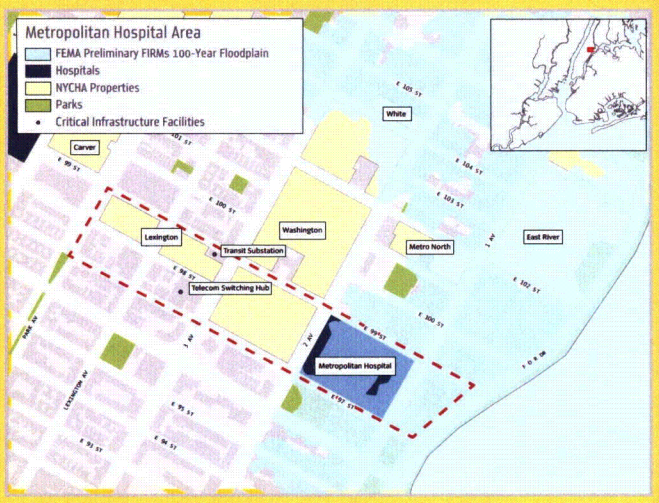
The Role of Microgrids

Microgrids, or neighborhood-scale networks of shared DG resources, have the potential to provide both resiliency benefits and reduce emissions, but have very few precedents in New York City. After Hurricane Sandy, while lower Manhattan was without power, a cluster of New York University buildings was powered by a 6 MW cogeneration system serving the campus.

At Hudson Yards, the development team of Related Companies and Oxford Properties Group are planning a large 12 MW cogeneration plant, which will generate power at twice the efficiency of a conventional natural gas power plant and enable "functional occupancy" of its retail, restaurant and office complex during even an extended grid outage. The complex is thermally connected to the developments' other 3 residential and office buildings to enable the distribution of thermal energy from the cogeneration plant throughout the mixed use neighborhood and the exchange of hot and chilled water so that the development's 5 individual building plants can be operated like a single plant for optimum energy and operational efficiency as well as maximum capacity and resiliency.

Microgrids that connect multiple customers are a promising new concept that could be applied elsewhere in the city, offering an opportunity to innovate alternative power generation and delivery models while accelerating adoption of smart grid technologies that are key to modernizing the electric grid. The City has several projects underway to study the implementation of microgrids, working closely with New York State, the Pace Energy and Climate Center, the New York State Smart Grid Consortium, and Con Edison to evaluate optimal technologies and business models for microgrids. This collaborative is currently analyzing the feasibility of a microgrid cluster in East Harlem that would serve both the Metropolitan Hospital and the Washington and Lexington NYCHA facilities, and possibly others.

The City is also evaluating distributed power options for the Hunts Point Food Distribution Center in the Bronx, a critical location for the city's food supply. Ensuring continuous power will limit supply chain disruptions by enabling uninterrupted facility operation and the maintenance of refrigerated storage capacity in the Meat, Fish, and Produce Markets. These options include cogeneration and trigeneration systems (generating electricity, heating, and cooling), the procurement and installation of backup generators, and the protection or elevation of existing utility infrastructure.



Source: NYC Mayor's Office

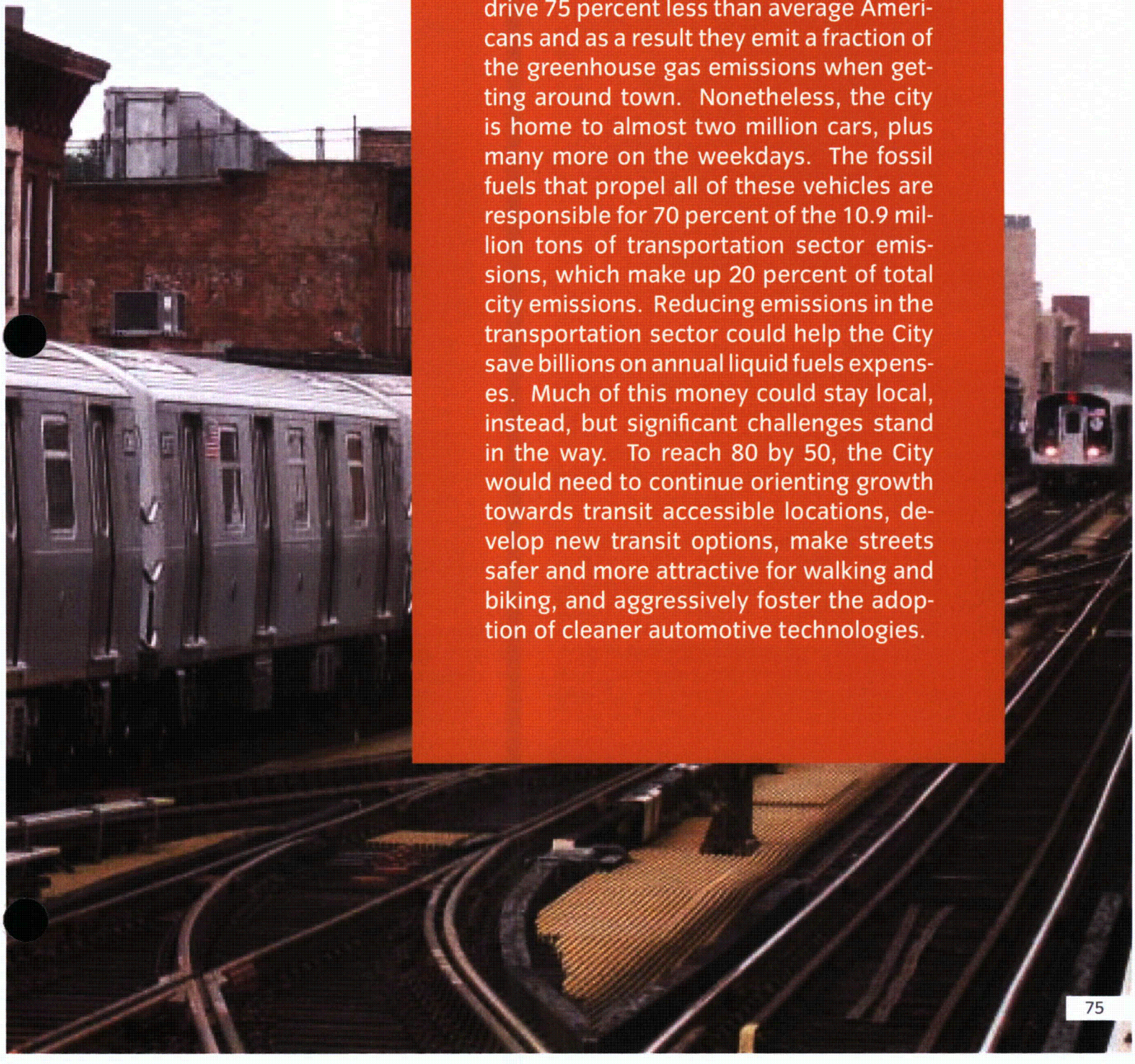
Source: NYC Mayor's Office

Credit: Adam E. Moreira

R160 M train entering Hewes Street, bound for Middle Village

Transportation

New York City has the most efficient transportation sector in the country because of its extensive mass transit system and dense urban environment. New Yorkers drive 75 percent less than average Americans and as a result they emit a fraction of the greenhouse gas emissions when getting around town. Nonetheless, the city is home to almost two million cars, plus many more on the weekdays. The fossil fuels that propel all of these vehicles are responsible for 70 percent of the 10.9 million tons of transportation sector emissions, which make up 20 percent of total city emissions. Reducing emissions in the transportation sector could help the City save billions on annual liquid fuels expenses. Much of this money could stay local, instead, but significant challenges stand in the way. To reach 80 by 50, the City would need to continue orienting growth towards transit accessible locations, develop new transit options, make streets safer and more attractive for walking and biking, and aggressively foster the adoption of cleaner automotive technologies.



Overview

Cyclist utilizing the Dekalb Ave Bike lanes, Brooklyn

In a city of endless destinations, New Yorkers are always on the move. Subways run round the clock, stretching from Rockaway Beach to Van Cortlandt Park. Federal and state highways are overlaid on a dense grid of busy local streets. A necklace of new ferry terminals and bike paths adorn the city's waterfront. Bustling international airports connect the city to every major destination in the world.

With the exception of walking and biking, all of this movement requires energy — and 99 percent of this energy originates from fossil fuels. All told, the city's transportation system is responsible for 11 million tons of emissions every year, or 20 percent of the city's total emissions. On a per capita basis, this compares well to other cities. Still, the potential exists to reduce transportation emissions further. More New Yorkers, particularly the newest arrivals, could live in dense, mixed-use, transit-rich neighborhoods; new transportation options like bus rapid transit and bicycling could reduce the need for driving; and, most significantly, vehicles on the streets could be far cleaner.

Several major challenges will make it difficult to reduce emissions in the transportation sector. Parts of the city are simply out of reach of mass transit, leaving residents with few options other than to drive. City streets are often better suited for cars and unwelcoming to pedestrians and bicyclists—although the City has made major improvements in recent years. Biofuels and electric vehicles offer great potential for reducing emissions, but demand growth for these new technologies is very gradual. Individuals do not consider the health and economic impacts of traffic congestion—nor do they have a price signal to do so—when they decide to drive. Finally, the City has only limited ability to influence the transportation system, which numerous other entities, public and private, play a role in operating.

City government and its partners nevertheless have tools that can be used to accelerate carbon reductions and put the city onto a lower-carbon pathway. The City is already using some of these tools to advance the goals of PlaNYC and can expand these efforts. Zoning and land use planning can encourage density and mixed-use development in parts of the city that are most accessible to transit. The City can work with the State to improve mass transit service, including expanding the Select Bus Service program that is now serving all five boroughs. The City can expand efforts to make streets safer for walking and biking. And it can foster cleaner transportation technologies like electric vehicles and biodiesel through pilots, purchasing in the City fleet, and early infrastructure development. These efforts will not only help to reduce carbon, but also improve quality of life, clean the air, and make the economy more competitive.

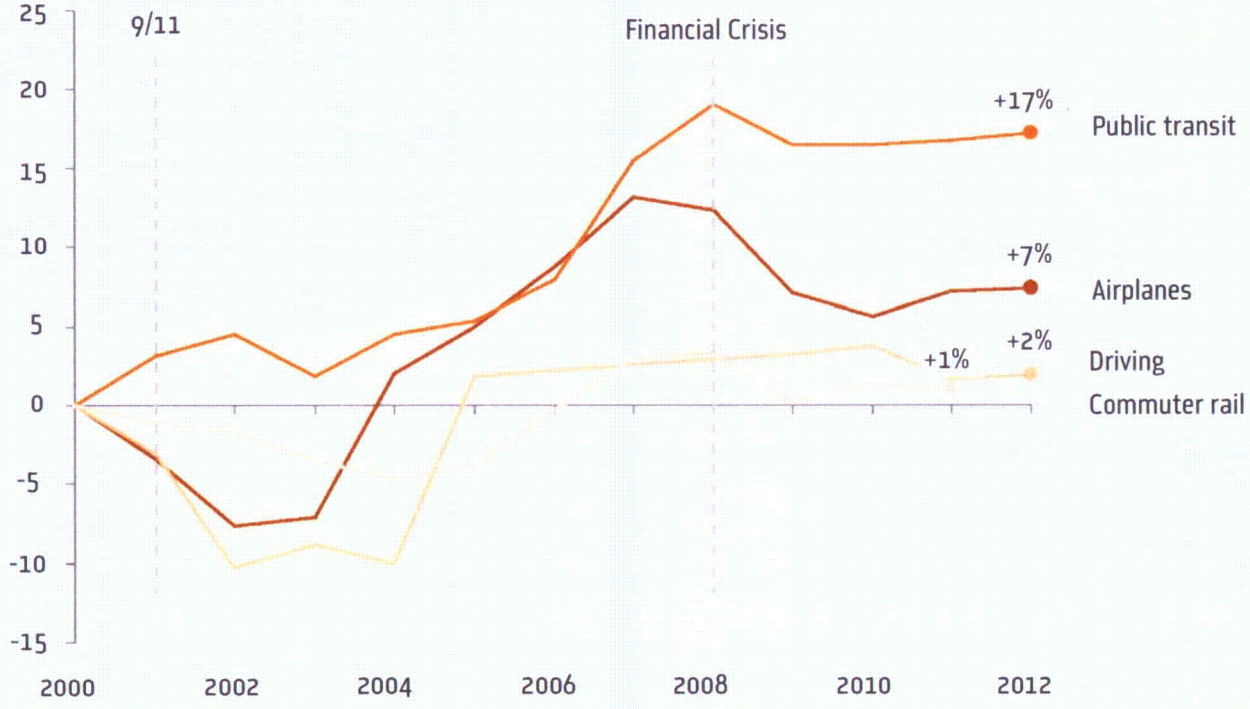
Transportation Fundamentals

The city's transportation system is a dazzling mix of activity, and New Yorkers place upon it high demands for service and reliability. From the city's extensive network of mass transit—rail, subways, buses, and ferries—to its crisscrossing streetscapes that accommodate cars, bikes and pedestrians moving in every direction. Daily commuters, business travelers and tourists are also growing in record numbers and accentuate demand on the transportation system. In fact, on Thursday, October 24, 2013, New York City's subways hit an all-time high for ridership, just shy of 6 million rides in a single day.

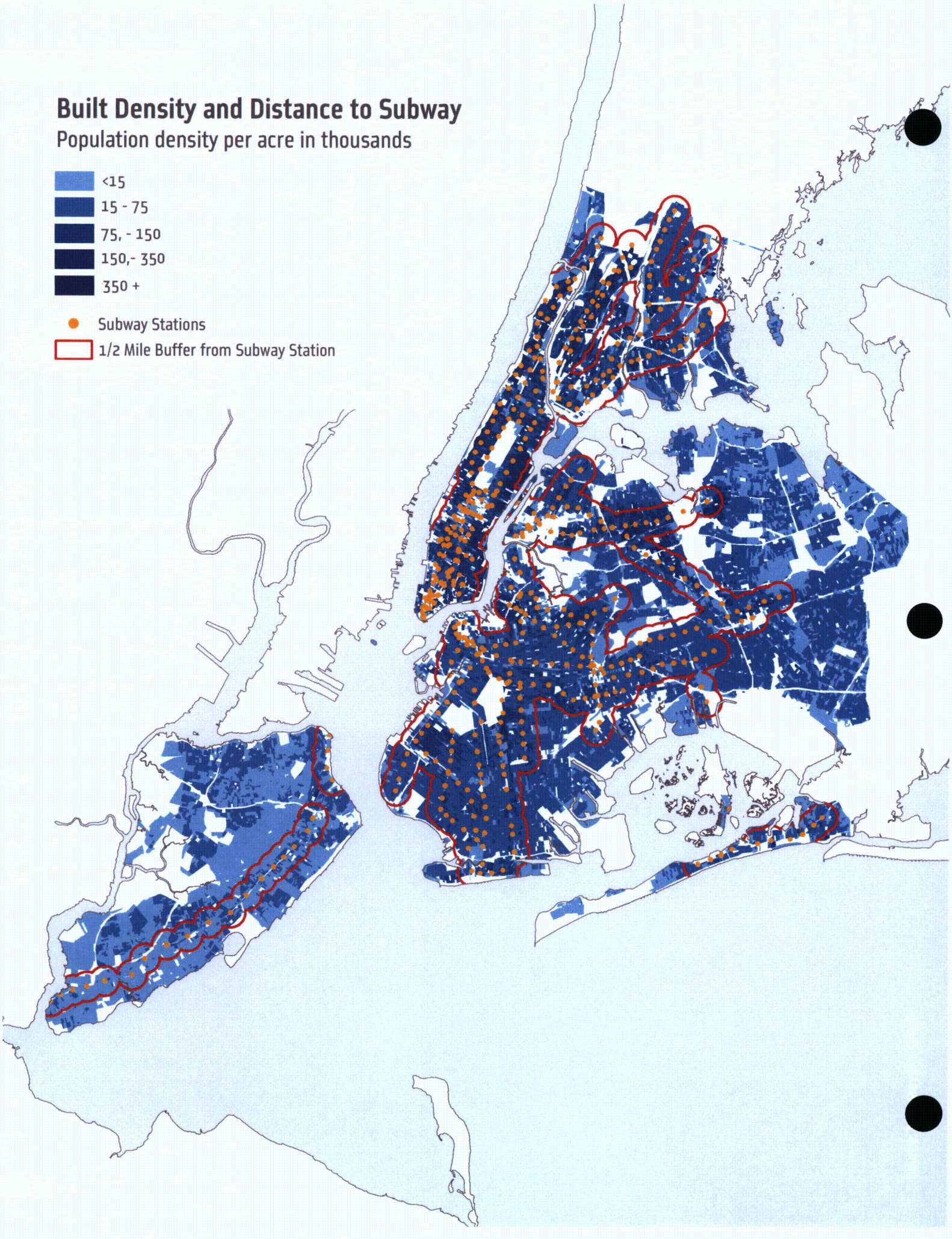
The city's on-road transportation system touches every corner of the five boroughs and allows for the greatest flexibility in travel. Over 13 thousand taxis, 6 thousand buses, hundreds of thousands of bikes, and more than two million private cars and trucks move on more than 6,000 miles of streets, nearly 800 bridges, and through 9 tunnels, connecting points in the city in millions of daily combinations. The bus system offers three types of service: regular local service, express service between boroughs, and Select Bus Service—a form of bus rapid transit that operates at greater speeds thanks to dedicated lanes, fewer stops, and off-board fare collection. The City has over 300 miles of bike lanes and recently launched the nation's largest bike-share system, Citi Bike, covering Manhattan below 59th Street and some parts of Brooklyn.

The subway and rail systems do not offer the range or flexibility of roadways because they operate along fixed tracks to a finite number of destinations, but their strength lie in their scope and capacity. The city's subways carry more than 1.7 billion riders each year along 21 interconnected routes that span 660 miles and connect 468 stations across the five boroughs. Subways are synonymous with density: 42 percent of the city's landmass is within a 10-minute walk to a subway stop, and these areas are home to 75 percent of the

Transportation Usage Patterns, 2000-2012
% change (adjusted for population growth)



Source: MTA, PANYNJ, NYMTC, NYC Mayor's Office


Built Density and Distance to Subway
Population density per acre in thousands
<15
15 - 75
75, - 150
150,- 350
350 +
Subway Stations
1/2 Mile Buffer from Subway Station

city's built area and 72 percent of its population. (See chart: *Built Density and Distance to Subway*)

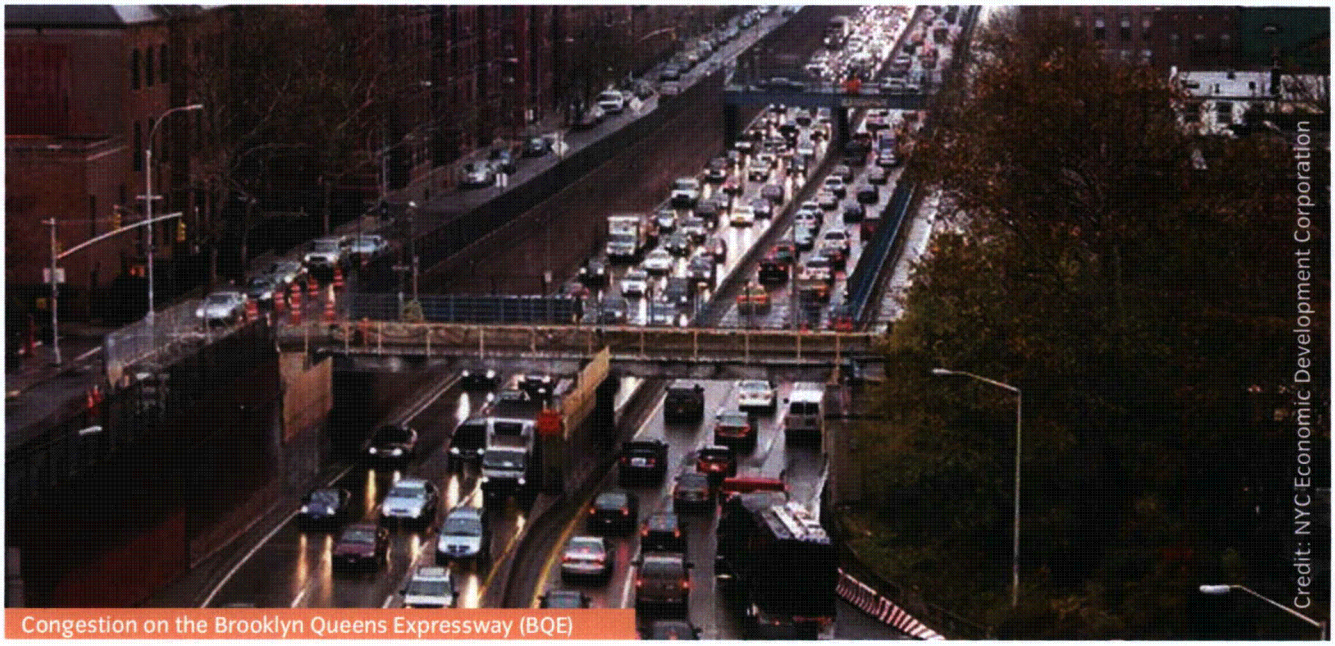
Marine transport used to be extremely important as well, mainly for delivering goods into the city – as recently as the 1970s, the waterfront bustled with commercial activity as ocean going vessels and local barges exchanged their wares. Containerized shipping caused much of this activity to disband throughout the region and the transport of goods shifted to truck. Recently, however, there has been a resurgence of marine deliveries with, for example, the opening of Red Hook Container Terminal; efforts are also underway to improve the connectivity of marine terminals and the freight rail network. The waterfront has also seen a recent renaissance in passenger transportation as ferry lines and terminals have sprung up across the city, including the East River Ferry Service, which launched in 2011 and has exceeded ridership expectations.

Farther into the surrounding region, Port Authority's PATH trains go to New Jersey, Metropolitan Transportation Authority's Long Island and Metro-North railroads connect to towns as far as Montauk and New Haven, and Amtrak's service carries passengers up and down the Eastern seaboard, most importantly to Boston and Washington, D.C. For longer distance trips, airplanes shuttle more than 54 million passengers a year out of the area's three major airports.

Multiple agencies own and operate different parts of the transportation system. The New York City Department of Transportation manages the city's streets and many of its bridges. The Metropolitan Transportation Authority, a New York State agency, runs the city's subways, buses, and regional rail. The Port Authority of New York and New Jersey, a public authority, manages some of the city's largest bridges, most of its tunnels, and the region's airports. Private companies operate taxis and livery cars under the supervision of the City's Taxi and Limousine Commission. And private companies operate most of the city's ferry terminals and port infrastructure, with some public support. Funding for the transportation system comes from a mix of sources, few of which the City directly controls.

During the past decade, the city's population increased by nearly 300,000 people. Over the same time period, transit ridership grew by 17 percent over this period, while driving only went up 2 percent and commuter rail stayed nearly flat. (See chart: *Transportation Usage Patterns, 2000-2012*) In response to increasing demand, major investments are being made to improve the city's mass transit infrastructure: two new subway lines are being built on the Upper East Side and in Midtown West; a new terminal for PATH trains is rising up next to the new World Trade Center building; tunnels for East Side Access, one of the largest public works projects in decades, are under construction and will ultimately save commuters nearly one quarter of a billion hours a week. Several other new transportation options were launched in 2013, including the bike share program, Citi Bike, and lime-colored Boro Taxis that are authorized to pick up passengers anywhere in the city except airports and Manhattan south of West 110th and East 96th Street.

Sources of GHG Emissions



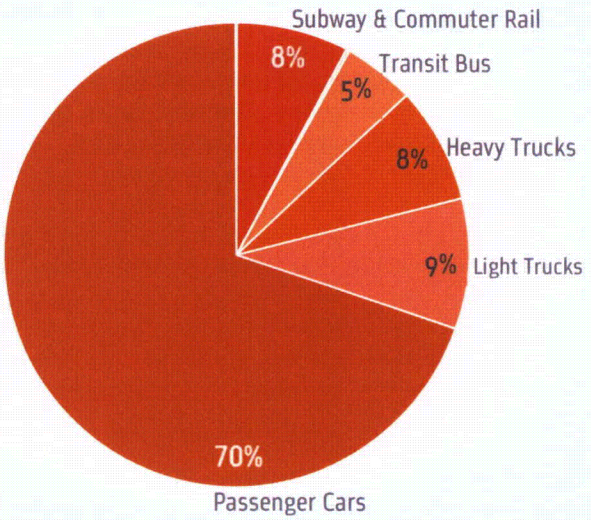
Congestion on the Brooklyn Queens Expressway (BQE)

The transportation system is responsible for 20 percent of the city's total emissions – 10.9 million tons in 2011. Of that amount, passenger cars account for 70 percent while trucks and public transit make up the remainder. Aviation, which is not counted as part of the city's greenhouse gas baseline or its 30% reduction goal, amounts to another 15.0 million tons. Without aviation, the city's per capita emissions from transportation are roughly 6.4 tons per year; by comparison, a single round-trip flight to London creates 1.2 tons of emissions (See chart: *Transportation Emissions*)

Emissions per capita vary by borough. Residents of Staten Island and Queens drive more than those who live in Brooklyn and Manhattan – but still far less in the rest of the U.S., with an average American producing roughly five times the driving emissions of an average New Yorker. (See chart: *Per Capita Emissions from Driving*)

Emissions fell nearly 5% since 2005, when they stood at 11.5 million tons – even as the city's population grew. Most of the decline was due to less carbon intensive electricity for mass transit; lower per capita VMT; and improved vehicle fuel economy. (See chart: *Drivers of Change to Transportation Emissions, 2005-2012*)

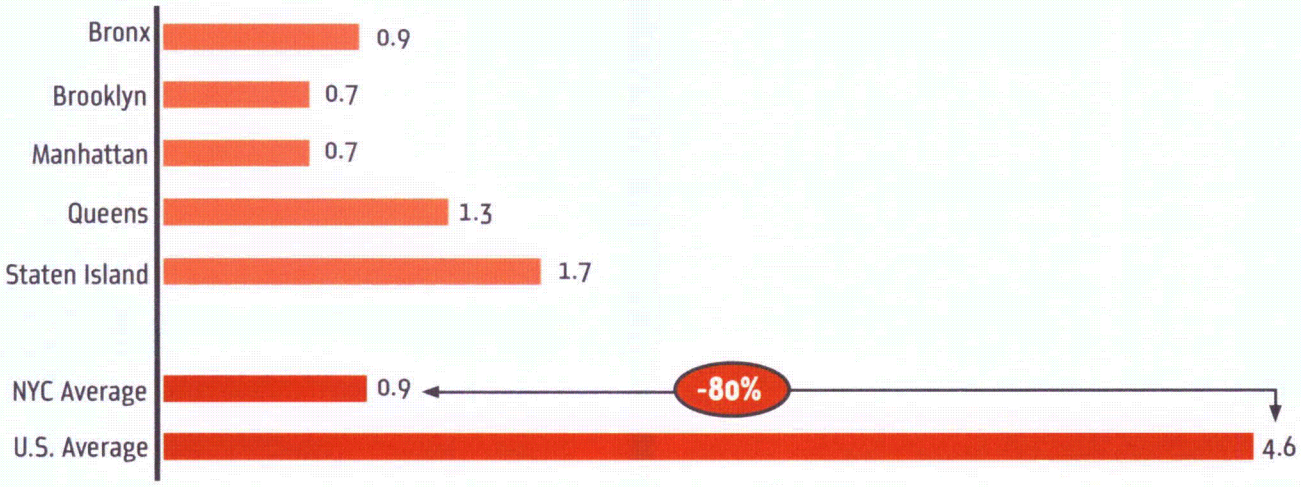
Transportation Emissions
$MtCO_2e$



Source: NYC Mayor's Office

Per Capita GHG Emissions from Driving

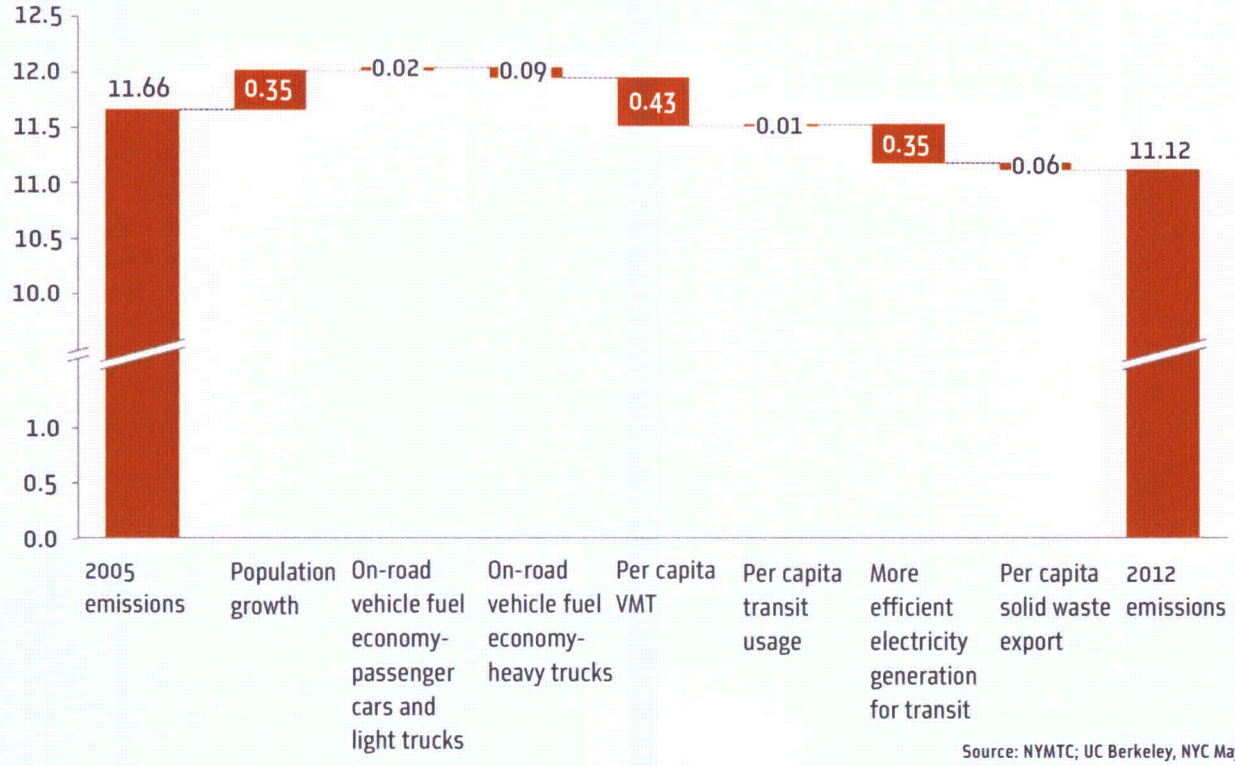
Metric tons CO_2e per year, 2011



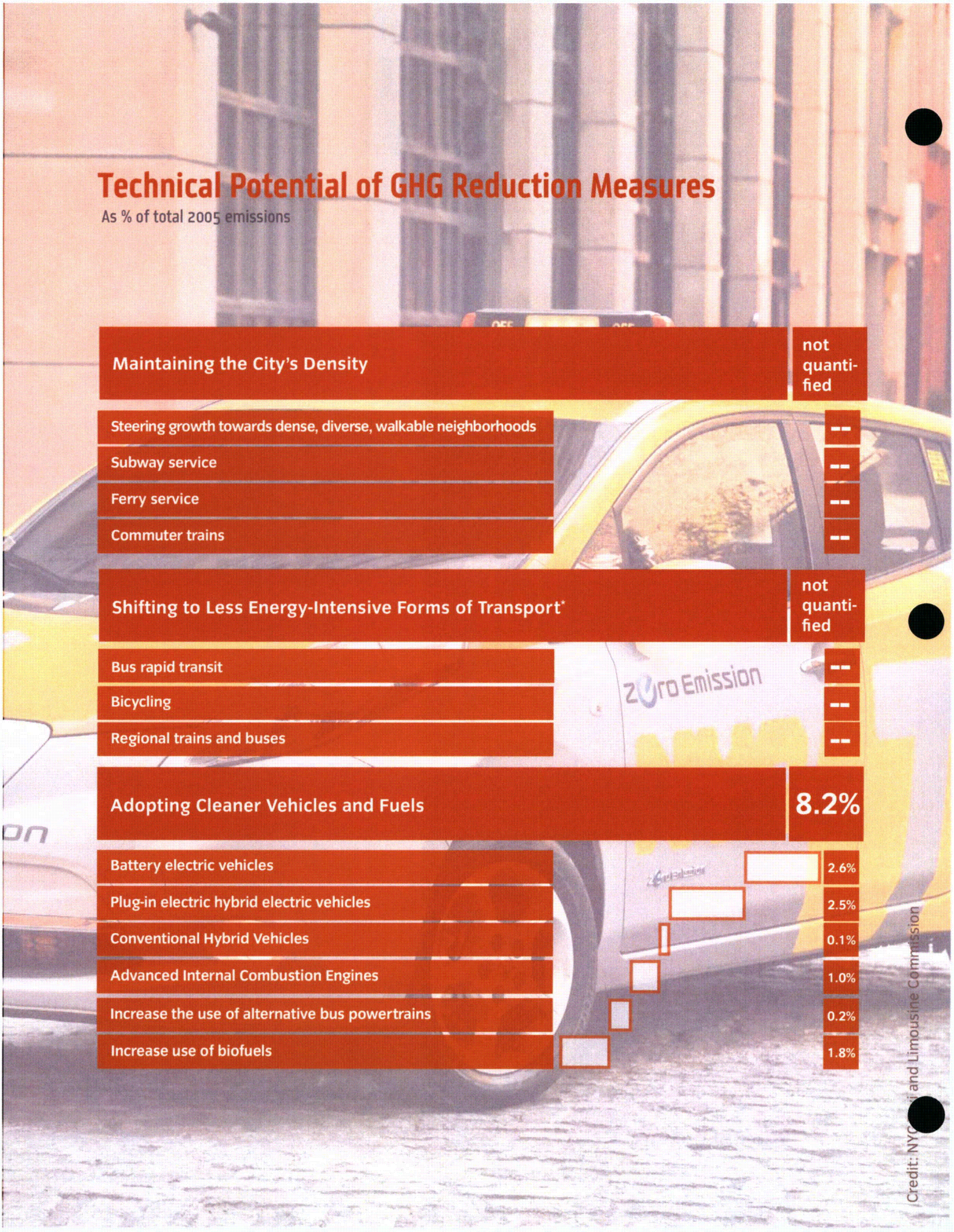
Source: NYC Mayor's Office

Drivers of Change to Transportation Emissions, 2005-2012

Metric tons CO_2e



Source: NYMTC; UC Berkeley, NYC Mayor's Office


Technical Potential of GHG Reduction Measures
As % of total 2005 emissions
Maintaining the City's Density
not quanti-fied
Steering growth towards dense, diverse, walkable neighborhoods
--
Subway service
--
Ferry service
--
Commuter trains
--
Shifting to Less Energy-Intensive Forms of Transport*
not quanti-fied
Bus rapid transit
--
Bicycling
--
Regional trains and buses
--
Adopting Cleaner Vehicles and Fuels
8.2%
Battery electric vehicles
2.6%
Plug-in electric hybrid electric vehicles
2.5%
Conventional Hybrid Vehicles
0.1%
Advanced Internal Combustion Engines
1.0%
Increase the use of alternative bus powertrains
0.2%
Increase use of biofuels
1.8%
Credit: NYC and Limousine Commission

Emissions Abatement Potential

Maintaining the City's Density

Steering growth towards dense, diverse, walkable neighborhoods

The city's density is one of its greatest assets. Many New Yorkers simply do not need to travel as far as most other Americans, whether because their friends live up the block or because the pharmacy is around the corner – and when they do, they can typically take mass transit. Over the past decade, over 94 percent of new building permits filed with the city were for construction located within ½ mile of transit. Continuing to encourage transit-accessible density as the city grows will help make sure that emissions remain low for new arrivals and existing residents alike.

Expanding Mass Transit

Subway service

Subways make the city's density possible. The system's reach is extensive—72 percent of the city's population lives within a half-mile walk of a subway station. Two expansion projects are also underway. The Second Avenue Subway will connect 96th Street to 63rd Street in the first phase and stretch all the way to Financial District at Hanover Square in later phases, while the 7 line extension will go west along 42nd Street and then down 11th Avenue to 34th Street. Carbon abatement is not these lines' primary function and therefore they are not quantified as part of the 80 by 50 reduction strategy. The Second Avenue Subway will relieve congestion on the 4/5/6 line and make living farther east on the Upper East Side easier for existing residents and more attractive for new ones. The 7 line extension will support impending large-scale development in Hudson Yards that would not be possible otherwise. Nevertheless, creating additional lines and connections over the coming decades could encourage mode shifting and densification in areas that are poorly covered by subways.

Ferry service

Ferries have enjoyed remarkable success in New York City in recent years. Use of the new East River Ferry, for example, more than doubled initial estimates within a year of its launch in June 2011. There is potential to add more ferry service and connect new points along the waterfront—which could help to foster density, improve travel experiences, and make it possible to live in parts of the city that were previously less attractive because of their distance from mass transit. But new ferries are not likely to have a significant effect on reducing New Yorker's driving or carbon emission and so they were not quantified as part of the 80X50 reduction plan.

Commuter trains

Commuter trains are extremely important for the region, as millions of commuters use Metro North, Long Island Railroad, and New Jersey Transit to get into New York City on a typical workday. The train lines have shaped settlement patterns in the NYC metropolitan area, and they have so effectively displaced driving that only 16 percent of workers commute to Manhattan's central business district by car. New commuter lines are not in the works currently, but service will improve once the East Side Access project—one of the region's largest public works projects in decades—allows travelers from Long Island to arrive into Grand Central Terminal instead of Penn Station if so desired. Construction of additional lines or expansion and improvement of existing ones would have similar effects: better access to the city and better service for existing commuters. For the purposes of this report however, the direct emissions potential of any additional lines was not estimated.

Shifting to Less Energy-Intensive Forms of Transport

Bus rapid transit

A BRT line can cost 50 times less than a new subway line and take months instead of decades to build. It is also faster than conventional buses. The city's Select Bus Service, which uses dedicated lanes and off-board fare collection, and is now located in all five boroughs, offers a 20 percent speed advantage compared to convention lines. Introducing additional Select Bus Service routes throughout the city would have two effects: first, it would save time for passengers who were riding the same routes on regular buses, which would have no effect on carbon emissions, and second, it would encourage those who were previously driving to switch to the bus instead, which would reduce emissions. The exact cause-and-effect abatement potential from expanding SBS coverage is difficult to estimate, but, as an example, increasing the share of trips taken on Select Bus Service to 7 percent – in line with what Ottawa and Bogota achieved with large-scale implementations of their respective systems – would reduce emissions by 0.4 $MtCO_2e$ compared to the business as usual case. Because of the uncertainty in the range of possible reductions attributable to SBS, the cost per ton of carbon abated was not quantified.

% n/a[1]
0.4 million tons[b]
$ n/a[c]

Bicycling

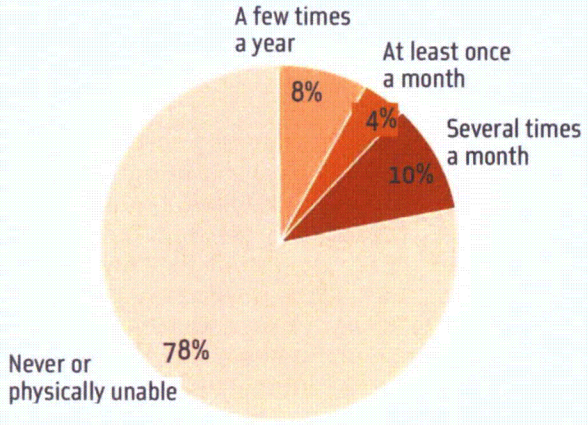
Of all the car trips in New York City, 10 percent are under half-mile, 22 percent are less than 1 mile and 56 percent are less than 3 miles – distances that could be readily served by bicycle. In recent years, cycling in New York City has grown much more popular than it used to be: 22 percent of New Yorkers ride a bike at least a few times a year, and NYC DOT's Commuter Cycling Indicator grew 2.5 times since 2000 – though the share of New Yorkers who use bicycles for their daily commutes is still relatively low, at 1 percent. (See charts: *NYC Population Bike Usage Status and NYC DOT Commuter Cycling Indicator*)

% n/a
0.5 million tons
-$300 per ton

[a] Percentage sector wide reduction
[b] Amount of CO_2e abated
[c] Cost to abate carbon

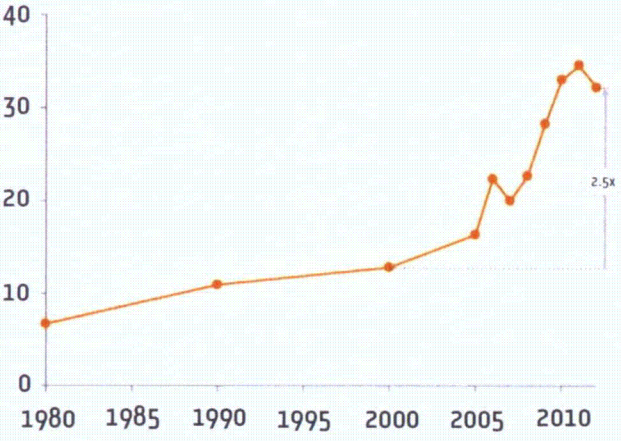
The carbon emissions impact of higher cycling rates is difficult to estimate because of limited data about mode-shifting potential, but it is certainly positive. Bikes do not reduce emissions when new riders switch from subways, buses, or walking, but they do reduce emissions when they replace rides in taxis or private cars. Carbon abatement potential of bikes is highest in areas that rely on cars, whereas in dense areas the expansion of biking and associated infrastructure is likely to bring about more convenience, health benefits, and traffic safety improvements than carbon emissions reductions. A detailed sizing of the carbon reduction potential of biking is beyond

NYC Population Bike Usage Status
% of total population, 2012



Source: NYC DOHMH Community Health Survey

NYC DOT Commuter Cycling Indicator
Thousands



Source: NYC DOT

the scope of this report, but for the sake of illustration, if New Yorkers' share of trips taken by bike increased to 15 percent (which Berlin achieves and Copenhagen far exceeds with its record 33 percent) and just half of those trips displaced car travel–carbon emissions would fall by 0.5 MtCO2e.

Regional trains and buses

% n/a

0.29 million tons

$ n/a

Of the four options for traveling along the Eastern Seaboard – driving, taking a bus, taking a train, or flying – driving and flying are by far the most carbon intensive. Reliable data is not available for the exact number of bus or car travelers between New York and Boston and Washington, D.C., but the share of train travel has risen from 37 percent to 75 percent between Washington, D.C. and New York from 2000 to 2011, and from 20 percent to 54 percent between New York and Boston in the same period. The share could be higher yet: in countries where true high-speed rail took off – Spain and China are two examples – regional trains and buses have become so popular that airlines have largely stopped serving routes under 300 miles. From an emissions standpoint, shifting all existing passengers on routes to Boston and Washington DC from planes to trains would lead to emissions savings of at least 0.1 MtCO2e. Cleaning up the grid in line with the 80 by 50 pathway would increase this potential to 0.29 MtCO2e.[14] As with subway expansions, high-speed trains are not primarily about carbon emissions abatement; therefore, the direct cost per ton of carbon abatement was not calculated.

Adopting Cleaner Vehicles and Fuels

No matter how good the city's transit system is, or how dense and mixed-use its neighborhoods, some trips will still require cars. Moving two tons of metal through space will always require a lot of energy, and reducing the emissions from this movement comes down to three options: switching to different vehicle technologies (hybrid electric and battery electric, for now), making conventional vehicles more efficient, and using biofuels. (See chart: *Vehicles on Road by Powertrain Technology*)

Battery electric vehicles

2.6%

1.6 million tons

-$10 per ton

Battery electric vehicles (EVs), which rely on a large battery pack for all (or nearly all) of their energy and need to plug into the grid to recharge, emit 70% less carbon per mile traveled than conventional vehicles do. Over time, conventional and electric vehicles alike will become cleaner (due, in large part, to strict CAFE standards), but the EV advantage will persist, especially as the grid becomes cleaner. (See chart: *Carbon Intensity of Battery Electric and Conventional Vehicles*)

Electric vehicles could play an extremely important role in carbon abatement, but all across the country, they still represent a tiny share of new purchases. Even in San Francisco, they amounted to only 0.9 percent of new registrations between 2010 and 2012; in New York City, the share was lower yet at 0.2 percent. (See chart: *Electric Vehicle Share of New Auto Sales by Location*)

Today's electric vehicles are far superior to prior incarnations that were plagued by limited range, charging challenges and high cost. Today's vehicles have sufficient range for daily driving, charging is simpler and more options are available, and prices are falling. In 1995, GM's EV1 – the first electric vehicle sold to consumers by a major automaker – was almost twice as expensive as an average vehicle, but today's Nissan Leaf, costs essentially the same as an average car after accounting for federal tax credits. (See chart: *Electric Vehicle Price Dynamics*)

Technology will improve further yet, and if, as modeled, battery electric vehicles represent 2 percent of all vehicles by 2020, 8 percent by 2030, and 41 percent by 2050, they could abate 0.1, 0.4, and 1.6 $MtCO_2e$, respectively. The societal cost of abatement would come in at $80/ton

in 2020 (not taking tax credits into account, EVs would still be more expensive than conventional vehicles), then drop to -$10/ton in 2030 as EV prices drop.

Plug-in hybrid electric vehicles

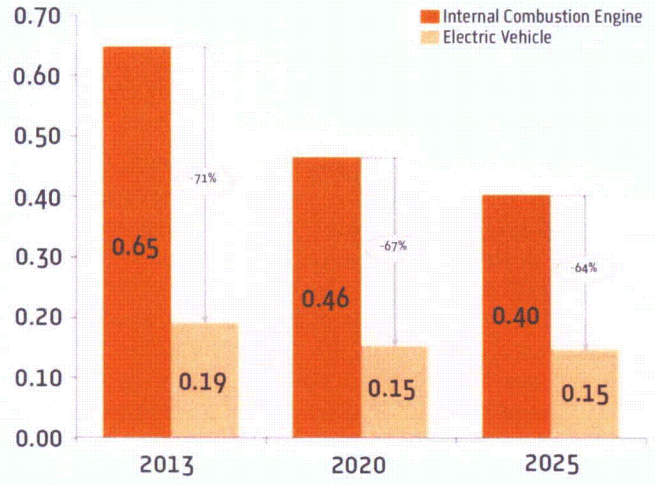
2.5%

1.6 million tons

-$10 per ton

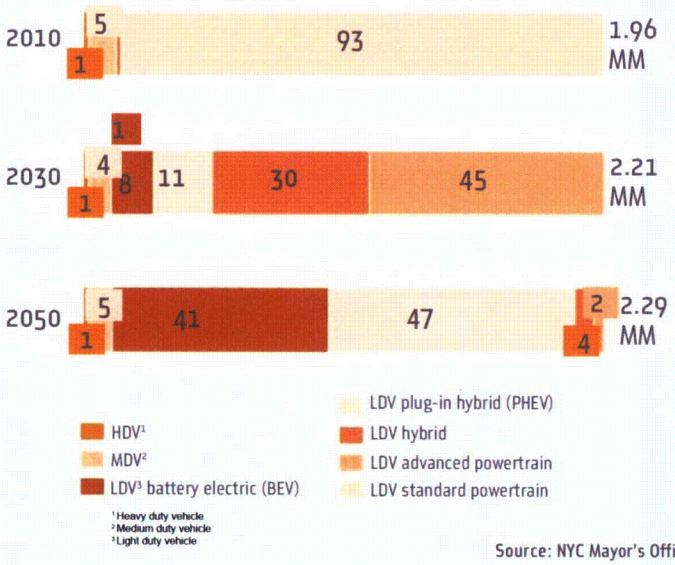
Today's plug-in hybrids can only rely on their batteries for between 7 and 35 miles. Once the battery is depleted, a small gasoline engine engages to extend the vehicle's range (to 340 miles in the case of one such vehicle, the Chevy Volt). Plug-in hybrids are not as beneficial as battery-only EVs, but they are nearly as good, especially for in-city driving. And compared to EVs, they do not induce range anxiety or require as robust a charging network, and because of their smaller batteries they cost less. As modeled, PHEVs could account for 6 percent of all vehicles on the road by 2020, 11 percent by 2030, and 47 percent by 2050, abating 0.3, 0.5, and 1.6 $MtCO_2e$, respectively. The cost of abatement would be $90/ton in 2020 and -$10/ton in 2030 as vehicle prices continue to drop.

Carbon Intensity of Battery Electric and Conventional Vehicles
CO2e (lbs/mile): NYC-specific grid intensity along 80 by 50 pathway



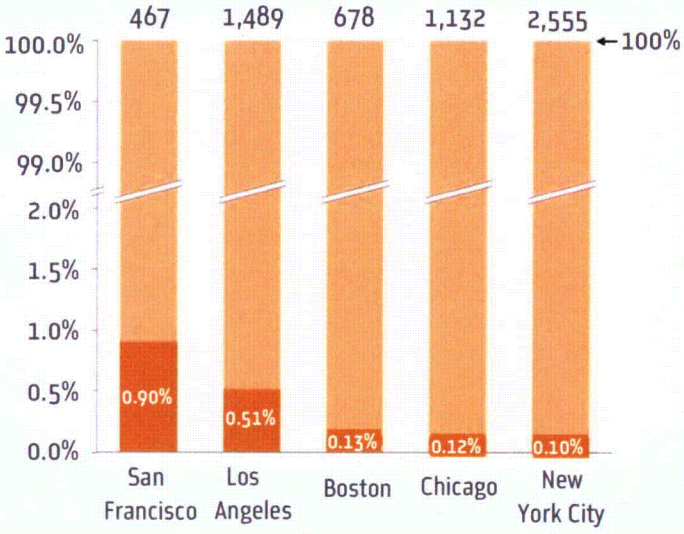
Source: US EPA, NYC Mayor;s Office

Vehicles on Road by Powertrain Technology
% of total vehicle stock (Millions)



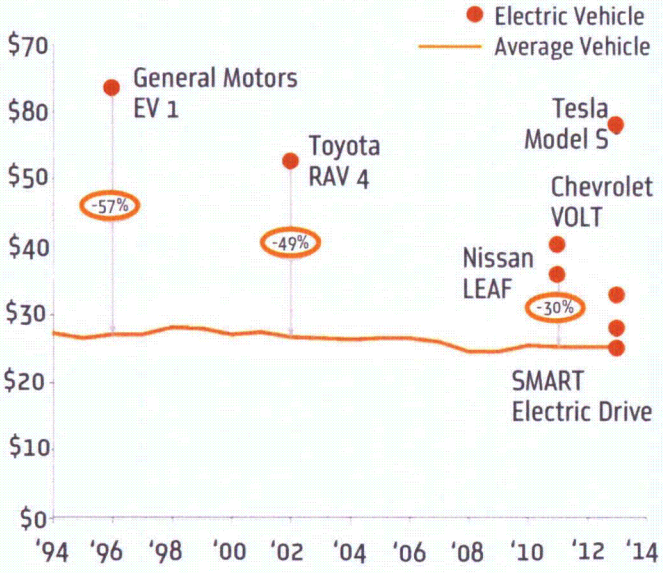
Source: NYC Mayor's Office

EV Share of New Auto Sales by Location; 2010-2012
Battery EV and PHEV as % of total registrations; total registrations in thousands



Source: Polk Automotive

Electric Vehicle Price Dynamics
MSRP in thousands (all values indexed to CPI inflation of 2011)



Source: US DOE; Transportation Department, NYC

Conventional hybrid vehicles

The carbon benefits of conventional hybrid vehicles, which recharge their battery from their internal combustion engines, are small but nevertheless helpful and very cost-effective as an interim step towards 80X50. These vehicles are expected to represent 30 percent of all vehicles in 2030, but practically disappear by 2050, as battery electric and plug-in alternatives continue to improve. The abatement potential is 0.2 MtCO2e in 2020 and 0.1 MtCO2e in 2030, achieved at large societal savings: -$170/ton in 2020 and -$530/ton in 2030.

0.1%

0.1 million tons

-$530 per ton

Advanced internal combustion engines

Federal CAFE standards are leading to dramatic improvements in the fuel efficiency of conventional vehicles, and their impact is already captured in the business-as-usual emissions scenario. However, the standards only dictate improvements through 2025, and their impact on vehicle emissions will be limited by the speed of vehicle turnover. The potential exists for additional emissions reductions from conventional vehicles, whether through more aggressive vehicle standards in the future or through accelerated upgrading to vehicles that meet the standards that are in force today. By 2020, accelerated uptake of more efficient vehicles could abate up to 0.7 MtCO2e; by 2030 and 2050, tighter standards and accelerated switching could abate 0.6-0.7 MtCO2e. Because the incremental costs of cleaner vehicles pay off through fuel savings, the range of abatement costs would be between -$170/ton and -$150/ton.

1.0%

0.7 million tons

-$150 per ton

Alternative bus powertrains

In recent years, MTA has upgraded portions of its 6,000-unit bus fleet to cleaner-burning diesel, compressed natural gas, and hybrid electric units. There is a balance to be struck in the upgrade process: hybrid vehicles may be the cleanest of the three, but they also cost more to purchase and maintain, and the incremental money may be better directed – at least in the short term – to replacing old diesel vehicles in their fleet with more cleaner models. A cleaner mix of buses featuring predominantly hybrids has the potential to abate approximately 0.1-0.2 MtCO2e at a cost of between -$190/ton and -$230/ton.

0.2%

0.2 million tons

-$230 per ton

Biofuels

Different biofuel technologies have been available for some time, but it was only in recent years that their cost and availability expanded enough to make them a viable option for local car fleets. All city vehicles running on diesel currently use B5 year-round and over the next two years the entire fleet will be increased to B20 for the non-winter months. Scaling up biofuel use could abate 0.2 MtCO2e in 2020, and up to 1.2 MtCO2e between 2030 and 2050. Biofuels command virtually no cost premium over conventional fuels which means that the they would lead to negative abatement costs at -$70/ton in 2030.

1.8%

1.2 million tons

-$70 per ton

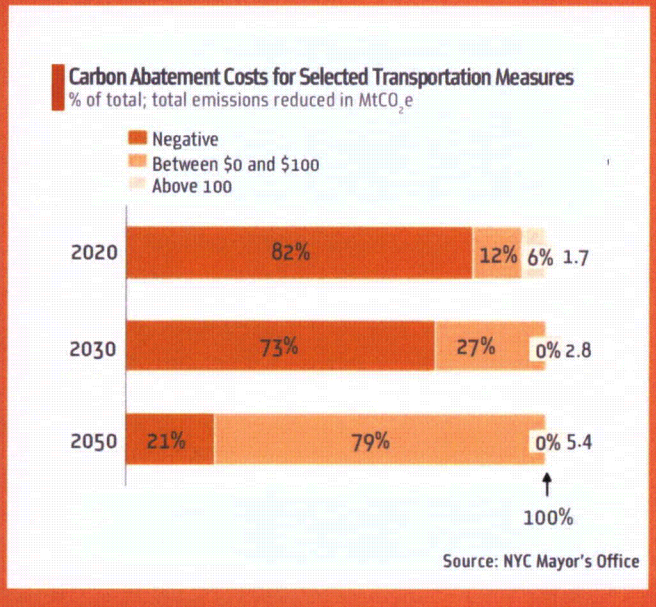
The Costs & Economics of Carbon Abatement for Transportation

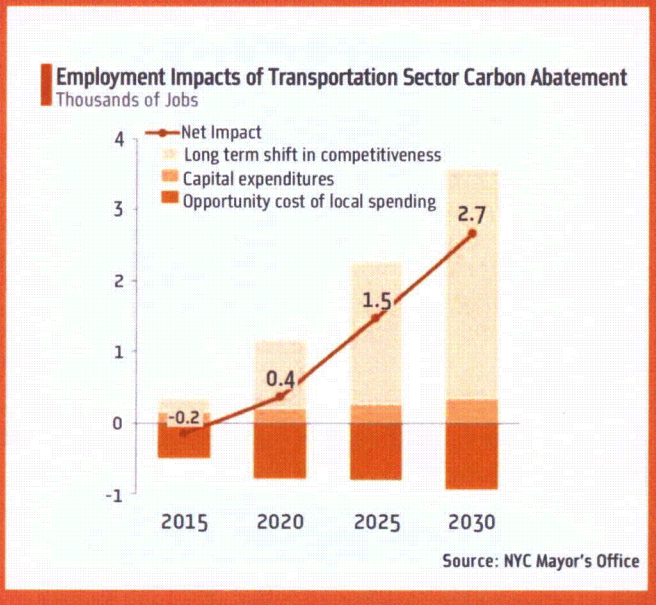
New Yorkers spend $5.4 billion on vehicles, $7.9 billion on transportation fuels, and $5.5 billion on public transit fares each year. More than 90,000 people work in transportation-related jobs, from the 27,000 that support passenger aviation to the 7,000 employed in car dealerships. Decarbonizing the sector would spell a degree of change – but most of the change would benefit the economy in the end.

Many of the abatement measures require upfront investments. Yet through the 2020s and the 2030s, 70 to 80 percent of these measures could achieve carbon reductions at a negative societal cost because of fuel savings. Even assuming, conservatively, that improvements to neighborhoods and mass transit would not significantly affect the amount of driving within the city, the total required incremental investments along the 80 by 50 pathway – on the order of $300-500 million a year, mostly to pay for the higher upfront costs of cleaner vehicles – would be more than offset by the operational savings of up to $3.5 billion a year once decarbonization progresses far enough.(See chart: *Carbon Abatement Costs for Selected Transportation Sector Measures*)

The first order effects of these changes would be positive for the economy. The increase in spending on cleaner vehicles would help car dealerships, but it would be offset by a decrease in activity in other sectors of the economy, leading to net job-year losses on the order of 500-600 annually. However, the positive economy-wide effect of fuel savings would more than compensate for those losses. A net gain in employment would result by 2020; by 2030, as alternative vehicles become more widespread, they would be responsible for more than 2,600 net new jobs and a $300 million increase in gross regional product. (See chart: *Employment Impacts of Transportation Sector Carbon Abatement*)

Existing transportation jobs may experience some disruption: if, for example, demand for liquid fuels falls far enough, gas station employment – currently at 3,000 – might shrink. However, the impact would be contained: dealerships would still sell new vehicles, subway trains will still run, and planes will still be taking off from area airports, providing the same jobs they provide today. In the transportation sector, carbon abatement may be tough to accomplish, but the overall economic impact appears positive.





Challenges

The transit network is vast but still finite and infrastructure is in need of modernization.

Subways make the city run, but they don't go everywhere: 28 percent of New Yorkers do not live within a half-mile of a subway station. Even if a subway station is near, not all routes are convenient: traveling from the Bronx to Queens or from Manhattan to JFK can take a long time – and driving may become the preferred option. Where subways do go, they may not always provide a speed and frequency of service or level of comfort that potential travelers find preferable to other modes.

Walking and biking can be uninviting, unsafe, or both

The city's street grid was laid out in the days of the horse buggy, but more than two million vehicles traverse it today, and it shows. Cars, buses, bicycles, and pedestrians compete for limited space, and while a neighborhood like the West Village can be very pedestrian and bike-friendly because of its small right-of-ways, walking or biking along Queens Boulevard is a different story altogether. The city has made great strides in reducing traffic fatalities through a raft of street design measures, but there is more to be done.

New technologies are available, but adoption has been slow

EVs and biofuels hold a lot of promise, but their adoption is gradual and will take time to get to scale. EVs account for just 0.1 percent of all new vehicles purchased in the metropolitan area since 2010, and biofuels are mainly available only through bioethanol added to gasoline, which does not lead to a significant emissions reduction. Unlike ethanol, biodiesel use is not required and not available in the retail market even though it is far better environmentally. For EVs, the incremental cost, continued concerns about range, and scarcity of charging stations are obstacles to growth despite their increasing affordability.

The economics of driving are not fully efficient

For any practice that carries a cost, reflecting it directly is usually a good idea – charging for electricity per kilowatt-hour instead of monthly makes people watch their usage, and taxing cigarettes deters smoking and recovers some of the indirect costs imposed on society at large from the illness they cause. Driving comes with a multitude of costs, but the only costs that are tied directly in proportion to the amount of miles driven are fuel and maintenance costs. Insurance is priced based on a measure of risk for accidents, but not amount driven, and the negative externalities of driving – congestion and air pollution – are not priced at all.

Planning jurisdiction and operational authority spans agencies and levels of government

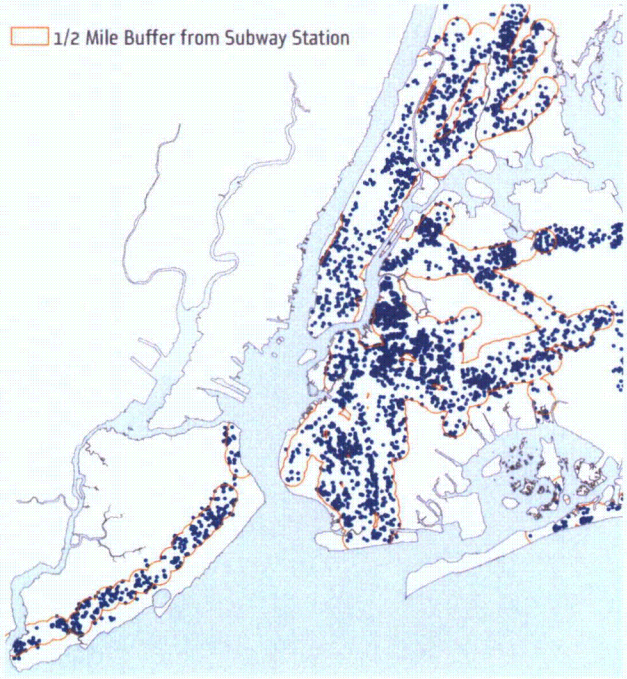
All of the city's systems feature a complex mix of players – but transportation is perhaps the most varied of them all. City government may control streets and zoning, but agencies at other levels of government fund, construct, and operate major components of the city's transportation infrastructure. As a result, major projects often take decades to materialize. Most importantly, vehicle choices come down to millions of individual decisions – and unlike with buildings, where the local building code governs construction, the parameters of those choices are set at the federal level, and then only loosely.

Capturing the Potential

Strategy 1
Zone for Neighborhood Density and Diversity

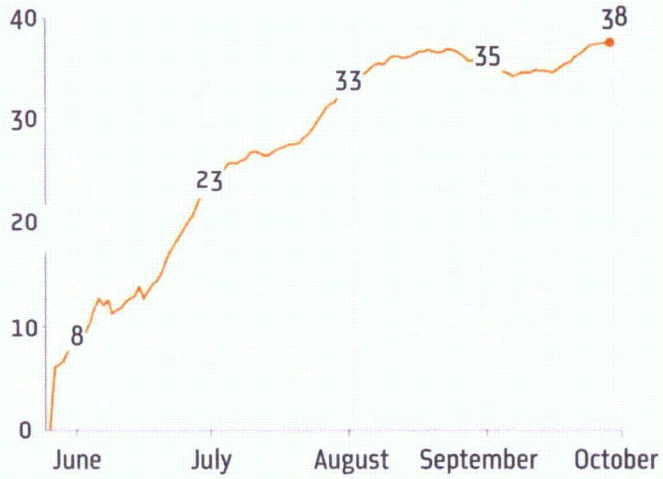
Much of the city is already dense and mixed-use, but opportunities for improvement still exist – and zoning, which determines how a given plot of land can be used and how much can be built on it, is the best tool at the City's disposal. Over 120 City-initiated rezonings were completed in the city in the last decade, allowing greater density in areas close to transit while limiting growth in auto-dependent areas. The combination of City policy and market activity ensured that more than 87 percent of new building permits between 2007 and 2012 were issued in areas within ½ mile of a subway or commuter rail station. (See chart: *New Building Permits and Transit Coverage*). As the city continues to attract new residents and grow,– careful use of zoning proceeding in tandem with transit improvements could ensure that opportunities for development continue to get created in areas where many residents will find car ownership is not a necessity.

New Building Permits and Transit Coverage
2007-2012; all construction types



Source: NYC Mayor's Office

Daily Citi Bike Ridership Trends
Thousands; 2013; normalized for weekly fluctuations

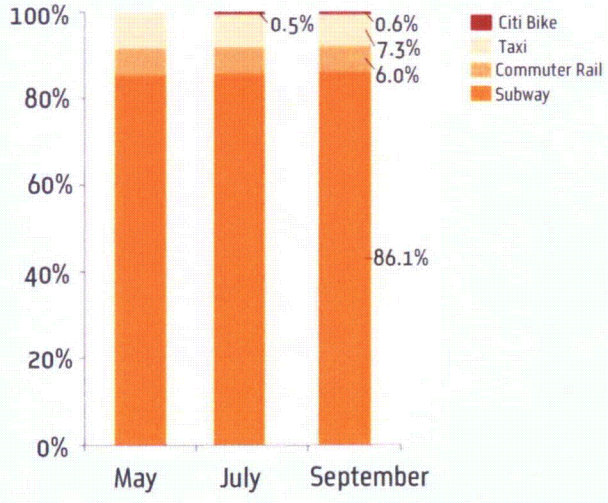


Source: Citi Bike

Strategy 2
Build and Maintain Transit Infrastructure

Transit infrastructure takes time to build and is expensive to maintain – but it is indispensable when it comes to carbon abatement. Putting the city onto an 80 by 50 pathway would require improving transit where it already

Taxi and Transit Ridership by Share of Total Monthly Trips
Percent of total; 2013



Source: MTA, NYCTLC, Citi Bike, NYC Mayor's Office

Possible Bike Share Expansion Areas from 2009 Study
Segmented into 3 phases

Source: NYC DCP

exists and taking it to areas that it does not yet cover – while being careful to invest in the options that deliver the greatest marginal benefit for the amount of money spent.

Bus rapid transit

Of all the transit options, BRT lines may have the most to contribute to carbon abatement: they are quick to set up and require little enough investment that multiple ones could be set up along major transport corridors. The city's BRT offering, Select Bus Service, already runs on four routes, and several route expansions are in the works, including on Webster Avenue in the Bronx and Nostrand Avenue in Brooklyn. More SBS routes could continue to encourage drivers to shift away from cars, save time for existing commuters, and make neighborhoods more attractive.

Bicycle share expansion

Citi Bike, the city's bike share-program, saw excellent growth since its launch in May 2013: by October, more than 90,000 annual members had joined, and the daily number of rides was on track to reaching 40,000 – still far below 470,000 daily taxi trips, let alone millions of subway rides, but picking up quickly. (See chart: *Daily Citi Bike Ridership Trends* and *Taxi and Transit Ridership by Share of Total Monthly Trips*)

The system, however, is only in its first phase – and there is potential for it to expand. The 2009 study from the Department of City Planning that evaluated the potential for bike share in New York City envisioned three stages of implementation: the first one, with 10,500 bicycles, would cover the densest areas of Manhattan and Brooklyn; the second one, bringing the system to 30,000 bicycles, would expand into Queens and the Bronx, and further into Northern Manhattan and Brooklyn; and the third one, increasing the capacity to 50,000 bikes, could cover the city as far as Coney Island and Pelham Bay Park, spanning 81 square miles. (See map: *Possible Bike Share Expansion Areas from 2009 Study*)

The damage from Hurricane Sandy to bike share infrastructure stored in the Brooklyn Navy Yard shrank first stage deployment, but most of the area mentioned in the original study is now covered. Covering the remaining areas would make it possible to reduce short car trips and would also make it easier for New Yorkers to access new Select Bus Service routes. However, the main obstacle to the program expansion is funding, both for capital and operating costs. For the first phase, sponsorships by Citibank and MasterCard paid all of the initial capital costs and membership fees are covering the operating costs. The financing model, for subsequent phases, is yet to be established. City capital or private sponsors could pay for the capital costs, but membership revenues may not be enough to cover the operating costs because the number of users per bike would decline as residential density falls. In that case, an ongoing financial commitment from either the City or a private sponsor would be required to expand the system.

Subways

Because subways are so expensive and take so long to build, new lines would not serve as a marginal carbon

abatement method for the short or even the medium term. The more immediate concern for the system is to maintain the quality of service on existing lines, and the biggest challenge to that is funding. As with any other transportation option, the system requires taxpayer support and cannot be funded by user fees alone. The finances of the MTA, the New York State agency that runs the city's subway system, would need to be strengthened in order for service to remain convenient and reliable.

One possible exception that could reduce emissions in the short to medium term is the extension of the N line to serve LaGuardia airport, which was last seriously discussed last decade. Because the only transit option for getting to LGA is the bus, the project would have the potential to reduce emissions directly. In the longer term, better connections between Queens and Brooklyn – including possibly those that rely on existing unused right-of-ways – would merit consideration, though as with the current two extensions, economic development concerns would likely drive the decision-making.

Ferries

The East River Ferry service already brings commuters from Long Island City and Brooklyn waterfront to Wall Street. As the city's waterfront continues to be redeveloped, ferries will grow in importance, and opportunities for new routes will arise. The former Domino factory in Williamsburg is just one example of a new project that could benefit from ferry connectivity. As with subways though, new ferry projects would be driven primarily by economic development considerations and would require near-term subsidies.

Streetcars

Streetcars ran in the city's streets up until the 1950s – then, the service was shut down and the rails were removed; the last remaining cars from that era are now rusting behind a Fairway supermarket in Red Hook. Proposals exist to resurrect streetcar service in parts of the city but the marginal cost of construction is still substantial enough that any projects would have to be weighed carefully against cheaper alternatives such as bus rapid transit.

Regional and commuter rail

For rail, the greatest abatement potential lies in launching true high-speed service between Washington D.C. and Boston – and displacing car and airline travel as a result. Amtrak recently proposed a plan to upgrade the speed of its trains by 2041, and while a discussion of the funding and planning challenges of the endeavor are beyond the scope of this report, local support would still be important. For commuter rail, the drivers of expansion would be less about incremental abatement and more about the availability of funding and need for capacity increases. Two rail tunnels connecting to New Jersey under the Hudson River are more than 100 years old and both are over capacity. A new link, perhaps following in the footsteps of the now-suspended project called ARC (Access to the Region's Core), could improve the passenger flow into and out of the city.

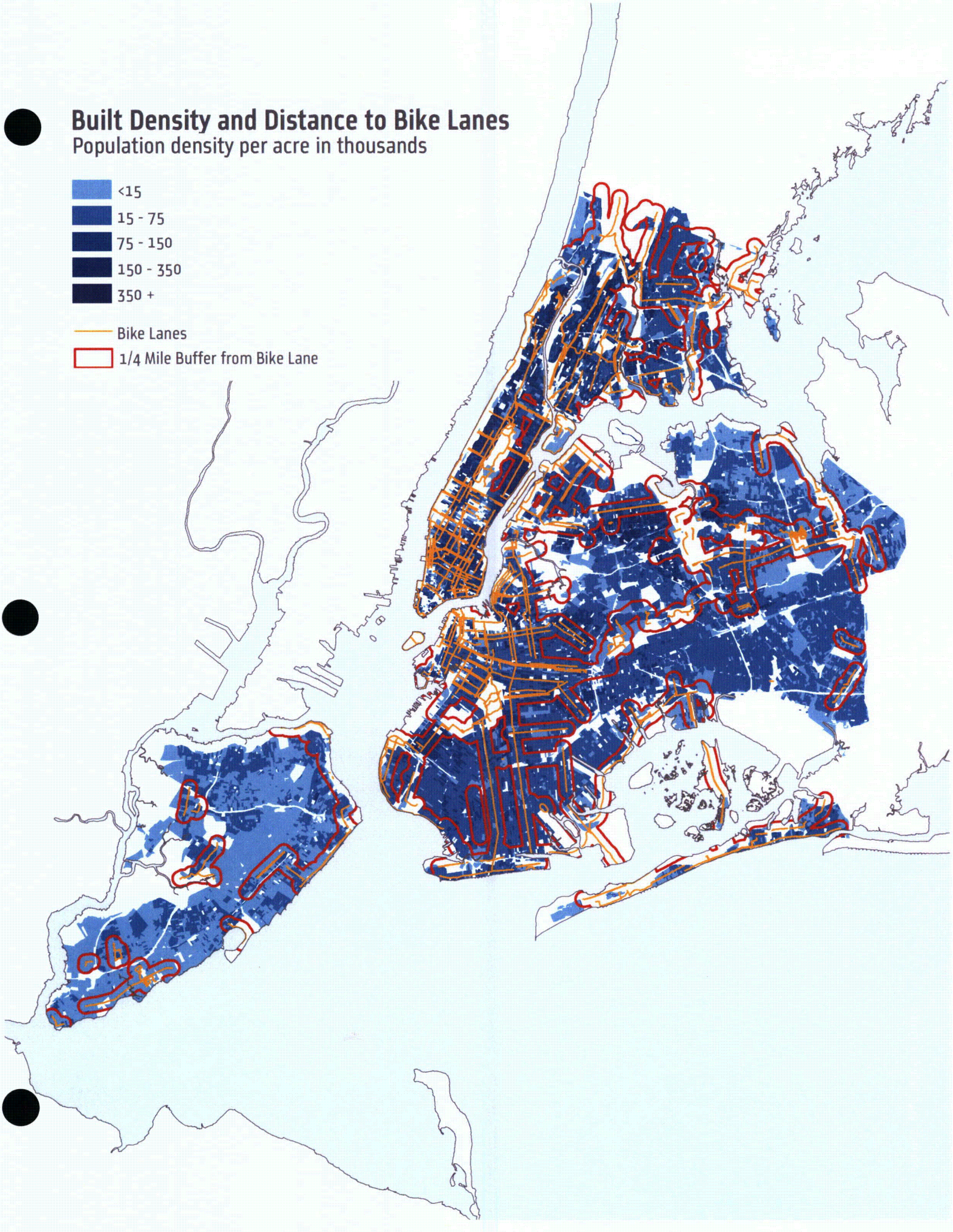
Strategy 3
Improve the Streetscape

Safer, pedestrian-friendly streets

Neighborhood plazas, wider sidewalks, pedestrian islands, and an assortment of traffic calming measures have been popping up across the city and making streets better and safer for all New Yorkers. Seniors and schoolchildren have received special attention through programs like Safe Streets for Seniors and Safe Routes to Schools. Thanks to these and other measures, the city's streets are safer than they have been at any point in the last 100 years. As the city grows and changes, more will need to be done. The difficulty lies in the extremely fragmented nature of needed improvements: no two intersections are the same, and many changes require long approval and community engagement processes. A methodical focus on incremental improvements all over the city – often relying on piloting and testing to quickly establish what works and what does not – has proven to work and could be a template for the future.

Bike lane expansion

Cycling is most effective as a marginal carbon abatement tool in areas that are not well served by transit – it is in those areas that it replaces driving instead of subway rides. Incidentally, these are the areas that aren't well served by the existing bike lane network either (See map: *Built Density and Distance to Bike Lanes*) – which means that focusing the network expansion efforts on those areas may be the best way to capture the carbon abatement potential of cycling. The process can be lengthy and challenging, and each mile of a new bike lane would


Built Density and Distance to Bike Lanes
Population density per acre in thousands
<15
15 - 75
75 - 150
150 - 350
350 +
Bike Lanes
1/4 Mile Buffer from Bike Lane

serve fewer riders than it would in a dense neighborhood – but with the bike lane network already well-developed in denser parts of the city, the less dense areas represent the next frontier.

Bike bridge access

The bike lane network may be well developed within some neighborhoods, but the city's boroughs could be connected better. Bridges are part of the answer – and while Manhattan, Williamsburg, and Queensboro bridges all have separate paths for cyclists, the same is not true of all the major connections. Some, like the Verrazano, from Brooklyn to Staten Island, and the Whitestone, from Queens to the Bronx, have no accommodations for bicyclists at all. Others, like the Henry Hudson, Robert F. Kennedy and Marine Parkway bridges, require riders to dismount. Still others have bike paths that could use improvement: on the Brooklyn Bridge, the narrow walkway can be congested for cyclists and pedestrians alike, while on the Pulaski bridge from Long Island City to Greenpoint, the shared pedestrian and bike path can be as narrow as 8 feet. Creating bike paths where none exist and improving them where they do will be critical to making biking in the city more viable.

Strategy 4
Support Cleaner Vehicles

Clean vehicle incentives

Most incentives for clean vehicles arrive in the form of federal tax credits – those for EVs, for example. Still, there are options at the state and local level to encourage clean vehicle ownership among private and commercial users alike. For commercial vehicles, two programs are already available: the Hunts Point Clean Truck Program, managed by City DOT, aims to take at least 500 of the oldest, most polluting trucks off of the streets of the Bronx; the Citywide Private Fleet Alternative Fuel Programs, co-managed by DOT and NYSERDA, offers rebates of up to 80 percent of the increased cost of choosing an electric or alternative fuel vehicle over a conventional one. The NYSERDA Program has been operating for over 10 years and has funded hundreds of clean advanced technology vehicles. Another program is on the way as well: NYSERDA will be providing rebates to commercial sector fleets exclusively for the purchase of new electric trucks. No incentive programs are in place for private vehicles yet, but one option is a local or regional "feebate" program – a revenue neutral initiative that encourages vehicle buyers and car manufacturers to invest in efficiency. Under this framework, vehicles with above average efficiency would receive a rebate while those with below average efficiency would be assessed a fee.

EV charging infrastructure

Charging is perhaps the biggest barrier to EV adoption: although there are over 180 public charging stations throughout the city, it is not enough – and only three are of the fastest variety that can charge a vehicle in 30 minutes or less.. To improve charging infrastructure around the city, three strategies could help. First, there could be more EV charging points in garages and parking lots (which is where most of the existing 180 are today). The City has been partnering with the private sector, as well as Federal and State governments to develop these – and more are on the way. (See map: *Existing EV Charging Points*) Second, the issue of parking would need to be addressed: at least some street chargers would need to be available if EVs are to be adopted en masse. A pilot to evaluate the feasibility and utilization levels of dedicated EV parking spots could be a helpful starting point. Finally, the City can implement a recently passed local law that will require 20 percent of new residential and workplace parking to be "charger ready." The incremental cost to developers will be negligible – the measure only requires the installation of wiring and not of actual chargers – but will help prevent costly retrofits in the future.

Electric taxi pilot

If an electric taxi can make it in New York it can make it anywhere. Few vehicles drive as much every day and suffer as much abuse as the New York City's yellow cabs. Several electric taxis, all Nissan Leafs, are already cruising the city's streets as part of an electric taxi pilot, and a Taxi and Limousine Commission study of what it would take to electrify 1/3 of the fleet is underway. Such a fleet would reduce emissions by 90,000 tons a year — but at least three issues arise.

The choice of vehicle is one: the Leaf is not custom-built for full-time taxi operation, and it does not have much passenger space. An electric version of the Nissan NV200, a custom-built taxi designed just for New York or a similarly sized vehicle would likely replace the Leaf in any large-scale electrification, but that vehicle is still being tested and developed.

Existing EV Charging Points
2013

Source: NYC Mayor's Office

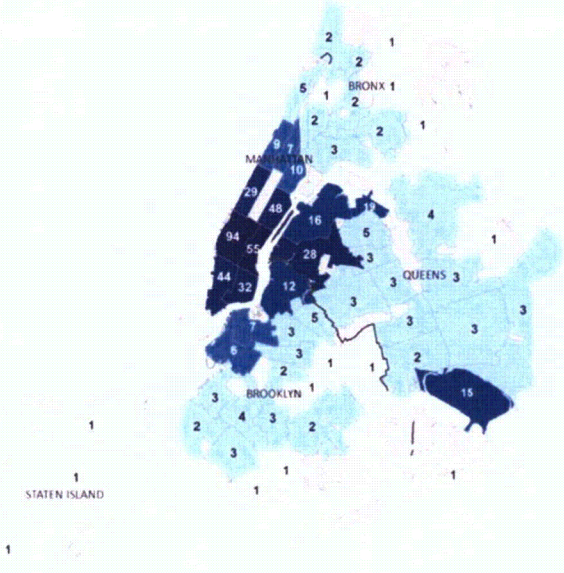
The charging network – or lack thereof – is another obstacle. Because each taxi drives more than 50 passenger miles per 12-hour shift (as well as additional miles spent cruising for fares and traveling to and from home or a fleet garage), it would need to recharge after each shift — and existing chargers are too slow to work with the economics of the industry. A citywide network of quick chargers, which can recharge a battery to 80 percent in 30 minutes or less, would have to be installed instead. Quick chargers would require more space and could draw up to 15 times more power. To get the network installed, City, State, and the private sector would have to cooperate. (See map: *Potential Quick Charge Network for Electric Taxis*)

The economics of the electric sector present a final challenge: electricity is billed not just on the amount of energy consumed, but on the speed it is used. The rationale is that just as it costs more to build and maintain a highway than a dirt road, it costs more to build and maintain a higher voltage electricity distribution system that can supply large amounts of energy quickly. At the price of $12-22 per kW for demand charges could add $30,000 a year to the cost of running a quick charger — these added costs are particularly problematic if a charger has low utilization. Within the taxi electrification effort, it may be possible to rely on mobile technology to increase charger utilization But in the longer term, the City, the electric utilities and regulators may need to address the fundamental economics of standby charges to make quick chargers more viable.

EVs at Hunts Point market

The Hunts Point Food Distribution Center (FDC) is the City's primary food hub, with more than 100 wholesale distributors supplying more than 50 percent of the City's produce, meat, and fish. Most commodities arrive by truck, and most trucks run on conventional diesel. To promote the conversion of truck fleets to alternative fuels, the City is partnering with a private developer to build a retail alternative fueling station in the FDC. In addition to offering biodiesel, CNG, ethanol, and limited conventional fuel, this project also plans to offer electric vehicle charging stations, which will make electric vehicles more attractive and help electrify some of the 12,000 daily truck trips to the FDC.

Potential Quick Charge Network for Electric Taxis
Number of chargers per district



Source: NYC Mayor's Office

Strategy 5
Support Biofuels

Biofuels are already available, but just as with EVs, their adoption has been gradual. Supply is not the limiting factor – plenty of capacity is available locally, however little retail infrastructure exists. To promote biofuel adoption, City and State governments could work to explore biofuel mandates. The City's own fleet could serve as a testing ground for progressively higher biofuel blends. New York City's municipal fleet has emerged as one of the largest purchasers of biofuels on the East Coast: some City vehicles already use blends of up to 30 percent, and blends of up to 90 percent are being tested. The municipal fleet average could approach 30 percent by 2020 already, setting an example for other large fleets around the city. Biofuels requirements for City contractors have not been introduced yet, but could be considered.

Strategy 6
Make Driving More Economically Efficient

Use fees for vehicle travel

Use fees – a regional vehicle miles travelled charge or congestion pricing – can help reduce VMT and increase available funding for transit. New York City proposed a congestion pricing program in 2008, with the idea of charging drivers for entering the Central Business District and using the revenues to fund transit – but it did not advance past the State Assembly despite support from the City Council. Several European cities have successfully put similar programs in place: in one example, bus use in Stockholm's core rose 9 percent after the city introduced a congestion charge; in another, Singapore experienced a 73 percent decline in the use of private cars, a 30 percent increase in carpools, and a doubling of buses' share of work traffic.[15] In the case of New York, a similar use fee tool could offer a 0.3 MtCO2e reduction and generate nearly a billion dollars a year for transit investment.

Dynamic pricing for parking

Dynamic pricing for parking helps match parking supply to parking demand and avoids situations in which drivers cruise endlessly for available parking spots, which contribute to congestion. San Francisco (SFPark) and Los Angeles (LAExpresspark) already have such programs in place, and New York City is conducting pilots in Greenwich Village, Park Slope, Jackson Heights, and Atlantic/Smith/Court Streets as part of the PARK Smart program. Depending on the results of the pilots, the program could be expanded further, making parking in the city more efficient.

Pay as you drive insurance

As its name suggests, "pay as you drive" insurance (PAYD) allows drivers to pay for insurance based on the amount of miles they drive. Newly available thanks to simple devices that car owners can install to share driving data with their insurance companies, PAYD rewards drivers for driving less, thereby contributing to reductions in the number of miles traveled. Two insurance companies began offering PAYD insurance in New York in early 2013; in the longer term, if the experience proves successful, a 50 percent switch to PAYD insurance could abate as much as 0.5 MtCO2e.

Selectively Improving Air and Freight

Air travel and the movement of freight are two large sources of emissions not counted in the City inventory. Although large-scale changes to either are often beyond the purview of the City and its partners, targeted opportunities for improvement do exist.

Assisted airplane towing

% n/a

1.2 million tons

-$640 per ton

Airplanes produce most of their emissions while airborne, but a surprisingly high share takes place on the ground, where planes use their jet engines for taxiing during takeoff and landing. Precise amounts differ depending on the level of airport congestion, but a 2007 study from MIT[6] estimated that a short/medium range A320 jet could expend up to 5-10 percent of its fuel on the ground. Assisted towing – moving planes to takeoff positions using either diesel tugs or electric in-wheel engines – would allow planes to run their engines less, resulting in net on-the-ground CO2 emissions reductions that the MIT study put at 70-77 percent depending on airport.

None of the three airports in the New York City area use towing yet; nor do any of the airlines that fly into them. Diesel tugs present operational and safety challenges that arise any time that additional equipment is added to the airfield, and airplane manufacturers do not yet guarantee that their everyday use would not damage the planes; in-wheel tugs are still being tested. Yet the potential for reducing emissions, 0.7 million tons if 80 percent of flights out of the city's three airports relied on assisted towing, is comparable to the potential of large-scale vehicle electrification. Thanks to the fuel savings, the cost of abatement would be deeply negative, at -$640/ton. In the coming years, pilot projects could help establish whether assisted towing could be an option for the area's airports.

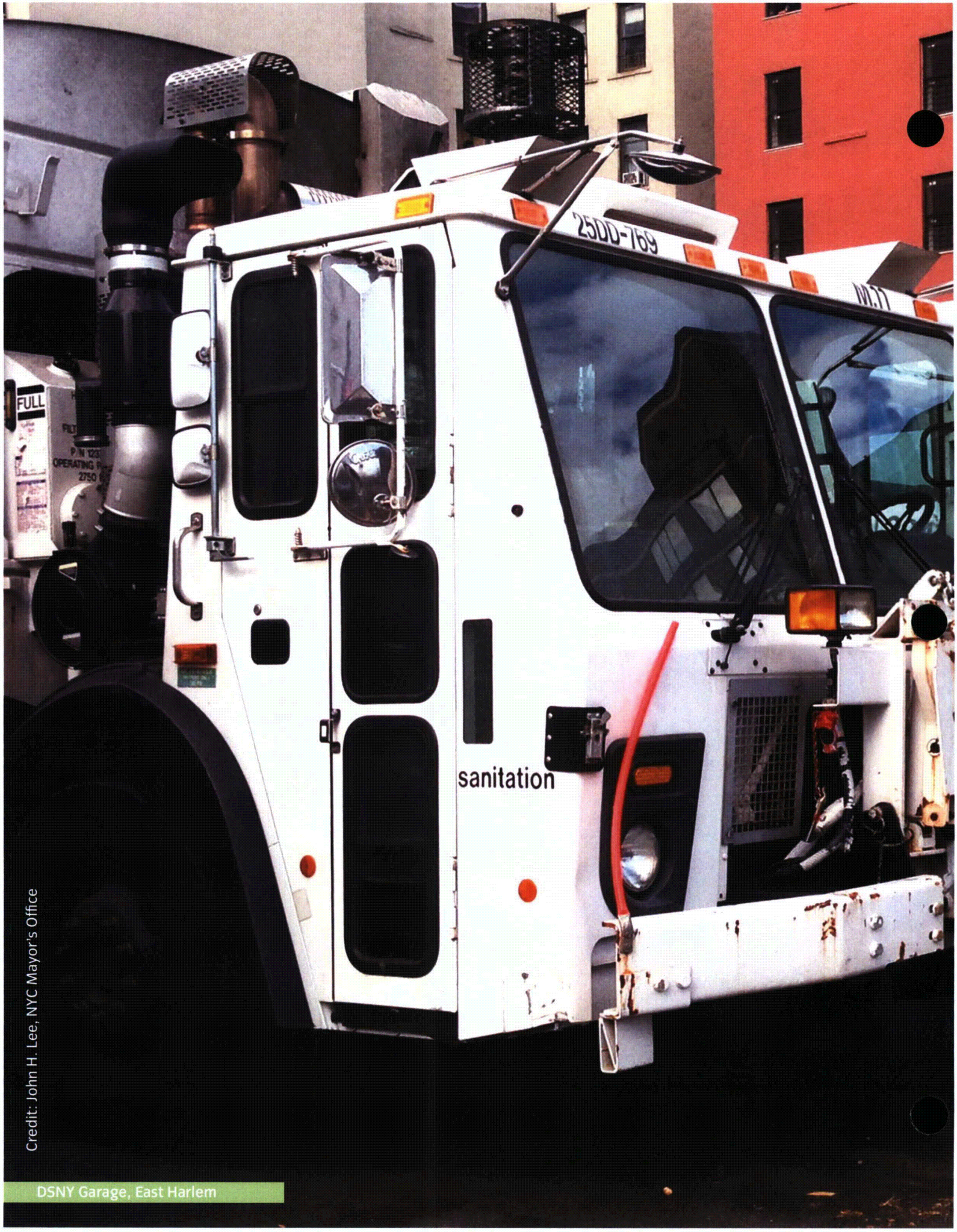
Improved freight operations

% n/a

2.7 million tons

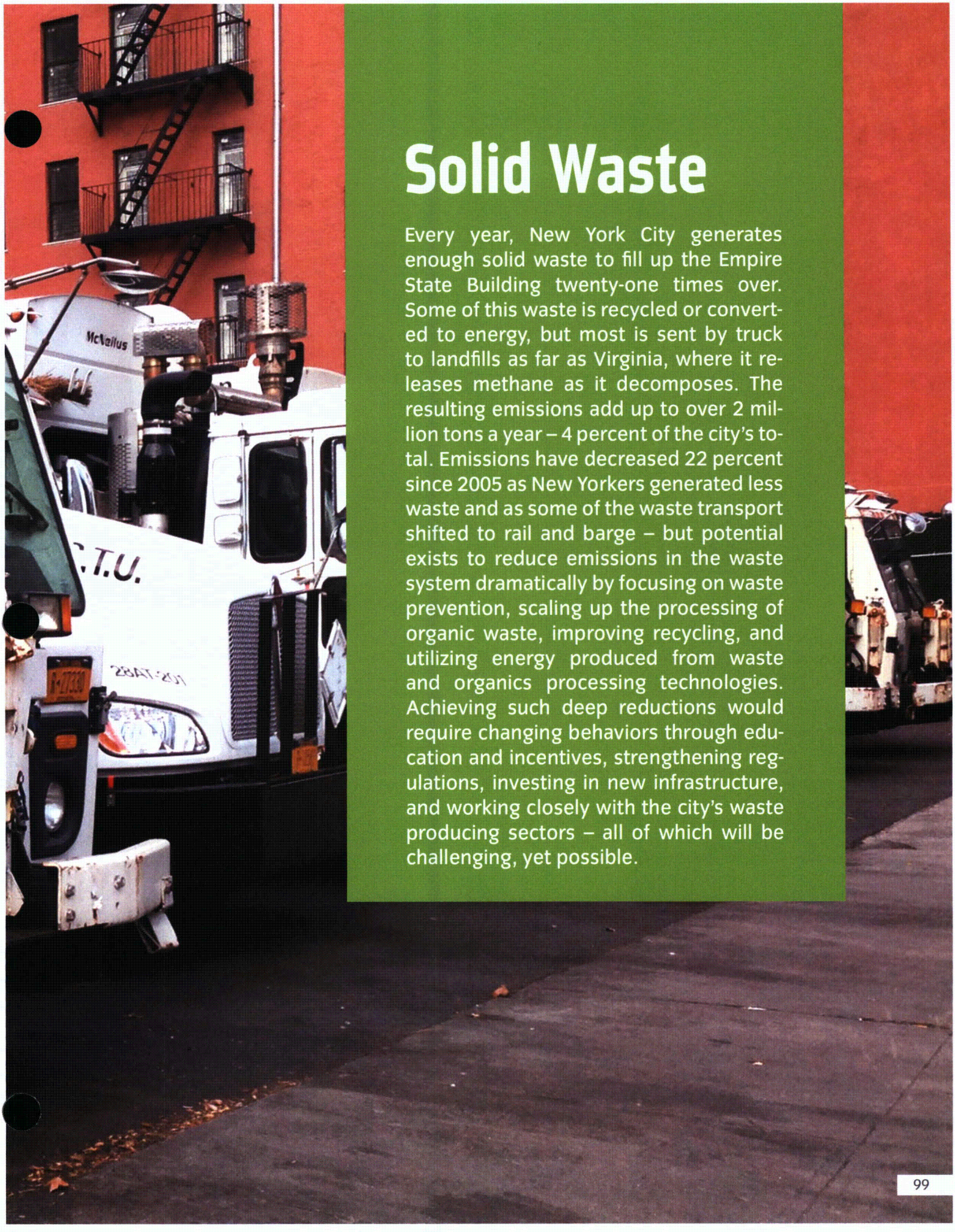
$ n/a

Decades ago, most freight arrived in New York City by rail and by sea. The piers from those days are mostly gone, but their numbering – say, Pier 71, indicates just how many of them used to accept goods coming into the city. Today, most freight comes into the city by truck – but trucking, at 0.37 pounds of CO2 per ton-mile, is far more carbon intensive than rail freight, at 0.22 pounds, let alone seaborne shipments, at 0.09 pounds. Carbon intensity of trucking will decrease as fuel economy improves and as new technologies appear. Shifting 70 percent of inbound freight away from trucks or to low emitting technologies could result in carbon emissions savings of between 1.6 and 3.7 MtCO2e. Because the exact amount is difficult to estimate this potential was not counted together with other 80 by 50 levers. PortNYC, a program of the New York City Economic Development Corporation (NYCEDC), has been working for years to boost the volumes of traffic coming in by sea and by rail, including through reopening the Staten Island Railroad, improving rail facilities at the Hunts Point Food Market, and upgrading the capacity of South Brooklyn Marine Terminal to allow transloading of sea cargo onto trains. Future PortNYC projects will continue to improve non-truck freight options available.



Credit: John H. Lee, NYC Mayor's Office

DSNY Garage, East Harlem



Solid Waste

Every year, New York City generates enough solid waste to fill up the Empire State Building twenty-one times over. Some of this waste is recycled or converted to energy, but most is sent by truck to landfills as far as Virginia, where it releases methane as it decomposes. The resulting emissions add up to over 2 million tons a year – 4 percent of the city's total. Emissions have decreased 22 percent since 2005 as New Yorkers generated less waste and as some of the waste transport shifted to rail and barge – but potential exists to reduce emissions in the waste system dramatically by focusing on waste prevention, scaling up the processing of organic waste, improving recycling, and utilizing energy produced from waste and organics processing technologies. Achieving such deep reductions would require changing behaviors through education and incentives, strengthening regulations, investing in new infrastructure, and working closely with the city's waste producing sectors – all of which will be challenging, yet possible.

Overview

Mayor Bloomberg Announces Start of Expanded Recycling Program

On the city's sidewalks, black bags pile up at night; by morning, they disappear into the bellies of garbage trucks. Leftover food and old clothes, used paper cups and coffee shop grinds, wood and metal and concrete debris all add up to 10 million tons of waste a year — enough to fill the Empire State Building 21 times over, or to load up more than 3,000 large trucks every day. Around 15 percent of this material ends up at recycling plants; another 10 to 15 percent is converted to energy at facilities in New Jersey; less than 1 percent becomes compost; and the remainder travels as far away as Virginia and South Carolina to end up in landfills. City taxpayers fund the residential part of the system, spending more than $100 for every ton that goes to landfills, but earning back up to $20 for every ton that is recycled, for a net expenditure of more than $300 million a year for the export of waste. Collection costs run an additional $700 million. Commercial waste is paid for by businesses directly.

Annual emissions from waste amount to 2.1 million metric tons — most from paper and organic waste as they decompose in landfills, and the rest from waste-to-energy facilities and from the trucks and trains that move the waste within the city and away from it. Emissions fell more than 20 percent in recent years because New Yorkers generate less waste, and because some of the waste now travels by rail and barge instead of truck – but reductions consistent with an 80 by 50 goal would need to go far beyond that. On that pathway, the volumes of waste would have to drop, most recyclable waste would have to be recycled, most organic waste would need to be composted or turned into biogas, and the rest would be converted to energy with minimal environmental impact. Very little would be landfilled.

The potential does exist to achieve these outcomes – and nearly all of the individual measures to get there would lead to savings in the long term. Yet unlocking this potential will be challenging. New Yorkers would need to improve recycling habits, which will be aided by the recent simplification of rules and improved messaging. Waste processing infrastructure improved significantly this fall with the opening of the new Sims recycling facility in South Brooklyn – but the infrastructure to process organic waste would need to be expanded. Plants in New Jersey convert some of the waste-to-energy – but newer, cleaner, and more efficient plants are yet to be built.

These challenges are real, but they may be possible to overcome – and initiatives of the last years have already pushed New York City towards a more sustainable solid waste system. With the appropriate long-term commitment, emissions from solid waste could continue to drop and potentially even be neutralized.

Solid Waste Fundamentals

New York City's residents, workers, and visitors generate more than 10 million tons of waste every year. Approximately two-thirds of this waste is generated from everyday activities and typically left for pickup on the curb. The remaining third is debris from the construction and demolition of buildings (also called C&D waste). An additional 4.8 million tons of fill – essentially dirt from excavations – is generated each year but nearly all of it is reused within the city and thus is not a major source of exported waste or GHG emissions.

Uniformed City workers from the Department of Sanitation (DSNY) pick up waste from residents, City government buildings, and some large institutions like hospitals and universities. More than 200 commercial carters pick up waste from businesses. Residents are required to separate their waste into three streams: paper and cardboard, metal/glass/plastic, and all the rest.[17] Businesses are also required by law to recycle and some are now required to source separate organic waste. (See chart: *Residential Waste Composition*)

Once picked up, residential and commercial waste is typically transported to one of four types of destinations: recycling facilities, organic waste processing facilities, waste-to-energy facilities, or landfills. A small but potentially growing amount of organic waste is processed at the City's wastewater treatment plants; several hundred tons a year are also composted locally at neighborhood community gardens. In 2011, recycling rates for residential, commercial, and C&D waste were at 20 percent, 46 percent, and 45 percent, respectively. Between 8 and 19 percent of waste was converted to energy, one percent was composted, and the rest was sent to landfills. (See charts: *New York City Solid Waste by Source and Mode of Disposal* and *New York City Residential and Commercial Solid Waste Flows*)

Solid waste transfer and processing facilities are spread throughout the city and far beyond it as well. The majority of DSNY's recyclable content is managed at the new Sims facility in South Brooklyn; composting is taken to locations in Staten Island, Rikers Island, and most recently, to the Newtown Creek Wastewater Treatment Plant; and everything left over is taken to waste-to energy facilities outside of the city or to transfer stations in the city that coordinate delivery to landfills as far away as Virginia and South Carolina. In the case of commercial carters, recyclables are taken to a variety of private processing facilities; compostable waste mostly travels to a facility in Delaware — though large commercial facilities are now under development closer by; and the remaining waste either goes directly to waste-to-energy facilities or is offloaded at a network of private transfer stations in and around the city and exported to remote landfills, mostly by truck. (See chart: *New York City's Solid Waste Infrastructure*)

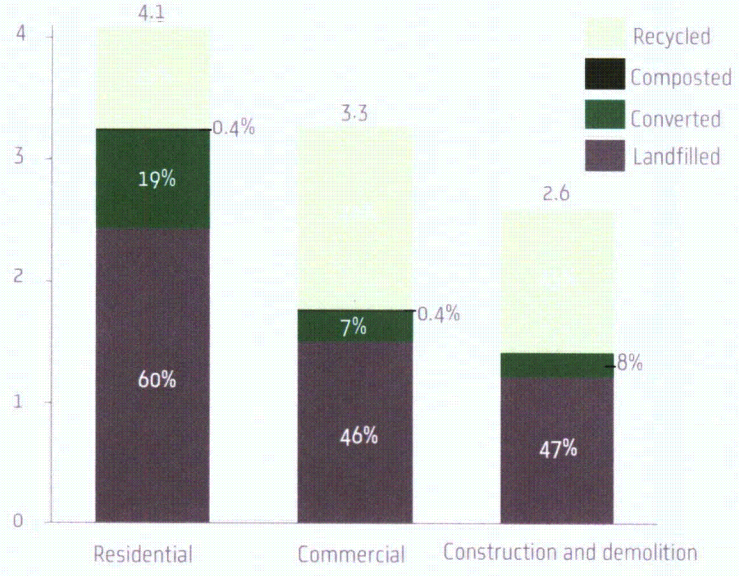
The costs of managing the city's waste are substantial. DSNY spends more than $700 million a year to collect the waste, and more than $300 million to export it, paying on the order of $100/ton for landfill exports, around $60/ton to recycle metal, glass, and plastic, and earning $20/ton on paper recycling. Businesses spend comparable amounts.

The system has evolved over the years. In the first half of the twentieth century, building-based incineration was common, and disposal in local landfills was the standard until municipal landfills started closing, culminating in the closure of Fresh Kills Landfill on Staten Island in 2001. In 2006, the City's Comprehensive Solid Waste Management Plan (SWMP) addressed the issues of geographic equity in the siting of waste transfer infrastructure. Historically the Bronx and Staten Island hosted a disproportionate part of the city's waste infrastructure. The SWMP sought to minimize in-city waste truck traffic by committing to construct a network of marine transfer stations throughout the city, where waste would be loaded onto barges and then taken to transfer stations outside the city, in order to be put into rail cars and trucks and exported to landfills. Each borough would manage the waste it generates at facilities located within the borough. The City is in the process of signing long-term export contracts with landfills in the Northeast; five marine transfer stations are under construction and are scheduled to become operational in 2018.

Approaches to managing waste are also evolving: in the 2011 update to PlaNYC, the City committed to diverting 75 percent of solid waste from landfills by 2030 (the number includes fill). In 2013, the City also undertook the largest expansion of the recycling program in its 25 year history by accepting all rigid plastics for recycling for the first time.

New York City Solid Waste by Source and Mode of Disposal

Millions of tons of waste; %, 2011



Source: NYC Mayor's Office

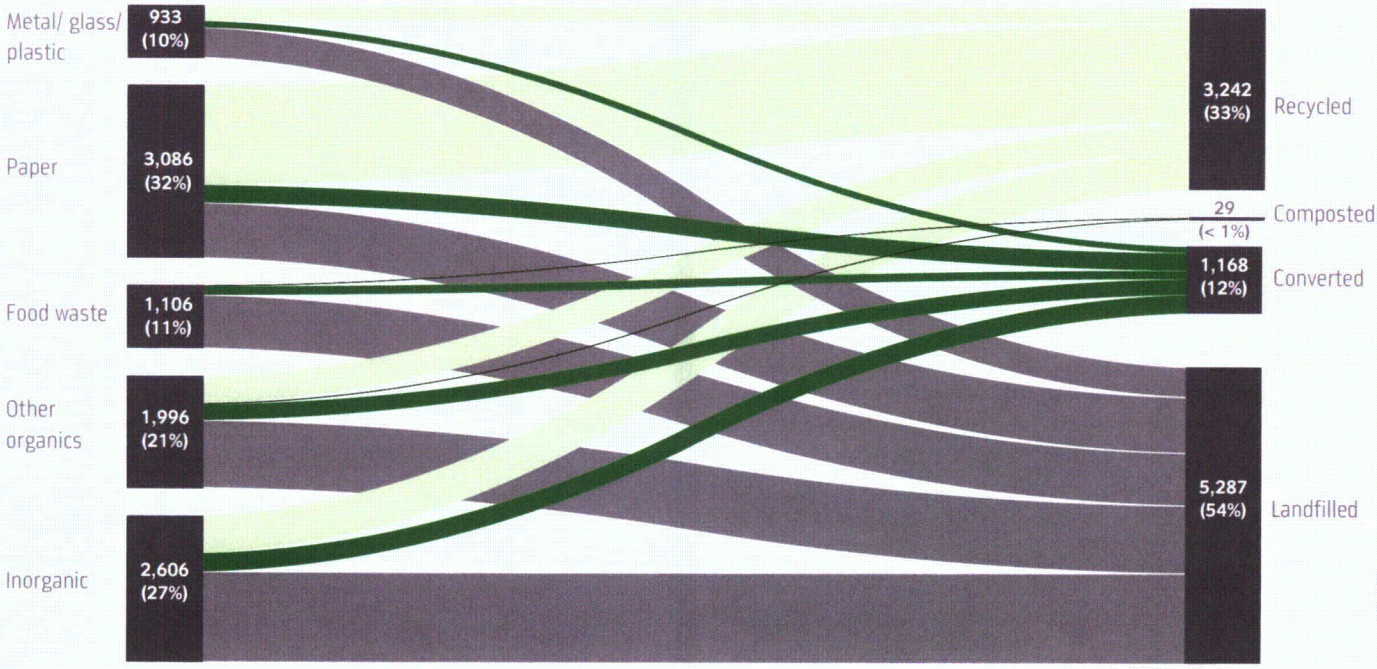
Residential Waste by Composition

Millions short tons; % of total; 2004-2005

Source: NYC Mayor's Office

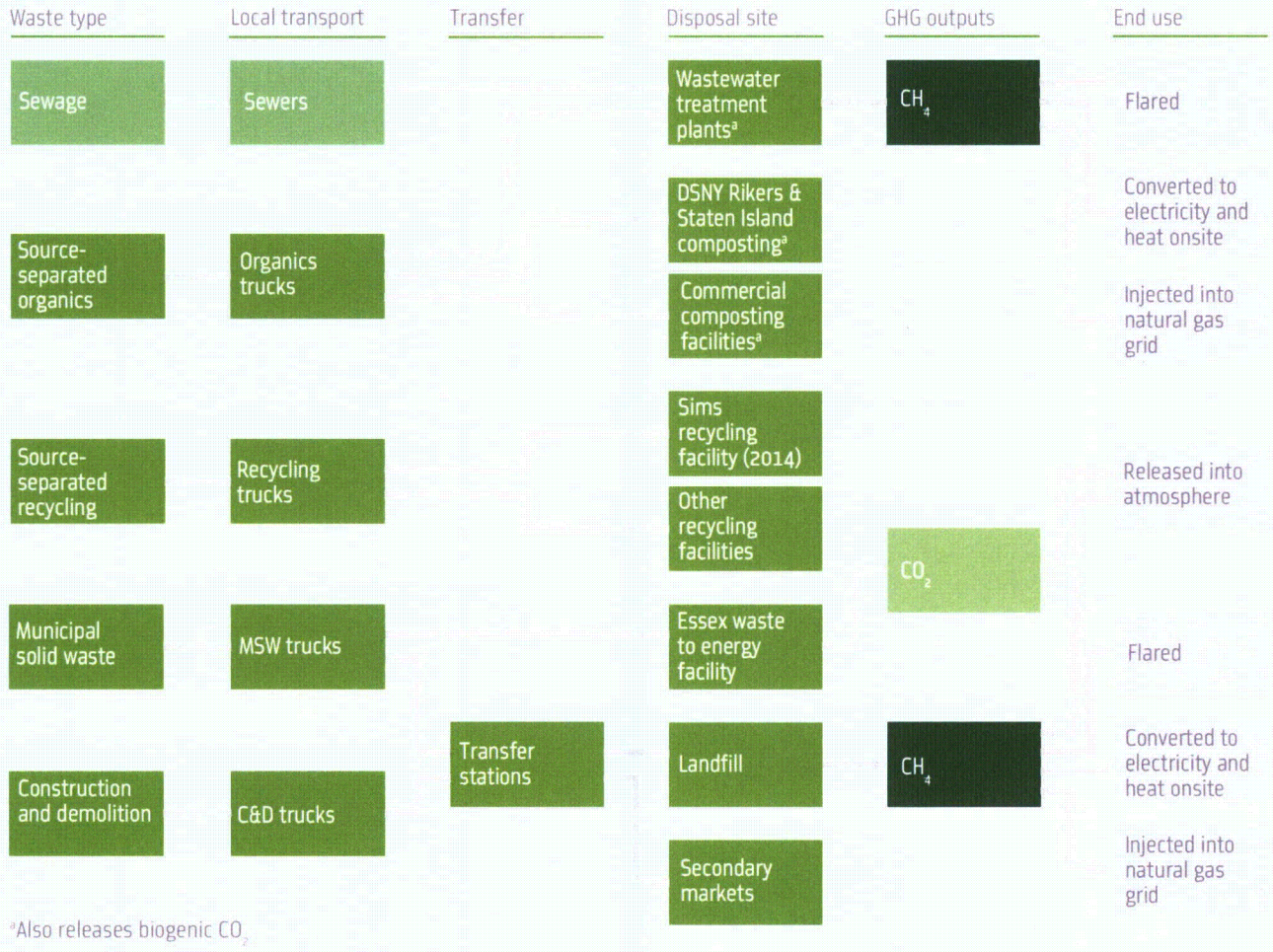
New York City Residential and Commercial Solid Waste Flows[18]

Thousands of tons; 2011



Source: NYC Mayor's Office

New York City's Solid Waste Infrastructure
As of 2013



[a]Also releases biogenic CO_2

Source: NYC Mayor's Office

Most recently, the processing of organic waste has come to the fore as the City is beginning to pilot curbside composting pickup in several neighborhoods in all five boroughs. In addition, working with the restaurant sector on a Food Waste Challenge requires participants to commit to diverting at least 50 percent of their food waste from landfill, and most recently, passing a requirement that large generators of organic waste source separate that content, beginning in 2015, in order to divert it from landfills. The City is also working with a waste management company to process food waste collected from Public Schools into a slurry and then use spare anaerobic digester capacity at the Newtown Creek Wastewater Treatment Plant to turn the food waste into biogas that can then be fed back into the utility grid.

Sources of GHG Emissions

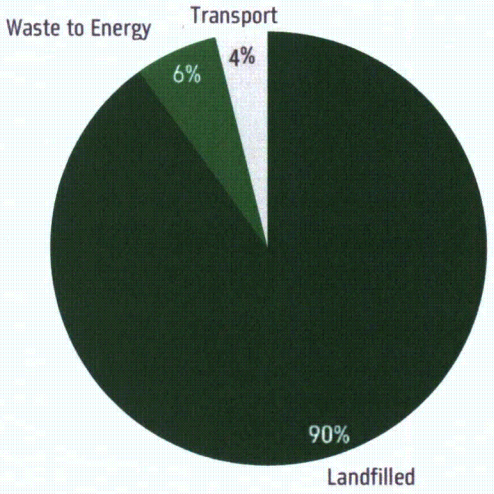
New York City's solid waste emissions come from three sources – landfill methane, waste-to-energy, and transportation – that in 2011 added up to more than 2.1 million tons.

Landfill methane is by far the biggest source: it is responsible for 89 percent of all solid waste emissions (See chart: *Solid Waste GHG Emissions by Source*). The methane is generated when paper and organic waste decompose in landfills without oxygen (if oxygen were present, the decomposition would produce CO2 instead). Most landfills install equipment that captures up to 90-95 percent of the leaking methane and either flares it, produces electricity with it, or cleans it and feeds it into the gas grid. However, because the global warming effect of methane is 25 times as high as that of CO2, even the relatively small amounts of fugitive emissions should be avoided.

Emissions from processing waste at waste-to-energy facilities are the second, but far smaller, source of emissions, with a 6 percent overall share. Transportation represents an even smaller share of the overall emissions, but has been a source of emissions reductions in recent years as export of municipal solid waste has shifted from truck-based to rail- or barge-based transportation.

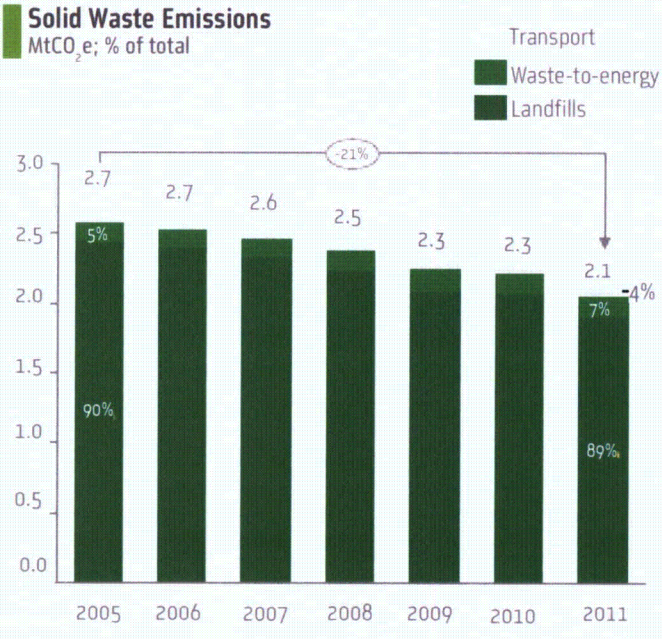
The relative composition of these three components has remained relatively unchanged since 2005, but the total fell by 21 percent, mostly because New Yorkers began to generate less waste per capita and because of the aforementioned mode shift. Exact reasons for the decline will not be known until DSNY completes a new waste characterization study (the previous one dates from 2005), but the technology-related decline in paper use and newsprint circulation might offer a partial explanation.

Solid Waste GHG Emissions by Source
% of total; 2012



Source: NYC Mayor's Office

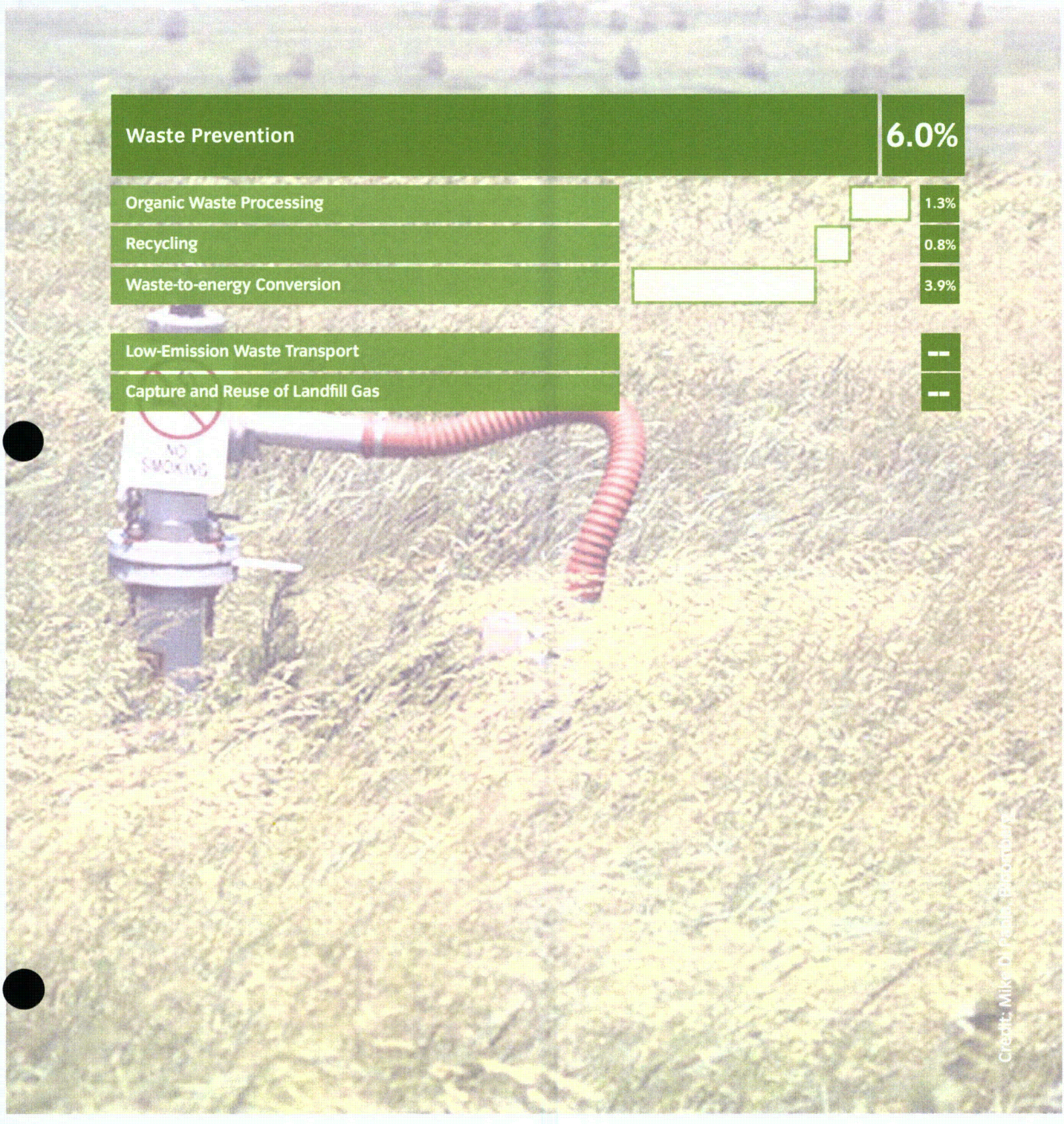
Solid Waste Emissions
$MtCO_2e$; % of total



Source: NYC Mayor's Office

Technical Potential of GHG Reduction Measures

As % of total 2005 emissions



Emissions Abatement Potential

The "three R's" of solid waste management – reduce, reuse, recycle – are also a strong framework for limiting greenhouse gas emissions from the sector. On the 80 by 50 pathway, volumes of waste would need to drop as consumers use fewer disposables and manufacturers of goods pay greater attention to packaging. Nearly all organic waste would need to be composted or processed in anaerobic digesters within the region; nearly all recyclable material would need to be recycled; and most of what remains would need to be turned into to energy at state-of-the-art, low-emission conversion facilities. Only a very small portion of remaining waste would be sent to landfills, which would lead to savings both for businesses and residents. The sector that produces more than 2.1 million tons of emissions today would need to be nearly carbon free to reach 80 by 50.

Waste prevention

The best way to reduce carbon emissions from waste is not to generate it in the first place. Volumes of waste generated per capita usually go hand in hand with prosperity. The wealthier a city, the more its residents tend to consume, and the less they tend to reuse. For example, New York City residents generate nearly 1,800 pounds of waste per year on average, while residents of the average city in China generate nearly half that — a reflection of higher consumption and income levels in the U.S. compared to China.

In recent years though, New York City's waste generation volumes have been falling. Since 2005 they have fallen by more than 20 percent. While the reasons behind the decline are not entirely clear — explanations include lighter packaging, a decline in paper use because of computerization, and a shift in consumption patterns away from goods and towards services), they mirror the national trends: solid waste generation in the U.S. stood at 980 pounds per year back in 1960, climbed to 1,730 in 2000, and has since declined to 1,606 — a drop of more than 7 percent.

Still, potential exists to reduce the volumes of waste further – for example, another 20 percent reduction would eliminate 0.4 million tons of emissions. For example, reducing the use of disposable paper and plastic bags by 75 percent — the kinds of reductions that cities like Washington DC and Dublin that introduced bag fees or bans are seeing — could reduce emissions by almost 20,000 tCO_2e. In another example, reducing the use of plastic foodservice packaging by 55 percent could reduce emissions by 11,000 tons. These numbers are highly understated given that they only capture local emissions and not the upstream emissions embedded in these disposables — a factor that is important to consider in any discussions of the impact of better solid waste management. This study however assumed, conservatively, that per capita generation rates will remain flat.

Organic waste processing

1.3%[a]
0.8 million tons[b]
-$60 per ton[c]

Organic waste makes up about 35 percent of the city's waste stream but less than one percent of that amount is composted or otherwise processed. The rest goes to landfills, including over 1.2 million tons of discarded food waste alone. Organic waste is the greatest contributor to New York City's solid waste emissions because the decomposition of organic materials in landfills in the absence of oxygen produces methane — a greenhouse gas that is 25 times stronger than carbon dioxide. While modern landfills can capture as much as 90 percent of their methane — which they either flare, feed back into the natural gas grid, or convert to electricity onsite — older landfills may emit methane at higher rates. Two favorable alternatives to landfilling organic waste can help to reduce emissions.

The first alternative, composting, involves the decomposition of organic waste in the presence of oxygen at either small-scale facilities in backyards or community gardens, or at a larger scale in windrows. Because the decomposition is aerobic, organic compounds break down into CO2 instead of methane — and because these materials (plants, for example) originally captured CO2 from the air, the net impact on global emissions is zero (such emissions are also called biogenic).

The second option, anaerobic digestion (AD), involves the accelerated decomposition of organics without the presence of oxygen in the same process that sewage undergoes at wastewater treatment plants after it received initial treatment. Digesters break down the waste into water, methane, and sludge. The sludge is then exported

[a] Percentage sector wide reduction
[b] Amount of CO_2e abated
[c] Cost to abate carbon

to specialized landfills or turned into fertilizer, while the methane is captured and, just as with landfill methane, is either flared, burned to produce heat and energy, or cleaned and returned into the natural gas distribution grid, as will be the case at the City's Newtown Creek Wastewater Treatment facility.

Of the two options, scaling up of anaerobic digestion holds the greatest carbon reduction potential. Initiatives like backyard and community garden composting are important, particularly to build public awareness, but regular composting fails to capture all of the energy embedded in organic waste (which is why composting heaps heat up), whereas AD captures most of it. Anaerobic digestion also makes economic sense. Societal cost of carbon reductions is on the order of negative $60/ton in 2030 because processing waste locally and turning it into energy is far cheaper than sending it to landfills by truck. The GHG reduction potential from it amounts to at least 0.8 MtCO2e in 2050.

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Recycling

0.8%
0.5 million tons
-$130 per ton

Non-organic recyclables that end up in landfills contribute less to the City's Scope 2 emissions than organics do. This is because of the recyclables that New York City collects, only paper decomposes, while metal, glass, and plastic only contribute to transportation emissions. That said, the real benefit of recycling comes from reducing upstream emissions by tempering demand for virgin materials like paper and aluminum that require large amounts of energy to produce (aluminum smelters require so much energy that they are usually sited based on proximity to cheap electricity). The avoided emissions from recycling far outweigh those emissions that New York City's current carbon inventory would capture.

Just like anaerobic digestion, recycling is also attractive economically: the City is currently paying around $60/ton to process metal, glass, and plastic – an almost 50 percent reduction from the cost of landfilling, and it is actually earning up to $20/ton for paper. As a result, improving recycling rates can offer cost-negative reductions at a cost of around -$130 per ton of carbon.

The city's current recycling rate is relatively low compared to other major cities which is why such aggressive efforts are underway to increase participation. Only about 20 percent of residential waste is recycled. Recycling rates in the commercial sector are higher — around 46 percent, in part because much of it is paper, which is a valuable commodity. If recycling rates were to increase to 30 percent on the residential side — which is the City's current 2020 goal — and, very conservatively, stay at least unchanged on the commercial side, the city could reduce annual GHG emissions by at least 0.5 MtCO2e by 2050.

Waste-to-energy conversion

3.9%
2.5 million tons
-$100 per ton

Approximately 19 percent of the city's non-recycled residential waste and 7 percent of its non-recycled commercial waste travels to conversion facilities in Essex County, New Jersey rather than to landfills. These facilities utilize high temperatures to combust waste and then use the heat from the combustion to produce steam, which then powers the turbines that generate electricity.

A newer technology called plasma gasification is beginning to emerge as a viable alternative: in gasification facilities, waste is not combusted, but is rather heated up to such a high temperature that it breaks down into basic molecules that form synthetic gas (syngas) which is then used to produce electricity – a cleaner and more efficient way of turning waste into energy. The technology is not yet available in or around New York City, but the plants are clean enough and can be small enough to potentially site them in or near the city and connect them to either the local district heating systems or even potentially the steam system. Plasma gasification facilities could also be retooled to turn syngas into methane and then export it to the grid or to turn it into liquid fuels.

Several pilots have already been constructed around the U.S. and globally and the technology is becoming more promising. Although the siting of waste-to-energy facilities within or close to the city could be met with opposition from local residents, other cities — most notably Copenhagen — have successfully integrated small scale waste-to-energy facilities into their district heating systems, ultimately gaining public acceptance for the idea of processing waste closer to where it is generated.

The total potential carbon abatement from plasma gasification is 2.5 MtCO2e by 2050, which would enable the waste sector overall to become a carbon sink — i.e. it would create a net reduction in the city's overall emissions inventory. It is important to note, however, that although waste conversion using plasma gasification may be attractive from a carbon accounting point of view, it should not become a replacement for waste prevention, recycling, and composting, all of which are preferable from an overall environmental standpoint. As with organics processing and recycling, the cost per ton of carbon abated would be negative — around -$100/ton in 2030.

Low-emission waste transport

Waste transport accounts for just 4 percent of the city's solid waste emissions. A small share comes from the trucks that collect waste within the city; the majority is from larger long-distance export trucks that travel hundreds of miles to landfills out of state because landfilling is cheaper where land values are lower. The City's 2006 Solid Waste Management Plan called for transitioning to rail and barges for exporting waste as an alternative to trucks and implementation of the plan has already reduced emissions by 50,000 tons. Transport emissions could be reduced further through additional mode-shifting or through using more efficient vehicles and cleaner fuels for the long-haul export trucks. Because of the small size of the impact of mode-shifting, the exact potential was not quantified.

Capture and reuse of landfill gas

All landfills to which the city exports its waste capture fugitive methane, which they flare, turn to energy, or sell into the natural gas. The average landfill capture rate is around 85 percent. At landfills within the city, all of which are now capped, generation of methane is declining and methane capture is improving, which in recent years contributed to a 30,000 tCO2e reduction in emissions. While small additional improvements may be possible with better technology, further analysis was not conducted.

Challenges

The solid waste system could one day be nearly carbon-free — but three challenges stand in the way, having to do with choices, incentives, and infrastructure.

The right choice is not always the easy choice within the existing system

Every day, eight million New Yorkers make decisions about waste — whether to reuse, or recycle, or to compost, or to send something into a landfill. These decisions compete with hundreds of others — and if it comes to a choice between putting a water bottle in the trash, recycling it, or not buying it in the first place, the simplest option will often win. Recycling is available, but can be complicated; composting is thought of as an option for only the most environmentally minded. And even environmentalists can be frustrated by resource choices and packaging decisions that are made upstream, where the consumer has little influence. As a result, most waste ends up in landfills – even if the people who send it there would prefer that it did not.

Many residents and businesses are not concerned and have no incentive to be

Some New Yorkers pay enough attention to recycling and composting that they will begin to recycle new types of waste on the first day a new option is announced. But others will express little or know interest in learning new rules or changing behavior. They might benefit from having more information — but that may not stop them from feeling that "green" options are too varied or inconvenient. They might choose to modify their behavior if they had the incentive — but with waste pickup included in the tax bill, they have few reasons to do so.

Infrastructure to support new waste handling methods is unavailable locally

New York City exports most of its waste, and local facilities for processing it are in limited supply. The situation improved this fall with the opening of the Sims Recycling Facility in South Brooklyn, but more infrastructure is needed, particularly for organic waste processing. Small-scale, community- based composting programs are spreading to Greenmarkets and neighborhood facilities throughout the city thanks to a partnership between GrowNYC and the NYC Department of Parks and Recreation, but these sites do not offer sufficient processing capacity for a city-wide organic composting effort. Additional processing infrastructure is expected to come online now that the City passed legislation that will require large generators to divert organic waste from landfills by 2015.

Capturing the Potential

Strategy 1
Making it Easier to Compost and Recycle

Recycling in the public realm

New Yorkers can recycle at home and at work—but until recently their only option on most city streets was to toss their recyclables in garbage cans. In March 2013, Mayor Bloomberg launched the city's first public space recycling pilot, inaugurating 30 BigBelly solar-powered recycling compactors in Times Square that will serve more than 500,000 people who pass through the area every day. Conventional recycling containers are on the way as well: by the end of 2013, the City will place more than 1,000 of them around New York. Future efforts to encourage recycling would have to continue expanding the availability of public recycling options.

Recycling in apartment buildings

Many of the city's apartment dwellers may want to recycle but may not know enough about their options or may lack room for separate recycling bins in their buildings. To expand the availability of space for recycling in apartment buildings, the Green Codes Task Force—a group of more than 200 design and real estate professionals that were convened by the Urban Green Council at the request of Mayor Bloomberg and New York City Council Speaker Christine Quinn—recommended that new and fully renovated buildings with more than 12 units include a designated waste and recycling room. This proposal was enacted into law.

Existing buildings without dedicated recycling rooms can still benefit from better information and simpler recycling rules. To this end, DSNY recently expanded the recycling program to include for the first time the recycling of all rigid plastics, including toys, hangers, shampoo bottles, coffee cups and food containers, which will reduce confusion about which plastic types are recyclable and which are not. The City also simplified its information materials and messaging about recycling to educate New Yorkers about these changes.

Composting options

In 2013, DSNY started collecting organic waste from several neighborhoods in Staten Island, Queens and Brooklyn, picking it up from single- and multi-family homes several times a month and delivering it to transfer stations, from where it is sent onward to composting and anaerobic digestion facilities. The program has proven successful and is now being expanded to other neighborhoods and building types.

Strategy 2
Changing Behaviors through Education, Challenges and Incentives

Improving marketing and education

Individual actions can have a huge impact in changing the marketplace. New Yorkers are certainly open to the idea of changing their behaviors: a recent study by GreeNYC, PlaNYC's public education arm, found that the city's residents were collectively willing to take simple actions that could reduce up to 200,000 tons of paper, textile, and food waste per year—2 percent of the city's waste stream. Converting this willingness into real reductions will be challenging. Collection for commercial and residential waste streams operates entirely independently and this can cause confusion and frustration. To address the issue, the City is already working to improve its educational tools and is working with the commercial waste sector to achieve consistent messaging; the work will need to continue.

Food waste challenges

Mayoral Challenges, where several organizations within an industry are asked to commit to sustainable goals on a voluntary basis have worked well for greenhouse gas emissions – and the model can be expanded to solid waste. The Mayor's Food Waste Challenge, a voluntary challenge to the private sector to commit to divert from landfills at least 50 percent of the food waste that they generate is doing just that. The program requires participants to conduct a baseline waste generation audit and then use simple tracking techniques to measure diverted waste on an ongoing basis. It will also be complemented by a professionally branded, "consumer facing" campaign that could engage diners and the public to build awareness and support for organic waste composting. A high-profile group of participants and a successful program could prove that organic waste diversion is feasible, affordable, and good for business.

Price signals

Waste collection and export may cost the City hundreds of millions of dollars annually, but most New Yorkers would not notice since they are not billed directly but rather indirectly through their tax bills. As a result, households have no monetary incentives – other than fines for non-compliance – to either recycle more or to reduce the amount of waste they generate. Cities across the country have developed creative solutions to setting price signals that incentivize waste reduction. For example, the City of Philadelphia and others have partnered with private companies to incentivize recycling by providing discounts and gift certificates at leading retailers. Other cities have set direct price signals through Pay-As-You-Throw programs in which homes are charged for non-recyclable waste they generate, which becomes an incentive to produce less waste. In New York City, implementing these programs in multifamily housing could be challenging; one and two-family homes could present less of an obstacle.

Strategy 3
Spurring Action through Mandates and Enforcement

Targeted waste reduction measures

According to the City's 2005 Waste Characterization Study, paper and plastic bags represent 3.4 percent of the city's residential waste stream, or 120,000 tons a year. Cities like Dublin and Washington DC have already launched targeted campaigns to reduce disposable bag use – one program to impose small bag fees succeeded in reducing their volume by as much as 90 percent and significantly reduced pollution in rivers and water bodies. In New York City, similar measures to manage bag use could divert large amounts of waste from landfills at a negligible consumer cost.

Organics collection from the largest generators

The top 10 percent of food waste generators — large hotels, banquet halls, cafeterias, and food wholesalers — produce approximately 40 percent of organic waste. Policies and programs to introduce organics collection for at least these largest generators — including through mandates–would help jumpstart organics processing. To this end, the City recently passed into law a requirement that large generators of organic waste — those that generate at least one ton per week — divert it from landfills through source separation. When fully enacted in 2015, the law could result in up to 30 percent of the city's organic waste being diverted from landfills while only affecting less than 5 percent of businesses that generate organic waste and less than 0.5 percent of businesses overall.

Diversion of construction and demolition waste

Construction and demolition accounts for more than a quarter of the city's waste. The City is already addressing the issue through the Green Codes process: a recently passed local law requires at least 30 percent recycled asphalt in new streets, which will divert up to than 300,000 tons of asphalt away from landfills every year. Two more proposals are moving through City Council: one establishes requirements to recycle C&D waste from construction sites; the other requires a minimum percentage of recycled concrete in certain types of building materials. The proposals are expected to be introduced in the first half of 2014.

Packaging waste reduction

Governments, corporations and institutions across the country have begun to implement "Extended Producer Responsibility" (EPR) programs that allow large purchasing entities to use their buying power to encourage product suppliers to reduce packaging waste and end of life disposal costs without imposing an explicit tax. These programs allow producers to find the most efficient means of reducing waste, which can include reuse, buyback, or recycling, often with the assistance of a third party. These typically occur at the level of states – California's EPR programs have achieved significant reduction in the types and volume of packaging that end up in the waste stream, for example – but city-level measures could be just as viable.

Recycling enforcement

In 2010, Mayor Bloomberg signed legislation to raise the penalties for failing to recycle for the first time in over a decade. The new system created tiered penalties depending on building size; the penalties increase with building size. As new recycling programs come into effect, strong and effective enforcement will be crucial.

Strategy 4
Developing New Infrastructure to Support Better Waste Disposal

For years, New York City's waste processing infrastructure was focused on sending waste to landfills quickly and efficiently – first locally, in places like Fresh Kills, and then to other nearby states. Recycling infrastructure is beginning to catch up, but modern waste-to-energy and anaerobic digestion facilities would still need to be constructed if the city is to achieve its diversion goals and support the processing of higher volumes of waste diverted from landfills as education and incentives begin to take effect.

Recycling

The city's recycling infrastructure is improving: working in partnership with Sims Metal Management, the City is now constructing a state-of-the-art recycling facility at the South Brooklyn Marine Terminal that will process metal, glass, and an expanded variety of plastics. Another facility key to increasing the diversion rate is the Gansevoort Marine Transfer Station, located on the Hudson River in downtown Manhattan. The station, now under construction, will accept metal, glass, and plastic, along with paper from residential and commercial sources, and will become Manhattan's primary recycling marine transfer station, connecting by barge to the Sims facility and the Visy paper mill in Staten Island. Not only will this allow Manhattan to collect and transport its own recyclables for the first time, it will also eliminate nearly 14,000 truck trips per year to the Bronx and New Jersey.

Construction of the Gansevoort Station will also allow the City to convert Manhattan's West 59th Street Marine Transfer Station to the borough's only construction and demolition transfer facility. This will make it possible for C&D waste to leave Manhattan by barge instead of by truck, which is how the 400,000 tons of waste generated by construction activities in Manhattan leave the borough today.

Anaerobic digestion

Anaerobic digestion would have to play a major role in capturing the abatement potential of organic waste – but no dedicated facilities are yet available anywhere near New York City. The closest major organics processing facility is located in Delaware – but it uses the aerated windrow method, which ensures that the waste releases CO2 instead of methane as it decomposes but does not capture its full energy potential. A pilot AD facility in or near the city could help improve the economics of composting, make it more attractive to local businesses, and begin to solve the self-reinforcing problem of constrained processing capacity preventing the takeoff of demand, and vice versa.

Organics processing at wastewater plants

If food waste challenges and, down the road, a potential organics mandate succeed in generating high enough food waste volumes, the private sector will inevitably step in to offer processing solutions. Yet the necessary AD infrastructure might take several years to permit and build – and in the meantime, processing capacity is readily available within the city. Of the city's 14 wastewater treatment plants, 4 have spare capacity to process up to 560 tons a day of organics, of which 500 tons are at Newtown Creek, the city's newest plant. There, the Department of Environmental Protection (DEP) is partnering with a private company called Waste Management to process up to 60 tons of food waste a day, increasing to 250 tons by 2017 as long as all technical challenges are resolved. DEP will also launch a study to examine the economic and technical feasibility of repairing the digesters that are currently out of service or even potentially building new ones to handle higher volumes of organic waste.

Onsite food waste processing

Large-scale AD facilities are central to processing the city's organic waste, but not all of the waste needs to be picked up for processing. Where enough of it is generated in one place, it can be processed locally. Technologies to do so are available and large waste generators like produce markets could be possible candidates for piloting on-site processing of food waste.

Waste conversion

Fully capturing the abatement potential of waste conversion through plasma gasification or other comparable technologies would require constructing a network of facilities throughout the city – but a pilot would have to be developed first. A small-scale advanced conversion technology facility could serve as a proof concept for New York City, making it possible to test the economics

of the project, potentially integrate it into local heating systems, and develop it into a blueprint that could later be used citywide.

Strategy 5
Improving Solid Waste Transportation

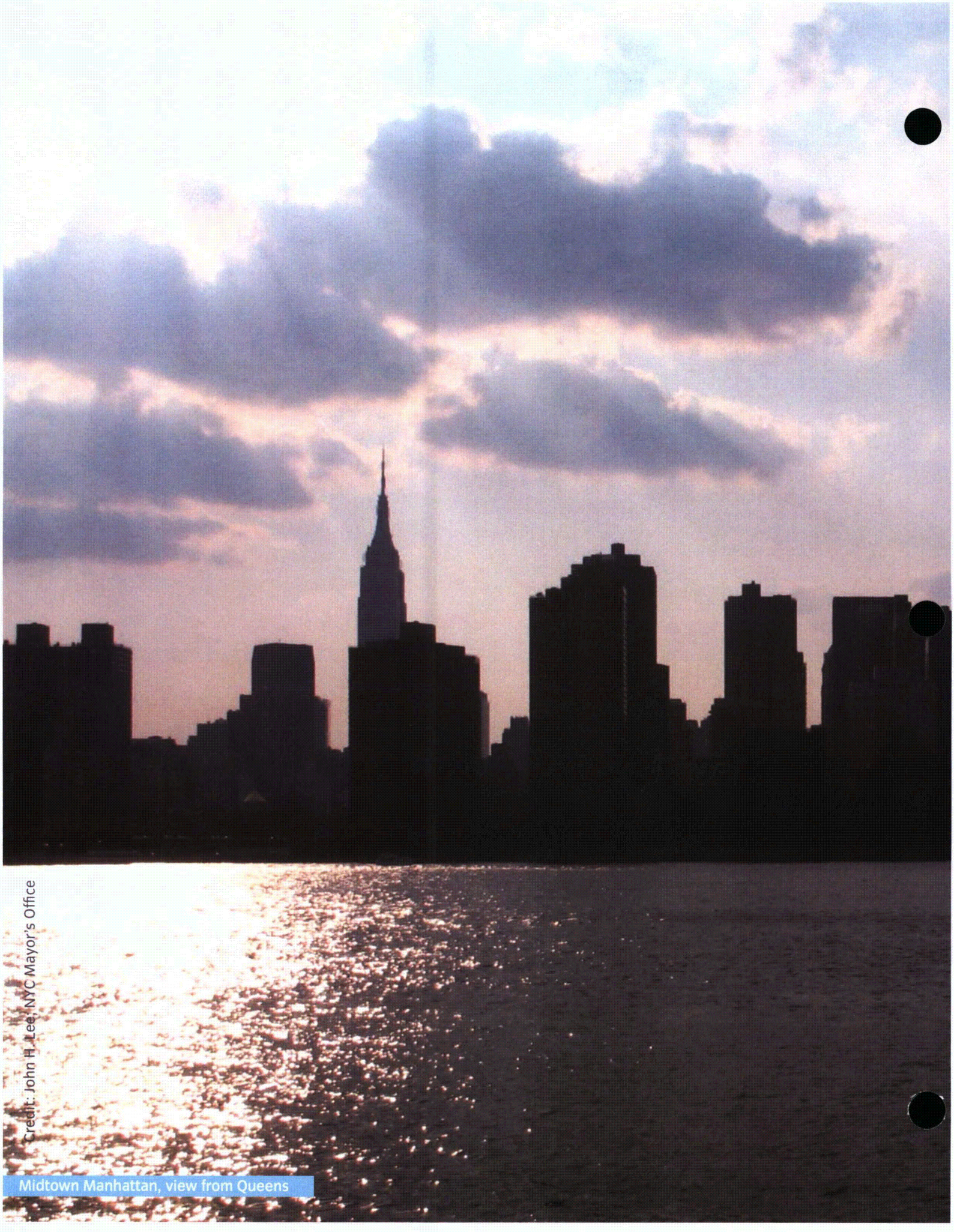
Transportation only represents a small proportion of solid waste emissions, but opportunities to improve it do exist for both municipal and commercial fleets.

Biofuel use in City waste fleets

The Department of Sanitation has pioneered the use of biodiesel in its fleets and over time this practice has been adopted across agencies. All diesel-powered City vehicles now utilize a 5 percent blend of biodiesel (B5) and as of 2016, these vehicles will be required to use B20 between the months of April and November. Expanding to higher concentrations of biodiesel in City fleets would present an opportunity to "close the loop" in solid waste management because biodiesel can be processed from waste cooking oil and agricultural by-products at local facilities.

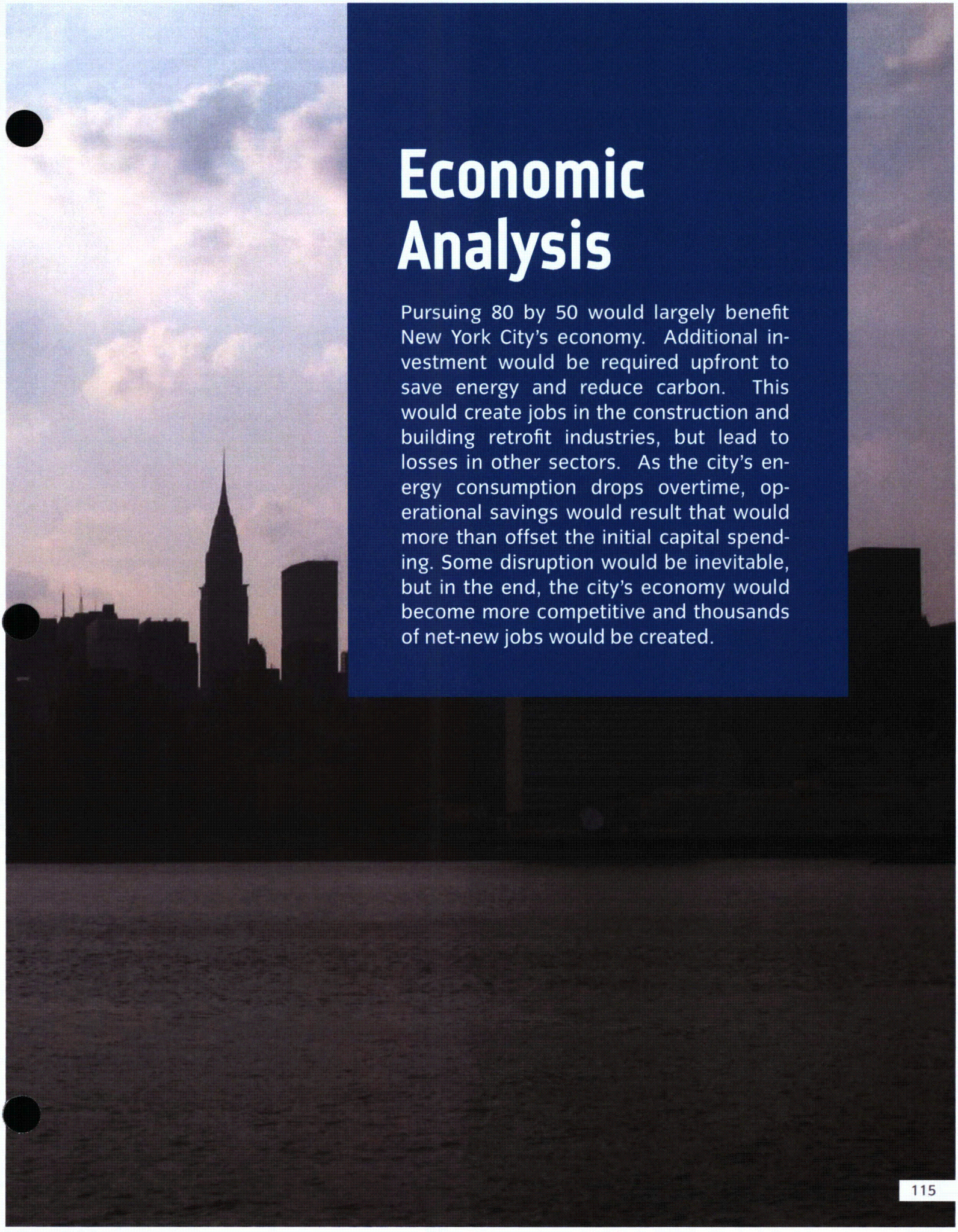
Modernization of private waste fleets

Many of the city's more than 200 commercial carters operate trucks that are over 15 years old and inefficient compared to newer models. Carters will gradually replace their trucks with models that comply with recent federal fuel efficiency standards – but the process could be accelerated through a mixture of requirements and incentives, helping reduce not only carbon emissions, but also emissions of airborne pollutants, which would have a direct positive impact on public health.



Credit: John H. Lee, NYC Mayor's Office

Midtown Manhattan, view from Queens



Economic Analysis

Pursuing 80 by 50 would largely benefit New York City's economy. Additional investment would be required upfront to save energy and reduce carbon. This would create jobs in the construction and building retrofit industries, but lead to losses in other sectors. As the city's energy consumption drops overtime, operational savings would result that would more than offset the initial capital spending. Some disruption would be inevitable, but in the end, the city's economy would become more competitive and thousands of net-new jobs would be created.

Abatement Cost-Effectiveness

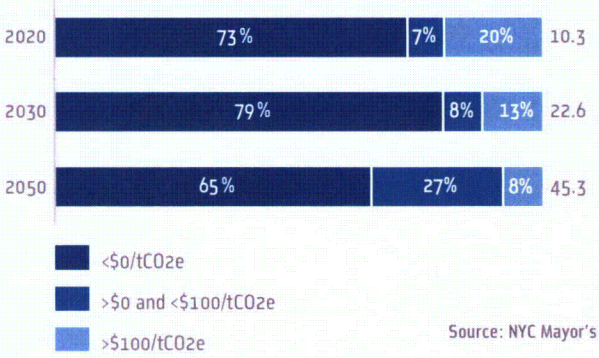
As described in the preceding chapters, reaching 80 by 50 would require a portfolio of actions to reduce carbon across all sectors, year in and year out. Many of these measures would come with an incremental cost or need for upfront investment. However, as long as measures are timed to coincide with natural replacement and retrofit cycles, the majority would more than pay for themselves because of savings in energy consumption, solid waste export fees or other operational expenditures. At a 4 percent discount rate, these measures would be beneficial from a societal standpoint or, in other words, they would have a "negative-cost."

In 2030, for example, nearly 80 percent of carbon abatement measures are estimated to be cost-negative. Another 8 percent of measures would cost less than $100/ton, and only 12 percent cost more than $100/ton. As 2050 approaches, more expensive measures would eventually need to be implemented to achieve an 80 percent reduction, but overall, two-thirds of measures would be cost-negative.

The cost effectiveness of abatement measures would vary significantly by sector. In the solid waste sector, for example, 100 percent of measures would be cost-negative because the fees that the City and private companies currently pay for waste export are so high and diverting waste to recycling and composting is nearly guaranteed to save money. Likewise, over 80 percent of abatement measures in buildings would be cost-negative because savings from reduced energy consumption would typically exceed upfront costs.

In the power sector, however, approximately 95 percent of measures would cost above $100/ton.[19] This does not include behind-the-meter technologies such as solar PV, which are assumed to enter the market on an economic basis (e.g. at grid parity). Large-scale renewables might reduce the need for fossil fuels in electricity production, but the amount of upfront capital investment they would require would exceed any savings over time. Nevertheless, achieving 80 by 50 without cleaning up the electric grid would be nearly impossible. But at the same time it is essential to reduce electricity demand as much as possible in order to reduce the amount of clean power generation that would need to be built and therefore to minimize costs. (See chart: *2030 Abatement Costs by Sector*)

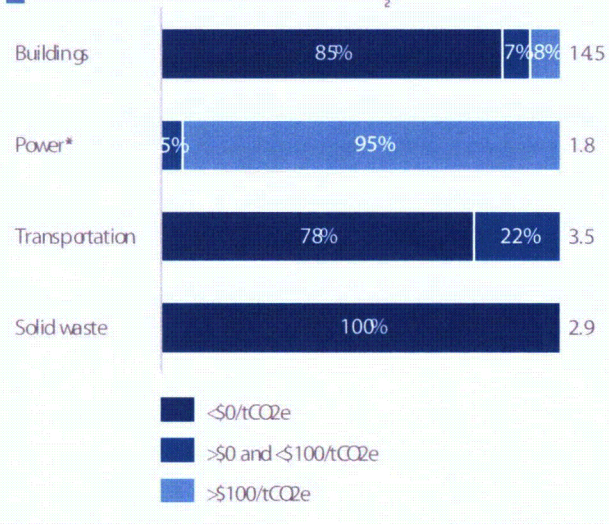
Abatement Potential by Cost per Ton
% of total; Metric tons Co_2e



Source: NYC Mayor's Office

Ranking abatement measures by their cost effectiveness on a marginal abatement cost curve demonstrates a theoretical pathway to reach 80 by 50. The lower cost abatement measures like plug load reduction and lighting upgrades—appearing on the left hand side of the abatement curve—are tapped first and consistently over time as more and more buildings replace their equipment on a natural time cycle. In contrast, more expensive measures like electrifying heating systems or building out large-scale renewable energy resources are delayed until later years when technology costs fall and other abatement options becomes scarce enough that capturing this potential becomes necessary. (See graphics: *Emissions Abatement Potential by Year*)

2030 Abatement Costs By Sector
% of sectoral abatement: Metric ton CO_2e

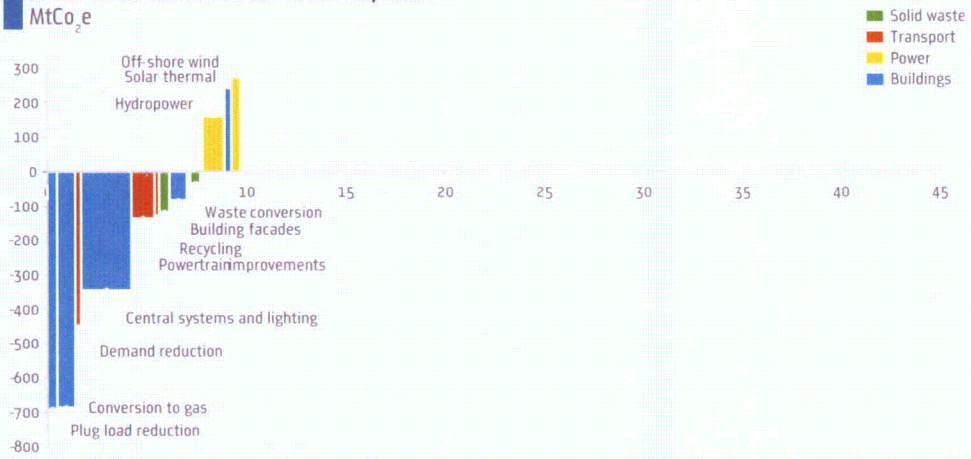


* does not include behind the meter technologies

Source: NYC Mayor's Office

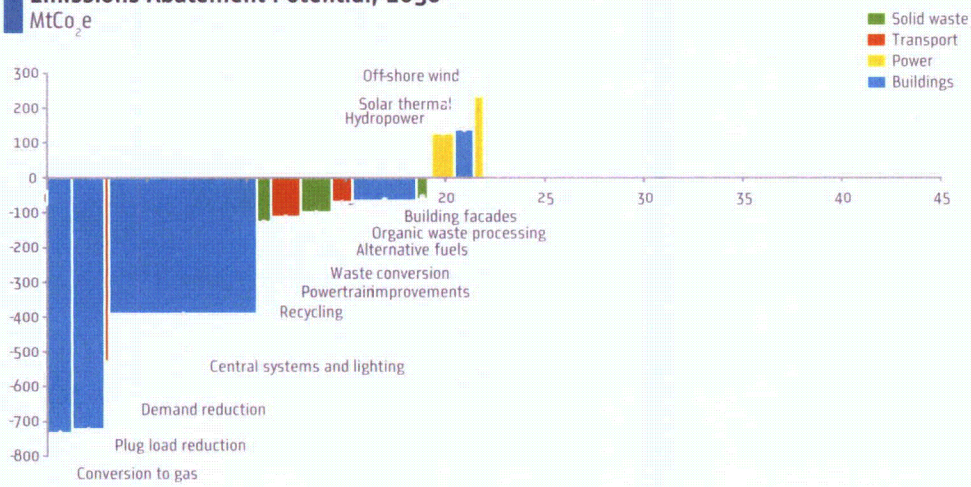
Emissions Abatement Potential; 2020

$MtCo_2e$



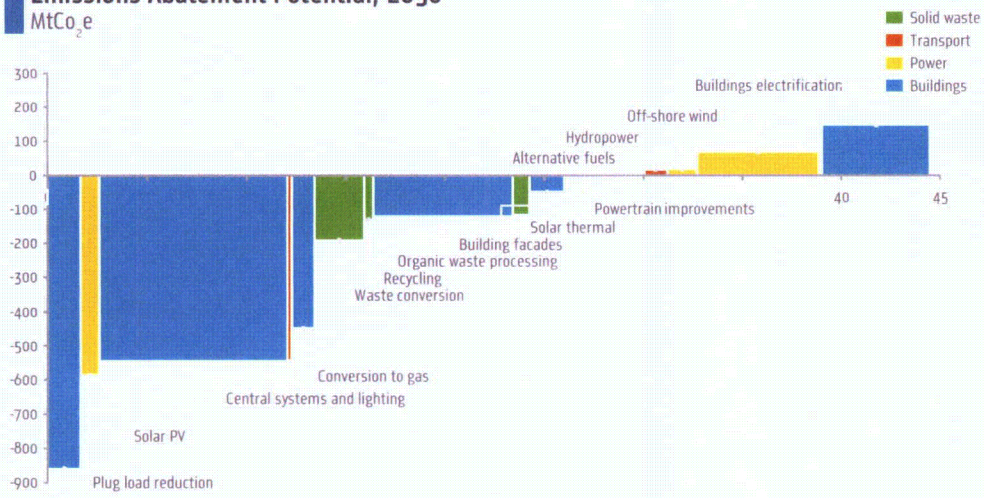
Emissions Abatement Potential; 2030

$MtCo_2e$



Emissions Abatement Potential; 2050

$MtCo_2e$



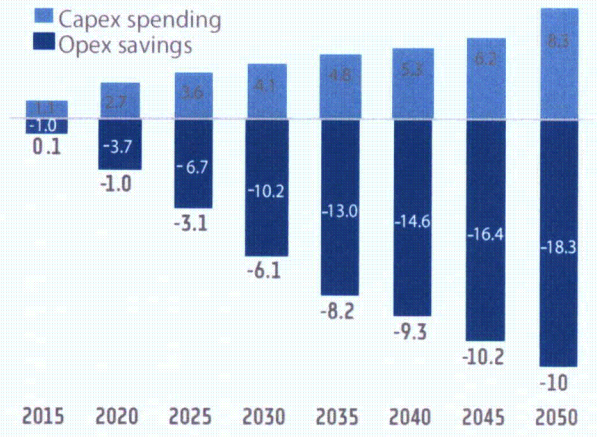
Source: NYC Mayor's Office

Changes to Capital and Operational Expenditure Flows

To achieve 80 by 50 would require billions of dollars of incremental capital investment. Over the next twenty years, the majority of this incremental investment would go towards energy efficiency retrofits in buildings. Investments in clean power would ramp up after 2030, while incremental spending on more efficient and less polluting transportation would be smaller but steady throughout the next several decades. The effect of these investments would be felt in the near term as buildings begin to utilize less electricity, natural gas and liquid fuels, and as vehicles become more efficient. As a result, annual savings on operational expenditures (opex) would exceed the required annual capital investments by 2020. By the 2030s, the annual savings would equal more than $6 billion a year. (See chart: *Changes in Annual Capital Spending and Opex*)

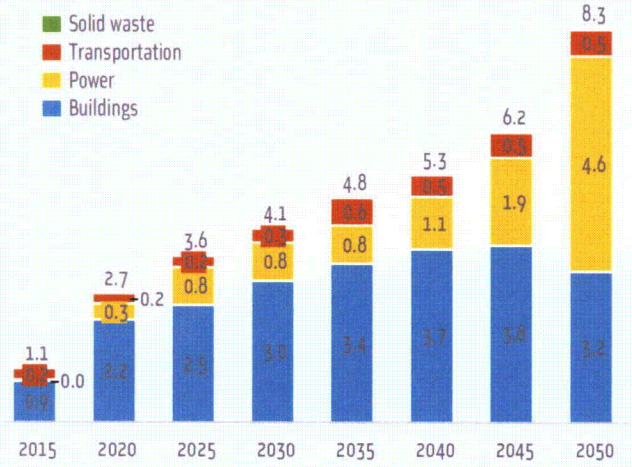
The amount of capital investments required – $1 billion a year in 2015 and scaling up to more than $4 billion a year by the 2030s – is comparable to the entire capital investment programs of Con Edison or the Department of Environmental Protection (DEP), the city's water and sewer utility. However, the number needs to be seen in the context of citywide investments that occur every year in the course of normal construction and activity. In 2012, for example, more than $30 billion was spent on construction in New York City; an additional $4 billion a year would represent 13 percent of this amount.

Changes in Annual Capital Spending and Opex
$ billions; net difference in bold



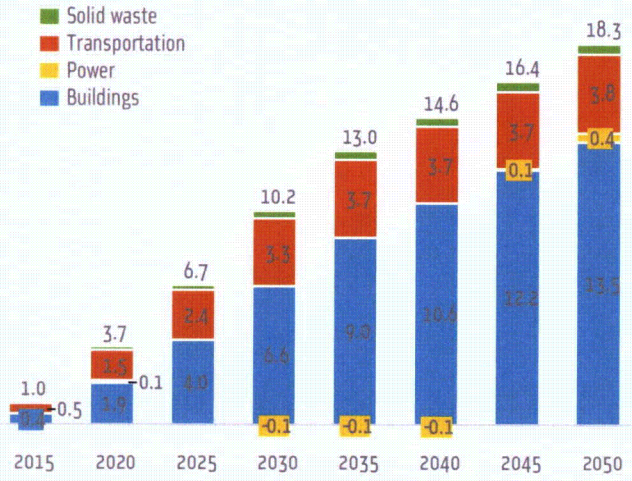
Source: NYC Mayor's Office

Changes to Annual Capital Investment Flows by Sector
$ billions



Source: NYC Mayor's Office

Changes to Annual Opex Flows by Sector under 80 by 50 BAU
$ billions



Source: NYC Mayor's Office

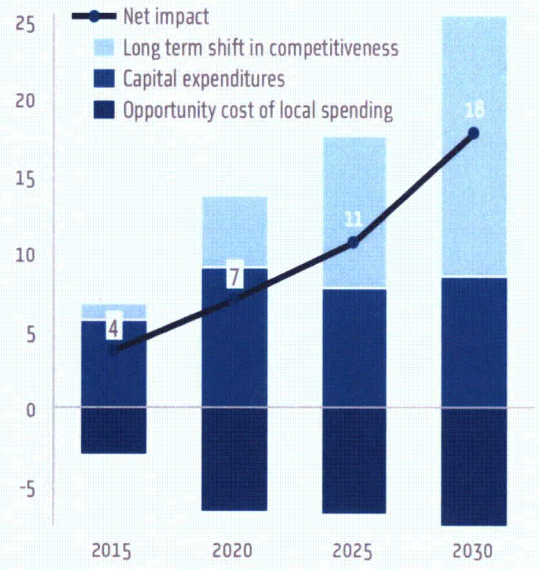
Changes to Energy Demand on the 80 by 50 Pathway vs. BAU
Indexed to 2010

Source: NYC Mayor's Office

Changes to Energy Demand

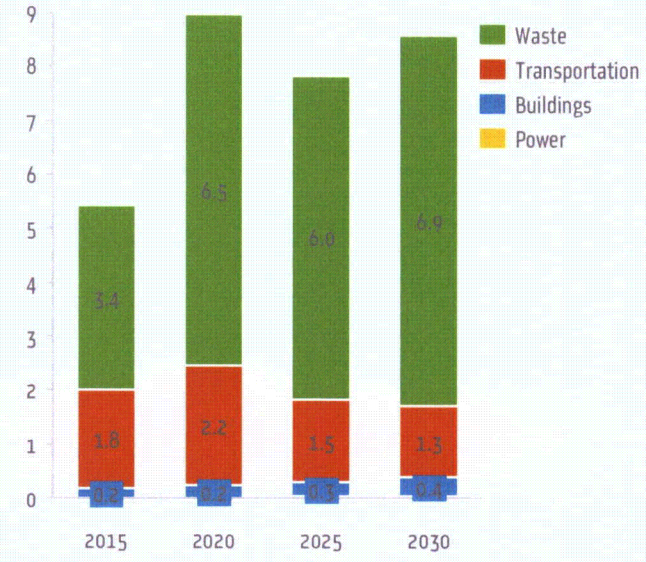
Reductions in energy demand would be the primary driver of operational savings in the economy. Electricity demand would initially drop as buildings become more efficient, but recover partially as vehicles (and potentially building heating systems) electrify. By 2050, electricity demand would be 12 to 36 percent below 2012 levels depending on how many buildings electrify. Gasoline demand is expected to drop even under the business as usual case because of aggressive federal standards to improve automobile efficiency—Corporate Average Fuel Economy or CAFE standards. On the 80 by 50 pathway, gasoline demand would decline even faster due to an accelerated switch to electric vehicles, reaching a 73 percent reduction from today's levels by 2050. Natural gas demand would first increase to accommodate buildings moving away from heavy fuel oils and then gradually drop as investment in energy efficiency grows. The extent of declining natural gas demand by 2050 would depend on how widespread electrification of buildings is, but it would exceed 25 percent and could be much higher. Demand for heating oil is also expected to drop in the business as usual (BAU) case because of the current pacing of oil-to-gas conversions, as well as the competitive economics of natural gas, but demand reductions could exceed 70 percent by 2050 on the abatement pathway. (See chart: *Changes to Energy Demand on the 80 by 50 pathway vs. BAU*)

Employment Impacts by Type
Thousands; by type of impact



Source: NYC Mayor's Office

Jobs Created Through Capital Expenditure, by Sector
Thousands



Source: NYC Mayor's Office

Impact on Local Economy

The changes to the patterns of capital investment and operational expenditures would impact the economy directly: jobs would be created in some sectors and lost in others, personal income would increase, and gross regional product would grow. The economic impact, only estimated through 2030 due to the level of uncertainty past that date, would occur via three main channels:

- **Direct impact of capital expenditures:** Capital investment directly creating jobs in construction and related sectors
- **Opportunity cost of local spending:** The diversion of spending from other sectors to pay for the investment in (1) leads to negative economic impacts in other sectors of the economy
- **Long-term shift in competitiveness:** Decrease in energy use resulting from capital investment helps to lower production costs and make the economy more competitive in the long term

The jobs impact from the combination of these three channels would be positive: by 2030, the 80 by 50 pathway could create up to 18,000 jobs — mainly because the economy would become more competitive. While the direct job creation spurred by capital investment would be offset by losses in other sectors, the resulting energy savings from capital investments would have enough of an impact on the economy's production costs to create thousands of net-new jobs over the next two decades. (See chart: *Employment Impacts by Type*)

Capital expenditures in buildings would play the most important role in the creation of jobs, contributing between 60 and 80 percent of all the new jobs. Power investments would account for most of the remaining job benefits, with solar PV installations contributing the most and offshore wind playing a role as well. The employment impact of transportation and solid waste measures would be negligible. (See chart: *Jobs Created Through Capital Expenditure, by Sector*)

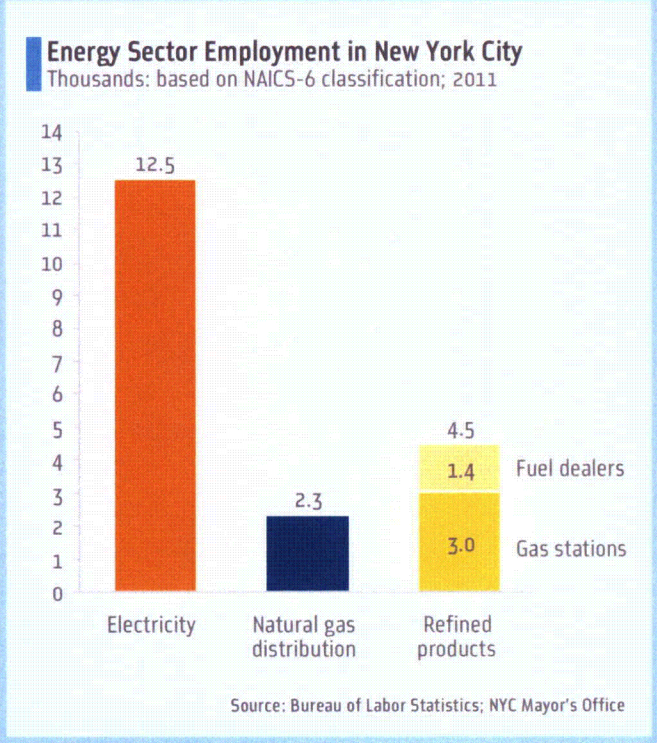
Gross regional product (GRP) — or the measure of the strength of the region's economy — would benefit as well. By 2030, GRP would increase by nearly $1.9 billion a year. Investments in buildings, again, would provide the greatest contribution. Investments in cleaner power, on the other hand, would lead to losses because of its relatively higher costs. Personal income levels would experience similar effects, with cost savings from using less energy more than offsetting the higher prices consumers would pay for cleaner energy — leading to a net increase in income of $2.2 billion a year by 2030.

Economic Disruptions of Carbon Abatement

Impact on Energy Sector Jobs

Every year, New Yorkers spend almost $30 billion on energy – approximately $11 billion on electricity, $10 billion on natural gas and liquid fuels in buildings, and $8 billion on transportation fuels. Part of this spending goes towards the extraction and refining of fossil fuels, which takes place outside of New York City, but other parts support local jobs – 20,000 in total, or 0.2 percent of the city's total 2011 private sector employment of 3.1 million. More than half of these jobs are in electricity distribution (primarily Con Edison); the rest are in natural gas distribution, fuel distribution, and retail gasoline operations (See chart: *Energy Sector Employment in New York City*).

On the 80 by 50 pathway, the 12,500 jobs in power transmission and distribution would be relatively unaffected. The city would still have to maintain its electrical grid regardless of changes to either demand or the carbon intensity of electricity. The 500 jobs in power generation would be unaffected by 2030 – gas-fired power plants would still be playing a prominent role – but by 2050, the importance of gas-fired generation would decline, and at least some of those jobs would likely shift to other power generation technologies. The 2,300 jobs in natural gas distribution would remain relatively unaffected as well – just as with electricity, the city would still have to maintain its natural gas grid, though demand for natural gas would likely fall off because of energy efficiency and building electrification. Businesses serving the gasoline marketplace — 4,400 jobs in all — would likely feel the impact of decarbonization the most. Some of these businesses would reorient their services (gas stations, for example, could add EV charging); some would go out of business.

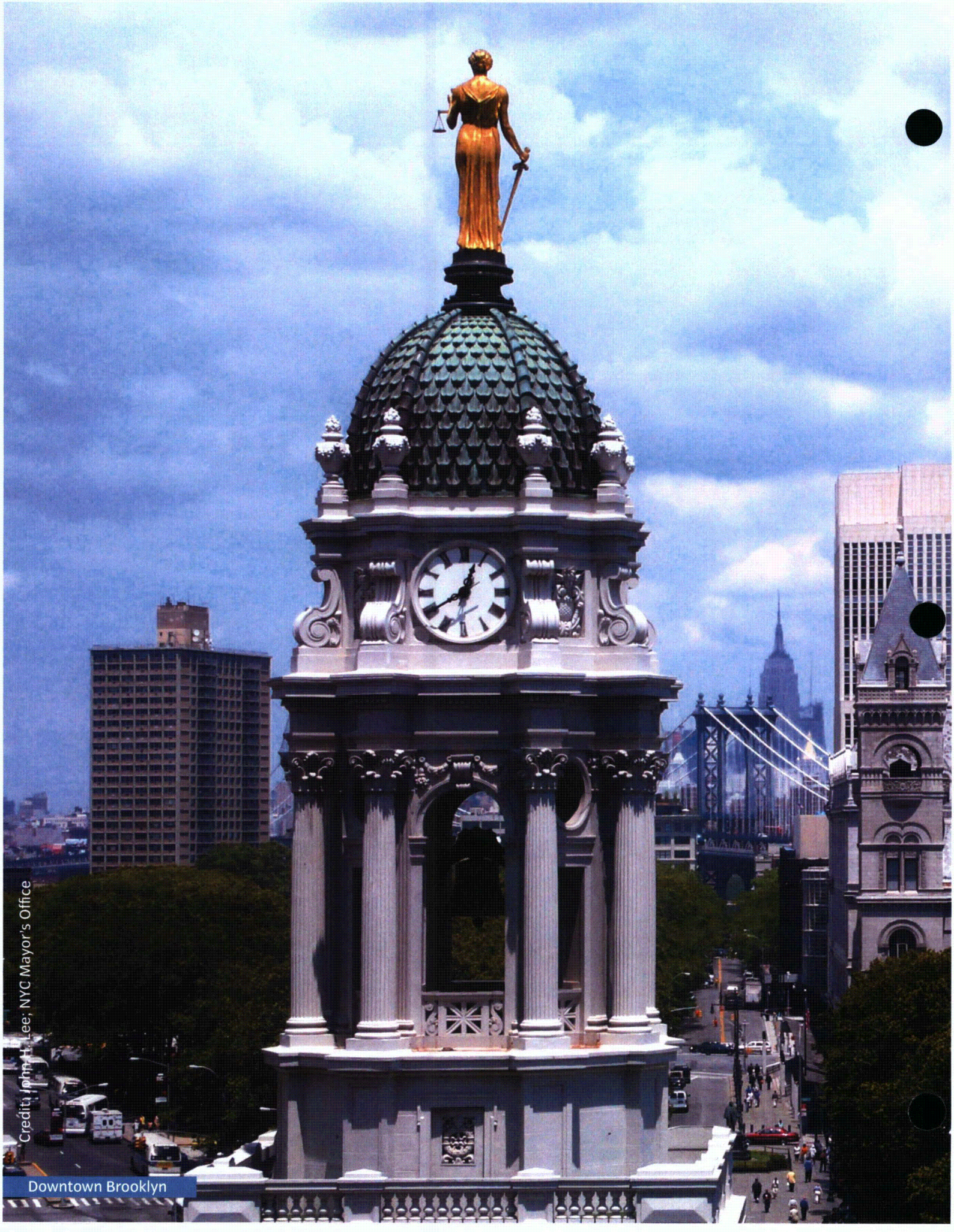


Impact on Lower Income Residents and Energy Intensive Businesses

Pursuing 80 by 50 could also have equity implications: total energy costs might drop for the city overall, but electricity prices would increase, affecting energy intensive manufacturing and residents who live on fixed income or low wages. Both cases would call for some form of assistance – and the necessary programs may already exist.

Manufacturing no longer accounts for as many New York City jobs as it used to – but industrial companies still employ tens of thousands of New Yorkers. These companies would stand to benefit less from energy efficiency than, for example, office buildings. Two existing programs administered by the New York City Economic Development Corporation, BIR (the Business Incentive Rate), and NYCPUS (the New York City Public Utility Service), have for years been providing discounts and rebates of up to 20 percent to local manufacturers. These and similar programs could be used to help energy intensive businesses mitigate the impacts of higher electricity prices related to decarbonization in order to maintain competitiveness of local manufacturing. As discussed previously, decarbonization would ideally occur at a national or at least regional scale in order to level the playing field, so that New York City's industries are not disproportionately impacted.

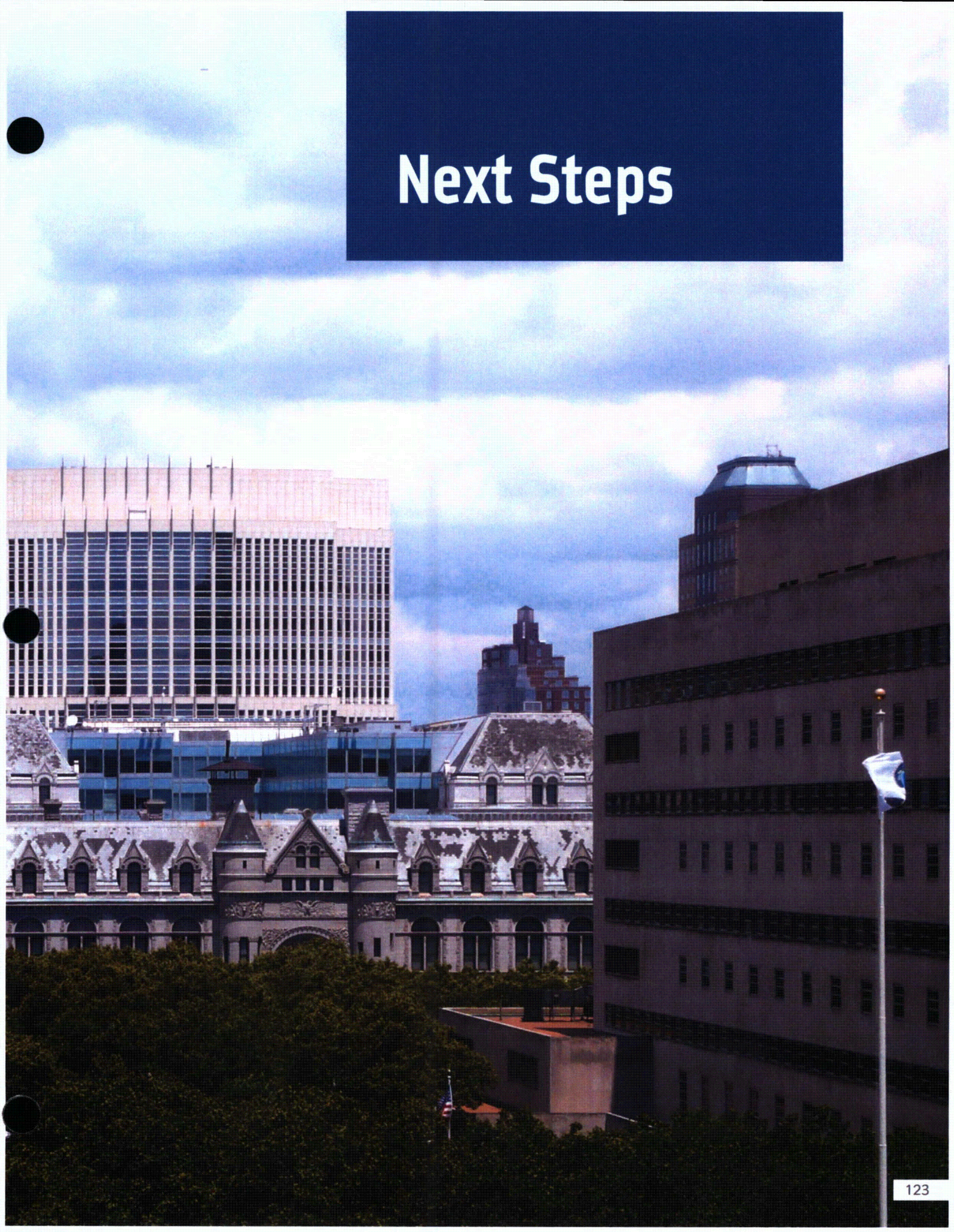
City residents that live on fixed incomes or low wages could benefit from energy efficiency measures if they were able to partake in them, but practical obstacles could limit uptake and help would be required to mitigate cost of living impacts. NYSERDA's EmPower New York program provides income-eligible New Yorkers with energy efficiency services for no cost, while the New York State Department of Housing and Community Renewal provides free and low-cost weatherization services through its network of contractors. The federally-funded Low Income Home Energy Assistance Program (LIHEAP) helps income-eligible residents to pay for the costs of home heating. These programs could be adapted to help residents cope with higher power prices that result from switching to a lower carbon grid.



Credit: John H. Lee; NYC Mayor's Office

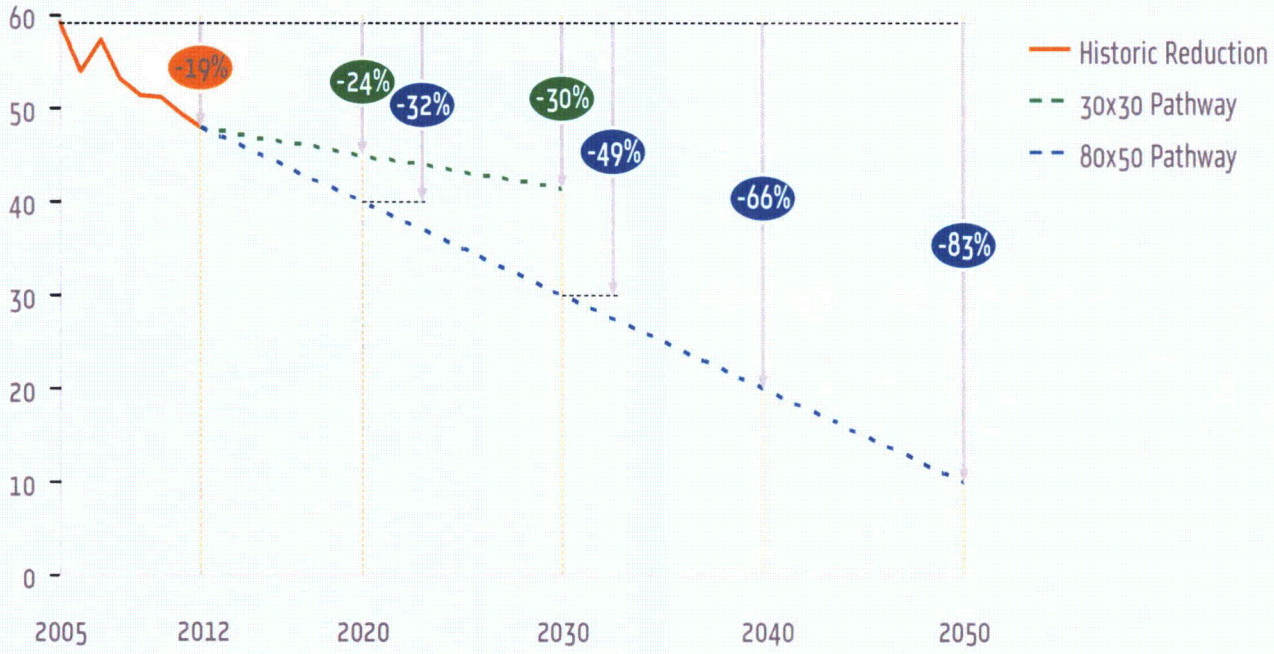
Downtown Brooklyn

Next Steps



GHG Emissions Pathways

Metric tons Co_2e; % reduction vs. 2005 in a give year



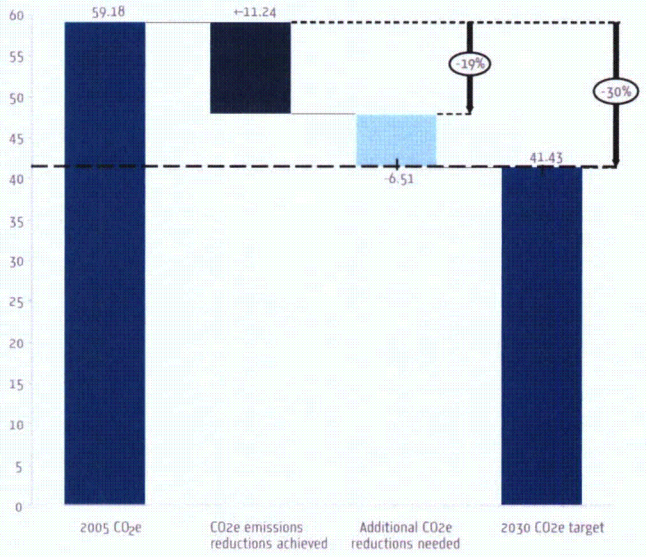
Source: NYC Mayor's Office

Even though the exact shape of a low-carbon city is uncertain today — and the 80 by 50 goal itself may well be too aggressive for a relatively efficient city like New York — the city has both the tools and the momentum to accelerate carbon reduction efforts this decade. As the city is now close to two-thirds of the way to the PlaNYC 30 percent greenhouse gas reduction goal, it could consider accelerating the target date for reaching the goal, from 2030 to 2020. Doing so could put New York City on a trajectory to achieve 80 by 50 while maintaining focus on what is achievable today.

To reach a 30 percent reduction, emissions would need to fall another 6.4 million tons below 2012 levels. If the City aggressively implements and strategically expands several existing initiatives it could achieve the 6.4 million ton reduction within this decade. These reduction actions are focused on the buildings, transportation and waste sectors. Given the long-lead times and expense of projects it is not assumed that any major abatements will accrue from the power sector. However, several promising near-term opportunities exist and could be pursued in tandem with the hope of providing an

Citywide CO_2e Emissions Reduction Summary

$MtCO_2e$

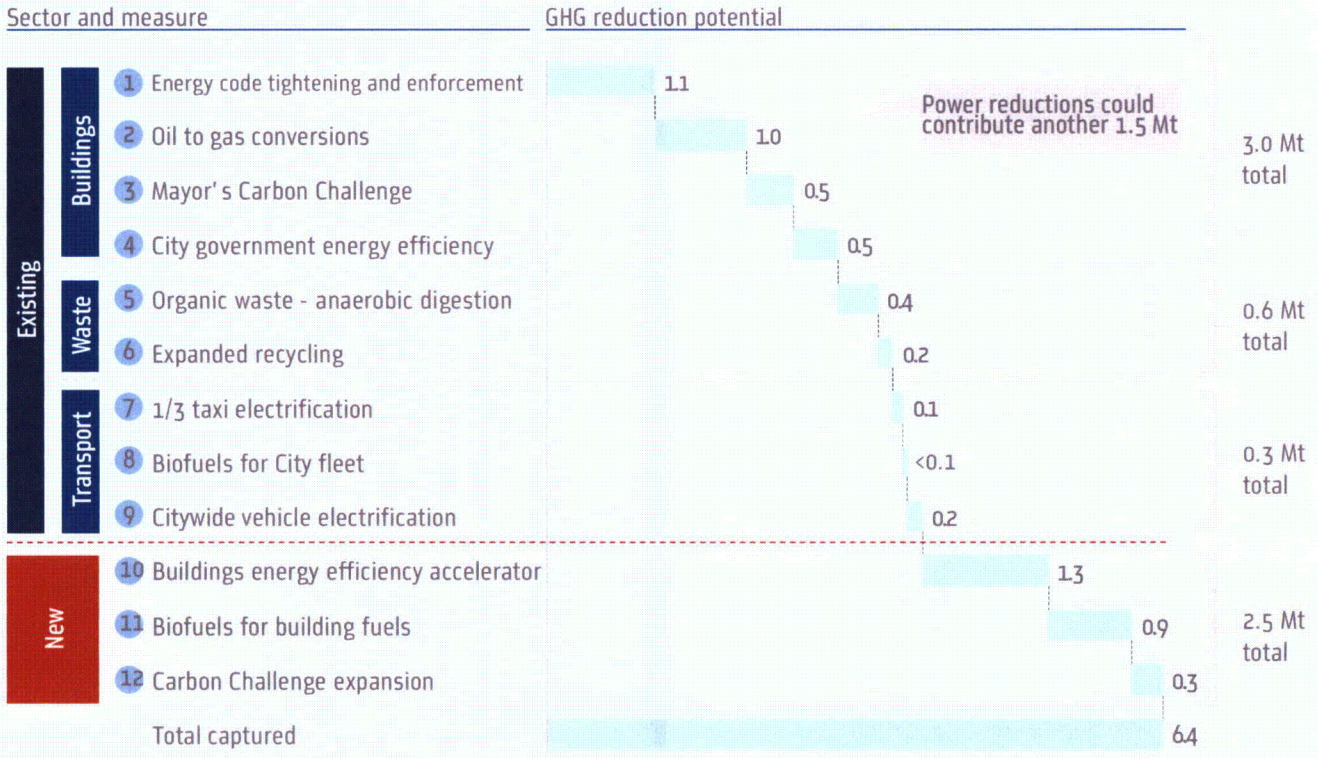


Source: NYC Mayor's Office

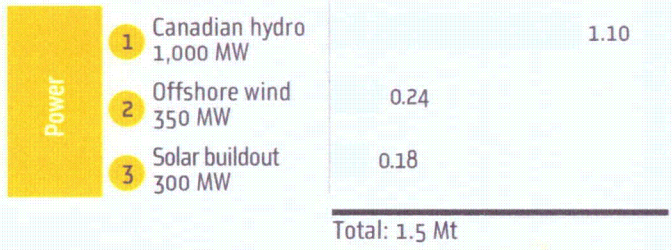
additional buffer to achieve 30 by 20. The following section briefly describes these possible efforts.

Achieving 30 by 20 will require tremendous effort and consistent reductions of 2 percent per year through the end of the decade. This will not be easy, but New Yorkers stand to gain along the way. Reducing energy consumption in buildings will lower operational expenses and create jobs. Converting to cleaner fuels in buildings and electrifying or using biodiesel in vehicles will improve air quality. And diverting waste from landfills will save city residents and businesses on waste export costs and could promote local industries. These and other measures could reinforce and strengthen New York City's global leadership in responding to climate change, while making the city more competitive, livable, and resilient.

GHG Reduction Potential of Existing and New Policies
Sector and GHG reduction potential



Power, not counted towards main reductions, would add 1.5 MT



- Support transmission siting in PSC process
- Work with NYPA and State to accelerate pilot project
- Reform solar interconnect rules and incentives

Source: NYC Mayor's Office

Emissions Abatement and Climate Resiliency

Even as the City works to reduce greenhouse gas emissions, the climate is still changing, and the climate risks that the city has always faced are becoming worse. However, the very strategies that help reduce emissions can also make the city more resilient.

Storm surges and heat waves are the two most important climate risks for New York City. Both struck in recent years, and both affected the city's energy infrastructure: Hurricane Sandy left 800,000 customers in the dark and devastated liquid fuels supply infrastructure in 2012, Hurricane Irene came close to shutting down the electric grid in 2011, and intense heat waves led to highest-ever periods of peak demand in the summers of 2012 and 2013 – though the electric grid held up relatively well in both cases.

These risks will intensify: according to the New York City Panel on Climate Change, a scientific advisory body that Mayor Bloomberg originally convened in 2008, by the 2050s, sea levels around New York City could rise by as much as 2.5 feet, and heat waves would become a far more regular occurrence, with more than 50 days every year above 90°F, compared to less than 20 today.

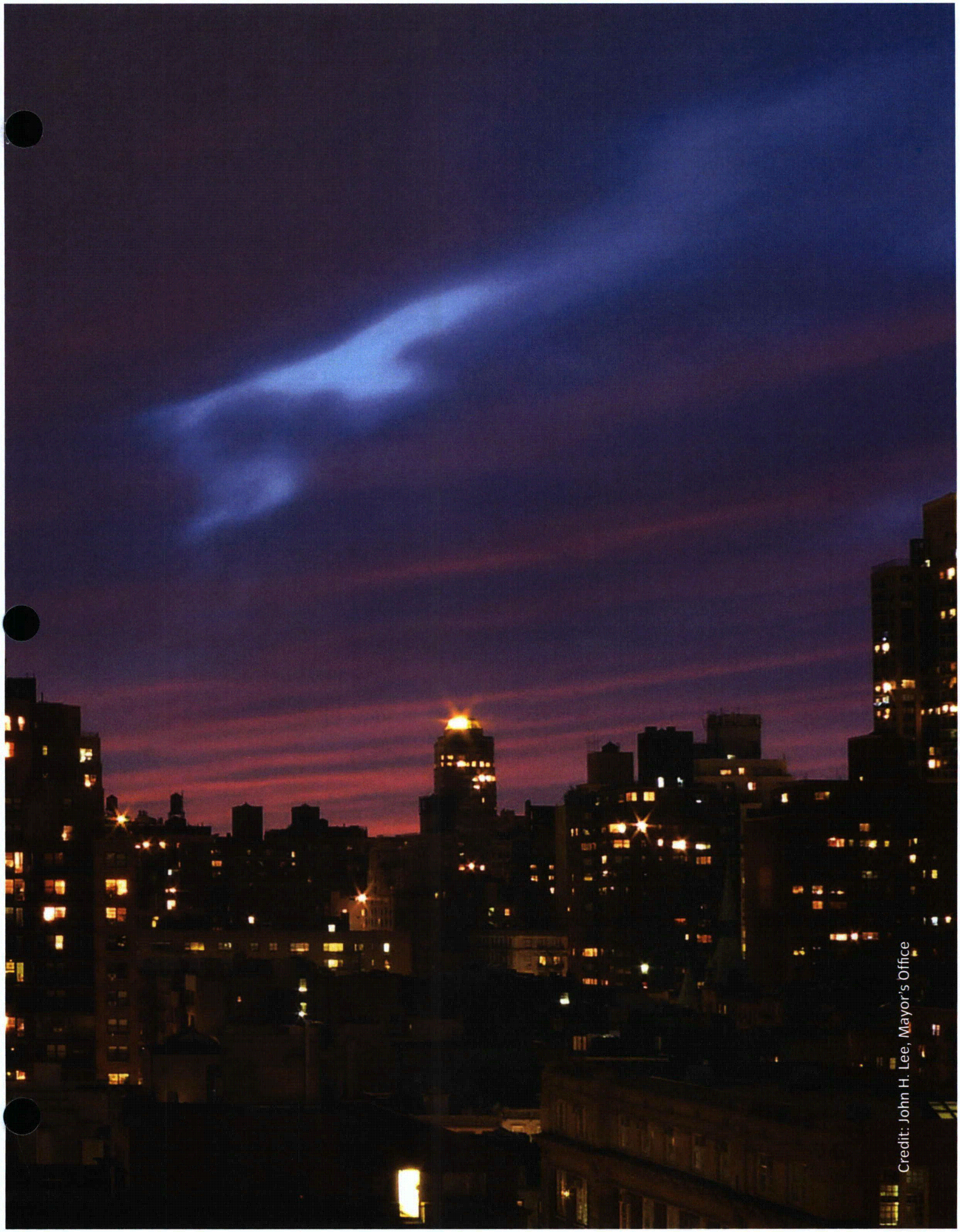
In this context, any strategy that reduces emissions by reducing energy demand and diversifying its sources can help make the city more resilient to storm surge and heat wave-related disruptions to energy supply infrastructure. Measures that advance building energy efficiency, promote distributed generation, and increase the penetration of electric vehicles help do just that.

Building energy efficiency measures reduce baseline electricity demand – and that alleviates the strain on the electric grid during periods of high demand that occur during heat waves. To mitigate the consequences of heat waves, utilities rely on programs that pay large customers to reduce their demand if necessary (called demand response), but an 8 percent reduction in citywide electricity demand achieved through energy efficiency would provide double the demand reduction available through demand response programs today and obviate the need for hundreds of millions of dollars in spending to upgrade the electric distribution system that would otherwise be required. An additional benefit of energy efficiency is that if outages do occur, more efficient buildings can remain comfortably habitable longer because it takes longer for them to heat up in summer or cool down in winter.

Distributed generation systems allow customers to produce their own electricity – including when the grid is down. Properly installed combined heat and power systems and fuel cells – both running on natural gas – can supply buildings with enough electricity to operate normally even if the electric grid is completely down. Smaller scale distributed generation systems – primarily rooftop-mounted solar panels – usually cannot cover a building's electricity needs during an outage, but if properly installed, they could provide enough energy to operate at least several lights and power outlets in a typical one or two-family home.

Electric vehicles lessen the city's dependence on liquid fuels for mobility at the cost of greater reliance on the electric grid – but the electric grid is generally more reliable in the face of storm surges than the liquid fuels infrastructure is. They also make it possible to provide power to one or two-family homes during power outages: a fully charged EV with a 26 kWh battery could power a one or two-family home for at least a day, as long as the home is pre-wired to be able to connect to the vehicle. In the next few years, once the necessary interconnection standards are developed, EVs might also be able to help shave peak load, feeding their stored energy back into the grid during periods of high demand.

These and other strategies are discussed in detail in the context of resiliency in PlaNYC: A Stronger, More Resilient New York, a 438-page report that Mayor Bloomberg launched in the aftermath of Sandy and released on June 11, 2013. The report puts forward more than 200 initiatives to protect New York City's residents, buildings, and infrastructure from climate threats today and in the future and is available online at nyc.gov/resiliency.


Credit: John H. Lee, Mayor's Office

Appendix: Assumptions

Assumptions used to evaluate the emissions reduction potential throughout this study include the following information below.

Population and economy

Population, employment, and GDP growth figures were taken from the New York Metropolitan Transportation Council (NYMTC) forecasts for 2010-2030 and 2031-2040. This information was proportionally adapted to forecast figures through 2050. On average: population growth increases at 0.4 percent annually; employment increases at 0.8 percent annually; and GDP grows at 3 percent annually.

Energy consumption

According to Consolidated Edison, Inc. Annual Energy Outlook, annual energy demand grows by 0.7 percent for electricity, 0.7 percent for natural gas, 0.1 percent a year for steam, and -0.8 percent a year for oil. 2031-2050 growth across energy sources is driven by growth in residential and nonresidential floor space, or residential compound annual growth (CAGR) of 0.3 percent and nonresidential CAGR of 0.4 percent.

Energy consumption figures for the report presumes no new energy efficiency policies, programs, nor use of current technologies. Additionally, GHG emissions reductions from the Greener, Greater Buildings Plan and the Green Codes Task Force were not taken into account.

Buildings

Population growth drove an increase in residential square footage from 3.6 billion sq ft in 2010, and is expected to rise to 3.9 billion sq ft in 2030. By holding the 2010 sq ft per capita figure constant, a 2050 square footage of 4.1 billion sq. ft. is projected. For nonresidential square footage, holding the 2010 figure of 1.8 billion sq ft constant, square footage for 2030 and 2050 is projected for increases of 1.9 billion and 2.1 billion sq ft, respectively.

Although building stock is divided into low and high rise categories, new growth was evenly allocated between the two groups. For low rise buildings, an additional impact of demolition is included; 0.6 percent of buildings are demolished annually, which translates into an average building lifetime of less than 150 years. With the occurrence of low rise demolitions, the 2050 share of high rise buildings increases.

Climate change

According to the New York City Panel on Climate Change, average temperatures may rise up to 3 degrees Fahrenheit by 2050.

Other

Other analysis includes the following assumptions:

- Waste per capita remains constant, according to the New York City Mayor's Office of Long-Term Planning and Sustainability (OLTPS).
- NYMTC forecasts also include an increase in vehicle miles traveled by 17 percent.
- All non-City measures currently in place take effect, such as Corporate Average Fuel Economy (CAFE) standards, electricity grid upgrades, and transit system upgrades from the NYMTC Regional Transportation Plan.

Endnotes

1. Compared to 2005 levels.
2. RCPs, or Representative Concentration Pathways, are an evolution of the IPCC's approach to forecasting emissions. Instead of trying to develop emissions scenarios from economic and social ones, the RCP approach develops carbon pathways first; from those, economic and social scenario combinations can be derived if necessary.
3. 2010, an EU nonprofit had already set a precedent for releasing a comprehensive study of this type: Roadmap 2050, a report funded by the European Climate Foundation, analyzed the technical potential and costs of deep union-wide emissions reductions, with a particular focus on the energy sector. In 2013, a study by Urban Green Council, the New York Chapter of the U.S. Green Buildings Council called "90x50" examined the technical potential for deep carbon reductions in New York City, focusing most heavily on buildings and finding that even with existing technology, such reductions indeed appear possible in the long term. Also in 2013, a study by the International Energy Agency drew renewed attention to the issue at the global level by suggesting that targeted energy efficiency measures, partial phase-out of coal-fired power plants, reduction in fugitive emissions from fossil fuel production, and a partial phase-out of fossil fuel subsidies could stop the growth in worldwide emissions by 2020 at no net cost to the global economy.

   "ROADMAP 2050." Roadmap 2050. N.p., n.d. Web. 31 Dec. 2013. <http://www.roadmap2050.eu/project/roadmap-2050#>.

   "90 By 50: NYC Can Reduce its Carbon Footprint 90% By 2050." Urban Green Council. Urban Green Council, 14 Feb. 2013. Web. 31 Dec. 2013. <http://www.urbangreencouncil.org/servlet/servlet.FileDownload?file=015U0000000nD3r>.

   "Redrawing the Energy-Climate Map." World Energy Outlook Special Report. N.p., 10 June 2013. Web. 31 Dec. 2013. <http://www.worldenergyoutlook.org/media/weowebsite/2013/energyclimatemap/RedrawingEnergyClimateMap.pdf>.
4. In the energy sector, fugitive emissions are mostly caused by methane escaping from gas pipelines and by sulfur hexafluoride (SF_6)—a highly potent GHG that utilities used for insulation in the past--leaking from electric equipment.
5. Scope 1 and 2 only.
6. Although it is possible to assess these impacts through 2050, the usefulness of this analysis is limited by the very long time horizon, which becomes more of a constraint in economic modeling than in the estimation of technical reduction potential.
7. Full abatement potential would be achieved by 2050, but unless otherwise noted cost per ton is for 2030 given greater cost uncertainty in the outer years.
8. Cost per ton value shown is for 2050, since heat pumps do not play a significant abatement role in 2050.
9. The potential for having GSHPs replace cooling loads was not estimated given the added costs of integrating them into building cooling systems – particularly if cooling is provided by packaged terminal air conditioners (PTACs) installed directly in windows and walls.
10. In the Bronx and in Manhattan, the forecast adoption rates could be 15 percent and 10 percent respectively, mostly from standing column systems serving low-rise buildings. In Staten Island, the rate could be higher: 25 percent served by open loop and standing column systems. In Queens and Brooklyn, the rates could be up to 35 percent and limited only by the need to balance heat extracted from the aquifer in winter and returned for cooling in summer.
11. Approximately 50 percent of New York City's buildings use steam radiators for heat, with the balance being hydronic, forced air, and electric window units. Air source heat pumps can integrate with most hydronic and forced air heating systems at a negligible cost. Integration with steam radiators is prohibitively expensive, but it can be bypassed at least in residential applications through replacing PTACs directly, where ASHPs – unlike GSHPs – could provide cooling as well for no added cost.
12. 2050 cost.

13. A 20 MW Goteborg Energi facility in Sweden is under construction, a 12 MW unit sponsored by the Energy Research Centre of the Netherlands is in planning, and a 200 MW plant by E.ON, also in Sweden, is targeted for a 2015 completion.
14. This number does not take into account the impact of shifting car passengers onto trains, which is was beyond the scope of this exercise.
15. "Congestion Pricing: A Primer." Federal Highway Administration Publications. U.S. Department of Transportation Federal Highway Administration, n.d. Web. 31 Dec. 2013. <http://ops.fhwa.dot.gov/publications/congestionpricing/congestionpricing.pdf>.
16. "Opportunities for Reducing Surface Emissions Through Surface Movement Optimization." Technical Report #: ICAT-2008-7. MIT International Center for Air Transportation (ICAT) Department of Aeronautics & Astronautics Massachusetts Institute of Technology, n.d. Web. 31 Dec. 2013. <http://dspace.mit.edu/bitstream/handle/1721.1/66491/Balakrishnan-ICAT-2008-07.pdf?sequence=1>.
17. Residential waste is at least 41 percent recyclable and 40 percent compostable
18. Excludes fill.
19. This does not include solar energy, which is considered a demand-side or building sector measure.

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