Waste

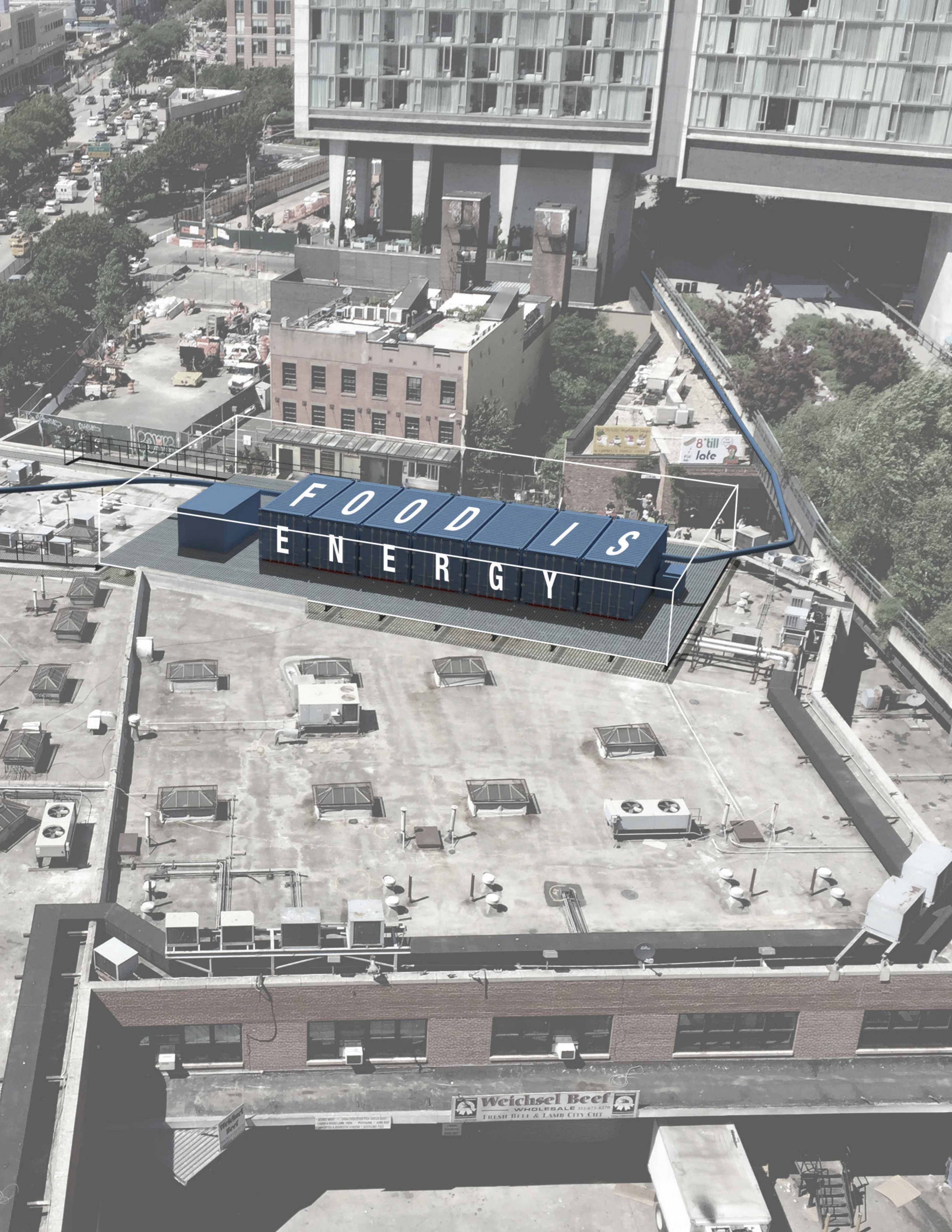
MANAGING NEW YORK'S MUNICIPAL SOLID WASTE TO SUPPORT THE CITY'S GOAL OF REDUCING GREENHOUSE GASES BY 80% BY 2050

July 13th, 2017

GETTING NYC TO 80X50

A policy forum series on NYC'S 2050 goal to reduce greenhouse gas emissions by 80% from 2005 levels

This paper was prepared for the New York League of Conservation Voters Education Fund by Benjamin Miller of ClosedLoops


FOOD IS
ENERGY
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WHOLESALE
FRESH BEEF & LAMB CITY CUT

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EXECUTIVE SUMMARY

New York City's Roadmap to 80 x 50 clearly identifies the destinations the City will need to reach in order to achieve its goal of reducing greenhouse gas (GHG) emissions by 80% by 2050:

- Minimized waste generation
- Maximized reuse and recycling
- Energy and material recovery from separate collection of recyclables and food waste that spurs economic activity and catalyzes a citywide circular economy
- Smart collection routes
- Cleaner vehicles
- Reduced emissions from transport and processing through the use of new technologies,
- Diversion of all waste from landfills
- Net-zero energy use at wastewater treatment sites through food-waste digestion with methane capture and use[1]

It is less explicit in delineating the actual means to these admirable ends. Developing a comprehensive long-term action plan will require initial efforts in two areas. One involves proactive measures to provide the infrastructure needed for the vision to become a reality—the facilities to spin these aspirational notions into actual energy and materials instead of buried waste and GHG emissions. The other requires an examination of the implicit assumptions baked into current plans and operations that hamper the ability to shift toward more productive directions. Breaking free from these conceptual constraints will require re-thinking twentieth-century notions of the most productive ratios for deploying labor in mechanized transport (and snow-removal) functions vs. operational management, maintenance, and monitoring roles. It will also demand a laser-like focus on the net economics and emissions associated with all the integrated components of collection operations, and on the geographic relationships between collection routes and processing facilities.

In other words, achieving the Roadmap's objectives will require deploying the City's property holdings and securing access to any other sites that may be needed to develop processing capacity, and developing a clear-eyed cost-benefit assessment of how much bang (and GHG reduction) the City is getting for its bucks and truck trips.

The strategic plan the City needs for realizing the Roadmap must be based not only on an understanding of the logistical operations in which any waste-management system is embedded, but of the other phenomena that constrain the range of practicable possibilities for system design, and the dynamics that will affect these conditions over time.

Image *(facing page)*: Concept for a micro-anaerobic digester on the roof of the NYC EDC-owned Gansevoort Market. It would process 900 tons of food waste a year from the Meatpacking Coop and nearby restaurants. The biogas would be converted to electricity to run the building's refrigeration system. The digestate would be used as soil amendment for parks. A network of micro-AD systems fed via handcarts, or connected directly to commercial kitchens via pneumatic tubes, could produce renewable energy from a meaningful portion of the organic waste produced by the City's food businesses. ClosedLoops, Image: Caliper Studio.

1 City of New York, Mayor's Office of Sustainability, *New York City's Roadmap to 80 X 50*, 2016, pp. 99-100.

WASTE AS FLOW: THE ROLE OF LOGISTICS

A heap of variously colored bags at the curb might appear inert, but for the occasional glimpse of a darting rat. It is not. Its eighteen hours of immobility (say, from 4 p.m. to between 7 and 10 a.m. when it is collected by three different trucks) are but a micro-blink in geological time, during which its constituents have already begun their entropic dissolution onto the street and into the atmosphere. The plastic-enclosed materials moved through a building before they reached the street, their heterogeneous components handled multiple times, perhaps by multiple people. They will be picked up (by human hands), and hauled and dumped and transferred and transported and re-dumped and processed or disposed. Then their elements will be transported again to be made into new products for distribution and consumption, or will simply escape in various forms into our air, soil, and water.

Each step in this process involves various forms of "friction"—including costs, energy use, and GHG emissions. Our goal is not simply maximizing diversion from landfills (which are indeed the greatest source of waste-related GHG), but to minimize the net friction of the overall materials loop.

This means that transport operations, which produce over 80% of the overall economic costs and an appreciable portion of the overall GHG emissions, play an important role in the equation.[2] So do processing impacts, particularly if they are energy-intensive or release significant volumes of carbon. It is easy to imagine systems that decrease material volumes going into landfills but increase GHG volumes going into the atmosphere. Our current collection, transport, and processing arrangements for source-separated organics, which generally involve separate truck trips for small, dispersed, relatively contaminated quantities of post-consumer organics prior to transfer and pre-processing, then long-distance transport, then composting, may well be a case in point.

Fixed Constraints: Geography, Demographics

Even if New York were no longer an archipelago separated from most of the continent by a river and harbor (although we no longer use our waste to extend our shoreline, planners from time to time still propose landfilled connections across stretches of water),[3] it is unlikely—given patterns of settlement and development in this section of the Eastern seaboard, constraints on available upland (especially in the face of global warming), and historic patterns of immigration and migration due to the city's place in global trade flows—that our ratio of population to land-area will decrease much in the next three decades. Given the composition of our current population and the structure of our economy, it is also likely that we will remain demographically (ethnically/linguistically and economically) diverse for the foreseeable future.

2 Costs: Citizens Budget Commission, *12 Things New Yorkers Should Know About Their Garbage*, 2014-05, p. 2: $307/ton for refuse and recycling collection and $126/ton for disposal, based on FY2012 data. (No breakdown is provided for the transport portion of "disposal" costs. Estimated at 50%.) GHG: City of New York, *PlaNYC: NYC's Pathways to Deep Carbon Reductions*, 2013-12, p. 104: Transport = 4% of GHG emissions from waste management, but this does not include the additional emissions associated with source-separated organics collection. Mohareb, Eugene A. et al., "Greenhouse Gas Emissions from Waste Management," *Journal of the Air & Waste Management Association*, 61: 480-93, 2011-05, p. 9: In Toronto, the transport portion of organics management contributes an estimated 10-13% of overall GHG emissions.

3 Chaban, Matt, "More on LoLo, the Great Landbridge to Governors Island," *New York Observer*, 2012-0112, http://observer.com/2012/01/more-on-lolo-the-great-landbridge-to-governors-island/.

This means that the demand for consumable goods will remain high, as will the demand for employment—and that our waste-generation volume will remain relatively large even if our waste-generation rate decreases significantly.

It also means that our mobile, linguistically and culturally diverse population will constrain the extent to which it will be desirable to change waste-separation and -management rules over time, or significantly increase the degree of complexity involved or the level of effort required.

The fact that we are likely to continue to have dense populations on islands also means that the efficiency of our material transport systems—our roadways, railways, pipes, and waterways—will remain critically important.

These linear transport networks—and the aggregation, transfer, and distribution nodes they connect—are not arbitrarily arranged in our archipelago's limited space. They are intrinsically and organically connected not only to the region's underlying geology (shorelines and elevations) but to the development and land-use patterns they produce and support. They are not going to move. And because they cannot be replaced—it would be almost as difficult to establish new rights-of-ways through our highly developed density as it would be to create new land for development—these existing lines and nodes will continue to exert a dominant influence on waste-management operations in the city for generations to come. It is therefore critical that their use and effectiveness be safeguarded for future logistics purposes. This is particularly true for waste-management networks, given the significant association between economic and environmental impacts (GHG emissions among them) and the distance between origin and destination sites (garages and transfer stations) and collection routes (residential and commercial development).

The locations of past and present waste-management facilities—garages, transfer stations, processing plants—are of paramount importance in designing a low-friction system. Historic sites once used for purposes such as marine transfer stations and incinerators were determined through the city's organic evolution for their utility in linking geographic units of population (waste-sheds) with truck, barge, and/or rail routes. They should not be abandoned for other use unless a rational alternative network capable of managing all of the city's waste output for the indefinite future is in place elsewhere.

> "Our goal is not simply maximizing diversion from landfills (which are indeed the greatest source of waste-related GHG), but to minimize the net friction of the overall materials loop."

CHANGING PHENOMENA: MATERIAL COMPOSITION, PROCESSING AND PRODUCTION TECHNOLOGIES, MARKETS

All life forms evolve. A city's evolution is mediated by the evolution of the technologies that sustain it, and by the materials these technologies produce for its citizens' consumption.

The composition of New York's waste stream has changed dramatically over the past centuries and even decades. Cattle no longer march into town "on the hoof," leaving said hooves and other body parts behind as remnants of human repasts. Horses—the primary source of street waste in their day—no longer provide our primary form of surface transport. Neither wood, nor its successor, coal, any longer provide our primary heat-and-power source—or the ashes whose cans once characterized our artists' way of looking at the world. Though these trends might someday revert, within the past few decades we have all but stopped cooking at home with primary ingredients (that have peels and husks)[4] or drinking bottles of daily-delivered milk, or reading newspapers dropped on doorsteps. The beer bottles that have not been replaced by light-weight aluminum cans weigh only a fraction of what they did twenty years ago. Our plastic yogurt containers are lighter, and have often lost their separate plastic caps. Because of increasing global shipping and internet shopping, we are using vastly more cardboard than we did even a few years ago. We can anticipate continuing changes in the decades ahead—probably even less glass, metal, and the kinds of paper used for reading and writing, perhaps even more plastic of more types, and more cardboard or whatever other lightweight rigid material comes into use for making stackable, collapsible shipping containers. But given the constraints of materials-handling, change in the technologies for managing most physical commodities since the dawn of the Industrial Revolution has been more limited. Like modern railroad tracks, the purpose of much of the equipment for handling many types of material—whether in primary extraction and production, or in secondary sorting and manipulation for end use—would still be recognizable to the labor force that managed automated industry in its earliest days. Though they may be handling different percentages of different types of materials in 2050, our waste managers are likely to still be using some forms of conveyors (belts or pipes), bag-breakers, screens (drums or flat, vibrating or ballistic), shredders/sizers, air-classifiers, eddy currents and magnets (drum or belt), and densifiers (balers, compactors, crushers, pelletizers). Our forebears wouldn't have recognized optical, laser, or near-infrared scanners that activate material-sorting air jets, but given the basic physical properties of paper, glass, and plastic, it is likely that some form of these contemporary devices will be with us for a long time to come. Robotics, which has been used in other industries for decades, is just now becoming economically viable for recycling applications. It too is likely to find a long-term role as another tool for automated sorting, particularly since it promises to offer "trainable" flexibility that will be useful as the waste stream evolves.

Many of the basic technologies for converting secondary materials into new forms would also be recognizable to our early-industrial ancestors. After we leave the Neolithic technology of landfills behind, we are likely to still be composting and anaerobically digesting

4 E.g., Ferdman, Roberto A., "The slow death of the home-cooked meal," *Washington Post*, 2015-0305.

organics with equipment that (minus its digital control components) would still look familiar. Likewise combustion equipment and gasification processes. Likewise the basic processes for re-melting glass and metal and re-pulping post-consumer fiber.

Market demand is a dependent variable linked to many factors. Among these, along with other phenomena linked to technological possibilities, are the forms of energy in use and the relative prices of this energy. Energy costs, in turn, affect the viability of various transport modes, while market locations determine how materials must be shipped. The relative strength of Chinese demand for fiber, for example, requires that (except for material processed in Staten Island by Pratt Industries), New York's paper is exported by ship in shipping containers. Because European beer and wine are the source of most green glass in the US, Europe is the primary locus of demand for recovered green cullet; this means, given this material's inherent low value, that little of it is remanufactured into bottles: the industry has instead had to develop other markets, such as fiberglass. As the demand for specific materials continues to shift over time, secondary-materials-processing plants will need to continue to adapt to these changes.

SOME CONTEXTUAL PROGNOSTICATIONS

Streets

Though their locations may not change, our streets will be used differently. On-demand livery services, self-driving cars, and shared-ownership systems for cars and bikes will reduce demand for personal vehicle ownership and for on-street parking.[5] A virtuous circle of reduced car trips (starting with the startling percentage of in-city miles driven to find parking spaces or to comply with alternate-side street-cleaning regulations)[6] may lead to an increase in walking and biking. Some types of freight movement too (including the "first-block" movement of waste) may go back to the future—as in the days when pushcarts were a primary means of delivering goods to and from the region's rail yards.[7] Waste collection will become increasingly automated, with real-time routing based on digital monitoring of demand, driverless trucks, and automated or semi-automated pickup or emptying of containers. In combination, these shifts in logistics may have a significant effect in reducing GHG emissions due to waste-collection.

Rail and Tubes

Before inbound freight gets to the last mile and after outbound freight (primarily waste products) gets past the first mile, much of it will be on rail. In some cases, where conditions for pneumatic-tube transport are favorable, even the first and last blocks will be handled by tubes, with pneumatic tubes for outbound waste fractions (as in the case of Roosevelt Island and hundreds of municipal installations in Europe and Asia) and with pneumatic/electromagnetic tubes for inbound goods.[8] These developments, too, will contribute to GHG reductions due to waste-handling.

5 Arcadis, HR&A, Sam Schwartz, *Driverless Future: A Policy Roadmap for City Leaders*, 2017.

6 Shoup, Donald, "Cruising for Parking," *Access* 30:16-22, 2007-Spring.

7 E.g., Braunstein, Leslie, "E-Commerce Retailers Solving for Last Logistical Mile as Projected Sales Top $2 Trillion," *Urban Land Magazine*, 2016-1121.

8 Miller, Benjamin, Juliette Spertus, Camille Kamga, *Eliminating Trucks On Roosevelt Island For The Collection Of Wastes*, University Transportation Research Center, Region 2, 2013, http://www.utrc2.org/sites/default/files/pubs/pneumatic-waste-roosevelt-island-report-Final.pdf; Parasie, Nicholas, "Dubai Aims to Be the Transportation City of Tomorrow," *Wall Street Journal*, 2017-0413, https://www.wsj.com/articles/dubai-aims-to-be-the-transportation-city-of-tomorrow-1492092911.

Local Manufacturing and Agriculture

Though global and national trade will continue to play a major role in the city's life, more products will be produced closer to the source of consumption. And more food will be locally grown, not just in the surrounding region but within the city itself. Advanced manufacturing technologies such as 3-D printing, and advanced agricultural techniques such as vertical and hydroponic farming, may be able to absorb some of the output of the city's secondary-material processing facilities, while artisans fashioning furniture and other objects will also use secondary streams of glass, metal, fiber and other outputs from the city's waste-management system. In some cases—in repurposed shipping/manufacturing/warehouse/loft districts such as the Brooklyn Navy Yard or Industry City, or reclaimed expanses such as Governor's or Riker's Island—artisans and manufacturers and sorting and processing plants will be linked by shared flows of secondary materials and recovered energy. Shortening these closed-loop transport distances will also contribute to GHG reductions.

POLICY RECOMMENDATIONS

Collection Components

It would be logical to begin an outline of suggestions for reducing GHG emissions from New York's waste by addressing waste-prevention. But the most-significant type of waste-reduction measure—the economic incentives associated with Save-As-You-Throw (SAYT) programs, which will catalyze the kinds of innovative techniques and behavioral commitments needed to drive discard rates down[9]—is based on the design of collection systems. Aspects of collection operations are discussed below.

Another logical place to begin a discussion of collection would be inside the building, where the discard is "generated." This issue poses design problems for architects, developers, building managers, and businesses that—at least in New York City—have been all but ignored until now.[10] But since, on the one hand, the design conditions that affect the intricate choreography of waste handling within the building vary widely, while, on the other, the range of options for how the waste materials leave the building for collection on the street are quite narrow—and all of these are discussed below—the waste flows within the "black box" of buildings are beyond the scope of this paper.

One issue concerning the relationship of building design and the flow of outbound wastes does however deserve mention here. It concerns the obvious point that any waste material that ultimately exits the building originated as "pre-consumer" material entering it. Since both directions of flow are equally predictable (in their general form if not in the specific details of types and volumes over time), and since the respective "first-" and "last-" miles that these flows represent are equally subject to the constraints imposed by the range of available transport modes and by the local street network and geography, the design of building features for both flows should be understood as integrally related. The building-level operations for managing both flows should also be designed and managed as peristaltically-

9 The economic incentives felt by consumers will spur "upstream" innovation—as has been widely demonstrated in achieving light-weighting by manufacturers and distributors—as well as "downstream" innovation such as the shared-use arrangements that are increasingly found both in residential buildings and neighborhoods and in workplaces. From a pure operational-logistics perspective, it could be argued that such consumer-directed signals produce the most efficient form of "manufacturer responsibility."

10 This important issue is the subject of a study being conducted under the auspices of the Center for Architecture, with funding from the Rockefeller Foundation. The "Design Guidelines for Zero Waste" consultant team is led by Kiss + Cathcart; ClosedLoops and the Foodprint Group are the other members. A wide range of stakeholders, including City agencies, developers, building managers, and architects, have participated in the project. Many of the collection recommendations that follow were developed by ClosedLoops through this process. https://aiany.aiany.org/index.php?section=press-releases&prrid=346

"To the extent that such collection efficiencies reduce the number of truck trips required and the number of workers per truck (although two workers would probably continue to be necessary on semi-automated toter routes), the OTPS and labor savings could be redeployed in ways that could achieve more-effective diversion of as many material types as possible from landfills."

joined components of the same digestive system—particularly since the volume, timing, and composition of inbound flows would be expected to be directly correlated with those of outbound ones.

Separate Streams

When New York no longer sends its post-consumer materials to landfills for disposal, all of these secondary commodities will be processed to recover materials and energy for productive use. To a significant extent these productive uses—and the value of the products they provide—will depend on the degree of separation of the city's heterogeneous waste stream prior to collection.

At one extreme, the City could roll back the clock and pick up all material in one truck. The truck would compact the materials together, since not compacting would double the GHG emissions and other forms of "friction" by doubling the number of collection trips needed. Unless this compacted heterogeneous material is then processed en masse for energy recovery (e.g., in a mass-burn waste-to-energy or gasification facility, perhaps with magnetic and screen sorting of the residual to recover metal and aggregate)—which would not minimize the GHG emissions associated with its disposal (given the GHG emissions that would be required to use virgin materials in place of those consigned to energy-recovery purposes)[11]—this material would need to be sorted before further processing for material and energy recovery. This sorting could be manual, mechanized, or both. However it is accomplished, the recovered commodities—particularly those made from fiber (paper, cardboard, textiles)—would have a significantly lower market value, because they would have a narrower and lower-value range of end-use options. It would also be harder to find a market for them (in competition with superior materials from other sources) and any markets found would be likely to be farther away, which would further decrease net revenues and increase GHG emissions.

The City's currently planned three-stream program for regularly scheduled curbside collection—recyclables (metal/glass/plastic/paper-cardboard); compostable organics; and refuse (with separate collection of textiles and e-waste on a periodic voluntary basis)[12]—strikes a credible balance between the friction involved in separate truck trips (and the use of space and labor on the part of generators) and the enhanced economics and reduced GHG emissions associated with higher-grade recovered materials. A strong argument could also be made in favor of a two-stream program, in which all "wet" materials (food waste and other organics, including contaminated paper) would be put in one bin and all "dry" materials (metal/glass/plastic, dry paper, cardboard, textiles, and other packaging) would go in the other.[13] In either case, the efficiency of the collection trips is a critical factor in determining whether or not this balance is indeed favorable from a GHG perspective.

As the composition of the City's secondary commodities changes, or as processing technologies or end-use markets change, the categorical delineations of the current three-stream curbside program may need to be adjusted. But they provide a reasonable starting point for present planning purposes. The primary objective of the following recommendations is maximizing collection efficiency.

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11 Mohareb et al., op. cit.

12 In 2017, the three separations mandated by DSNY are metal/glass/plastic, paper/cardboard, refuse, but the City has announced its intention to transition to a three-stream system with these fractions: metal/glass/plastic/paper/cardboard; organics; refuse. This currently envisioned delineation is the one assumed here.

13 No matter how many separations the program requires, certain materials that are designated as hazardous (such as e-waste, medical waste, pharmaceuticals, and pesticides) should not be collected along with the standard fractions.

Containerization with Automation

Plastic bags of refuse and recyclables are now as indelible a part of New York's image as are the Empire State Building and the Brooklyn Bridge. Visitors from other parts of the country and the world are amazed at the towering heaps even on the city's ritziest streets. As well they should be—garbage bags received their first wide-spread use in New York. (The "Glad Bag" became world-famous after McCann Erickson featured "The New York Experiment" in its 1970 television-advertising campaign.)[14] The city also pioneered the widespread use of colored bags for recyclable fractions.[15] Without mid-block alleys, New York's trash bags are more visible than they would be elsewhere, but New York may also be more dependent on naked bags piled on the street—without enclosure in a rigid container—than any other major city.

Semi-automated collection of rolling carts in San Francisco. [SF Environment]

In addition to the obvious problems they produce—they are unsightly causes of congestion for pedestrians; they leak litter, liquid, and odors that repel humans and attract rats; they conceal hazards that can cause injury or death to collection workers—they directly increase GHG emissions in a number of ways. While technology is available to hoist and empty rigid containers, bags must be lifted and slung into rear-load trucks that idle their engines and cycle their compaction blades in the middle of the street, with the workers vulnerably wedged between them and a line of backed-up traffic. While containers for automated collection can be large enough to serve all the businesses in a large building or all the inhabitants of a residential complex, manual rear-loaders need to stop to collect bags in front of every building. While large-scale, sealed, compactor-containers might need to be collected only once a week, bagged refuse needs to be collected multiple times a day or week.

Finding space for large-scale (e.g., 30-40 cubic-yard) compactor-containers is a major issue. Relatively few large buildings have loading docks available for this purpose, or truck-accessible courtyards or other exterior private space. But many buildings have space to support smaller wheeled containers (e.g., 1-8 cys). As in the case of buildings capable of using larger-scale equipment, their building managers could also benefit from the avoided labor costs of multiple handlings of bags and recover space that would otherwise be used for intermediate storage. And most buildings could adapt to the use of smaller (e.g., 32-96-gallon) wheeled toters.

There are also a variety of actions the City could take to reduce GHG through expanded containerized collection, while also achieving municipal savings due to decreased truck trips and lowering the rate of worker injuries. Some of these are discussed below.

14 Bird, David, "Cans That Go Clang in the Night May Yield to Paper and Plastic," *New York Times*, 1970-1212, p. 35.

15 City of New York, Department of Sanitation, *Comprehensive Long-Term Solid-Waste-Management Plan and Generic Environmental Impact Statement*, 1992-12.

Battery Park City porters delivering refuse to be tipped into shared roll-on/roll-off compactor [Carl Glassman/Tribeca Tribune]

Aggregated Collection

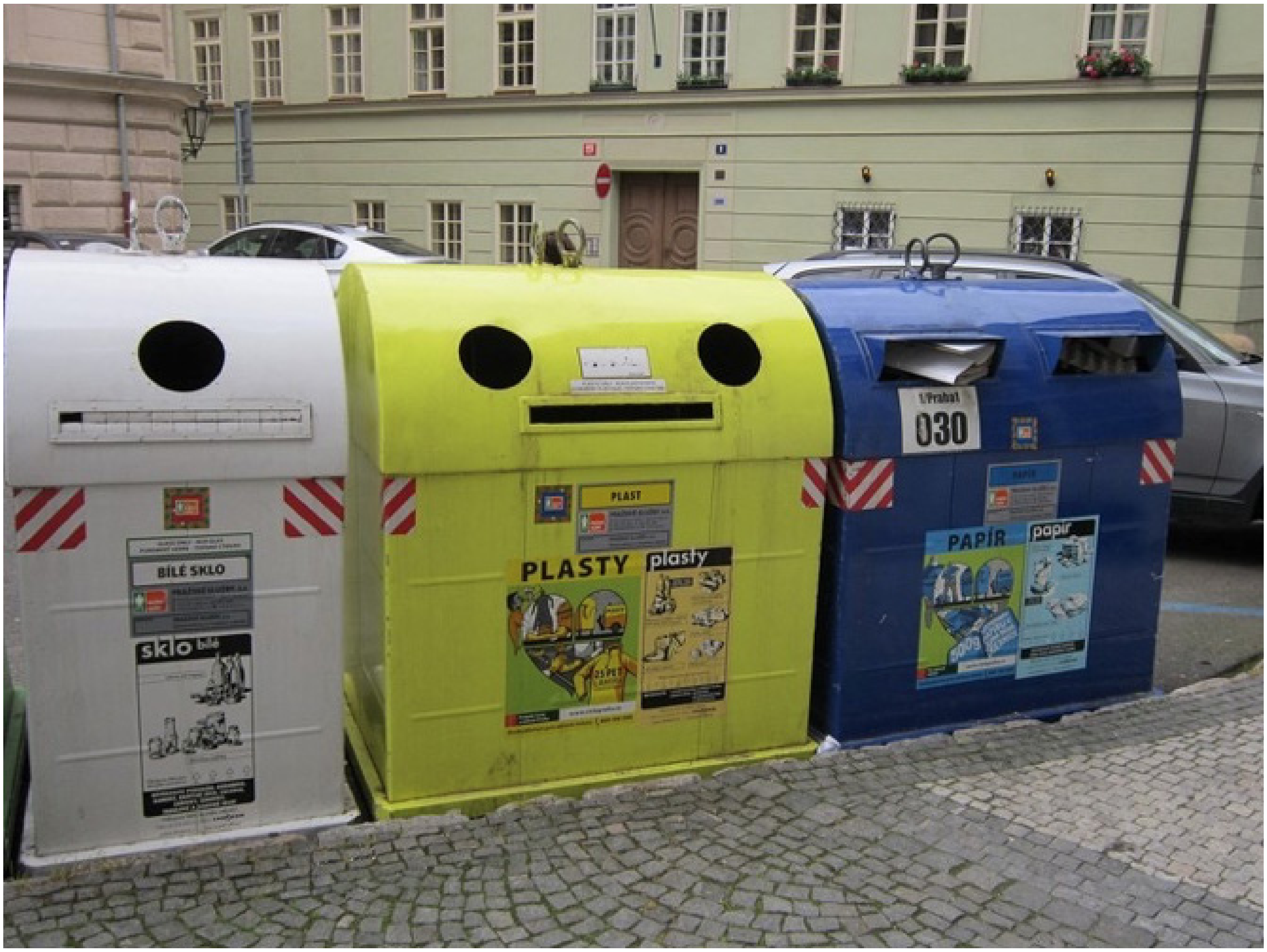
Existing buildings with adequate loading-dock space could be offered tax or other incentives to share access to their compacting containers with adjacent buildings—as four of the high-rises in Battery Park City do for the thirteen other buildings in that complex (thanks to the requirements of their NYS property leases). Planned buildings could be incentivized with floor-area-ratio credits or simply required to create such shared waste-logistics access.

In the case of neighboring buildings where none of them has either an available loading dock or exterior space in a courtyard or elsewhere, the shared container could be placed somewhere in the public realm (street, sidewalk, or other public space) where it would not interfere with emergency vehicles or otherwise conflict with necessary or desirable street uses. The widespread use of former parking spaces and other repurposed public space for Citi Bike stanchions demonstrates the feasibility of such arrangements. This type of shared collection could be used for all three separate fractions that New York's current waste-management plans envision.

The building staff in large multi-family buildings who currently manage waste set out by piling bags at the curb could instead roll the bags to the neighborhood compactors in large, tippable carts.

Litter bins in areas maintained by Business Improvement Districts and other forms of local associations could also be managed in this way. Staff who are currently deployed simply to bag litter-bin waste and stage it in piles for pickup by the Department of Sanitation could instead roll carts of bagged waste to centralized compactors so that trash bags would never be heaped on the street awaiting pickup.
In areas where a large-scale container is not practicable, mid-size (EZ Pack) containers could be rolled between the building and a pickup location at the curb if an accessible pickup space in a loading dock or on the lot is not available. In areas or in buildings where the largest practicable container is a toter, toters could be rolled to the curb or other designated set-out area prior to pickup and then returned to the building they serve.

In order to provide collection access for toters, the City's parking regulations or street designs may need to be altered, so that a line of parked cars does not prevent direct access between the toters and semi-automated collection trucks. It is possible that direct truck-toter access could be achieved simply by rolling the toters to the curb during the time-windows currently devoted to alternate-side parking. Alternatively, a space the size of a car-length (or two) could be reserved in front of each major building, or in the middle of each block front.



Shared drop-off containers for specific secondary commodities are common in Europe [Max Pixel, freegreatpictures.com]

Designed Use of Public Space

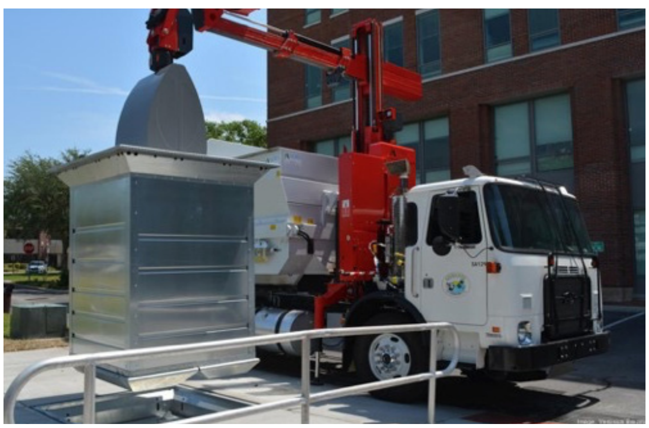
Other types of containers designed to be part of the public realm could be used either by building staff or by passing residents for the source-separated deposit of smaller-volume fractions. These might include such items as textiles and e-waste that a typical generator does not discard on a daily basis. These materials would be placed in material-specific enclosed bins or kiosks that also would be collected with automated trucks. The kiosks could be equipped with wireless connections to capacity sensors to secure just-in-time pickups. These would reduce GHG emissions by eliminating inefficient truck trips for less-than-full containers.

Imaginatively-designed uses of the public realm for fixed waste-management equipment[16] could significantly enhance the city's public spaces. These new streetscape uses could be integrated with other design changes to meet other needs, such as providing public social space, street trees and plantings that promote cooling and water-runoff, and kiosks offering information, entertainment, wireless access, and lighting.

16 "Fixed" is used in distinction to the ad hoc use of street and sidewalk space that—since it involves only part of every day or every week—is considered "temporary" rather than "permanent." Only "permanent" installations are currently subject to planning or design by the City agencies responsible for managing streets.

Submerged Containers

One way that aggregated automated collection equipment might be integrated into the design of the streetscape is by submerging the container. Where underground conditions make their installation practicable, they can offer a range of advantages over above-ground receptacles. Submerged container equipment is available from a number of manufacturers and is used in dozens of European and North American cities. The containers of various types are hoisted from the ground by a truck-borne crane, swung over the loading compartment on the back of the same truck, and an opening at the bottom of the container released so that its contents drop into the truck. The bottom of the container is then reclosed and the crane sets it back in the ground.



Submerged container being emptied. Kissimmee, Florida [Veronica Brezina, Orlando Business Journal]

Centralized Ownership of Pooled Containers

Ideally—especially in the case of the roll-on/roll-off containers that are picked up and transported to dump sites one at a time and then carried back empty to the generator site—a pooling system would be used so that there would no longer be any need for two round trips for each pickup. Instead, the truck would always arrive at a pickup site with an empty container with which to replace the full container it was picking up. The containers would be owned and leased by a central entity—just as most U.S. rail cars, for the same reasons of transport efficiency, are now owned by the railroads' shared entity, TTX, or most trailer chassis that service the nation's ports are centrally owned. While such an arrangement would require more space for maneuvering and would somewhat increase handling time at the pickup/drop-off site, it would cut truck miles and GHG emissions nearly in half.[17]

Redeploy Manpower to Advance Diversion of a Wider Range of Materials

To the extent that such collection efficiencies reduce the number of truck trips required and the number of workers per truck (although two workers would probably continue to be necessary on semi-automated toter routes), the OTPS and labor savings could be redeployed in ways that could achieve more-effective diversion of as many material types as possible from landfills. The avoided truck and fuel costs could be used to provide well-designed containers and automated collection vehicles, while the labor could be used to manage and maintain these new forms of additional containers and for the additional truck trips required to collect these new source-separated streams.

Pneumatic Collection

As the *Roadmap* points out, a sub-category of automated aggregated collection that may be practicable and provide GHG reduction and other benefits in appropriate situations is collection of multiple waste fractions via

1 Pneumatic Tube; **2** Inlet for Food Waste; **3** Inlet for Recycling; **4** Inlet for Refuse; **5** Pneumatic Tube for Restaurant Food Waste; **6** Micro Anaerobic Digestor

Pneumatic collection concept proposed for High Line viaduct [ClosedLoops, Image by Colin Curley]

pneumatic tubes equipped with separate inlets for different material types.[18] Hundreds of these systems have been installed over the past half-century in Europe and Asia. One of these is on Roosevelt Island. (Because it was installed in 1975, prior to the introduction of municipal recycling in NYC, it handles only one fraction—refuse.) ClosedLoops is engaged in preliminary planning for a pneumatic system proposed for the corridor adjacent to the High Line Park on Manhattan's Far West Side.[19] Additional pneumatic retrofit facilities could be installed, without tunneling, in a range of other New York neighborhoods, while greenfield pneumatic systems (such as Roosevelt Island's, or the one proposed for Hudson Yards) would be appropriate for many large or campus-scale new developments.

On-Site Management

Organics are the waste component for which on-site processing and on-site use of recovered products is most likely to be practicable in a given situation. While it is possible—because of economies of scale, GHG emission rates relative to other technologies, energy-conversion efficiencies, or other case-specific factors—that an on-site solution might not achieve the most favorable overall cost-benefits, there are clear advantages to eliminating the need for collection and off-site transport of waste and the delivery of inbound secondary products.

On-site composting in backyards and residential complexes, and drop-off composting programs in parks and schools, are already being used to divert waste from landfills and to provide soil amendments for local use without generating truck trips. But it is also possible to recover energy as well as fertilizer ingredients

18 City of New York, Mayor's Office of Operations, op. cit., pp. 100-1, 103; Miller, Benjamin, Juliette Spertus, Camille Kamga, "Costs and benefits of pneumatic collection in three specific New York City cases," *Waste Management*, 34:11:1957-66, 2014-11, http://www.sciencedirect.com/science/article/pii/S0956053X14002645.

19 Rosengren, Cole, "Below the High Line: How pneumatic tubes could alter the future of urban waste collection," *Smart Cities Dive*, 2017-0406, http://www.smartcitiesdive.com/news/below-the-high-line-how-pneumatic-tubes-could-alter-the-future-of-urban-wa/439922/.

on-site through anaerobic digestion. As the *Roadmap* points out, small-scale technology for managing relatively uncontaminated food-waste streams, which is suitable for urban applications, is now becoming available.[20]

One such facility is being developed in a large building in downtown Manhattan, and, working with NYC EDC, ClosedLoops is proposing another digester of this type to serve high-volume food-waste generators in the vicinity of the High Line corridor.[21] By 2050, modular digesters could be expected to play a useful role in many large-scale developments or adjacent to relatively dense agglomerations of food-waste generators across the city.

The Waste-Collection Hierarchy

Just as waste-managers have long followed a "waste-management hierarchy" (prevention/re-use/recycling/biological energy recovery/thermal energy recovery/landfilling), they should also follow the "waste-collection" hierarchy to the extent that site-specific circumstances allow. The elements of the hierarchy are described above.

For refuse and large-volume recyclable streams:

- Aggregated automated containerized collection, with manual carting or pedestrian drop-off used as necessary to access shared inlets (and/or, in appropriate situations, with pneumatic collection)
  - First priority: large-scale containers, preferably with compaction (one per standard roll-on/roll-off truck, e.g., 30-cubic yard compactors);
  - Second priority: mid-scale containers (tipped over the cab or into the back), preferably connected to on-site compactors (e.g., 2-to-8 cy EZ Pack-size containers);
  - Third priority, covered, wheeled toters, the larger the better (e.g., 32-to-96 gallons) that would be picked up by side- or rear-loading arms.

For small-volume recyclable streams (such as textiles, e-waste):

- Aggregated drop-off into containerized kiosks/receptacles for automated collection

For organics:

- On-site management
- Semi-automated collection of sealed containers (to the extent practicable, the larger the better)

Save-As-You-Throw

The City has already taken initial steps toward developing a Save-As-You-Throw (SAYT) system, which global experience suggests is the most significant single initiative it could take to reduce volumes destined for landfills.[22] Instead of simply sticking tags on garbage bags (or implementing some functionally equivalent system), the City's SAYT program should be designed to effect operational changes that would send an economic signal to the generator while also accomplishing the other objectives discussed above. One way to do this would be to accompany the introduction of SAYT with a shift to containers. This would not only facilitate the identification-and-measurement tasks required by SAYT but also achieve GHG savings through some of the other means mentioned above.

Using a SAYT system that relies on bags or tags—objects that are disposed of with each collection and must therefore be continuously

20 City of New York, Mayor's Office of Operations, op. cit., pp. 61, 101-3, 108.

21 Rosengren, op. cit.

22 E.g., Lisauskas, Stephen, Pay-as-You-Throw and the Power of Incentives for Solid Waste Reduction, 2015-0609, http://www.nrra.net/wp-content/uploads/Lisauskas-WasteZero-NRRA-Presentation.pdf

produced and distributed and sold and monitored—is more logistically cumbersome than a system that relies on relatively fixed parameters such as the assignment of a specified number of containers of specified size to particular generators. And variable container use (numbers of set-outs by container size, weight within containers) can be more readily measured by automated systems such as RFID readers and automated scales. RFID and other digital tracking devices could also be used to associate material volumes deposited into shared-collection equipment with specific generators.

Exclusive Franchise Zones

The City is already committed to developing exclusive franchise zones for collecting commercial waste. These should have a significant effect on reducing the number of miles traveled by waste-collection vehicles, which (for a number of reasons) are the most energy-intensive, GHG-emitting type of truck on our streets.[23] With optimal design, the beneficial impacts of zoned collection would be greater than those due to merely requiring that only one hauler serve a designated area using collection equipment that meets specified energy and emissions criteria. Ideally, the system would also

A. require that all businesses within a given building (or block) receive pickups at the same time of day;[24]
B. use containerized collection of the largest practicable container size, with compaction in the container whenever feasible, with shared access to these containers between businesses and/or between buildings whenever practicable;
   a. to the extent that it may be necessary for the development of such shared-collection arrangements, the City should provide public space on streets or sidewalks if no private space is available—or provide such other public incentives or requirements as may be necessary to foster such opportunities;
C. require the use of optimally located origins and destinations for the collection trucks in a given zone, so that the negative impacts due to the siting of garages and first-dump facilities are minimized;
   a. to the extent that such optimal sites are under City control, these sites should be made available for that purpose;
   b. to the extent that such sites are under private control, the City should provide whatever support it can offer which is consistent with other public objectives to secure any permitting or regulatory approvals that are needed to use the site for these purposes;
D. encompass collection of all waste materials, whether generated by commercial or non-commercial sources, with one collection route per fraction—rather than perpetuating the current inefficient dividing line between public and private collections as is currently envisioned by the City's zone-system planners. (A logical first step in this direction would be to use combined collection for the smallest source-separated fractions, e.g., textiles and e-waste, since the low volumes involved would offer the greatest advantages in efficiency over bifurcated collection.)

23 Miller, Benjamin, Juliette Spertus, *Trucks, Trains, Tugs, and Tubes: A Model for More-Efficient Collection and Transfer of Solid Waste, the Predominant Form of First-Mile Urban Freight*, MetroFreight Volvo Center of Excellence, 2015-06, p. 2.

24 If operational requirements (e.g., volume or waste characteristics, or access issues) necessitated more than once-a-day collection to a given building or block, the additional pick-ups should be coordinated between all businesses to keep the number to the minimum practicable.

MANAGEMENT FACILITIES

Conceptual Design: Modular, Scalable, Able to Be Disassembled and Reassembled

When all of New York's secondary commodities are delivered in three major fractions (recyclables, organics, refuse) and multiple minor fractions (textiles, e-waste, and other specific commodity types) to various locations to begin their transition to becoming new products or useful forms of energy, the single most important planning criteria—from a long-term perspective—will be the locations of these first-destination facilities. The composition of the secondary commodities, the technologies for processing them, and their end-use markets will all change. The only constant—because of the stringent and relatively immutable geographic constraints that determine the suitability of the relatively small number of locations that are appropriate for the purposes required—will be the sites where these materials are tipped, pre-processed, transferred for transport (if necessary) to other secondary processing, manufacturing, or energy conversion locations, or used on-site in manufacturing or energy-conversion processes.

Once they are secured (if they are not already under the City's control or that of an accommodating private entity willing to grant long-term access), the development of these sites should be designed to accommodate changing configurations of technologies capable of handling changing mixtures of secondary commodities for changing end-uses.

Though the configurations of the processing trains will vary over time, there will be a consistent pattern to which the process logic will conform. Materials will be delivered; they will move through a series of handling procedures that will separate them into further fractions; the outputs from these sorting processes will be directed to further transfer or processing destinations either on- or off-site; and varying material and energy products derived from the respective processing lines for the three fractions will be aggregated downstream as individual types of commodities, residues for energy conversion, or forms of energy.

The three major fractions may be delivered to the same location or to separate locations. A single location for managing all three streams would be the preferred alternative if site size and configuration allow, since this could allow more-efficient collection via two-compartment trucks[25] or other efficiency-enhancing equipment and facilitate the exchange of materials and residues between process lines and the combined transport of materials and residues off-site.

Whether or not all three fractions are managed at the same location, the process logic for their respective equipment trains would be similar, for two reasons. First, the three fractions of specified material types as delivered will contain portions of non-designated materials: that is, there is likely to be a significant overlap between the three sets. Second, there will be a significant overlap between the types of equipment used for sorting and pre-processing these respective materials and in converting them into new products or forms of energy.

25 Two-compartment trucks are rear-load compactors whose bodies are split longitudinally to allow two waste fractions to be collected and separately compacted in one truck trip. (They were first-used in New York City. City of New York, DSNY, op. cit.)

Except in the case of organics (which will not be compacted before or during transport), most of the material will arrive in compacted containers or compactor trucks. The processing train for each of the three fractions will begin with the material being dumped from the collection truck onto an enclosed tipping floor or directly into some form of trough or hopper. From there it will proceed through a series of bag-openers and screening and classification devices suited to the incoming stream and the materials targeted for marketing or end-use. Size-reduction or pulverization will be used for the organic stream, for particular commodities from the other streams (the "refuse" stream itself will be sorted into the three basic fractions—recyclables, organics, and residuals), and for the "residuals" stream (the material that has been negatively selected as the end result of all three process trains).

The (non-residual) outputs from the recycling train will be relatively pure volumes of designated commodity types meeting certain specifications. These will either be densified (by baling or crushing or shredding) or processed for further use on-site through means such as washing, melting, pulping, or depolymerization. Depending on whether there are also end-use manufacturing or artisanal facilities at or near that location, these materials may then be further processed into products for end-use. The residuals from this process may be further separated into separate streams targeted for different purposes, with the organics perhaps designated for biological conversion into energy and/or soil amendments, the inert aggregates for some sort of construction or utility use, and the remaining materials for waste-to-energy incineration, gasification, pyrolysis, enzymatic conversion, or some other energy-recovery technique, after which any remaining inert residue would be processed as aggregate for construction or utility purposes.

The (non-residual) outputs from the organics train would either be processed on-site, probably in some form of anaerobic-digestion facility, but perhaps in another type of conversion facility using pyrolysis, gasification, or enzymes, or transported off-site for energy-recovery elsewhere. (Composting is not likely to be used except in local, on-site applications not requiring collection and intermediate transport, since the net GHG impacts could be greater, while the net economic costs would likely exceed those of alternative options.) If the pre-processed material is transported off-site, it is likely to be in the form of a thick slurry capable of being pumped to and from a tanker truck, railroad tank car, or covered barge. Since the greatest amount of anaerobic-digestion capacity in the region may continue to be the wastewater treatment plants (WWTPs) sited along the region's waterways, it is highly likely that barges will provide the most GHG-efficient and cost-effective form of transport between the first-tip site and the AD plant. (The fact that barges offer the inherent advantage of water-cooling would increase their relative utility over trucks and trains.)

The residual output of the refuse train would be directed to some form of energy recovery facility either on- or off-site. If the recovery facility is on-site, its products (steam, electricity, liquid or gaseous fuel, by-product heat) may be used to power other processing or manufacturing lines at that location. It would otherwise be shipped by barge, train, or truck to an off-site energy facility. Since this pre-processed residual material would be a form of refuse-derived fuel, it should find off-site markets at existing power plants, cement kilns, and other utility or manufacturing facilities. The positively sorted recyclable commodities would be combined with those coming from the other material-processing trains, as would the positively sorted organics. Positively sorted inert aggregates would be combined with those from the other process trains and with the aggregate and slag from any on-site energy-recovery process.

Individual system components for conveying, sorting/classifying, sizing, densifying, cleaning, and converting various mixtures and types of material for various end-purposes would be used in various sequences and combinations for various streams at various times, with specific components replaced as technologies advance.

The buildings themselves should be designed to be adaptable over time, and disassembled and reassembled as necessary for changing waste-processing requirements.

In cases where site size and configuration—and the site's relation to adjacent populations—allow, downstream end-users of secondary materials and recovered energy could co-locate their manufacturing and craft facilities on-site. These users may also include agricultural producers using advanced, high-efficiency techniques such as hydroponics and vertical farming. Through aquaculture, insect farming, or other forms of husbandry it may also be possible to grow other kinds of protein from the processed organic outputs.

Siting

It would be considerably easier to find sites suitable for the City's waste-management purposes within an hour's transport distance from New York, but some such sites could be found within the city. The majority of them may already be owned by the City.

Among the best prospective sites for these purposes—although their footprints will generally be too constrained to allow more than one fraction to be tipped at a single site—are the City's network of current marine transfer stations, including, as possible, any potential assemblages of adjacent upland.[26] These facilities are well-sited to connect wastesheds of significant size with barge transport to secondary treatment facilities, such as WWTPs that could digest processed organic slurry.

Also ideally suited are the waste-to-rail facilities that the City will no longer need for shipping waste to landfills hundreds of miles away. Advances in rail-freight-handling technology will allow driverless short-haul trains to shuttle materials between primary and secondary processing sites or to more-remote end-users, and car-moving technology will allow efficient on-site shifting of materials. These movements will produce lower GHG emissions than trucks will be able to achieve. The City's Staten Island rail-transfer site, in particular, offers a large footprint that could be repurposed for multiple interconnected uses.

The City's network of abandoned incinerator sites provides other siting possibilities. There were fourteen incinerators in operation prior to the mid-1970s. Each served an adjacent

> "Among the best prospective sites for these purposes...are the City's network of current marine transfer stations..."

wasteshed of significant size and had reasonable roadway access; some also had barge access and were adjacent to marine transfer facilities. Some were—and remain—connected to Sanitation garages, which significantly increases their GHG-reducing advantages, since they would eliminate intermediate trips between first-dump sites and garages (as they were initially designed to do).

Other site opportunities may be on or adjacent to the City's former landfills. Floyd Bennett Field, next to the former Barren Island landfill and secondary-commodity processing facilities,[27] has space controlled by the City that is not used for park purposes and could be put to such use. Certain areas at the former Fresh Kills landfill where there are disused buildings and piers might also be repurposed.

The rail transfer stations currently used by private carters for shipping wastes on behalf of the City and the truck transfer stations they use for the commercial materials they collect could also serve these first-dump purposes when there is no longer a demand for remote export to landfills.

A site that could offer a wide range of opportunities as a first-dump location is Rikers Island after it is no longer used for jail facilities. Because of its unique assets as a blank canvas for development, buffered from adjacent populations but with direct road and barge access and a location near the geographic center of the city, many alternative uses will continue to be proposed for it. But with 415 acres and over three miles of shorefront it could accommodate a wide variety of compatible activities.

All of the first-dump sites that are eventually developed should be used by either municipal forces or private companies—depending on who is responsible for managing wastes from the adjacent wasteshed at any point in time—so that, in the event of private operations, no company has a monopoly or significant advantage over its competitors through access to a prime site, and so that the most economically and environmentally favorable location is used. To the extent that the City will rely on the private sector to develop new first-dump facilities through competitive procurement, the City and State should make available to the bidders the use of parcels in their respective inventories, not only to enhance the degree of useful competition but to optimize siting from a transport-distance/GHG-emissions perspective.

> "The locations of past and present waste-management facilities—garages, transfer stations, processing plants—are of paramount importance in designing a low-friction system."

27 For an account of Barren Island's role as the historical epicenter of New York's waste-management operations, see Benjamin Miller, *Fat of the Land, New York's Waste: The Last Two Hundred Years*, NY: Basic Books, 2000.

NEXT STEPS AND TOP PRIORITIES

1. Organics Processing Capacity

This fraction deserves highest-priority attention because it is the City's newest diversion target, one with which the City has had no prior management experience as a separate stream, and the City's cart is currently ahead of its horse. While it is rushing to expand its organics collection program, generating large numbers of truck trips and miles to pick up relatively small volumes of material, it does not yet have in place an adequate amount of processing capacity that is within an efficient transport distance.

The City's highest priority should therefore be securing this capacity. A number of alternative approaches should be explored simultaneously.

It is highly unlikely that there will ever be enough on-site processing capacity, either with local composting or micro-anaerobic digestion, to handle the City's overall organics volumes. Nonetheless, since such facilities are inherently small-scale and adapted to local conditions, they are eminently suited to pilot demonstrations in various types of locations. The City should encourage such installations by means such as financial support, expedited permitting, and access to City-owned sites.

It seems very likely that a significant portion of the City's demand for organics-processing capacity will be met by co-digestion at WWTPs that are either City-owned or are on waterfront locations in nearby jurisdictions along the Hudson, the Harbor, the Sound, or the southern shore of Long Island. The most efficient system for accessing such facilities, from a GHG and cost perspective, is likely to be by barge delivery of a pre-processed slurry, with the pre-processing occurring at a transfer point within the City. The City's current marine transfer stations, which will no longer be used for shipping refuse a few miles to a rail-transfer facility for long-distance transport to distant landfills, would be ideally suited to this purpose—and it may well be possible to adapt them for such use in the near-term while they are still being used for their current refuse mission. Steps to advance in this direction should be taken immediately, along with steps to secure access to as much WWTP capacity within and outside the city as may be appropriate.

To the extent these two options do not provide enough capacity for all of the city's needs, new, relatively large-scale facilities will need to be developed. It is most likely that these will be anaerobic digesters. The development of such facilities will require that the City be willing to provide the long-term supply commitments that their financing will require. The City could also encourage their development by providing access to appropriate City-owned sites or by expediting the permitting and review processes that would be required for such facilities on a private site. It is possible that a marine transfer site could be used for anaerobic digestion rather than simply as a pre-processing site, or that an anaerobic digester could be installed in conjunction with the management of other waste fractions at another first-dump site the City may develop.

2. Collection

The 21st-century systems described above will require changes in the way our streets, sidewalks, and other public spaces are managed. These responsibilities fall well beyond the purview of any one agency. To develop a well-designed set of arrangements for maximizing the utility and aesthetic and social benefits of this public realm, the efforts of a mayoral task force comprised of all the involved departments will be required. This task force will need to work in close coordination with representatives of all relevant public stakeholder interests.

As in the case of on-site organics processing, where the small scale and inherent need for customized adaptation to local circumstances make it not only relatively easy but highly desirable to implement near-term pilot projects, the variety of conditions in the city's public realm, the range of potential alternatives available, and the relatively small-scale at which it would be possible to design useful demonstration initiatives all support the case for fast-tracking some such pilots as well.

2050 is only a few decades away: this mayoral inter-agency task force will need to begin work immediately!

3. Siting

Unfortunately, along with other invaluable parcels given up over the past couple of decades by other agencies, some of the Sanitation Department's strategic assets have also been lost. But many still remain under its control. Their use-value for the range of first-dump purposes described above should be assessed immediately, and concrete steps taken to advance the pursuit of any opportunities identified.

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