use as a model. These stakeholders are the major owners along the corridor who have expressed, and demonstrated, a willingness to participate in this project both as members of its advisory committee and as potential users (and, possibly, co-owners) of the proposed ensemble of facilities.

Another group of stakeholders that the study team was fortunate to work with are a group of City officials who, in support of some of their agencies' key policy objectives,⁶³ consistently demonstrated a high degree of enthusiastic interest and creative support for the project and played a crucial role in coordinating interagency cooperation. Of special note has been the role played by the Mayor's Office of Sustainability in driving these efforts forward.

The keystone role in the advisory committee arch has been played by the Meatpacking Business Improvement District's executive staff. Their very direct understanding of the truck-traffic and garbage-bag problems the district faces, their enthusiastic support for an exploration of alternative waste-management methods, and their willingness to entertain the possibility of playing a key role in the project's implementation, have played a decisive role in the initiative's development to date.

The project will not be implemented if it does not have a core of businesses committed to using the system, the support of the City agencies whose decisions will determine whether the project can be built and operated, and an entity, such as the BID, that is willing to assume the responsibility of management. The project also depends on the willingness of the Friends of the High Line (FotHL) and the New York City Department of Parks & Recreation (NYC Parks) to consider the use of the High Line Park viaduct as an armature for the project, provided it is able to clear all the other hurdles to implementation.

8.1.1 Advisory Committee

During the course of this project phase, the team met with members of the advisory committee individually, in small groups, and as a whole. As the project concept and design have evolved, the study team has continued to meet with the individual stakeholders directly to discuss the form of their potential involvement in the project's next stages.

The members of the advisory committee are the following:

- Meatpacking BID
- Friends of the High Line
- Avenues School
- Google
- Jamestown
- RXR
- Standard Hotel
- Taconic/Sidewalk Labs⁶⁴
- Terra Bright Green
- Vornado
- NYC Department of Buildings
- NYC Department of Sanitation
- NYC Department of Transportation
- NYC Department of Parks & Recreation
- NYC Economic Development Corporation
- NYC Mayor's Office of Sustainability
- Community Board 4 (Observer)
- Manhattan Solid Waste Advisory Committee (Observer)

The role of the advisory committee will continue into the next project phases, with individual and group meetings to review project developments and to discuss the forms of their individual participation in implementation.

8.1.2 Steering Committee

Representatives from the six City agencies most directly responsible for the activities and land uses encompassed by the initiative's proposals form the project's steering committee:

- Mayor's Office of Sustainability
- Department of Sanitation
- Department of Transportation
- Department of Parks & Recreation
- Department of Buildings
- Economic Development Corporation

At a late point in the current stage of the project, as the increased system capacity allowed the potential participation in the project, NYCHA also joined the City-agency steering committee.

The team met with our designated liaisons from these agencies as a group and individually throughout the course of this project phase, with the Mayor's Office of Coordination taking the lead. This group, too, will continue to coordinate the City's ongoing involvement in the project.

8.1.3 Business Improvement District

BID staff have played an instrumental role in fostering discussions between the initiative team and their member companies. Their role in this process has been useful not only for advancing the exploration of issues to be addressed, but has provided a means for the BID to assess the degree of its members' interest in and potential support for the project—information that will be needed in their determination of if and when to present a motion framing its proposed involvement in the initiative to its Board for their formal consideration.

8.1.4 Potential System Users

The team has held a series of meetings with potential system users, both individually and as a group, to discuss the possibility of their making an agreement to use the system, the possibility of their making an ownership investment in the system's construction, and the possibility of making a near-term investment in the more-detailed planning and design required to advance the project through the next project phase toward implementation. The general tenor of these conversations has been encouragingly positive, but all conversations to date have been at the senior staff level rather than at the level of final executive decisions. In each case, meetings at this level will be needed before any agreements can be reached. Planning to arrange these meetings is under way.

The entities with whom the team has thus far held discussions about their potential participation in the system generate a total of about 28 tons of waste a day, four of which are pre-consumer food waste that could be processed locally in the proposed micro-AD infrastructure. This leaves about 36 tons of capacity available for use by other buildings along the corridor. Since multiples of this amount are potentially accessible within a few blocks of the viaduct, this allows a significant degree of flexibility in targeting and recruiting additional generators. These users could be either commercial buildings without loading docks of their own or residential buildings willing to pay the user fees associated with the system.⁶⁵ The team's work in another business improvement district, as well as its work on the Zero Design Guidelines, identified a latent appetite for aggregated, off-site solutions along the lines of the Battery Park City model,⁶⁶ which would have the potential of offering owners space and labor savings as well as the quality-of-life advantages associated with not having bags at the curb or waste-collection trips. In addition, recruits to the system could take credit for supporting sustainable waste-management practices within their community. Since there are existing examples of residential building owners absorbing the costs of private collection in order to receive the benefits of containerized collection, it is plausible to imagine that buildings in one of the wealthiest districts in the City would similarly consider paying private-carter-equivalent rates to realize the advantages of pneumatic collection. It is even easier to imagine that businesses that currently depend on collection of bagged wastes from in front of their entrances and retail windows would prefer to realize the advantages of pneumatic collection at a price not dissimilar from their current costs.

Providing collection services to non-system owners would require approval from the Business Integrity Commission (BIC).⁶⁷ Should a franchise-zone system be introduced, a logical expectation would be that operation of the pneumatic system would be integrated into the franchise design.

8.2 Inlet Locations, Shared Access

The team asked building owners within the BID boundaries whether it might be possible for them to allow BID staff to load litter bags into the system via inlets on their properties. This question was posed in two forms with regard to (1) ongoing shared use once the pneumatic system is in operation and (2) the possibility of near-term shared use, prior to development of the pneumatic network, using compactor-containers. Thus far the owners with whom we have had this discussion have indicated a willingness to entertain this possibility provided that the limits of this access were acceptably defined, and that the logistical and financial issues related to both types of use (near-term compactors, longer-term pneumatic inlets) could be addressed.

In addition to private spaces, shared inlets (either near-term, using compactors, or longer-term, using pneumatics) may also be located on publicly owned spaces along the viaduct. NYC DOT and New York City Economic Development Corporation (EDC) control these properties. The team has had preliminary discussions with both agencies about potential options. If, in the next project stage, such a City-owned site appears suitable to the project's needs and to provide the best likelihood as a site for the first pilot installation, an agreement will need to be reached with one of these agencies.

8.3 Pneumatic Tube Path

The current study found three types of conditions: (1) standard conditions where the pipe can be installed at the exterior of the columns as shown in Figure 23, (2) nonstandard viaduct conditions, and (3) locations where the adjacent buildings conflict with the default pipe path. Once input points are established, the pipe path can be located, and adjustments made for non-standard conditions. The major open question is whether any building through which the viaduct passes would contest the project's ability to install the pipe within the five-foot right-of-way envelope at the side and bottom of the viaduct structure.⁶⁸ If this should occur, the pipe would need to be installed without passing through a particular property. For example, for the distance of this building's interior, the pipe could run between the parallel beams on the viaduct's underside.

Installation access to the entire viaduct will require the formal approval of the structure's owner, the NYC Department of Parks & Recreation.

8.4 Pneumatic Terminal

Authorization to use this site will need to be secured from NYC DOT. The project team is engaged in ongoing exchanges with NYC DOT. If its approval to use the site is granted, the project team will need to secure a lease agreement with the City. Should the BID be willing to be the lessee for this purpose, the agreement could fall under precedents for such arrangements. Whoever the lessee entity is, it will be required to provide adequate provision against any risks or liabilities that might be associated with use of the site for the intended purpose, as well as assurance that NYC DOT will have the access to the site that it needs for its own ongoing operational and maintenance purposes and to accommodate any future plans it may have for that area.

If the proposed site at 34th Street and 11th Avenue cannot be secured—nor a similar site under the same ownership and control located beneath 11th Avenue to the south—alternatives would need to be considered. None of these would offer the same shortest-distance access both to the High Line viaduct and the existing rail tracks running north. These alternatives would likely be somewhere within or adjacent to the rail right-of-way running northward from 34th Street.

In addition to the City’s consent, approval to use the proposed site for this purpose would also need to be secured from Amtrak, which, as the eventual successor to the New York Central, controls a perpetual easement (a band 25 feet wide) through the site. The team has had a series of discussions and exchanges with Amtrak personnel, as well as with personnel from its sister railroads who control trackage rights for freight use, including a meeting with senior legal and real-estate staff in Philadelphia. The reaction thus far from Amtrak has been one of interest, but these exchanges have not yet reached the highest level of the company at which this decision must be made. In this chicken-and-egg process, support from the highest levels of City government and the stakeholder corporations, if and when it is secured, is expected to play a helpful role in Amtrak’s decision.

8.5 Code Issues

The components of pneumatic networks fall within several categories regulated by the NYC Building Code. The horizontal transport pipes and valves and air intakes are essentially ducts. Like other air-handling systems, the major concern for the Building Department is transmission of fire from one space to another through the network. Pipe material must meet fire-resistance standards, and fire-suppression equipment must be provided, including fire dampers and sprinklers. Where make-up air is drawn into the system, ventilation must be provided. Gravity chutes are covered in the building code. Buffer tank-style input points are not. The argument could be made that these are similar to compactor-containers and should be deemed code-compliant if they are located in the same type of fire-rated loading areas. Input points used by building staff would be considered public access locations and will have to meet Americans with Disability Act (ADA) criteria. It is likely that stand-alone input points that are not in existing loading docks would be treated like compactor-containers within a screened enclosure, which would require a slab adequate to support the weight of the equipment, with floor drainage and utility service for electricity and water/waste-water. Because of the connection to the pipe network, fire protection would also be required.

The terminal is similar to a large boiler room or to the mechanical space for a combined heat and power plant. It requires a slab adequate for supporting the weight of the equipment, ventilation, cooling, utility

hook-ups, emergency power, and fire-department access. As a stand-alone facility, depending on whether staff use workstations on site or only come to perform routine maintenance, it may require a bathroom and other amenities and need to meet accessibility requirements. Because the facility would carry waste, the New York City Department of Buildings (NYC DOB) may defer to New York City Department of Environmental Protection (NYC DEP) and New York City Department of Sanitation (DSNY) with regard to requirements for removal of containers and filtration of exhaust air.

Because the pneumatic pipe would run along the exterior of the viaduct and over public streets and sidewalks, a system installed under the High Line may require approvals from agencies other than NYC DOB. For example, NYC Parks, EDC and NYC DOT may impose requirements to ensure that the system does not interfere with operations in the park above or on the streets below.

The NYC building code currently does not include specific reference to pneumatic waste-transport systems.⁶⁹ In order to receive Building Department approval it is likely that a system developer would be directed to apply to its Office of Technical Certification and Research (OTCR) for a site-specific determination. In May 2018, OTCR released a technical bulletin that establishes general guidelines for pneumatic systems in residential-campus settings (such as Roosevelt Island's), which would enable developers of that type of project to avoid the need for filing a project-specific application. This bulletin is based on the conditions for pneumatic-waste systems specified in the National Fire Protection Association's (NFPA) and is titled, "NFPA 82 Standard on Incinerators and Waste and Linen Handling Systems and Equipment." The NFPA 82-2014 standard is based on the first-generation 20-inch in diameter steel pipe, and specifies that the pipe should be stainless or galvanized steel and have a diameter of at least 16 inches unless the material is processed through a shredder before it enters the system. In order to use a smaller-diameter composite pipe for the High Line project, the project team will need to submit a site-specific application at the point when the DOB would consider the project ready to proceed.

All of the OTCR and NFPA 82 requirements could be met, if necessary. If NYC DOB does not permit HDPE pipe, steel could be used. The team expects that the formator device could be considered a "shredder" since it serves the same function. The draft bulletin and the NFPA 82 standard do not address exterior applications such as a pipe installed under a viaduct or running along the exterior of a building. According to OTCR's informal review, an exterior installation is allowed, however the installation would still be subject to shaft-enclosure requirements, chute requirements,⁷⁰ and zoning requirements.

For further details on code compliance issues, see Appendix E.

8.6 Rail Issues

In order to establish rail service to the proposed pneumatic terminal, three conditions will need to be met:

- Securing Amtrak’s authorization to use its perpetual 25-foot-wide easement through the site. As the eventual successor to the New York Central (which built the High Line), Amtrak holds the right to use this easement for rail purposes. This easement covers the right-of-way on which the original Central track ran between the High Line viaduct to the south and the at-grade track to the north. In order to access the pneumatic terminal (at the northern end of the viaduct) and the existing track to the north, the lead track to the terminal would need to be laid on this right-of-way. It appears unlikely that Amtrak would have a future rail use of its own for this strip, since the viaduct to which it connects is now a park. And the proposed terminal would constitute a “rail use.” Another entity is using a section of this easement north of the proposed terminal site for a paved construction road.⁷¹ Therefore, with support from New York City, New York State, and the stakeholders along the corridor, securing a license to use this easement would appear to be a practicable possibility. If the license cannot be secured, the terminal could still be built on the City-owned land under the viaduct, adjacent to the easement, but it would need to be served by roll-on/roll-off trucks rather than rail.
- Securing Amtrak’s authorization for non-exclusive trackage rights to use the Empire Line, the rail line that runs north along the West Side from Penn Station to Spuyten Duyvil Creek at the border of the Bronx. As noted in Section 2.2, there is an abundance of available capacity on this line. Therefore, with support from New York City, New York State, and the stakeholders along the corridor, securing these trackage rights would appear to be a practicable possibility.
- Securing a lease for the City-owned land under a portion of 11th Avenue at 34th Street (and possibly under a portion of 34th Street) for the tube-to-rail terminal.

In addition, financial agreements will need to be negotiated with:

- The New York & Atlantic Railroad, the short-line railroad that has freight rights over the MTA/Long Island Railroad tracks, to provide haulage from their Fresh Pond Yard in Queens to Varick Avenue in Brooklyn (for organics cars) and to 29th Street in Brooklyn (for recyclables cars).
- CSX, to provide haulage from the drop-off point for project cars (the proposed siding near Spuyten Duyvil Creek) to Fresh Pond Yard and to a processing or disposal facility reached via tracks to the north and west of the Bronx, or to an interchange point to the north and west of the Bronx from which refuse cars would be taken to a processing or disposal facility.
- Amtrak, to permit the placement of an interchange siding near Spuyten Duyvil Creek (or with another entity to allow the use of an alternative interchange site to the north or east of Spuyten Duyvil).
- Rail Cents, the project’s pro bono rail partner (or another short-line railroad) to provide haulage service between the pneumatic terminal and the project interchange site.

Over the course of this phase of the project, Rail Cents has taken the lead in approaching the rail entities whose approval would be needed (or whose support could be helpful). Rail Cents has had meetings and other types of exchanges, in some of which ClosedLoops also participated, with high-ranking officials from Amtrak, Conrail, CSX, and NS (a co-owner, with CSX, of Conrail). No substantive agreements have been reached, but all avenues remain open as the exchanges continue. Progress in a range of potential directions—toward agreements with stakeholder-users, City-agency landowners, one of the railroads, or elected officials—could have a decisive effect in moving these rail entities toward decisions that would advance the project’s development.

8.7 AD Facility

The study team undertook a preliminary pre-feasibility analysis of the proposed site on the roof of NYC EDC-owned 832 Washington Street (the Meatpacking Co-op building), with assistance from SourceOne, who recently supported the development of a similar facility in the City, and Silman Engineers. The work included the following:

- Touring the building with the co-op president to understand current operations.
- Gathering data on the meatpackers’ waste volumes and current haulage costs and energy use (both by the central cooling plant and by individual users).
- Reviewing floor plans and touring the site with the team architect and mechanical and structural engineers from SourceOne and Silman.
- Gathering data on food-waste volumes from several large producers in the neighborhood and informally surveying the Meatpacking BID and other stakeholders to gauge interest in moving material several blocks to a shared micro-AD facility.

Neighborhood stakeholders have expressed enthusiasm for the concept of a rooftop digester at the Gansevoort site, seeing it as an opportunity to raise the profile of sustainable waste management, to improve options for organics collection in the neighborhood, and to spur development of on-site AD in the City. EDC asset managers for markets suggested that such a facility could be a model for other markets across the City. Were the project to move forward, concerns raised by the Meatpacking Co-op about potential disruption to operations during construction and potential impacts to a recently resurfaced roof would need to be addressed.

SourceOne's engineer reported: "We believe that the Gansevoort Meat Market is an ideal location for an Anaerobic Digestion system capable of providing sustainable waste management while reducing energy and trucking costs for the Gansevoort Meat Market. Based on the site walkthrough with myself and [an engineer from Silman Structural Engineers], this project is technically feasible based on the ... observations and information provided by the team."⁷²

Specific pre-feasibility technical observations:

- Meatpackers generate approximately 1,000 pounds of fat and bone per day. The system could accept 4,000 pounds of food waste from businesses in the community.
- Food waste, fat, and bone could be loaded into an 8 x 8 x 8 foot mouth unit at ground level. Waste could be ground into a slurry and pumped up to the roof-top AD system.
- A 5,000-pound AD system including digestion vessels, gas-storage unit, and auxiliary equipment, weighing approximately 150,000-200,000 pounds over a 5,000-square-foot area, could be housed on the roof.
- New steel dunnage beams could be supported on existing steel columns through roof penetrations, the existing parapet wall, or the concrete masonry unit walls that divide the spaces inside.
- The AD system would generate methane gas to power a 50-kW combined heat and power unit or blended with natural gas to fuel a generator of up to an 80 kW. The electricity produced could supply enough power to run the central refrigeration plant. The waste heat could be used for heating in the building.
- Interface controls linked with the New York Fire Department and Con Edison would be connected to the central refrigeration plant's fire-alarm panel and Con Edison switchboard, respectively.
- Nutrient-rich wet mulch created by the process could be pumped out of the digester and used as fertilizer for nearby parks and green spaces.
- The next step would be to perform a feasibility study to refine the technical, regulatory, and financial implementation of the project.

9 Next Steps Toward Implementation

A team is in place that is up-to-speed and ready to push forward to advance this project through the next stages. ClosedLoops, the project initiator, will continue to play the role of catalyst and advocate in the effort to develop a locally owned and operated network of facilities to provide essential neighborhood services. The key members of its team, Green Bending (pneumatic waste collection engineering), Foodprint Group (organics processing and commercial waste management), Caliper Studio (architecture), and Rail Cents (rail terminal and transport), are also committed to continuing to advance the project.^{73,74} Within the corridor, major stakeholders—including the Meatpacking BID, Jamestown, Google, the Standard Hotel, Vornado, and Avenues School—have indicated their continued interest in participating in the system, if it can be developed, as well as their interest in continuing to support as well as advance the project’s collective efforts. And from their vantage as primary sustainers and protectors of the public well-being, the Departments of Transportation, Sanitation, Parks, Buildings, the Economic Development Corporation, and the Friends of the High Line, under the coordination of the Mayor’s Office of Sustainability, are in position to continue to play their respective key supporting roles.

The current project phase focused on building consensus among numerous stakeholders around the concept of district-scale collection and exploring how such a system could serve the High Line Corridor. More work is needed to refine the design to a level of detail that will support a screening-level project budget and schedule, from financing to operation—in other words, to answer the question posed by property owners: how much will it actually cost and how long will it take to build? To answer these questions, and to secure commitments from stakeholders, the study team is proposing that stakeholders join together to fund the work required to provide the legal, cost, and time-frame information necessary to establish the business case and to seek commitments for sites and funding and the various other approvals and authorizations that would be required.

Task 1 of this effort would focus on confirming access to a terminal location and developing a strategy for passing the pneumatic pipe within the existing rail easement where buildings enclose the viaduct structure.

If the terminal site and viaduct access are confirmed, task 2 would focus on developing schematic-level designs for input points, the pipe path, and the terminal so that a rough order of magnitude (ROM) budget estimate can be produced. The proposed work includes site visits and 3D scanning of loading docks to accurately document existing conditions at input points; preparation of schematic-level plans and

sections for all components of the system; review of regulatory, building code, and legal requirements for installing pneumatic waste-collection equipment in New York City; and meetings with individuals and groups of stakeholders to validate designs.

Task 3 would develop the business case for the system based on the design developed in task 2. The team would generate a ROM budget for equipment and construction costs and project a time-frame from ground break to operation. In consultation with public and private stakeholders, the team would devise means to address the administrative, regulatory, and logistical issues associated with moving waste to input points, collecting user fees, and operating and maintaining the core infrastructure as well as the input points. An operations protocol, a projected annual operating and maintenance budget, and revenue stream projections would be developed in consultation with stakeholders. At the completion of task 3, stakeholders should be equipped to decide whether to move forward with the High Line Corridor Initiative.

The implementation study outlined above is projected to take five months if the phases are completed in succession, or it could be completed in three months if Phase 2 and 3 are undertaken simultaneously. The actual timing will depend on how quickly access to sites and data can be secured and meetings can be arranged.

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Endnotes

- ¹ MSW trucks use more fuel than other trucks of their size and weight because of they make more stops (one or more in front of every building multiple times a day or week) and idle at each stop while manual or automated loading takes place and while they use hydraulic power for compaction. On a collection route in Manhattan, for example, they average 1.65 miles/gallon. (New West Technologies, LLC, *Multi-Fleet Demonstration of Hydraulic Regeneration Braking Technology in Refuse Truck Applications*, NYSERDA, 12-2011, Table 21) This translates to more greenhouse gas emissions along with other air emissions that are harmful to public health, which are especially dangerous coming from MSW trucks because their stops occur on all residential and commercial blocks, where they are surrounded by pedestrians and other vehicles. They emit more noise because of the sounds of loading and compacting while they idle in front of buildings. They create more congestion than other vehicles because they typically block any traffic on a given block for the length of time it takes to collect all the waste on that block. They produce more traffic injuries and fatalities than any other kind of truck (43 pedestrian or bicyclist deaths in NYC between 2010 and 2017) because of the risks inherent in stopping and idling in front of every building and because of the conditions associated with private collection as it is currently managed in NYC (e.g., night-time collection in densely populated areas, with long routes that must be covered within limited time windows). (Sean T. Campbell, "How to fix New York City's dangerous private sanitation industry," *City and State*, 3-14-18, <https://www.cityandstateny.com/articles/opinion/opinion/how-fix-new-york-citys-dangerous-private-sanitation-industry.html>.)
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- ⁵ See, for example, the French Environment and Energy Management Agency's (ADEME) recent survey of the international experience with pneumatic waste collection. After listing its "undeniable societal benefits," it noted that "These strengths were sufficient to foster most of the major Scandinavian cities to adopt local legislation generalizing vacuum waste-collection systems in their new districts under certain population density criteria." ADEME, Olga KERGARAVAT, Gabrielle Trebesses (Moringa) and Marguerite Whitwham (Philgea) with the contribution of Annika Ekstrand and Daina Millers-Dalsjö (Urban Earth Consulting). 2017. "International benchmark study and cost analysis of automated vacuum waste-collection projects – Synthesis," p. 19. <http://www.ademe.fr/sites/default/files/assets/documents/benchmark-automated-vacuum-waste-201712-synthesis.pdf>
- ⁶ For a description of what pneumatic collection is, how it works, and where facilities have been developed since the first one was installed in Sweden in 1962, see Appendix A and Miller, Benjamin, Juliette Spertus, Eliminating Trucks on Roosevelt Island For The Collection Of Wastes, New York State Energy Research and Development Authority, Report Number 14-13, 2013b, <https://www.nyserra.ny.gov/-/media/Files/Publications/Research/Transportation/Eliminating-trucks-on-Roosevelt-Island-for-the-Collection-of-Wastes.pdf>, pp. 1-3 to 1-6.
- ⁷ Pneumatic systems are not used to transport glass (unless it is part of a mixed stream) because it abrades the inside of the pipes, or bulky items, including cardboard, that cannot fit inside a standard trash chute door.
- ⁸ See Appendix A.
- ⁹ The developer of Manhattan's mega Hudson Yards project has entered into a contract to install a pneumatic network for the residential buildings in this complex. E.g., Katherine Clarke, *New York Daily News*, June 27, 2014, <http://www.nydailynews.com/life-style/real-estate/trash-handled-pneumatic-tube-hudson-yards-article-1.1846588>; see also "Hudson Yards," Wikipedia, https://en.wikipedia.org/wiki/Hudson_Yards,_Manhattan
- ¹⁰ Miller, Benjamin, Juliette Spertus, Camille Kamga, "Costs and benefits of pneumatic collection in three specific New York City cases," *Waste Management*, Nov 2014, 34:11:1957-66; Miller and Spertus, 2013a; 2013b; 2015;

- 11 The pneumatic system would not collect cardboard. One of the most economically valuable waste-stream commodities, this non-putrescible material is relatively easy to manage and store in bales or bundles and is commonly collected for marketing by separate trucks.
- 12 The Clichy-Batignolles terminal is sited next to a rail-connected materials-recovery facility, to which it will deliver its filled containers over a short distance of rail track. In the 1960's a pneumatic facility was built in Monaco that connected directly to an incinerator.
- 13 Miller and Spertus, 2013a.
- 14 Miller and Spertus, 2015.
- 15 Three tanks at a given location to handle the three waste fractions would occupy a combined footprint of about 24 by 33 feet and a height of about 8 feet.
- 16 Battery Park City is a campus of 17 high-rise residential buildings developed by a State Authority on State-owned land. Following the destruction and reconstruction associated with 9/11, the development experienced a significant problem with rats. As a way of eliminating a primary food source—refuse bags set out on the curb for collection—the Authority asked the private owners of the buildings to consolidate their waste in compactor-containers that would be housed in loading docks in four of the buildings. Building staff from the other 13 buildings push tilt carts filled with refuse bags to these four loading docks. The area's rat problem was substantially eliminated. Owners, tenants, and staff from the 13 neighboring buildings were pleased to avoid the need to store waste within their buildings for pickup on only three days a week, to avoid the double-handling required to store and then take out bags, and to avoid having bags on the curb. The four host buildings were also pleased to avoid double-handling and bags on the street, and required no more space to handle their neighbors' waste than they would have required to handle only their own. Hosting the compactors fulfills a condition of the buildings' leases with the State, which is that a percentage of their space be used for public purposes. All parties with whom the study team spoke—including the Department of Sanitation, which supplies the roll-on/roll-off collection trucks rather than manual rear-loaders—are satisfied with this win-win arrangement.
- 17 Although the overall objectives of the Zero Waste Design Guidelines project do not completely overlap with those of the present project, both share the goals of reducing adverse quality-of-life impacts on public space by reducing the number of plastic waste bags on the street, the number of truck trips, and the other economic and environmental costs of waste collection. Like the current project, it aimed to reduce truck-trips and door-to-door collection by, among other techniques, aggregating collection through the use of shared equipment, using on-site strategies for material densification, and substituting some degree of automation for manual loading. The Zero Waste study was conducted by Kiss & Cathcart Architects, ClosedLoops, and the Foodprint Group, under the auspices of the Center for Architecture/American Institute of Architects, with funding from the Rockefeller Foundation. (www.zerowasteguidelines.net).
- 18 Small, dispersed, post-style inlets (such as are typically provided by pneumatic systems for use by pedestrians in public spaces) could be added to the Park at a later time, should its managers and the managers of the system choose to do so. This would somewhat diminish the system's capacity.
- 19 The four lines to accommodate refuse and recyclables would be connected to compactors; the two lines for organics would not be compacted (though a fifth compactor would be available on one of these lines to provide redundancy in the event of unscheduled maintenance needs).
- 20 A modest reduction in operating costs would be expected due to the decreased need for shifting the tube connections between containers for different fractions.
- 21 For information about MariMatic, its technology, and the facilities it has developed, see <http://www.marimatic.com/>.
- 22 There are other pneumatic-equipment manufacturers who offer different systems. Prior to implementation, the project team would conduct a competitive procurement based on the specifications that would be required to meet the needs of this project as it is finally designed.
- 23 See MariMatic specification sheet in Appendix D.
- 24 Albert Mateu, P.E., Green Bending. Professional experience.
- 25 This Sims facility currently handles metal, glass, and plastic, but negotiations are underway by the City and Sims to have it handle mixed paper as well, so that the City can move to a single-stream collection system for all designated non-organic recyclables. (Thomas Outerbridge, General Manager, SIMS Municipal Recycling, personal contact, 4-17-2018.)
- 26 Estimated quantities of potentially available pre-consumer organic material along the corridor total tens of thousands of pounds a day.
- 27 E.g., http://www.taifun.fi/vacuum_conveying/index.php/en/references/selected-references; <http://solucycle.com/en/>; <https://evac.com/>; http://www.envacgroup.com/products/our_products/kitchen-waste-systems
- 28 <http://impactbioenergy.com/>

- 29 Some prefabricated micro-AD facilities are designed to fit inside standard shipping containers and containers can be stacked to fit in a smaller space. Stacking has not been assumed for the current conceptual design.
- 30 The site shown is controlled by NYC EDC, who would have to provide authorization for this use, which it has not to date done. The image illustrates the basic volumetric requirements of such a facility.
- 31 These costs are based on costs projected for a similar system within a single building. Considerations include: number of input points, length of pipe, and complexity of retrofit within buildings. Operating cost includes technicians maintaining the system two hours/week and kitchen staff time to wash around input points.
- 32 This facility is Vashon Bioenergy Farm LLC. E.g., <http://vashonloop.com/news/local-news/vashons-island-spring-organics-to-install-biodigester-to-generate-energy/>
- 33 With a pneumatic system waste can be taken from its point of origin—say an apartment of an office-worker’s desk—and dropped directly into a pneumatic inlet, as opposed to moving it vertically through the building in an elevator, stashing it for temporary storage in a waste room, and removing it from the waste room and staging it on the curb for pickup on collection day.
- 34 Note however that chutes inside walls and basement valve rooms also require some space.
- 35 Lifting injuries from handling waste are a prime source of worker injury and among the greatest sources of worker-compensation claims at NYCHA. (ClosedLoops interview, NYCHA operations manager, 2013.) For the most recent year for which national data are available (2016), “overexertion in lifting, lowering” is the cause of the greatest number of missed days for any injury recorded at that level of specificity. (Bureau of Labor Statistics, “Case and Demographic Characteristics for Work-related Injuries and Illnesses Involving Days Away From Work,” <https://www.bls.gov/iif/oshcdnew2016.htm>), while refuse collectors experience the fifth-highest rate of fatalities and injuries among US workers (Cole Rosengren, “BLS: Refuse collection fatality rate down but still fifth most dangerous job,” *WasteDive*, December 19, 2017, https://www.wastedive.com/news/bls-refuse-collection-fatality-rate-down-still-fifth-most-dangerous-job/513413/?utm_source=Sailthru&utm_medium=email&utm_campaign=Issue:%202017-12-19%20Waste%20Dive%20Newsletter%20%5Bissue:13330%5D&utm_term=Waste%20Dive)
- 36 E.g., Alexandra S. Levine, “Return of the Rats,” *New York Times*, August 17, 2016, <https://www.nytimes.com/2016/08/17/nyregion/new-york-today-rats-in-new-york.html>.
- 37 Bill de Blasio, “De Blasio Administration Announces \$32 Million Neighborhood Rat Reduction Plan,” July 12, 2017, <http://www1.nyc.gov/office-of-the-mayor/news/472-17/de-blasio-administration-32-million-neighborhood-rat-reduction-plan#/0>
- 38 E.g., John Metcalfe, “Yo, I’m Trying to Sleep Here!,” *CityLab*, April 15, 2013, <https://www.citylab.com/life/2013/04/yo-im-trying-sleep-here-new-yorks-wonderful-map-noise/5279/>
- 39 E.g., José Holguin-Veras, et al “The New York City Off-hour Delivery Project,” *Procedia*, March 2014 (125:20:36-48), <https://www.sciencedirect.com/science/article/pii/S187704281401492X>.
- 40 ADEME, p. 9. (They cite “three” models, but their third is a variation on government sponsorship in which the owner buildings pay their own proportionate capital costs.)
- 41 One institutional precedent the team considered is an eco-district. An example of an eco-district is the Brewery Blocks in Portland Oregon, where a group of existing buildings agreed to switch from individual cooling to a more efficient central system that is owned and operated by Veolia. Another precedent considered was rural electric cooperatives. A study on financing district energy produced by MIT CoLAB found that large utility-service providers such as Veolia are better able to shoulder the long development periods and relatively high administrative costs associated with district-scale projects than are local developers dependent on grant funding. In addition, the labor and behavioral issues involved with switching from truck-based collection to pneumatic-tube network are more involved than converting to a different grid, not to mention the relatively low cost of conventional waste hauling. (<https://www.portlandoregon.gov/bps/article/112566>; Seidman, Karl F., Drew Pierson, “Financing Urban District Energy Systems,” Massachusetts Institute of Technology, Community Innovation Lab (MIT CoLAB), 2013, http://web.mit.edu/colab/gedi/pdf/Financing%20District%20Energy/DES_report.pdf)
- 42 E.g., FCC Citizens Services, (Lesseps; Sta. Catarina, and Raval in Barcelona; Torresana in Terrassa; <http://www.fcc.es/en/home/>); Urbaser (Vila Olimpica, Diagonal-Poble Nou, La Maquinista, and 22@ in Barcelona; <http://www.urbaser.com/en/>); Suez Environment (Vitry-sur-Seine and St. Ouen in France; <http://www.sita.fr/en/>); Veolia (Romanville, Clichy-Batignolles and Issy-les-Moulineux in France; <https://www.veolia.com/en/>); YIT Group (many systems in Scandinavia; <https://www.yitgroup.com/en/>); Marafeq Qatar (many systems in the Middle East; <http://marafeq.com.qa/>).
- 43 Cole Rosengren, “DSNY selects consultant for \$8M commercial waste zone implementation contract,” *WasteDive*, 7-28-2017, <https://www.wastedive.com/news/dsny-selects-consultant-for-8m-commercial-waste-zone-implementation-contra/448098/>

44 In April, 2018, the Sanitation Department announced its intention to design a program that had multiple franchisees within a zone rather than giving one franchisee exclusive rights within a particular zone. (E.g., Cole Rosengren, “DSNY: Commercial franchise zones will be non-exclusive,” updated 5-24-2018, <https://www.wastedive.com/news/dsny-commercial-franchise-zones-non-exclusive/522365/>). While an exclusive franchise zone might be more conducive to the business structure suggested here, a multiple-franchisee zone program could also accommodate such forms of participation in the management of a pneumatic system.

45 <https://www1.nyc.gov/site/sbs/neighborhoods/bids.page>

46 “Meatpacking District, 2017,” p. 3, http://www.meatpacking-district.com/wp-content/uploads/2015/08/2017-DistrictReport_WEB.pdf

47 From a City budgeting perspective, it would be less difficult to obtain authorization for an upfront capital grant for infrastructure or equipment than it would be to obtain a commitment to make ongoing payments over a period of years in return for the provision of services that would otherwise have been provided by City staff. Capital grants are not uncommon; long-term commitments to pay operating expenses are.

48 Pneumatic systems can provide digital sensors to monitor the volumes of specific waste-fractions inserted into the system by a specific user in order to generate volume-based bills.

49 When used in this general sense, “recycling” also refers to source-separation of organics for processing—i.e., any diversion of waste from disposal facilities.

50 This financing method (requiring no City user fees for a system that handles predominantly commercial waste), would also avoid institutional issues that might be associated with blurring the current dividing line between municipal and commercial waste, since the commercial waste would still be managed by a commercial entity and the City would not pay ongoing fees to this entity. The commercial entity would simply offer to accommodate some municipal waste in order to provide community benefits.

51 E.g., Miller and Spertus, 2013a; Thomas Kogler, “Waste Collection,” 2007, p. 61, http://www.iswa.org/uploads/tx_iswaknowledgebase/ctt_2007_2.pdf; 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>.

52 Note that in the case of the present project, which includes direct rail transfer and local transport as well as collection to a pneumatic terminal, the rail-transfer-local-transport component represents half of the overall system-operating costs.

53 The level of contingency is so high, given the number of unknowns, that capital costs and operating costs provided here are illustrative. They will be used as a point of departure for the development of a screening-level project budget once an ownership model and other critical factors are known.

54 The current cost spread between large and small generators is 38%. (NYC Department of Sanitation; Business Integrity Commission, “Private Carting Study: Executive Summary,” August 17, 2016, <http://www1.nyc.gov/a> NYC Department of Sanitation; Business Integrity Commission, “Private Carting Study: Executive Summary,” August 17, 2016, http://www1.nyc.gov/assets/dsny/downloads/pdf/studies-and-reports/Private_Carting_Study_Executive_Summary.pdf; http://www1.nyc.gov/assets/dsny/downloads/pdf/studies-and-reports/Private_Carting_Study_Executive_Summary.pdf, p. 6.)

55 Costs of separate organics for one generator in the corridor are \$3,000/month more than when the organics were collected with refuse.

56 Miller, Miller, Benjamin, “Managing New York’s Municipal Solid Waste to Support the City’s Goal of Reducing Greenhouse Gases by 80% by 2050,” *Environmental Law in New York*, Feb 2018, 29:02:19-30

57 <https://www.portlandoregon.gov/bps/article/112566>,

58 The facility would need to comply with BIC’s regulations relevant to such a processing facility. Compliance requirements may be less onerous if users share in ownership of the facility and were certified under that agency’s “self-hauler” provisions.

59 The Park has separate litter bins for refuse and recyclables year-round, and collects post-consumer organics during the warm-weather months when its food-concession businesses are open. The BID currently has bins only for all mixed waste (refuse), but it is conceivable that separate bins for dry recyclables might be added, as they have been in other areas of the city, at some future point.

60 An example of a way to achieve low-impact diversion from landfills—by maximizing the efficiency of truck trips—is using drop-off kiosks for low-volume waste streams such as textiles and e-waste, rather than collecting such materials door-to-door. The provision of such street furniture to serve waste-drop-off and -collection purposes may be integrated with other street furniture, such as “street seats” and wi-fi kiosks, and may be designed so that these various types of equipment have a similar look.

61 Miller and Spertus, 2013a.

62 <http://thelowline.org/>

63 Among these are New York City's goals for: Vision Zero ("ending traffic deaths and injuries on our streets" to make "New York the world's safest big city"); 80x50 (an 80% reduction in GHG emissions by 2050); Zero Waste (100% diversion of waste from landfills by 2030); NYC DOT's policy goals of moving freight transport from roads to rail and to develop micro distribution and waste-collection hubs; and the City's goals of reducing rat populations.

64 This committee member moved from Taconic to Sidewalk Labs (like Google, an Alphabet subsidiary that is located along the corridor).

65 Through its work on the Zero Waste Design Guidelines, the team discovered and investigated a number of buildings and developers who currently pay for private collection services in order to avoid the manual handling of bags on the street. Another possibility is that the City might be willing to underwrite or subsidize residential users of the pneumatic system, since the City would otherwise be responsible for providing collection service to them, and their use of the system would provide public benefits that would directly support a variety of major City policy objectives, such as Zero Waste and Vision Zero and rat-riddance.

66 www.zerowastedesign.org, pp. 202-3.

67 System owners providing self-collection services would also have to comply with Business Integrity Commission rules that require registration.

68 These access rights are part of the easement agreement conveyed by CSX to the City of New York as part of the High Line transfer.

69 https://www1.nyc.gov/assets/buildings/pdf/otcr1_ins.pdf

70 (BC 708.13, BC 1213.3, 1 RCNY 24-01)

71 Rail Cents site survey, 5-19-16.

72 Andrew Bennett, SourceOne, to Juliette Spertus, 6-6-2017.

73 The project team's collective goal is to catalyze and support the development of the proposed system, playing the role of project advocate rather than entrepreneur. It does not see itself as a project owner or investor, nor does it necessarily see itself as project manager or as receiving any revenues from the project. Its future role in any ongoing project operations is open to discussion as bridges are crossed.

74 MariMatic Oy, a manufacturer of pneumatic facilities, and Impact BioEnergy, a manufacturer of anaerobic-digestion facilities, have played a much-appreciated role with their pro bono technical support of this project. If the project is implemented, the team anticipates that there would be an open competitive procurement for the supply and installation of these two types of equipment. MariMatic and Impact BioEnergy would clearly be pre-qualified for consideration in such an eventual procurement.

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**New York State
Department of Transportation**

50 Wolf Road
Albany, NY 12232

telephone: 518-457-6195

dot.ny.gov

**New York State
Energy Research and
Development Authority**

17 Columbia Circle
Albany, NY 12203-6399

toll free: 866-NYSERDA
local: 518-862-1090
fax: 518-862-1091

info@nyserdera.ny.gov
nyserdera.ny.gov



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