New York City's Roadmap to 80 X 50

The City of New York
Mayor Bill de Blasio

Anthony Shorris
First Deputy Mayor

#ONENYC

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Table of Contents

Letter from the Mayor 3

Executive Summary 5

Introduction 15

Methodology 23

Energy 35

Buildings 55

Transportation 79

Waste 99

Actions New Yorkers Can Do 110

Next Steps 113

Glossary 117

Directory of Abbreviations 127

End Notes 129

Letter from the Mayor

Friends,

Two years ago, I joined 400,000 others as we marched for action on climate change and committed that New York City would continue to lead by reducing greenhouse gases 80 percent by 2050, or 80 x 50. We detailed this commitment in our *OneNYC* report.

Since that time, the nations of the world have come together to agree on a ground-breaking Paris Agreement, and just this month the world's two biggest emitters, the US and China, committed to joining that agreement, putting it on a path toward ratification.

Locally, we have continued to drive down our emissions, but we have much more to do.

OneNYC makes clear how much progress has been made toward ensuring that New York City is the most sustainable big city in the world. Our air is cleaner, our streets are greener, and we are sending less waste to landfills. Achieving 80 x 50 will require even more dramatic action, across all of New York City's buildings, infrastructure, parks, and open spaces.

That's why we have committed billions of dollars for energy efficiency measures in our own municipal buildings, ramped up the purchase of electric vehicles for our fleet, and dramatically expanded the use of solar power across the city. In each case, we are seeking to use our own purchasing power to transform the marketplace and create demand for the technology we know will be necessary to achieve 80 x 50.

Today, we are taking the next steps on this pathway to achieve 80 x 50. This roadmap includes world-leading analysis of our city's emissions, an analysis of difficult choices we have to make to drive down our emissions, and the types of actions that will be required to transform how we use energy in every part of our lives. This report lays out a platform for action—one that can guide our actions now and into the future.

Over the next several years, we will be doing more to build on these successes—including expanding initiatives that provide more just environmental outcomes for all New Yorkers—to reach our goals of a greener, more sustainable city. Anything less would be unacceptable.

Continuing to deliver on these commitments will require nothing less than bold, innovative solutions and strong partnerships—and New York City will be a model to inspire other cities around the world to do the same.

Everyday, our work only grows to build an even stronger, more sustainable, more resilient, and more equitable city—*OneNYC*.

Bill de Blasio

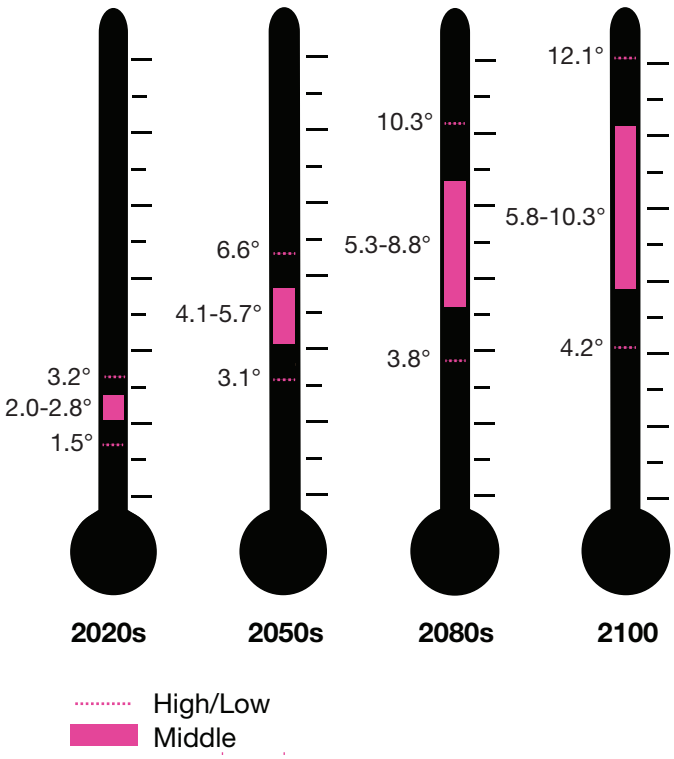
Mayor Bill de Blasio

Executive Summary

Climate change is an existential threat to our city, our country, and our planet. With the signing of the Paris Agreement in December 2015, 195 nations under the United Nations Framework Convention on Climate Change, agreed to limit global temperature increase to no more than two degrees Celsius above pre-industrial levels. The Agreement also recognizes the need to curb warming even further, and urges nations to increase efforts to limit global temperature increase to no more than 1.5 degrees Celsius above pre-industrial levels. To reach these ambitious but necessary targets, developed countries will have to reduce greenhouse gas (GHG) emissions, the harmful gases that are the cause of global climate change, by at least 80 percent by 2050 (80 x 50).

In September 2014, New York City committed itself to 80 x 50, with an interim target to reduce GHG emissions 40 percent by 2030 (40 x 30), and took immediate steps to achieve that goal. We committed billions of dollars to reduce our own carbon footprint with investments in energy efficiency for municipal buildings. We followed that up with the release of *One New York: the Plan for A Strong and Just City* (*OneNYC*) in April 2015, laying the blueprint for inclusive climate action that works for all New Yorkers across four key visions of Growth, Equity, Sustainability, and Resiliency. In *OneNYC*, we expanded our commitment to 80 x 50 with new investments in renewable energy, electric vehicles, and solid waste management that are improving air quality across the city and catalyzing an important shift away from fossil fuel-based sources of energy. With *New York City's Roadmap to 80 x 50* the City is laying out a comprehensive report, based on the best available science and state-of-the-art GHG emissions modeling, to assess what will be necessary to reach 80 x 50, and to promote economic opportunities that come from the investments that will be required.

Expected Temperature Increases in NYC through the End of the Century
Temperature - Mean Annual Changes
Baseline (1971 - 2000) 54°F



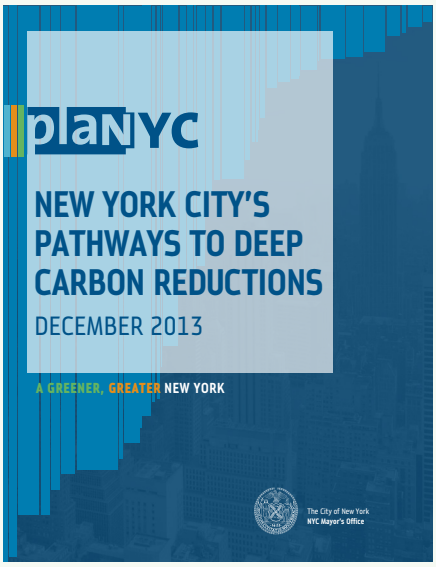
The low estimate (10th percentile), middle range (25th percentile to 75th percentile), and high estimate (90th percentile).

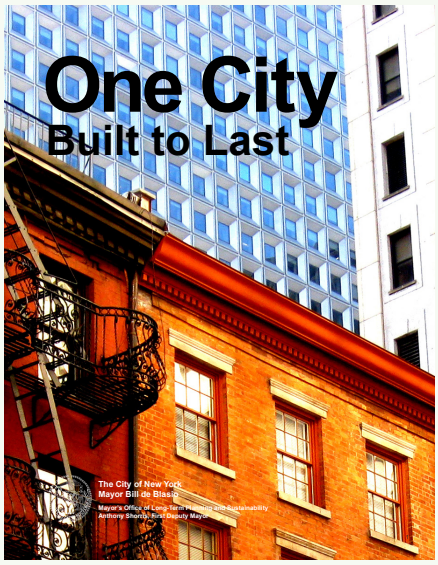
The Roadmap to 80 x 50

We now know what it takes to achieve 80 x 50. The City must accelerate efforts to make buildings and vehicles significantly more energy efficient, replace many fossil fuel-based heating and hot water systems in buildings with renewable or high efficiency electric systems, transition towards a renewables-based electric grid, significantly reduce the number of miles driven while transitioning remaining vehicle trips to electric and clean fuel vehicles, and achieve the goal of Zero Waste to landfills. The technologies necessary to shift away from fossil fuels and reduce waste-related emissions exist today. However, bold action is necessary from all levels of government and the private sector to make the investments, develop new regulatory frameworks, and drive institutional and societal changes necessary to achieve 80 x 50.

Benefits of 80 x 50 for all New Yorkers

On the path to 80 x 50, the city will take major steps that can improve the quality of life for New Yorkers and develop new industries that have significant potential for new job creation. Retrofits to buildings will improve the quality of housing, and the energy efficiency gained will help to keep homes affordable over the long-term. Shifts towards transportation options that are cleaner and multi-modal will improve air quality and public health outcomes in our communities, while also providing access to more transportation options to New Yorkers that currently lack them. An expansion of renewable energy across the city will provide communities with more choice, and will enhance the resiliency of critical services in neighborhoods that are currently vulnerable to outages and weather impacts. In the end, we know that this path is necessary and comes with a moral imperative that we pass on a stronger and more just world to the next generation.





December 2013
PlaNYC: New York City's Pathways to Deep Carbon Reductions, Evaluation of the technical potential of 80 x 50

September 2014
One City Built to Last, 10-year plan to reduce emissions from NYC buildings

NYC committed to 80 x 50

February 2015
Buildings Technical Working Group kickoff

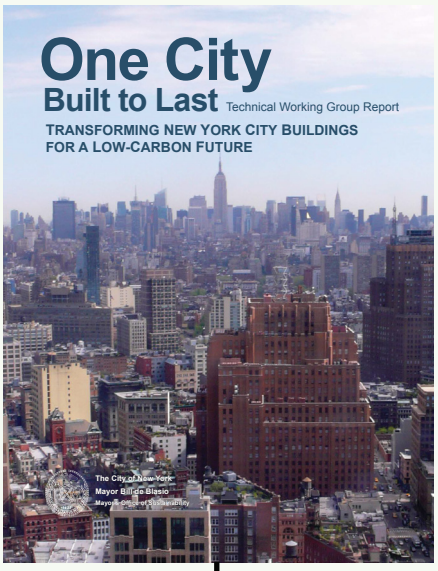
April 2015
One New York: The Plan for a Strong and Just City, NYC's comprehensive plan for a strong, sustainable, resilient, and equitable city

New York City already has one of the lowest levels of GHG emissions per resident among major national and global cities. In fact, the city's GHG emissions per capita are just one-third the U.S. average. In 2007, New York City committed to a first-ever goal of reducing greenhouse gas emissions 30 percent by 2030. Since that time, the threat of climate change has intensified; rising sea levels, increasing temperatures and precipitation, and the likelihood of more frequent and intense storms that leave our neighborhoods and infrastructure more vulnerable, while exacerbating many underlying social and economic inequalities. That is why we committed ourselves to enacting policies that achieve even deeper reductions in GHG emissions.

We are already on the path to 40 x 30

With the commitments in *OneNYC* and related efforts, the City is already implementing policies and programs that will significantly reduce GHG emissions. These initiatives, once fully realized, along with existing state and federal level policies and market trends, put us on track to achieve an interim target of a 40 percent reduction by 2030 (40 x 30). The City's analysis shows that the projected impact of these efforts will make it possible to bend the curve on GHG emissions. Our analysis also shows, however, that these efforts alone are not enough to reach 80 x 50. We must continue to do more to reduce emissions in New York City and lead progress across the globe if we are all to avoid the worst impacts of climate change.

In each sector—buildings, energy, transportation, and waste—the City has made progress toward 40 x 30, putting us on the trajectory necessary for 80 x 50. *New York City's Roadmap to 80 x 50* analysis has shown a feasible potential pathway to build on this progress with an integrated set of strategies to achieve 80 x 50.



January 2016
Energy, Transportation, and Waste sectors begin 80 x 50 planning

April 2016
OneNYC 2016 Progress Report, NYC's progress in delivering on the *OneNYC* commitments

One City: Built to Last, Technical Working Group Report, Comprehensive analysis of energy use in NYC's buildings and next steps to place buildings on a pathway to 80 x 50

September 2016
New York City's Roadmap to 80 x 50

Energy

The biggest driver of GHG emission reductions in New York City, to date, has been changes to our electricity supply. Since 2005, the baseline year for our GHG accounting, New York City's electric grid has become cleaner due a switch in power plant fuel sources from oil and coal to natural gas, which emits fewer GHG emissions when burned, as well as an increase in the efficiency of operations and the construction of new, highly efficient power plants. Efforts at the state level, most notably the Clean Energy Standard's mandate that New York's utilities meet 50 percent of electricity consumption with renewable energy by 2030, are expected to further reduce the carbon intensity of the grid.

The City is also making great progress increasing local renewable electricity generation through solar photovoltaic (PV) installations. Since 2014 alone, citywide solar energy installations have nearly quadrupled. This progress reflects the City's commitment to become an even friendlier market for solar power, invest in solar on our own buildings, and facilitate the adoption of systems on private property through group purchasing and community-shared solar PV projects.

Rooftop solar panels
Photo credit: NYC Department of Citywide Administrative Services

Buildings

More than 68 percent of citywide GHG emissions can be attributed to the energy used to power, heat, and cool buildings—which includes the emissions from burning fossil fuels to generate electricity. While our city's population and economy grew, citywide GHG emissions were reduced largely due to reductions in GHG emissions from the electricity supply, the conversion from heaving heating oils to cleaner fuels in buildings and modest improvements in energy efficiency. The majority of GHG emissions in buildings are from the use of natural gas and oil for heat and hot water, followed by use of electricity from the central grid.

The City is currently leading by example to reduce GHG emissions from municipal buildings and are on track to achieve a 35 percent reduction in our own City buildings by 2025. The City is retrofitting every City-owned building to reduce energy consumption and installing 100 MW of solar energy on these properties. Beginning in 2017, all new City-owned properties will be designed to consume at least 50 percent less energy than current standards.

The City has implemented policies to encourage or require private building owners and decision-makers to invest in energy efficiency and switch to cleaner sources of energy. The City's efforts help ensure building owners and decision-makers have access to their energy use information and require improvements to the energy performance in New York City's largest buildings. To date, these policies have helped large buildings that consistently benchmark achieve an eight percent reduction in GHG emissions.

The City also phased out the use of No. 6 fuel oil. Nearly 6,000 buildings have converted to cleaner fuels, many with assistance provided through the City's NYC Clean Heat program. As these buildings have switched to a cleaner burning fuel, New York City's air quality has improved,preventing approximately 210 premature deaths and 540 hospitalizations annually. Neighborhoods with the highest density of boiler conversions—such as northern Manhattan, northern Queens, and the South Bronx—saw the greatest improvement in air quality,

with the greatest proportion of health benefits occurring in vulnerable, high poverty areas.

The City launched multiple new or expanded programs as part of its *One City: Built to Last* plan, which include the NYC Retrofit Accelerator, Community Retrofit NYC, the NYC Benchmarking Help Center, and the NYC Carbon Challenge. Together, these programs are working with owners and decision-makers of nearly 4,000 properties, representing almost ten percent of the built square footage across New York City, to undertake energy efficiency projects and improve operations and maintenance. The associated reductions in utility of operational costs is helping, in part, to keep residential and commercial spaces affordable.

The City has continuously updated its local building codes to include more stringent energy efficiency and sustainability requirements, most recently with its 2016 update to the New York City Energy Conservation Code. The update will lead to an eight and a half percent reduction in energy use in new commercial buildings and a 25 percent reduction in new residential buildings.

Transportation

New York is home to the most extensive public transportation system in the country, and with it the highest percentage of public transit commuters. Still, over 90 percent of transportation-related GHG emissions come from on-road vehicles, and a majority of these emissions come from personal vehicles.

The City has been working to make more sustainable modes of transportation (public transportation, bicycling, and walking) more accessible options for New Yorkers to get around the city. The City has partnered with New York State to increase bus speed levels through the Select Bus Service and support the expansion of the transit system. This includes investments into the second phase of the Second Avenue Subway, the Penn Station Access project to bring Metro North trains into Penn Station, and the expansion of communications-based train control, to enable more frequent subway service. The City has also been working to make walking and bicycling safer and more enjoyable, pursuing investments in pedestrian plazas and enforcement efforts outlined in Vision Zero to make our streets safer for pedestrians. The City also continues to expand the citywide protected bike lane network and other bicycling infrastructure to double the number of cyclists by 2020. Together these efforts are helping more New Yorkers choose more sustainable transportation options over single-occupancy vehicles to move around the city.

Community Retrofit NYC launch event
Photo credit: NYC Mayor's Office

The City is helping to spur the market for electric vehicles and the use of renewable fuels for those trips that require vehicles. With the launch of the NYC Clean Fleet initiative, New York City set out to create the largest electric vehicle fleet of any U.S. city to date and reduce on-road emissions. The City has purchased over 500 electric vehicles since the program launched in December 2015.

The City has furthered this commitment to a more sustainable transportation sector with the release of the New York City Department of Transportation (DOT) *Strategic Plan 2016: Safe·Green·Smart·Equitable*. The strategic plan articulates how DOT will improve traffic safety and public health; expand travel choices for all New Yorkers; encourage New Yorkers to shift to lower carbon modes of transportation, including walking, biking and public transit; and maintain streets and bridges in a state of good repair. Greater use of technology will support data-driven parking and freight management programs.

Waste

Methane emissions from landfilled waste—especially from food and other organic material—and the processing of wastewater at the city's 14 wastewater treatment plants are responsible for four percent of citywide GHG emissions. As a leader on waste reduction initiatives, New York City is one of the largest cities in the world to make a commitment to Zero Waste. The City committed to meeting Zero Waste through a unique combination of waste reduction, reuse, and recycling programs and

diversion of organic waste from landfills to wastewater treatment plants for digestion and beneficial reuse. All of which reduce GHG emissions. The City's Zero Waste program relies far less on conventional waste-to-energy processing, and instead emphasizes highest and best use of commodities and materials in the waste stream. To date, the City has expanded curbside organics collection to more than 700,000 New Yorkers, launched the NYCHA recycling program in more than 1,600 public housing buildings, updated city regulations to make it easier for businesses to recycle, and through our public engagement program, GreeNYC, empowered New Yorkers to opt out of unwanted mail and reduce waste from single-use shopping bags, coffee cups, and water bottles.

Our groundbreaking methodology and strategies to achieve 80 x 50

New York City's Roadmap to 80 x 50 builds on the initiatives launched by the City to date as well as analysis done for the *Pathways to Deep Carbon Reductions* report, published by the Bloomberg administration in 2013. We know achieving 80 x 50 in New York City is feasible using existing technologies and strategies, although it will require significant social, economic, and regulatory changes. A key challenge will be moving away from our current dependency on fossil fuels to the greatest extent possible, which currently provide us with the vast majority of energy we use for power, heat, cooling, and mobility.

The City conducted an in-depth, integrated analysis to understand potential strategies to make this transition and achieve 80 x 50 in New York City. The study found that the 80 x 50 roadmap requires an integrated approach looking across sectors—buildings, energy, transportation and waste. It also requires actions to reduce GHG emissions at the individual, buildings, community, city, and regional levels. The benefits to New Yorkers are real: strategies to reduce the carbon intensity of the electric grid reduce emissions from vehicles and buildings and improve air quality; small-scale and on-site energy sources can improve the efficiency of buildings and reduce the likelihood of power outages to enhance resiliency; and the latent energy available from solid waste and wastewater can be used as a renewable energy source and this use mitigates the exposure to methane, and other pollutants.

Designated electric vehicle parking spaces
Photo credit: NYC Department of Citywide Administrative Services

Curbside organics collection
Photo credit: NYC Department of Sanitation

These strategies also advance the cause of social and environmental consiterations that are key components of the administration's equity agenda. When fully implemented, the results will be improved air quality and associated health outcomes in vulnerable communities; the emergence of new jobs and industries, as well as training programs to ensure that New Yorkers are prepared to fill these positions; and more affordable energy for residents and startup businesses alike. Equity and environmental conditions are inexorably linked, and this plan considers the environmental impediments to

economic opportunity, as well as disparities in health outcomes related to environmental hazards.

The City's analysis shows that we must continue to must move forward aggressively on all fronts to achieve 80 x 50. A renewables-based electric grid alone will not be sufficient to reach this goal, and neither will building retrofits alone. We need to pursue both, along with promoting distributed renewable community-scale electric, heating, and cooling networks; reductions in the number of miles people drive; a shift to electric vehicles and renewable fuels for remaining automobiles; and achievement of Zero Waste and net-zero energy at in-city wastewater treatment plants.

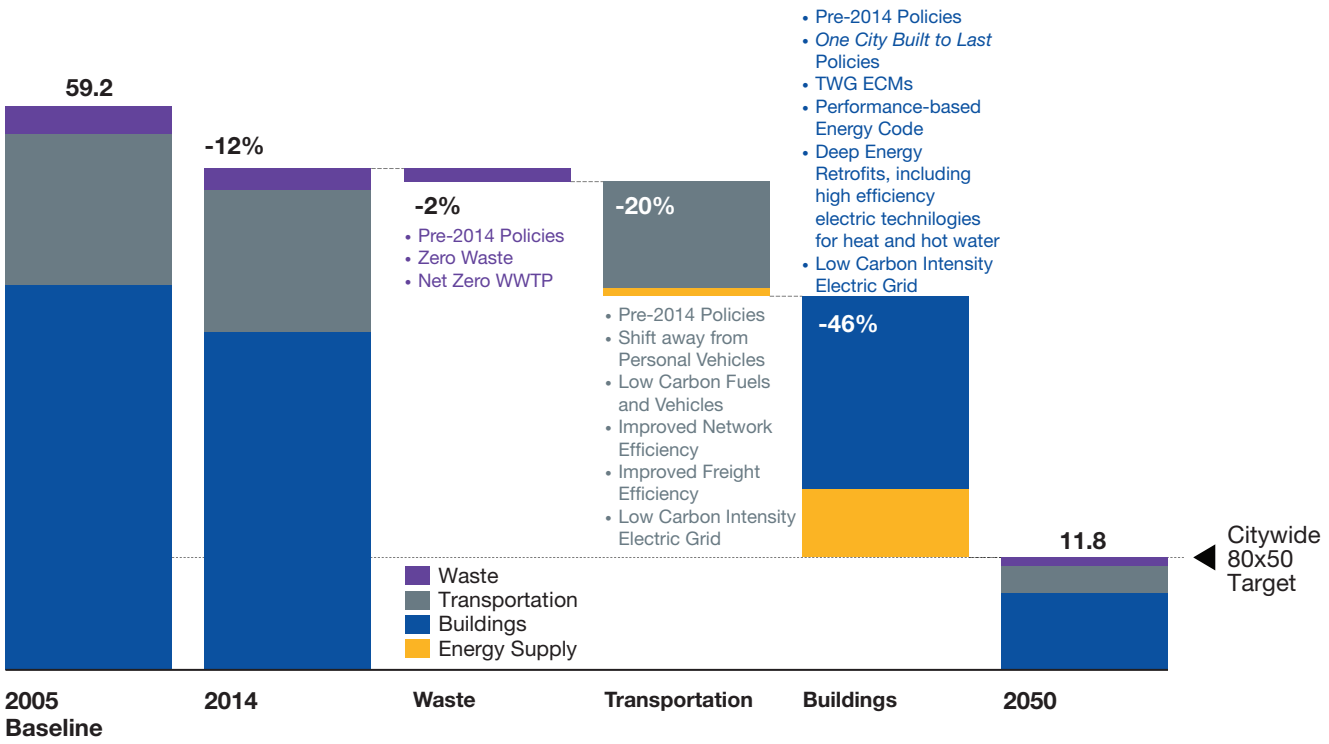
The City will use this analysis as a springboard to engage in an on-going implementation process that takes into account experience from existing, new, and future climate initiatives; the state of evolving technologies; and updated climate projections. The City is already taking numerous steps to reduce both municipal and citywide emissions, but there is plenty more that we New Yorkers need to and can do together.

We will have to transform New York City to achieve 80 x 50

Incremental steps can reduce emissions, but the level of reduction necessary for 80 x 50 requires transforming the financial, operational, and regulatory systems on which New York City depends. We know technologically this is feasible; turning this vision into a reality is a matter of guiding the essential social, economic, and regulatory changes.

The strategies laid out in this this report, and the actions that will follow, are the product of a leading-edge analysis that covers critical sectors with an integrated approach. Reaching 80 x 50 is contingent on technological innovation, strong political will, and social and behavioral changes on multiple scales. At the same time, this research has illuminated the path to 80 x 50 in specific and actionable ways. While the responsibilities are dispersed among different levels of government, the private sector, and individual households, we must act together and lead the world by example. **Our city, and indeed our planet, requires nothing less.**

A Roadmap to 80 x 50, in Million Metric Tons of Carbon Dioxide Equivalent ($MtCO_2e$)



*All percent reductions are relative to the 2005 citywide baseline

Strategy Matrix

		Energy	Buildings	Transportation	Waste
Energy	Increase direct and indirect investments in large-scale renewable energy and energy storage	●			
	Increase efficiency and emissions requirements for in-city generators	●			
	Make an unprecedented commitment to promote clean, distributed energy resources	●	●	●	●
Buildings	Implement cost-effective upgrades in existing buildings to improve energy efficiency in the near-term		●		
	Scale up deep energy retrofits that holistically address heating systems, cooling systems, and building envelopes and transition buildings away from fossil fuels	●	●		
	Expand distributed solar energy and install 1,000 MW of solar capacity by 2030	●	●		●
	Ensure building decision-makers have access to building energy use information		●		
	Provide assistance to the private sector to accelerate adoption of energy efficiency and clean energy	●	●		
	Streamline regulatory processes for building energy efficiency and clean energy	●	●		
	Ensure building owners can finance energy efficiency projects	●	●		
	Achieve exceptional energy performance for new buildings and substantial renovations		●		
	Lead by example in City-owned buildings	●	●	●	●
	Prepare New York City's workforce to deliver high performance buildings		●		
	Position New York City as a global hub for energy efficiency and clean energy technology	●	●	●	●

		Energy	Buildings	Transportation	Waste
Transportation	Modernize, expand, and reduce crowding on the city's transit system			●	
	Make walking and biking safer, more convenient options for all New Yorkers			●	
	Ensure that the City's policies prioritize walking, biking, and transit			●	
	Leverage technology and data to expand travel options and optimize the transportation network			●	
	Better manage and price parking to encourage efficient travel choices			●	
	Support new mobility options that reduce GHG emissions and prepare for autonomous vehicles			●	
	Accelerate purchases of zero-emission vehicles	●	●	●	
	Encourage the use of renewable and low-carbon fuels where electric vehicles are not an option	●		●	●
	Encourage increased efficiency of local and "last-mile" freight delivery			●	
	Invest in rail, maritime, and other infrastructure to increase the efficiency of freight movement			●	●
Waste	Engage all New Yorkers in reducing waste disposal to landfills				●
	Minimize waste generated by all City agencies				●
	Launch outreach campaigns to reduce food waste				●
	Implement proven incentive-based systems to minimize waste generation				●
	Support increasing citywide reuse and donation				●
	Accelerate diversion of recyclable materials from landfills				●
	Capture organics and ensure sufficient capacity to facilitate beneficial reuse in both the residential and commercial sectors	●			●
	Expand energy recovery from wastewater processing operations	●			●
	Reduce emissions from the collection and disposal of commercial waste			●	●

Introduction

Our Commitment to 80 x 50

In September 2014, New York City committed to achieving an 80 percent reduction in greenhouse gas (GHG) emissions from 2005 levels by 2050 (80 x 50), joining the world's leading cities in doing our part to reduce our contributions to catastrophic climate change. This will require nothing less than a transformative shift in how energy is used across the city and across the globe, with fossil fuels replaced by clean and renewable sources of energy. The feasibility of 80 x 50 was initially evaluated in New York City's *Pathways to Deep Carbon Reductions* report (*Pathways*, released December 2013 by the Bloomberg administration). In *One New York: The Plan for a Strong and Just City* (*OneNYC*), the City set out to expand upon that work to make New York City the most sustainable big city in the world and a global leader in the fight against climate change. With *OneNYC*, the City committed to develop an 80 x 50 roadmap to serve as a long-term guide in this ambitious effort.

In *Pathways,* the City found that 80 x 50 is technically feasible. The modeling and analysis for *New York City's Roadmap to 80 x 50* creates a roadmap to achieve this target. The City conducted sophisticated analysis and and integrated modeling across the four sectors responsible for New York City's GHG emissions—energy supply, buildings, transportation, and waste—to evaluate a number of 2050 scenarios. Our analysis helped us understand how far existing and new regulations, investments, and commitments will get New York City towards 80 x 50 and the set of feasible strategies the City, its governmental partners, and the private sector must pursue to fill the remaining gap.

The analysis summarized in this report reflects changes that have occurred since *Pathways*, including new regulations, advances in commercially available technologies, and evolving market opportunities that impact adoption of GHG reduction strategies. New regulations include New York State policies to reduce the electricity grid's carbon intensity—the amount of carbon dioxide equivalent per unit of energy. This includes the New York State Clean Energy Standard, adopted in 2016, which mandates that 50 percent of New York State's electricity must come from renewables by 2030. Similarly, the analysis incorporates new standards from the U.S. Environmental Protection Agency and the National Highway Traffic Safety Administration to reduce emissions and improve fuel efficiency for medium- and heavy-duty vehicles, which will encourage the development of new cost-effective technologies that reduce emissions from these vehicles. Additionally, since *Pathways*, the City has released a number of new initiatives that will increase the pace of GHG reductions in the city.

In addition to regulatory changes, over the past three years we have seen technological advancements, emerging financial tools, incentives, and declining costs that together have helped spur market changes for clean technologies and related services. For example, we have seen a significant increase in the penetration of solar photovoltaics (PV) due to decreasing costs and increasing availability of financing options. The portfolio of low-energy buildings in New York City has also expanded. The world's largest Passive House residential tower, currently under construction on Roosevelt Island, will achieve a 60-70 percent reduction in energy use from standard construction in New York City. The city's first net-zero energy school opened in 2016 that minimizes energy use and offsets the rest of its energy consumption with renewable energy sources. Off-shore wind in the U.S. seems more feasible now than it did just a few years ago due in part to the construction of the Block Island Wind Farm, which is expected to begin operations in fall 2016 and will be the first commercial offshore wind farm in the United States. Additionally, the electric vehicle market, while still small, is growing. In 2015, national electric vehicle sales were 60 percent higher than in 2014, and are projected to represent 35 percent of all new light duty vehicle sales by 2040.

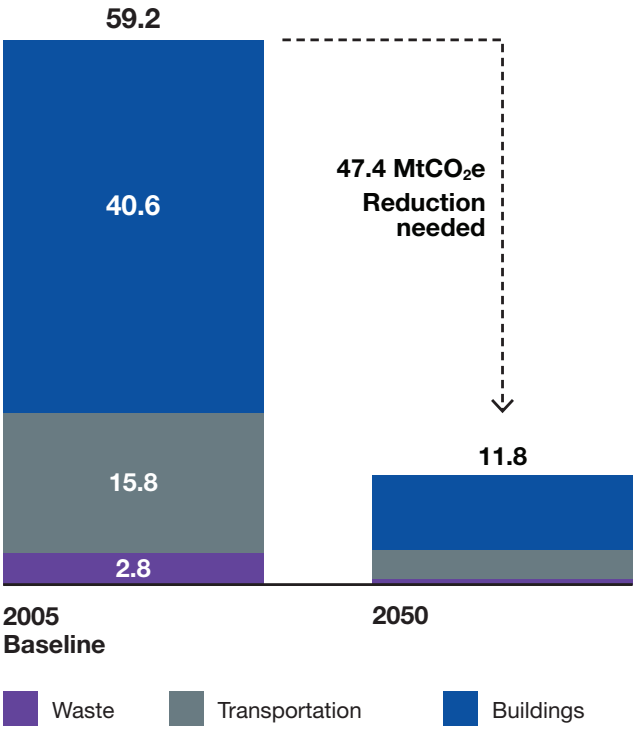
Advancements in climate science and GHG accounting mentodologies continue to inform our own analysis to reflect a better understanding of future emissions profiles and trajectories. In 2015, the City signed on to the United Nations Global Compact of Mayors for Climate & Energy, committing us to work with cities across the globe and use consistent best practices in GHG emissions accounting in a shared effort to track progress toward climate mitigation goals.

New York City's Roadmap to 80 x 50 offers a vision of a low-carbon New York City in 2050, based on the current state of technologies, regulations, and markets. In this document, the City presents the near-term actions that will achieve our interim target of a 40 percent GHG reduction by 2030 (40 x 30) and the long-term strategies that will be necessary to achieve 80 x 50—providing a platform for action to achieve our ambitious climate commitments while supporting the City's *OneNYC* visions of growth, equity, sustainability, and resiliency. In

doing so, this roadmap sets the stage for the transformations necessary to achieve dramatic reductions in New York City's contributions to climate change by the middle of the 21st century.

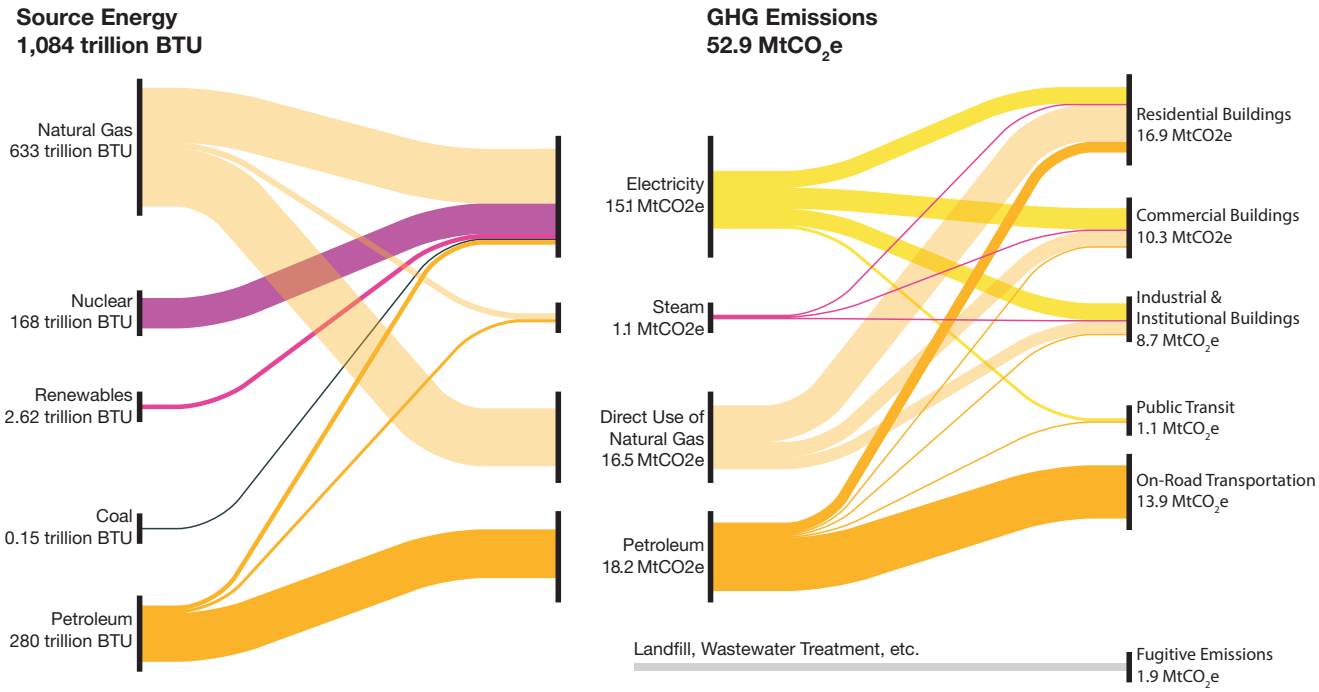
This report builds on the City's established climate actions and progress, and therefore contains a significant number of existing New York City initiatives, often expanding their scope and impact potential to further reduce GHG emissions. Our new investments in renewable energy, energy efficiency, electric vehicles, and solid waste management will also improve air quality across the city and catalyze an important shift away from carbon-intensive sources of energy. Our strategic short-term initiatives will continue the critical transformations of infrastructure, institutions, regulations, and markets needed to achieve 40 x 30 and place the city on a pathway to the long-term, GHG emissions reductions necessary for 80 x 50.

80 x 50 Target GHG Emissions Reductions, in Million Metric Tons of Carbon Dioxide Equivalent ($MtCO_2e$)



*GHG emissions from electricity production (Energy) is included in Buildings and Transportation

2014 New York City Energy Consumption and GHG Emissions



A Roadmap to 80 x 50

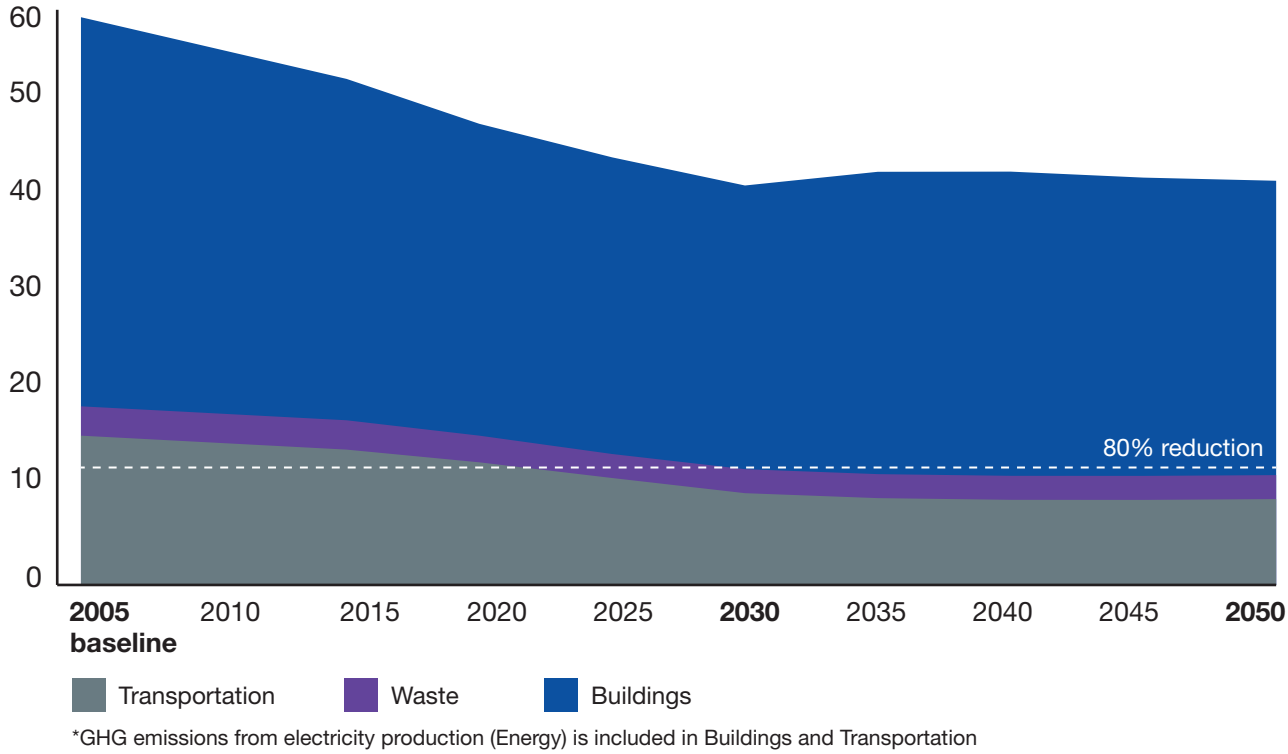
Current GHG emissions

In 2014, New York City emitted 52.9 million metric tons of carbon dioxide equivalent ($MtCO_2e$) of GHG emissions.[1] The vast majority of these emissions are the result of the combustion of fossil fuels, including natural gas and petroleum, to generate utility-scale electricity and steam, provide heat and hot water for buildings, and power vehicles. A smaller share of total GHG emissions are attributed to emissions from solid waste and waste management.

More than 68 percent of total citywide GHG emissions can be attributed to the energy used to power, heat, and cool buildings, which includes the emissions from burning fossil fuels both to produce heat and hot water in buildings and to generate electricity from power plants. The fossil fuels burned on-site in buildings account for over more GHG emissions than our entire electricity supply. Twenty-eight percent of the city's GHG emissions come from producing electricity and using petroleum to power mass transit systems and on-road vehicles. Another four percent of GHG emissions is emitted from landfilled waste—especially from food and other organic material —and wastewater processing at the City's 14 wastewater treatment plants. In addition to the contributions these uses have on global climate change, their emissions burden communities with poor air quality and exacerbate disparities in related respiratory health conditions in environmental justice neighborhoods.

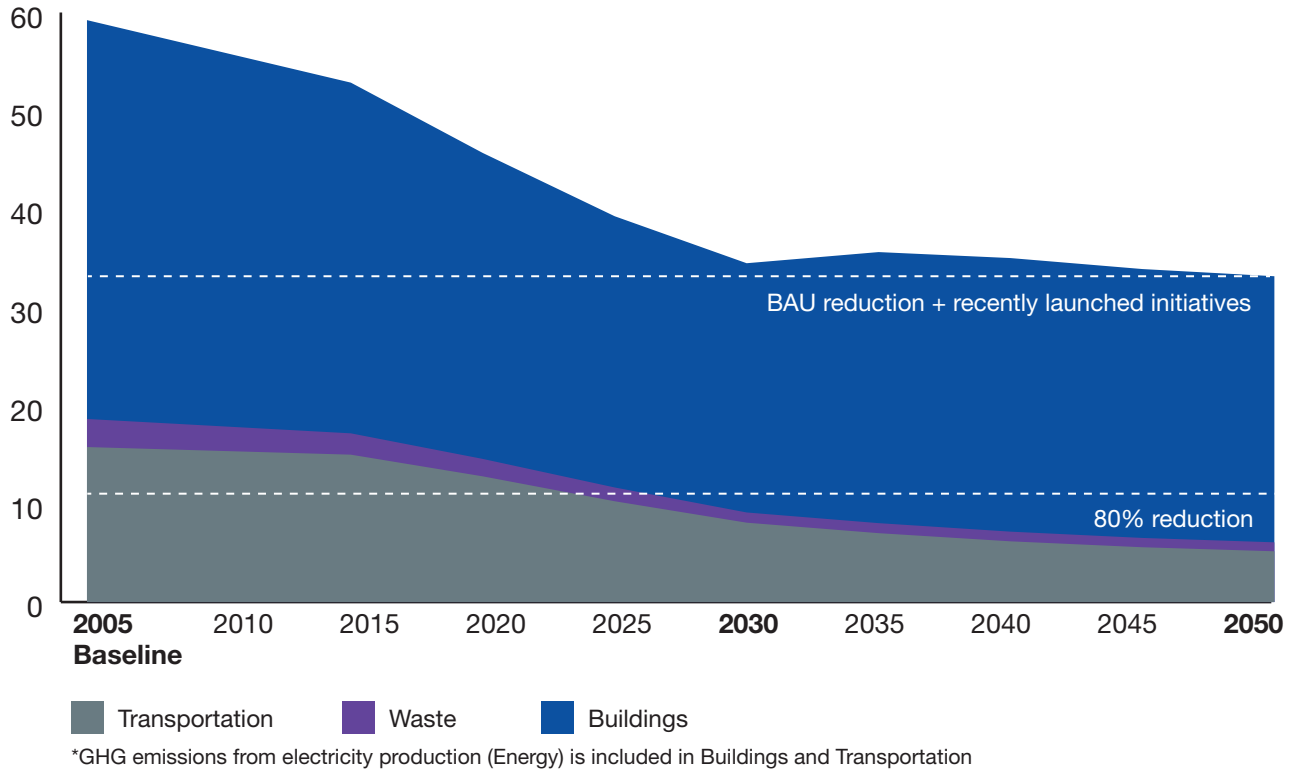
As tracked in the annual *Inventory of New York City Greenhouse Gas Emissions*, citywide GHG emissions showed an overall decrease from 2005 to 2012. In addition to a growing population and economy since 2012, the city experienced two of the coldest winters on record, which drove up heating demand. Despite this demand, citywide GHG emissions have remained relatively consistent since 2012. Most of the reductions to date are a result of improvements to the electricity supply, which includes switching from oil or coal to less carbon intensive natural gas, improved operational efficiencies at existing power plants, and the construction of new, highly efficient natural gas power plants both within and outside the city. Conversions from heavy heating oils to cleaner fuel sources in buildings and modest im-

Citywide Business as Usual Emisssions ($MtCO_2e$)



*GHG emissions from electricity production (Energy) is included in Buildings and Transportation

Business as Usual and Recently Launched Initiatives Emissions Reductions ($MtCO_2e$)



*GHG emissions from electricity production (Energy) is included in Buildings and Transportation

provements in energy efficiency have also resulted in a reduction in citywide GHG emissions.

Emissions

According to the *2014 Inventory of New York City Greenhouse Gas Emissions*, an 80 percent reduction in citywide GHG emissions requires an additional 41 $MtCO_2e$ reduction in emissions from the 2005 baseline.

Business as usual

Many efforts already underway at the state and federal levels will support reductions in GHG emissions, as will local policies and programs enacted prior to the de Blasio administration. Together, existing regulations, investments, and City programs prior to 2014 were projected to result in a reduction in citywide GHG emissions of nearly 30 percent by 2030. This is largely driven by expected changes in electric power generation due to the New York State Clean Energy Standard, changes in fuel efficiency due to federal emissions standards for vehicles, and the City's various initiatives to improve energy efficiency in buidlings.

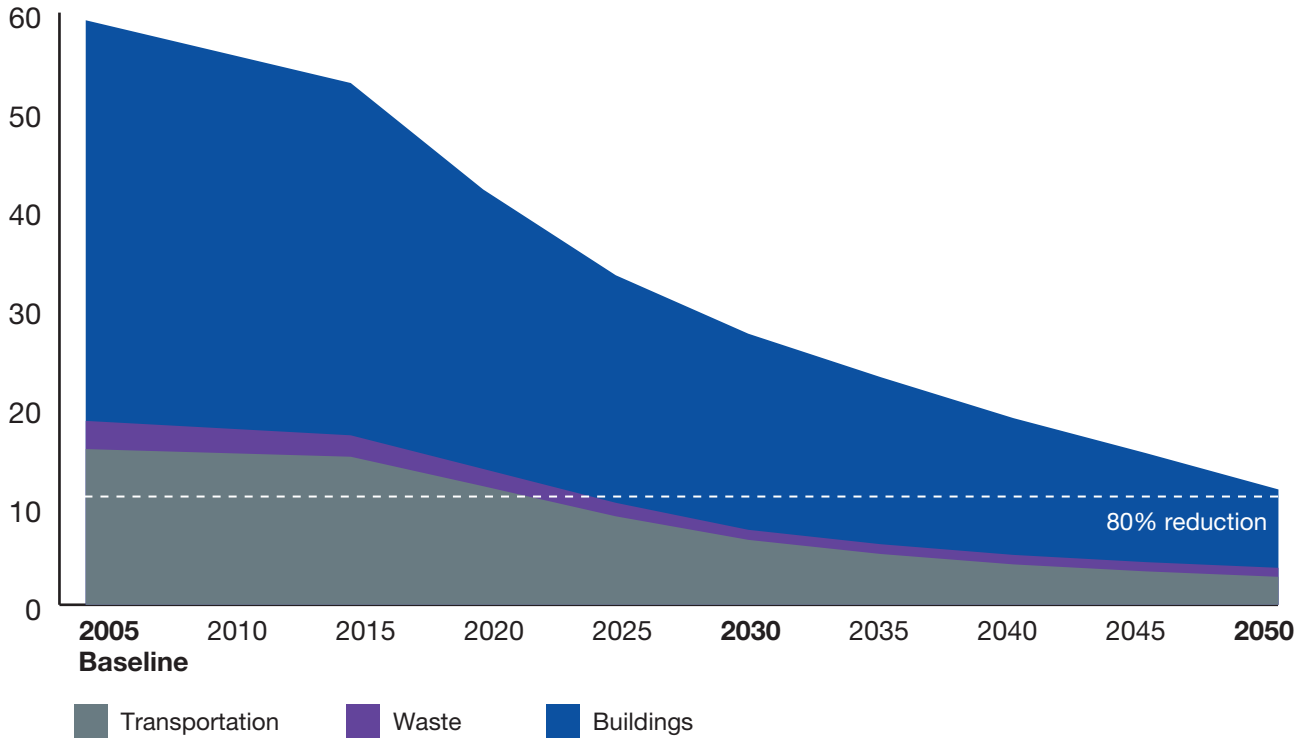
Business as usual and recently launched initiatives

With new City initiatives launched since 2014, citywide GHG emissions are now expected to exceed 40 percent by 2030. Those initiatives include new policies and programs announced in *OneNYC*; *One City: Built to Last*; DOT's *Strategic Plan 2016 Safe·Green·Smart·Equitable*. They also include Zero Waste, Vision Zero, NYC Clean Fleet, and DEP's commitment to achieve net-zero energy wastewater treatment plants,in which total energy use is offset by renewable energy sources.

The path forward

While significant, the reductions from existing programs are not sufficient to continue the pace of GHG reductions needed to achieve 80 x 50. Additionally, the city must overcome the expected increase in emissions from the potential deactivation of nuclear power in the grid serving New York City and the resulting increase in fossil fuel-based power plants to fill the electricity supply gap that it could cause. Greater GHG emissions reductions will also be challenged by legacy fossil fuel-based systems for heating and hot water production

80 x 50 Roadmap ($MtCO_2e$)



*GHG emissions from electricity production (Energy) is included in Buildings and Transportation

in buildings that are rarely replaced and the billions of vehicle miles powered by petroleum that are expected to continue to travel on city streets.

Modeling the path forward

The City modeled a number of scenarios to gain an understanding of what is necessary to achieve 80 x 50. Although we cannot perfectly predict future technologies or state and federal policies, we found that 80 x 50 is attainable with solutions available today by moving aggressively on all fronts across energy supply, buildings, transportation, and waste.

Our models project that New York City will achieve a significant portion of its GHG reductions as a result of a dramatic shift towards a renewables-based grid, supported by the implementation of New York State's Clean Energy Standard and the declining cost of renewable energy. Large-scale renewable energy sources, including off-shore wind, utility-scale land-side solar and wind, and hydropower—and the transmission of these resources into New York City's electricity grid—play an important role in making this vision a reality.

Within New York City's boundaries, achieving 80 x 50 will require installing a significant portion of the technical potential for distributed solar PV on buildings, lots, and underutilized land. It will also require investment into low-carbon district heating and cooling networks throughout the city that are powered by renewable technologies, such as ground source and water source heat pumps. Together, these building and community-scale renewable energy systems will provide New Yorkers with more energy supply choices and will enhance the resiliency of critical services in neighborhoods that are currently vulnerable to outages and weather impacts.

Nearly all of the city's existing buildings will need to undergo deep energy retrofits that holistically address heating, cooling, and the building envelope. Many will need to replace fossil fuel-based heat or hot water systems with renewable sources or energy efficient electric technologies to tap into a cleaner future electric grid. Retrofits to buildings will improve the quality of housing, and the energy efficiency gained help keep homes affordable over the long-term.

With over 90 percent of transportation GHG emissions attributable to on-road vehicles, the City must take steps to provide more sustainable transportation options for New Yorkers to reach their destinations, including transit, walking, and bicycling. For trips that still require driving, we must transition to electric vehicle technologies and renewable fuel sources. Taken together, these strategies will provide greater accessibility and choice for New Yorkers and have the potential to enhance public health by reducing air pollution and supporting for a more active lifestyles.

Additionally, the City must achieve its goals for Zero Waste and net-zero energy at wastewater treatment plants. The collection and reuse of our waste resources also have the potential to provide low carbon energy sources, supporting GHG reductions across the other sectors while spurring economic activity around the resulting products and services.

Strategies for GHG emissions reductions

The City is moving forward immediately with strategies to reduce GHG emissions from energy supply, buildings, transportation, and waste. Building on its strong climate action track record, the City has already launched a concrete set of initiatives since 2014 that will allow us to achieve our interim target of 40 x 30 and put us on a path towards 80 x 50. These have been developed with a practical sense of what is doable today and a vision of what must be accomplished by 2050. While it is not possible to predict every change that will occur between now and 2050, our analysis, provides direction for the future and a platform for action our near-term actions and the long-term the policies and innovations that will ultimately be necessary to achieve 80 x 50 and our *OneNYC* vision of a stronger and more just city. In the pages ahead, we dive deeper into the methodologies of this analysis and the strategies for energy, buildings, transportation, and waste that the City will pursue as part of its roadmap to 80 x 50.

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Methodology

Introduction

New York City's citywide greenhouse gas (GHG) emissions are calculated and reported annually according to the guidance of the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) and in compliance with the Global Covenant of Mayors for Climate & Energy. These methodologies, which are regularly updated based on the best-available science, provide a consistent approach for global cities to report on their progress to reduce GHG emissions. To develop this 80 x 50 roadmap, the City built upon its most recent *Inventory of New York City Greenhouse Gas Emissions in 2014* (*2014 NYC GHG Inventory*) and conducted enhanced analysis, using best-in-class modeling tools, to project forward the city's emissions scenarios from now until 2050. Moving forward, the City will continue to update the GHG analysis used for this 80 x 50 roadmap based on (1) the best-available science, (2) the newest technologies available, and (3) actual progress made. The City will update this analysis as part of *OneNYC*.

The methodology for this 80 x 50 roadmap began with developing distinct models for current GHG emissions and potential reductions for each of the four sectors—energy, buildings, transportation, and waste—which incorporate nationally and globally recognized methods that are adapted to the New York City context. The City also developed new models for decision-making, including a citywide community energy map and the NYC Greenhouse Gas Calculator. The City incorporated these models into an integrated scenario analysis that is able to compare possible future outcomes by considering alternative possible events, trends, and programs across sectors. The three main scenarios analyzed were: (1) business as usual (BAU), which includes projected

Inventory of New York City Greenhouse Gas Emissions

New York City has been a leader in greenhouse gas (GHG) accounting practices since 2007 and now has one of the richest GHG datasets of any city. The City codified this process with Local Law 22 of 2008, which requires the City to complete an annual GHG inventory to measure, report, and track both citywide GHG emissions and those from City government operations. In 2015, the City signed on to the Global Compact of Mayors for Climate & Energy, committing us to work with cities across the globe and use consistent best practices in GHG emissions accounting in a shared effort to track progress toward climate mitigation goals.

Accordingly, following the guidance of the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC), additional data sets and accounting methodologies were accounted for in the 2014 annual GHG inventory for the first time. The citywide GPC BASIC GHG inventory consists of all direct and indirect GHG emissions from energy used by buildings and other stationary sources; on-road transportation and public transit within the geographic borders of New York City; and fugitive GHG emissions from wastewater treatment and solid waste disposed out of the city; and natural gas distribution within New York City. GHG emissions measurement and reporting is a continually evolving science, as new data sources, emissions factors, and methodologies require consistent revision of past results and the adoption of new practices. As such, the City updates prior years' GHG results accordingly each year as it reports the most recent year's GHG emissions.

There are millions of data points that produce the final aggregate GHG emissions total for New York City. Changes in total emissions from year to year within a range of plus or minus one or two percent are well within the range of uncertainty. In other words, such small changes indicate our emissions are not changing significantly enough to suggest a clear change in either direction – an increase or a decrease. Annual results are also impacted by a number of factors outside the City's control, such as weather and population growth. Even with a growing population and a growing economy, our inventory results since 2012 have shown essentially this, a flat line. Although the City continues to keep its greenhouse gas emissions level even as the city grows (an impressive feat in its own right), it is clear that deeper reductions are necessary and there is much more work to do.

The City will release the Inventory of New York City Greenhouse Gas Emissions in 2015 report later this fall. Results indicate New York's citywide GHG emissions for 2015 decreased one percent relative to 2014. A detailed analysis of the drivers of these changes will be included in the report.

growth, existing state and federal regulations, and City programs and policies that were in place before 2014; (2) BAU plus recently launched initiatives such as the 2016 Energy Code, NYC Clean Fleet, and Zero Waste; and (3) additional strategies and actions to could be deployed to achieve 80 x 50. Finally, the City considered how GHG reduction strategies could produce specific cobenefits for New Yorkers by promoting affordability, health and wellbeing, reliability of utilities and services, climate adaptation, job development, access to services, safety, resource preservation, culture, and social capital. Throughout the process, the City engaged technical advisors and key stakeholders to help develop the assumptions for the GHG analysis and the transformative strategies and actions necessary to see meaningful GHG reductions and achieve 80 x 50.

Modeling GHG emissions

New York City's GHG emissions fall broadly into four sectors: energy, buildings, transportation, and waste. By using sector-specific modeling and integrating the outputs from each sector, the City was able to pursue a groundbreaking and granular analysis of for each sector and the cross-cutting impacts of potential strategies and actions to guide decisions and policies going forward. Integrating these models allowed the City to understand the potential of policies to simultaneously impact different sectors. For example, the City tested the impact that widespread electrification of vehicles and building heat and hot water systems in New York City would have on the carbon intensity (the amount of GHGs emitted per unit of energy) of the regional electric grid. The City was also able to assess the impact of mandated reductions in GHG emissions from heavy trucks on both transportation and waste sector, and the contribution that collected organic waste processed through an anaerobic digester could have on meeting multiple buildings' heating needs and the potential reductions in building- and energy-related GHG emissions. Together, these models provided an understanding of GHG impacts across sectors as well as at different scales—including buildings, the community, the city, and the region.

Models, however, are just models; they are not perfect predictions of the future and are driven by the numerous assumptions (e.g., commodity costs, population growth, adoption rates) on which they are built. Some of these assumptions, such as natural gas costs, are both very uncertain and may greatly influence the city's overall GHG emissions levels. Between now and 2050, new technological breakthroughs or fundamental economic shifts may occur that bring down costs or increase the feasibility of certain technologies. Additionally, there may be new state and federal regulations governing GHG emissions, or the introduction of a nationwide price on carbon, each of which would greatly impact GHG emissions levels.

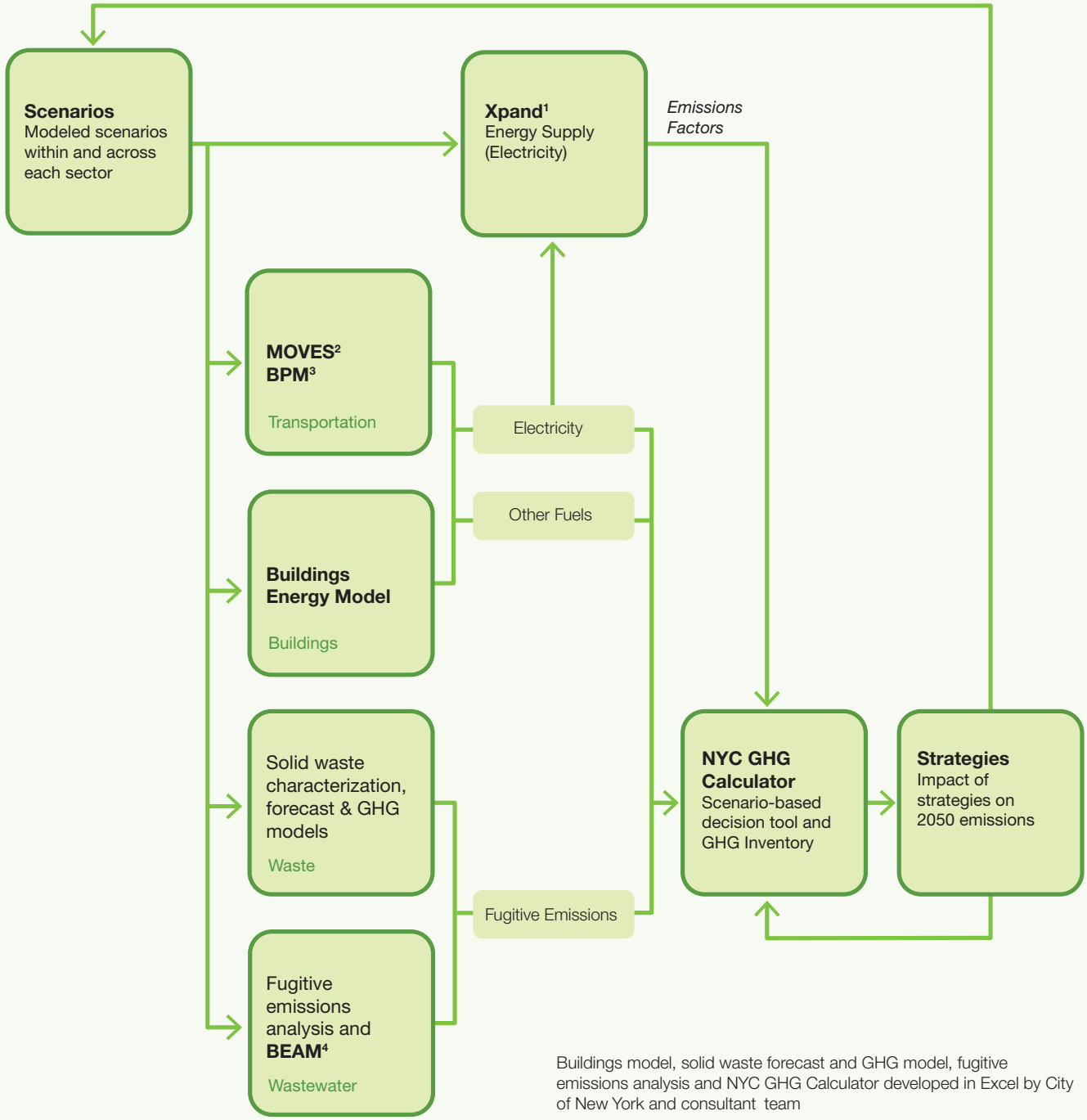
Instead of focusing on this uncertainty, the City modeled GHG emissions and potential reductions across the four sectors discussed below based on existing policies and technologies to understand how specific strategies may impact the future trajectory of GHG emissions what will ultimately be necessary to achieve 80 x 50.

Our buildings model

The City developed a customized Buildings Energy Model that builds on the analysis completed as part of the Buildings Technical Working Group (TWG). The model uses the city's reported building area from the NYC Department of City Planning (DCP) and the energy consumption by building sector reported within the *2014 NYC GHG Inventory* to estimate the citywide total annual energy use and energy use intensity (EUI) per square foot by building typology and fuel source. The model uses the 21 building typologies developed by the TWG, which break down New York City's building stock by size, age, and use. Building uses include one- to four-family residential homes, multifamily buildings, commercial buildings, industrial buildings, and institutional buildings. The City used population and employment forecasts developed by the New York Metropolitan Transportation Council (NYMTC) to project growth in the total number of buildings and built square footage for each building typology. The City also estimated the number of buildings and square footage demolished and substantially renovated based on historical NYC Department of Buildings (DOB) data.

To estimate potential future GHG reductions from buildings, the City built on analysis completed to estimate the impacts of the programs and policies announced in 2014 as part of *One City: Built to Last* (*Built to Last*), and three pieces of analysis from the TWG. The analysis from the TWG included: (1) the assessment of the potential citywide energy and GHG reductions and cost per square foot for nearly 100 "low- and medium-difficulty" energy conservation measures (ECMs) that were identified by the group, based on Local Law 87 data and industry expertise; (2) the potential energy and GHG reductions

80 x 50 Planning Process: Scenario Modeling



Buildings model, solid waste forecast and GHG model, fugitive emissions analysis and NYC GHG Calculator developed in Excel by City of New York and consultant team

1. Xpand is a proprietary model licensed to The Brattle Group from Lantau
2. MOVES is a GHG model developed by EPA for public use
3. Best Practice Model (BPM) is a tool created by the New York Metropolitan Transportation Council (NYMTC)
4. Biosolids Emissions Assessment Model (BEAM)

Electric Grid Modeling Assumptions

External Assumptions	Business as Usual (BAU) Grid	The business as usual grid represents the set of assumptions that represent the most likely trajectory of generation capacity, fuel prices, energy and peak demand growth, regional transmission capacity, and environmental policies, including the implementation of New York State's Clean Energy Standard.
	High Carbon Intensity (HCI) Grid	The high carbon intensity grid represents a set of assumptions that represent the least favorable trajectory for achieving 80 x 50. The HCI grid assumes wind and solar costs remain at their present levels, while natural gas prices remain depressed. It also assumes that the Indian Point nuclear plant closes within the next five years, and that statewide energy and peak demand grows more quickly than in the BAU grid.
	Low Carbon Intensity (LCI) Grid	The low carbon intensity grid represents a set of assumptions that represent the most favorable trajectory for achieving 80 x 50. The LCI grid assumes wind and solar costs decline more quickly than in the BAU grid, while natural gas prices rise more quickly.
New York City Demand Assumptions	BAU Demand	The demand assumptions represent changes in energy and peak demand within New York City that could result from City policies. The BAU demand assumes that the city's peak and energy demand follow statewide trends of moderate growth, resulting from a growing population and economy, and mitigated by moderate levels of energy efficiency and other distributed energy resources. The BAU demand assumes minimal adoption of electric vehicles and electrified heating systems in buildings.
	Low Demand	The low demand scenario assumes that the city's energy and peak demand declines with aggressive energy efficiency. This scenario also assumes that there is moderate adoption of electric vehicles and that the city achieves the technical potential for distributed solar PV, which lowers New York City's electricity consumption by 35 percent.
	High Demand	The high demand scenario assumptions also include aggressive energy efficiency, but assumes that the city's energy and peak demand increases with high adoption of electrified heating systems in buildings and of electric vehicles. Together these assumptions represent a 9 percent increase in New York City's electricity consumption.

per square foot from implementing multiple deep energy retrofit paths in a typical building from eight key building typologies, which were modeled using EQuest building energy modeling software; and (3) the potential energy and GHG reductions from implementing incremental Energy Code updates through 2050 based on historical ASHRAE 90.1 updates using U.S. Department of Energy studies completed by the Pacific Northwest National Laboratories (PNNL).

Our energy model

Electricity supply

To understand the influence of existing and proposed regulations, technology costs, and other factors on the regional electric grid that serves New York City, the City used modeling software called Xpand. Xpand is a regional long-term electricity generation planning and simulation model that identifies the least-cost electricity resource mix. Xpand simulates the electricity market's least-cost resource decisions through 2050, which include retirement of existing generating units, construction of new generating units, and the dispatch of electric generation across the fleet of new and existing units. Xpand also produces projected GHG emissions, electric capacity, and electricity prices that result from resource mix decisions.

The model's selection of the least-cost resource mix is based on the database of existing generators, clearly delineated resource expansion options, electricity transmission constraints, state and local electricity demand across sectors, fuel price forecasts, and environmental policies. Using these inputs, the City selected multiple scenarios, described in more detail below, for which the Xpand model generated a least-cost combination of generation capacity and dispatches specific to each scenario's set of input parameters. These scenarios included a "business as usual" grid scenario using the most likely assumptions, as well as bookended "high carbon intensity" and "low carbon intensity" electric grids based on assumptions for the inputs listed above as well as potential local policies.

Community energy

The City also conducted an analysis of the potential impact of community energy solutions towards achieving 80 x 50. Community energy solutions provide heating, cooling, and/or power to multiple buildings from shared resources. The City commissioned the development of a NYC community energy map, using Excel models and open-source Geographic Information System (GIS) software, to identify and prioritize opportunities for community energy at the block level. The community energy map was calibrated to the Building Energy Model and city tax lot data, taking into consideration the city's current demands for heating, cooling, and power across different building typologies, and the physical characteristics of each block. Additional data layers were incorporated to assess the technical potential and business as usual case for several technology types and estimate the GHG emissions reductions from deployment. Additional details on the community energy map are included in the Energy chapter.

Our transportation model

Reducing transportation-related GHG emissions will require both people and goods to move differently than they move today. In order to envision these future changes, the City created several models to quantify the necessary shifts to lower- or zero-carbon modes of transportation, improvements to the transportation network's efficiency, and the introduction of low-carbon fuels and vehicles to reduce GHG impacts of the vehicles that will remain on the road in 2050.

The analysis of transportation mode shifts was grounded in the use of the Best Practice Model (BPM) developed by NYMTC. The BPM forecasts travel patterns in the New York City region (28 counties in New York, New Jersey, and Connecticut) in response to changes in regional demographic profiles and transportation systems. The BPM provides a useful framework to evaluate changes in vehicle miles traveled and mode shares in the context of currently adopted transportation projects, along with potential future scenarios that result in an even greater share of trips by low-carbon modes of travel. Combined with an evaluation of Regional Household Travel Survey (RHTS) data, which breaks down current trips by mode, multiple scenarios were developed reflecting changes in mode shares to more efficient and cleaner modes of travel resulting from a range of transportation policies and programs.

The travel activity-based analysis provided information on various transportation sectors, which was then translated into GHG emissions estimates using the U.S. Environmental Protection Agency (EPA) 2014 Motor Vehicle Emission Simulator (MOVES) model. The MOVES model is the U.S. EPA's most advanced tool for estimating emissions from a wide range of mobile sources. The City employed the MOVES model to estimate average per-mile emissions rates from the various transportation sectors over time, which shows GHG reductions as the vehicles become cleaner, more efficient, use more renewable fuels, and include increasing amounts of electric and other zero and near-zero emission technologies. Combining the transportation activity data with emissions factors derived from MOVES provided the GHG emissions estimates used to model the City's path to 80 x 50 in the transportation sector.

Our waste model

The City assessed the GHG impacts of solid waste and wastewater management, both of which currently result in methane emissions, which is a GHG that is significantly more potent than carbon dioxide. For solid waste, the GHG analysis entailed forecasting generated waste materials out to 2050, characterizing the waste generated by material type (e.g., food waste, paper), and then modeling the GHG impact by the tonnage of material type that is either landfilled or composted.

The forecast of total solid waste includes a projection of waste and recycling materials generated by residents, businesses, and construction in New York City through 2050, using an econometric model based on historical New York City Department of Sanitation (DSNY) data. The econometric model incorporates the impact of real per capita income to approximate consumption and population, to which a linear trend is added to reflect the general trend towards reduced waste generation in the city and nationwide. For commercial waste, a long-term forecast was developed using sectoral commercial waste generation factors per employee (tons per employee per year) by specific industry. For example, restaurants will generate more food waste than commercial office buildings, so it was necessary to forecast the growth of New York City-specific industries by employment to be able to estimate the amount of commercial waste generated for different materials. After the total forecast was developed, the City completed a waste characterization of residential and commercial waste and for construction and demolition (C&D) debris.

The City initially used the U.S. EPA's Waste Reduction Model (WARM) to measure the GHG emissions resulting from various waste reduction strategies. However, because WARM calculates GHG emissions that are outside of the city's GHG inventory boundaries (e.g., upstream, life cycle emissions), the City elected to measure projected GHG emissions from landfilled and composted waste using the methodologies recommended by the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC), consistent with other sectors and with most cities globally. Per GPC guidance, GHG emissions from the incineration of waste are incorporated into the GHG emissions from the electricity supply. The associated reduction in landfilled waste from this strategy was included in future waste generation projections.

Emissions from wastewater treatment were developed based on electricity and fuel usage at the NYC Department of Environmental Protection's (DEP) facilities, as well as the fugitive emissions from anaerobic digestion methane production and nitrogen emissions resulting from the treatment process. City specific models were created using GPC methodology and the Biosolids Emissions Assessment Model (BEAM) to estimate the emissions associated with biosolids disposal alternatives.

The City's integrated GHG analysis: The NYC Greenhouse Gas Calculator

The City created the NYC Greenhouse Gas Calculator as a tool that brings together outputs from the modeling efforts across the four sectors to evaluate the impact of potential strategies and actions on New York City's GHG emissions. The model allows the City to calculate the GHG emissions associated with all fuel sources, including electricity, natural gas, petroleum sources, and waste streams and to calculate avoided emissions from potential strategies, such as transportation mode shifts or building retrofit paths. It also allows the City to test the impact of both individual and combined strategies on overall GHG emissions to understand the potential interdependencies of the sectors. The City compiled the outputs of GHG modeling for each sector into this integrated model, ensuring consistent emissions multipliers, referred to as carbon coefficients, to convert each source into GHG emissions and omit any duplicative accounting.

One important aspect of the NYC Greenhouse Gas Calculator is the ability to see the influence of changes in the carbon intensity of the electricity grid on the potential strategies implemented across the sectors. This allowed the City to develop bookend scenarios based on local strategies and actions as well as uncertainty for factors affecting the electric grid that are largely outside of the City's control. The resulting model highlights the interrelationships of the various sectors and strategies, helping to better understand uncertainties, impacts, and priorities.

Scenario analysis

Scenario analysis is the process of comparing possible future outcomes by considering alternative possible events, trends, and programs. During the 80 x 50 planning efforts, the City assessed three types of scenarios: BAU, BAU plus recently launched initiatives, and 80 x 50.

Business as usual (BAU) scenario

The BAU projection took into account expected population growth and economic development and incorporated the expected outcomes of existing city, state, and federal policies and regulations that took effect before 2014.

To estimate potential electricity sector emissions, this scenario includes electricity-related state and federal policies, including the New York State's Clean Energy Standard (CES), the Regional Greenhouse Gas Initiative (RGGI), and the federal Clean Power Plan, as well as expected trends for electricity demand from the 2015 NYISO Gold Book, natural gas prices (gas forward prices, AEO), and renewable energy costs (AEO, NREL), which were modeled in Xpand. This scenario also included the impact of different costs for utility-scale solar, offshore wind, and natural gas; levels of energy efficiency and distributed energy resources; new transmission lines to upstate large-scale renewable energy; and timing of retirements of the nuclear plants in New York State.

For buildings, the BAU scenario includes all GHG reductions achieved to date from buildings and the existing projections from all policies enacted before 2014. These include the Greener, Greater Buildings Plan, updates to the Energy Code, and the implementation of the City's regulations phasing out the use of heavy heating oil. The BAU scenario for buildings also includes projected reductions from the electricity supply under the BAU grid scenario.

For transportation, the BAU scenario involved adding to the MOVES model the benefits of the recently-adopted U.S. EPA/National Highway Traffic Safety Administration (NHTSA) fuel economy and GHG rules for medium- and heavy-duty trucks, federal Corporate Average Fuel Economy (CAFE) standards for light-duty vehicles, and existing New York City Local Laws that cover emissions in heavy-duty vehicles and buses. Additionally, the BAU scenario included committed expansions to citywide ferry service, Citi Bike (Phase 2), the subway system (2nd Avenue Subway Phase 1), and rail (East Side Access), among others, as well as reductions attributable to the reduced carbon intensity of the BAU electric grid.

To develop BAU projections for solid waste, the City modeled total waste volumes to the year 2050 to incorporate both expected population growth and employment trends. The City used current recycling rates of 16 percent for residential waste and 26 percent for commercial waste for the analysis to generate estimates of gross tonnage destined for disposal. These recycling estimates are based on DSNY's data from residential collections as well as information from carter reporting.

The transportation emission impacts of in-city waste collection incorporated DSNY-funded and/or implemented NYC Clean Fleet initiatives as well as implementation of NYC Local Law 145, which will require the conversion of commercial waste vehicles to cleaner trucks by 2020. The BAU analysis also included full implementation of the NYC Solid Waste Management Plan (SWMP), a twenty-year plan first approved in 2006 for the development of borough-based facilities to enable the export of waste via the use of rail and/or barge transport rather than long-haul trucking to landfills. Prior to the SWMP, trucking had been the sole method of export for the City's residential waste with the closure of the Fresh Kills landfill. However, while the SWMP results in lower GHG emissions from reduced trucking, these emissions are outside the city's boundary and are not included in the city's GHG inventory, per GPC guidance.

BAU scenario plus recently launched initiatives

The second scenario added recently launched (2014 or later) City-led initiatives to the BAU findings. This included estimates of the potential future GHG impact of these recent initiatives, many of which are still in the planning or early implementation phases.

For buildings, this included all policies and programs that were announced in Built to Last, as well as a number of initiatives announced or launched with the release of the *One City: Built to Last Technical Working Group Report* (*the TWG Report*). These include the 2016 Energy Code, new steam systems requirements that will be incorporated into Local Law 87, and mandates for several key low- to medium-difficulty ECMs. This scenario also included estimated GHG reductions from Local Law 31, which will set an energy performance standard for new municipal buildings of at least 50 percent lower than existing standards, and phasing in a performance-based Energy Code for privately-owned buildings meeting the same standard beginning in 2022. The City modeled these reductions using the BAU grid, which contributed additional GHG reductions from the electricity supply.

In the transportation sector, the City added several assumptions to the BAU scenario to capture the current or planned implementation of programs like Vision Zero, NYC Clean Fleet, and DOT's 2016 Strategic Plan. These also include expansions to Select Bus Service and the construction of the Brooklyn Queens Connector (BQX), future growth of Citi Bike and new investments in our bicycle network, the shift of all agency non-emergency sedan vehicle purchases to electric vehicles as of 2017, and a reactivation of the South Brooklyn Marine Terminal. The City modeled these reductions using the BAU grid scenario.

The City applied its Zero Waste diversion targets to the BAU future waste generation tonnages to estimate GHG reductions from the waste sector. The recovery factors applied are similar to the recovery achieved by high-performing municipalities in the U.S., such as Seattle and San Francisco, which have aggressive policies and regulations to target the recovery and diversion of municipal solid waste. Additional projected reductions in wastewater treatment-related emissions are based on existing DEP initiatives to reduce fugitive methane, increase methane capture and utilization, and reduce the electricity required for wastewater processing through the implementation of energy conservation measures. Reductions in electricity and fuel usage are based on detailed energy audits conducted by DEP at each of its wastewater treatment plants.

Scenarios to get to 80 x 50

The final scenario projects the impacts from various levels of plausible action across sectors to achieve 80 x 50, testing both moderate and aggressive efforts.
For buildings, the Buildings Energy Model incorporated the results of the deep energy retrofit path analysis

conducted by the TWG and applied the projected EUIs from each retrofit paths across all relevant buildings citywide, making appropriate updates for certain building typologies. The City built the model to be able to vary the rates of adoption for each retrofit path, allowing various rates for paths that include high efficiency electrified space conditioning (heating and cooling), electrified domestic hot water (DHW) production, and re-cladding of the building envelop.

The City also modeled proposed Energy Code updates that achieve between 50 and 70 percent reductions in energy use from current standards for all new and substantially renovated buildings, beginning in 2022. For new construction, the City established energy use intensity values based on ASHRAE 90.1 2013 guidelines and applied to the projected growth in built area. The City also incorporated projected GHG reductions from community energy systems from its community energy map analysis, which included community-scale wind, combined heat and power (CHP), ground source and water source heat pumps (GSHP, WSHP) and heat capture from power plants, substations, and building cooling systems. The City also included the technical potential for on-site and community-scale solar PV, based on the City University of New York's (CUNY) Solar Map, which was modeled as a reduction in electricity use based on multiple rates of adoption of the full technical potential.

For transportation, the City's model assumed four out of five intra-city trips would be made by sustainable modes (walking, biking, and transit) in 2050. This split reflects a reasonable expectation of potential mode shift as a result of increased and sustained investments in low-carbon mode service and infrastructure. An 80 percent sustainable mode split goal is also consistent with similar long-term targets in several of New York's peer cities. Such a reduction includes an approximate 40 percent reduction in person trips that are today made by car, from 33 percent to 20 percent. Of these remaining vehicle trips, almost half are made through taxi trips, shared mobility services, or new forms of on-demand, high-capacity "microtransit" services. Only 12 percent of total trips remain as traditional personal driving trips, a reasonable assumption given emerging mobility trends and a decline in traditional auto-ownership patterns. These vehicle trips were modeled to be much cleaner than today, with higher rates of adoption of low-carbon fuels and vehicles, especially in private fleets. The 80 x 50 scenario modeling assumes approximately 50 percent of new vehicles purchased in 2050 will create zero emissions, such as battery electric, plug-in hybrid, and fuel cell vehicles.

For waste, the GHG reductions from the implementation of Zero Waste by 2030 and net-zero energy at DEP in-city wastewater treatment plants were extended out to 2050.

To develop the final 80 x 50 scenario, the City assumed full implementation of all identified transportation and waste strategies. For buildings, the City tested various adoption rates across the retrofit paths to find the scenario that yielded the greatest GHG reductions with the lowest uptake of strategies that include electrification of heating and hot water systems or recladding of buildings, which ultimately yielded a scenario in which between 50 and 60 percent of buildings pursue these strategies. The City assumed full implementation of a performance-based Energy Code for new and substantially renovated buildings that achieves a 70 percent reduction in energy use from existing standards beginning in 2022. The City assumed uptake of full technical potential for solar PV and a portion of the potential for other community energy solutions. Finally, for the electricity sector, the City used a modified version of the "bookended" low carbon intensity scenario from the Xpand modeling effort, which included slight increase in carbon intensity of the electric grid from the low carbon intensity grid based on the increased adoption of electric vehicles and building electrification than what was included in that scenario.

All together, the modeling efforts across the energy supply, buildings, transportation, and waste demonstrates that achieving 80 x 50 in New York City is possible, but requires aggressive action across all strategies and across all sectors.

Stakeholder engagement

Throughout the process of developing its 80 x 50 roadmap, the City engaged technical advisors and key stakeholders to develop of the assumptions for the GHG analysis, ensure the approach was consistent with modeling underway for parallel local and regional planning, and to develop the potential GHG reduction strategies that were incorporated into the scenario analysis. The City hosted 17 focus group meetings with more than 100 technical and policy experts, including representatives from academia, regional think tanks, national environmental organizations, local environmental justice advocates, utilities, industry leaders, and state agencies and

authorities. These stakeholders helped envision New York City's roadmap 80 x 50 and the transformative actions that will ultimately be necessary to achieve it. They also provided feedback on potential policy options and implementation details that will result in meaningful emissions reductions.

Strategy analysis and benefits of 80 x 50

The City combined the modeling outputs, stakeholder feedback, and an assessment of existing City policies and programs to identify key opportunities and challenges to achieve 80 x 50 that are presented in each sector chapter. The City then developed strategies to amplify the opportunities and begin addressing the challenges. These potential strategies covered a variety of scales, from individuals and buildings to the entire city and the regional power grid, and considered overlaps across the buildings, energy supply, transportation, and waste sectors.

Achieving 80 x 50 presents a unique opportunity for New York City to continue its global leadership on environmental action. At the same time, 80 x 50 serves as a roadmap that provides the city with direction on how to grow a dynamic and inclusive economy to spur innovation, develop globally-recognized industries with the potential for high-paying jobs, and to make the city more resilient against climate change and other 21st century threats.

The City has made equity an explicit guiding principle of its environmental agenda—a lens through which we view all of our planning, policymaking, and governing. As such, the strategies and policy options necessary for 80 x 50 will be further evaluated and prioritized to access cobenefits across all four lenses of *OneNYC* through their ability to promote affordability, health and wellbeing, reliability of utilities and services, adaptation, economic opportunity, diversification, and flexibility of services, and access for all New Yorkers.

Stakeholders and technical advisors at an 80 x 50 focus group meeting

Energy

In 2050...

We envision that New York City's energy supply will have undergone a transformation. New York State will have a prevalent supply of large-scale renewable energy from sources outside of New York City. New transmission lines will connect New York City to those resources and will provide an added level of reliability to our energy system. Natural gas will continue to be an important resource, but will shift to a supporting role in the overall electricity mix by providing fuel diversity and supporting reliability. Distributed energy resources will be prevalent and deliver clean, affordable, and resilient energy to neighborhoods throughout the five boroughs, including to low- and moderate-income communities, which will allow New York City residents and communities to enjoy their benefits. We will have the technologies and market conditions to seamlessly manage demand and supply, from individual buildings to the electric grid, while consumers of energy will play a more informed and active role in how they use, manage, and even generate energy.

Achieving 80 x 50: Energy

The path towards 80 x 50 requires strong partnerships across all levels of government, and it requires working closely with utilities to ensure that our climate mitigation and adaptation goals guide infrastructure investment decisions. Achieving significant greenhouse gas (GHG) emissions reductions for buildings, transportation, and waste is contingent upon a transition towards a renewable energy-based electric grid. Since the City does not directly regulate energy supply, we will need to continue advocating for regulatory changes and infrastructure improvements that will allow renewable sources of energy to flow into the five boroughs. The City can leverage its purchasing power to help support this investment, as the City's municipal operations consume one-tenth of all electricity in New York City.

Within the city, existing power plants must improve efficiencies and reduce emissions in the near term. In the long term, the fleet of in-city power plants will need to transition towards more flexible sources of power that can be quickly ramped up or ramped down to help balance a renewables-based grid that will have more intermittent sources of power from solar and wind. In addition, the infrastructure needed to transmit and distribute electricity across the city will need to integrate technologies that improve efficiency and flexibility.

Distributed energy resources (DERs)—which include customer-owned renewable energy sources, energy efficient technologies and strategies, and energy storage—will need to be aggregated to meet electric demand or the needs of the electricity system as a whole. These resources will need to be scaled up at both the building and community levels, and new regulatory and financial structures will need to evolve to support the deployment of DERs in order to achieve the 80 x 50 vision of a clean, affordable, and resilient energy supply. The adoption of promising new emerging technologies must also be facilitated by pilot projects to demonstrate their performance and cost-effectiveness – a place where the City can play a key role.

Drivers of GHG Emissions

New York City's energy supply is primarily comprised of electricity that comes from the regional grid, which is used to power buildings and our electrified transportation networks; natural gas and petroleum used to power vehicles and provide heating, cooling, and hot water in buildings; and district steam from Con Edison that is also used for heating and cooling in buildings.

Approximately 30 percent of citywide GHG emissions are attributable to the power plants that generate electricity both within and outside of New York City. While most of those plants generate electricity by combusting fossil fuels, a significant portion also comes zero-carbon nuclear generation.

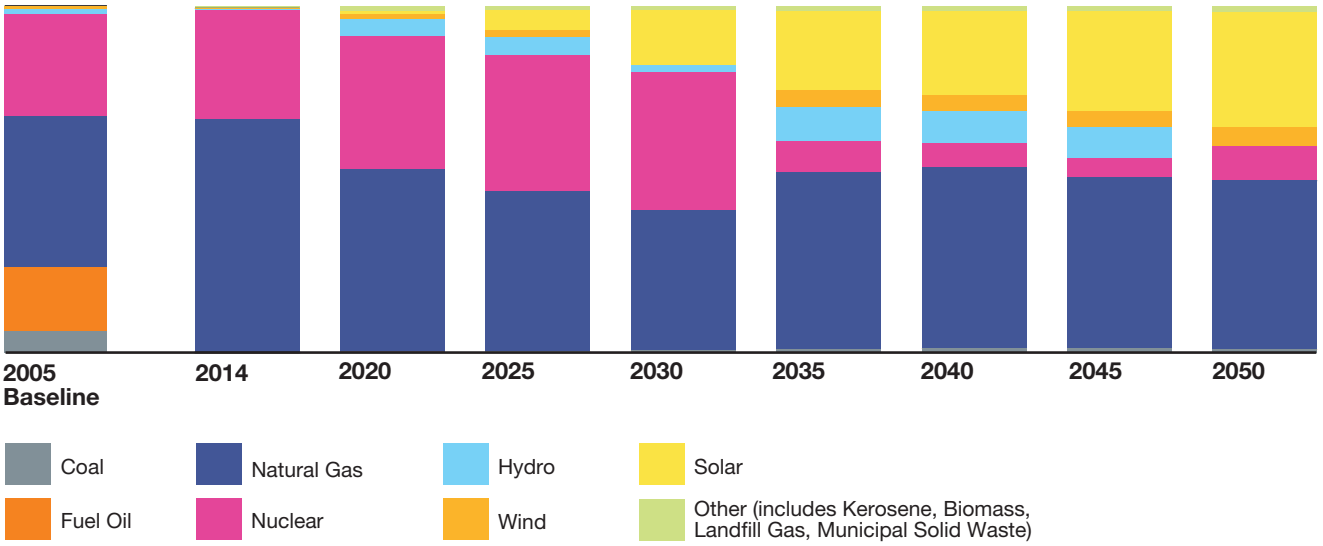
The 24 in-city power plants that directly serve New York City have a combined capacity of approximately 10,000 MW—enough to meet over 80 percent of the city's peak demand, which meets the reliability requirement of the New York State Reliability Council (NYSRC). On an annual basis, generation from these power plants provides approximately 50 percent of the electricity consumed in New York City. A majority of the balance originates from less expensive and cleaner sources elsewhere in New York State and surrounding regions.

Energy is imported into New York City from a regional system of high-voltage transmission lines. These amount to little more than a handful of lines that connect the city with approximately 6,000 MW of electricity supply from areas as close as the Hudson Valley and northern New Jersey, northern and western New York State, Pennsylvania, and New England. Each of these regions has a different fuel supply mix. In 2014, power transmitted into the city consisted primarily of natural gas (67%) and nuclear (31%), with less than 2 percent coming from landfill gas, hydropower, coal, wind, solar, and other fuel sources.

DERs are a small but growing source of energy for New York City. These include distributed generation (DG) technologies that provide energy to customers at the community scale or even the building scale, as opposed to the traditional model in which utilities centrally procure and distribute energy to customers. DG can include customer-owned renewable energy sources as well as fuel cells and combined heat and power (CHP) systems. CHP systems co-generate electricity and useful heat locally, which allows for greater efficiencies than a typical power plant. Depending on system size, the electric and thermal energy can be distributed to one or more buildings. To date, there is more than 300 MW of DG installed citywide. In addition, DERs such as energy efficiency and energy storage—spurred in part by local policies such as the City's Greener, Greater Buildings Plan (GGBP)—have contributed to a reduction in energy consumption in buildings since 2005.

Electricity was the city's largest source of GHG emissions prior to 2013, but has since been supplanted by petro-

Business as Usual Electric Grid Fuel Mix



leum, largely used for on-road transportation, which generates 34 percent of the city's GHG emissions. Natural gas burned on-site to provide heating and hot water in buildings generates 31 percent. GHG emissions from the city's electricity supply have decreased by roughly 40 percent since 2005, which is largely the result of conversion away from coal and oil in power plants towards cleaner-burning natural gas as well as the retirement of older, less efficient power plants. Operational improvements on the part of Consolidated Edison (Con Edison), the investor-owned electric utility that serves the majority of New York City residents and businesses, have further contributed to these reductions. At the same time, natural gas usage has been growing due to a combination of low natural gas prices and regulations enacted by the City in 2011 phasing out the use of No. 6 and No. 4 heavy heating oils by 2015 and 2030, respectively.

While natural gas burns cleaner than other fossil fuels such as oil or coal and has been the major driver of emissions reductions achieved since 2005, New York City will not meet its 80 x 50 commitment if we continue to consume natural gas at today's rate. In addition, with natural gas as the predominant fuel source for the city's power plants and for building heating and hot water, there is a need for the City to explore greater diversification of supply sources to enhance reliability and increase resiliency to potential supply interruptions.

Con Edison's district steam system is one of the largest district-scale heating and cooling network in the United States. District heating and cooling networks consist of pipes in the ground connected to an energy source that can provide heating and cooling to more than one building. The system has served New York City's buildings for over 130 years, and continues to serve close to 1,700 customers in Manhattan, including some of the city's most iconic skyscrapers. The district steam system contributes 2 percent of citywide GHG emissions and has been getting cleaner over time. District steam has experienced a 33 percent decrease in carbon intensity between 2005 and 2014, largely as a result of the transition to an increasing use of CHP units that generate electricity and steam in a single integrated system.

Business as usual findings

To understand what it will take to achieve 80 x 50, the City modeled projected GHG reductions under a business as usual (BAU) scenario for each sector through 2050. The BAU analysis for energy supply examines multiple potential trajectories for the New York City electric grid through 2050. The analysis takes into account expected changes in electric demand associated with population growth and economic development, as well as potential adoption of DERs. It also incorporates the expected impacts of existing state and federal policies and regulations by modeling electricity-related

Energy Policy in New York State

Reforming the Energy Vision

The New York State Public Service Commission (PSC), which regulates utility companies, initiated Reforming the Energy Vision (REV) in April 2014 to transform the State's electric distribution systems. Specifically, REV seeks to advance energy policies and markets to speed the adoption of energy efficiency and clean, locally produced power, as well as to modernize aging infrastructure and enhance the security and resiliency of the grid. This includes promoting smart grid technology and markets that enable greater efficiency and demand flexibility. Additionally, regulatory changes are expected to give customers new opportunities for energy savings as well as local power generation and enhanced reliability. These will result in safe, clean, and affordable electric service, empowering New Yorkers to make informed energy choices, creating new jobs, and reducing GHG emissions.

The City is supporting the REV objectives and is advocating for social, environmental, and physical considerations that are unique to the city to be integrated into the regulatory process. This includes the promotion of DER deployment to benefit all New York City communities.

Clean Energy Standard

The Clean Energy Standard (CES), adopted by the PSC in August 2016, was developed to lower GHG emissions and reduce air pollution from the state's energy generation resources and ensure a reliable and diverse energy supply. The CES is an enforceable mandate that will require 50 percent of New York's electricity to come from renewable energy sources by 2030.

Under the CES, utilities and other energy suppliers will be required to obtain Renewable Energy Credits through procurements of new renewable energy resources. The CES also includes directives regarding energy efficiency and additional renewable energy sources beyond land-based wind and solar. These include the evaluation of low-carbon heat sources such as geothermal heat pumps, a blueprint to advance offshore wind to be developed by the New York State Energy Research & Development Agency, and a commitment by the PSC to work with New York Independent System Operator and other stakeholders to ensure necessary investments are made in transmission, storage, and smart grid technologies to ensure the reliability of the grid. The CES also seeks to maintain zero-carbon nuclear power resources in the state by requiring investor-owned utilities to purchase Zero-Emission Credits.

renewable energy policies, including New York State's Clean Energy Standard (CES), the Regional Greenhouse Gas Initiative (RGGI), and the federal Clean Power Plan (CPP), as well as expected trends for electricity demand, natural gas prices, and renewable energy costs. The City sought expert opinions to assess the expected outcomes of policies that were in development at the time of analysis, such as the State's Clean Energy Standard (CES).

From this analysis, the City found that under the most likely scenario (the "BAU grid"), the carbon intensity of the city's electric supply—or the amount of GHG emissions per unit of energy—is projected to become 50-60 percent cleaner by 2030 relative to 2005 levels. The results of the analysis are driven by an increasing proportion of electricity from utility-scale solar photovoltaic (PV) systems and land-based wind turbines in the grid mix, consistent with the CES requirement to meet 50 percent of New York State's electricity with renewable energy sources by 2030 (see box above). Additionally, power plants within New York City are expected to continue to transition towards natural gas-fired combustion turbines, while older, less efficient power plants are expected to retire.

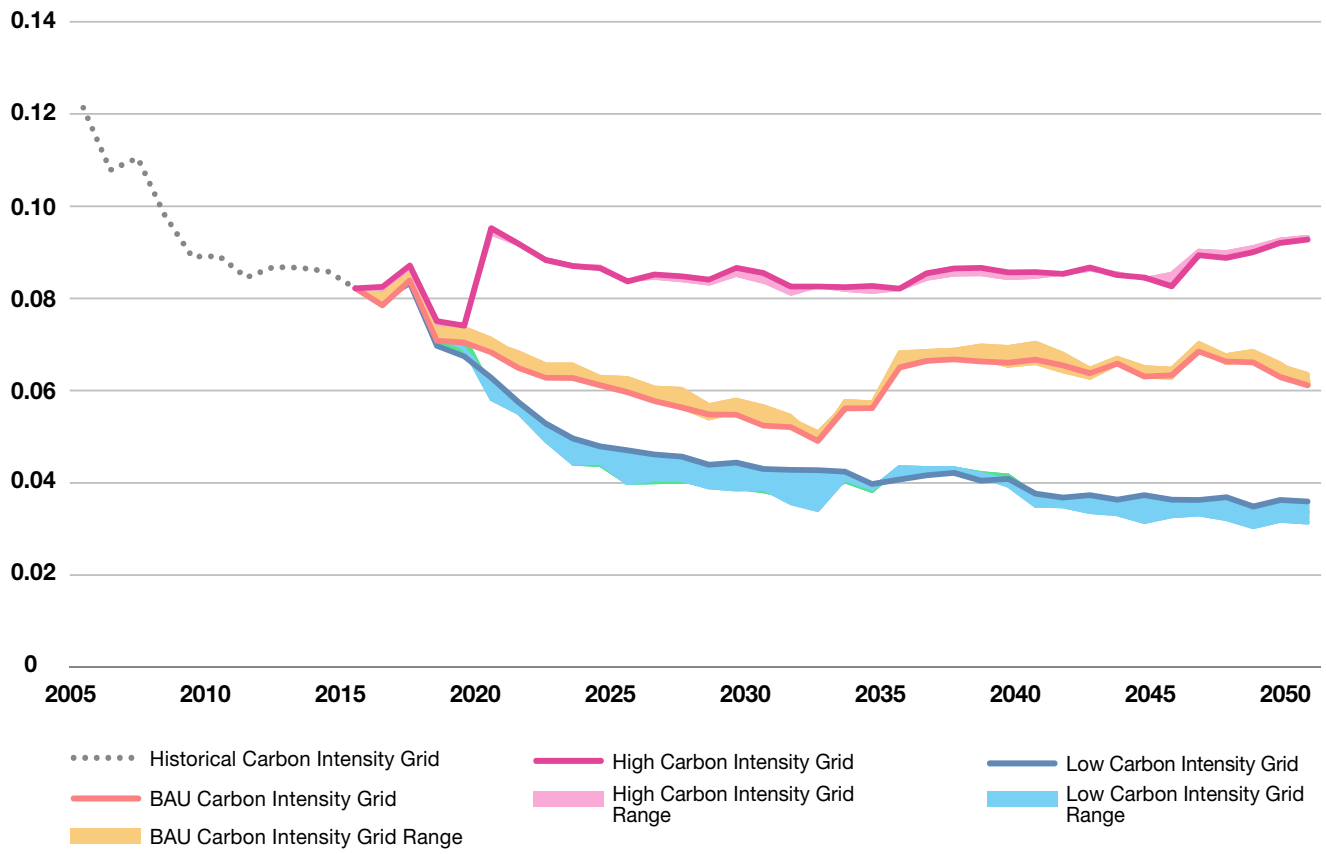
The carbon intensity of the grid is anticipated to begin to rise between 2030 and 2035 as existing nuclear power plants start to retire. Nuclear plants currently generate 31 percent of the city's electricity. When they retire, large-scale renewables such as wind and solar are expected to fill some but not all of the electricity gap. The remainder is projected to be met with natural gas capacity, which will lead to an increase in GHG emissions relative to zero-emission nuclear generation. As a result, the city's electricity supply is projected to be 50 percent less carbon intensive in 2050 relative to 2005 levels, and 23 percent less carbon intensive than today.

Generators will continue to exist within New York City to meet the NYSRC regulatory reliability requirement for sufficient in-city generation capacity, with the least efficient units replaced by fast-ramping combustion turbines by 2030. While in-city generators are expected to provide 40-50 percent of the city's electricity in the near term, in-city generators are projected to run for fewer hours each year as a greater proportion of electricity is delivered from outside New York City. Modeling results show they may provide less than 30 percent in 2050, facilitated by the addition of transmission across the state and into the city.

Given the level of uncertainty about how fuel prices and the capital costs of renewable energy generation will change over time, the City also modeled two "bookend" scenarios that reflect a "high carbon intensity grid" and a "low carbon intensity grid." The high carbon intensity (HCI) grid assumes natural gas prices will remain low and renewable energy costs stay comparatively high. The low carbon intensity (LCI) grid assumes the opposite, with gas prices rising and renewable generation costs falling, along with augmented transmission capacity throughout the state to facilitate the flow of renewable energy into the city. The City's modeling revealed that the carbon intensity of the low carbon intensity grid is expected to be more than 70 percent lower in 2050 than in 2005, with an estimated 70-75 percent renewables in the grid mix, while the high carbon intensity grid is expected to be roughly 25 percent lower, with roughly 50 percent renewables in the grid mix—the minimum needed for CES compliance.

Based on the BAU analysis, the main external drivers of the electric grid's carbon intensity are fuel prices, capital costs of renewables, and state environmental policies. The City also investigated how New York City electricity demand affects the electricity supply. The City developed one scenario in which New York City's annual electricity use and peak demand each increase by roughly 10 percent due to widespread electrification of certain building systems and electric vehicle adoption. The City devel-

Modeled Future Carbon Intensity of Electric Grid and Ranges based on Changes to NYC Electric Demand
(tCO_2e/MMBtu)



oped an alternate scenario in which annual electricity use and peak demand each decrease by 30-35 percent, due to the adoption of energy efficiency in buildings and community-scale DERs. When these scenarios were modeled on the BAU grid, low carbon intensity grid, and high carbon intensity grid, there was little change in the overall grid carbon intensity in any scenario.

Changes in New York City demand could have an impact on the amount of generation that would be constructed, but the analysis found that overall fuel mix and carbon intensity would not be influenced. In this analysis, increases in New York City demand were largely met by cleaner and less costly sources imported from outside of the city. This means that an increase in the number of electric vehicles and electrification of certain building systems could be effective means of reducing New York City's GHG emissions without generating significant unintended consequences for the carbon intensity of the electric grid.

Emerging Trends

The pace of innovation in sustainable energy has been accelerating. Advances in technologies including solar PV, energy storage, anaerobic digestion, and electric grid operations are allowing clean energy technologies to become more efficient, flexible, and cost-competitive with traditional sources of energy. These advancements, along with market growth and environmental policies, are resulting in lower costs and accordingly increasing demand for clean energy technologies.

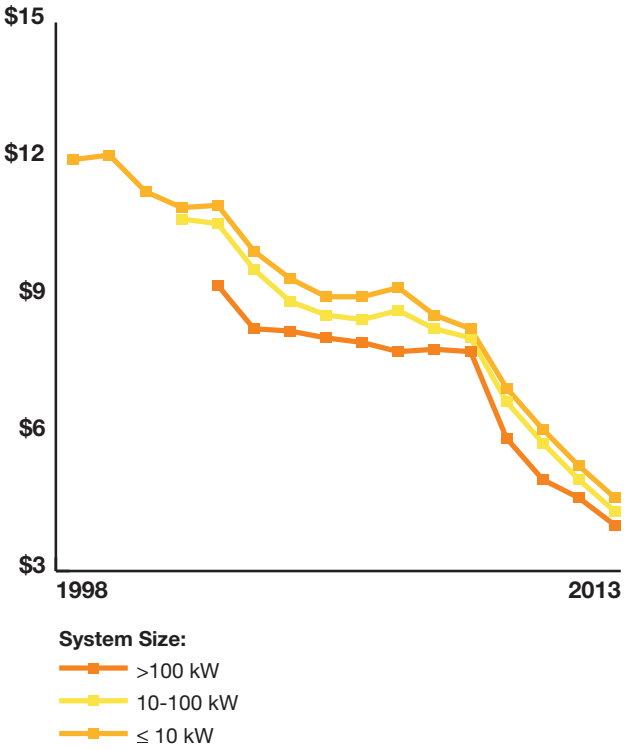
Solar PV. Renewable energy sources are becoming increasingly economically competitive with natural gas generation. The costs of solar PV have decreased dramatically, dropping more than 50 percent between 2002 and 2013, and are expected to continue their decline. According to the National Renewable Energy Laboratory (NREL), the capital cost of utility-scale solar is projected to decrease more than 40 percent between 2016 and 2030.[1]

Solar adoption is growing as a result of falling prices, as well as supportive policies like the federal investment tax credit and new financing mechanisms including solar loans and leases. In 2015, New York State installed 242 MW of solar electric capacity, a 65 percent increase over the previous year. While there are still financial and regulatory hurdles to solar adoption in New York City, there is currently 78 MW of installed solar in the city (private and public sector combined) and another 17 MW in the pipeline, compared to a total of 2 MW of installed solar in the city just ten years ago.

Various procurement and financing programs are helping to spur this growth. These include solar group purchasing programs, which pool demand to lower the cost of solar installations, and community shared solar policies, which allow multiple customers to purchase or subscribe to a portion of a common solar installation. With the enactment of community shared distributed generation (DG) in New York State just last year, multiple customers are now able to subscribe to shares of output from a common solar array, even if they live in another part of the city. This change has opened up the solar market to renters who until now have not been able to access the benefits of local solar energy.

Solar hardware is also rapidly evolving and reshaping the cityscape. The use of solar canopies in the city is rising and has the potential to grow. While space for solar PV installations has historically been limited to portions of rooftops due to competing infrastructure and fire safety requirements, solar canopies can help overcome this limitation by elevating solar panels nine or more feet above building rooftops. As a result, solar canopies have the

Historical Prices of Solar PV Systems
(2014 US$/W)



Solar canopy in Brooklyn
Photo credit: Situ Studio

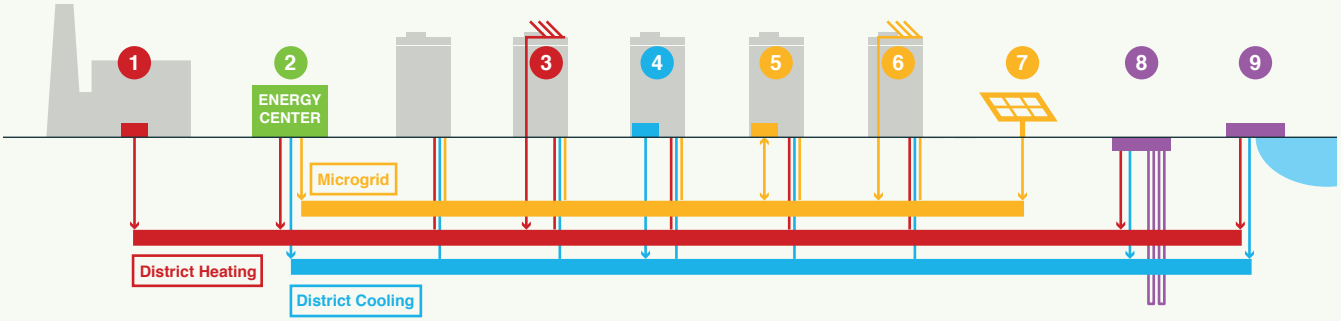
potential to enable two to three times as much solar PV capacity on a given roof relative to conventional designs.

Energy storage. Significant technological advancements have also occurred in the field of energy storage. Energy storage, through the use of technologies such as batteries, allows excess energy to be produced at one point in time and stored for later use. This helps overcome the problem of intermittency, which is common with renewable energy sources such as solar PV, in which energy cannot be produced at constant output due to the availability of natural resources such as sunlight or wind. Consequently, renewable energy production cannot always be matched to energy demand. Improvements to energy storage technologies such as lithium-ion and vanadium flux redox batteries are allowing for greater amounts of storage to be deployed at lower costs, which can allow for greater deployment of renewable energy sources.

Energy storage is another option to provide flexibility to balance energy demands and electric generation from the power grid. Energy storage has the potential to make both on-site and utility-scale renewable energy generation more useful, support microgrids, reduce peak demand, or shift demand to provide grid reliability and reduce electricity costs. At the utility scale, energy storage can provide flexibility to grid operators in managing the generation variability from intermittent renewable energy resources, which will become increasingly critical as New York City's electricity supply becomes more reliant on renewables.

One type of energy storage comes in the form of thermal energy storage (TES), which refers to technologies that make it possible to store heat or chilled water for use at a later time. For instance, a residential building with solar thermal collectors and TES can generate hot water over the course of the day and store it for use when residential heating demands are highest at night. Another example, sometimes referred to as "ice storage," is a cooling system used to generate and store chilled water mixed with glycol in tanks during off-peak hours, usually at night, when electricity is less expensive. TES can assist the transition to a renewables-based grid by balancing thermal energy demands between peak and off-peak hours, or even from season to season.

Community energy. Technological advancements have also improved the outlook for community-scale energy solutions, including microgrids and district heating and



Community Energy Solutions

Microgrid

Microgrid

A microgrid is an electrical distribution network that is connected to two or more buildings in a local area. With the appropriate controls and design, microgrids can enter into 'island mode' and provide power when there is a grid outage.

District Heating and Cooling

District Heating

District Cooling

District heating and cooling systems, also referred to jointly as "district energy," produce steam, hot water, or chilled water that is piped underground to multiple buildings. They can provide environmental, operational, and financial benefits by leveraging economies of scale.

Energy Sources

Heat Capture

1

Heat capture refers to a suite of technologies that recover waste heat from commercial and industrial activities. Heat rejected from building cooling systems can also be captured and utilized for space heating.

Combined Heat and Power (CHP)

2

Combined heat and power, also known as cogeneration, is the simultaneous production of two or more useful forms of energy from a single device. A CHP system will take fuel, most commonly natural gas, to generate electricity and heat. Combined cooling, heat and power also includes the production of cooling.

Solar Thermal

3

Solar thermal systems utilize solar energy to generate hot water that can be used for domestic hot water and/or space heating in buildings. It is often paired with thermal energy storage.

Energy Storage

4 5

Energy storage technologies save generated energy and use it when demand is high. Energy storage includes electric systems such as batteries as well as thermal systems such as hot and cold water storage tanks. Energy storage can operate critical systems during outages.

Distributed Generation

2 6 7

Distributed generation technologies allow customers to generate electricity onsite through solar photovoltaic (PV) systems, combined heat and power (CHP), and other technologies.

Community Shared Solar

7

Community shared solar installations allow multiple customers to subscribe to shares of output from a solar PV array. The array can be connected to a microgrid or it can be located in another part of the city.

Geothermal Heat Pumps

8

Geothermal heat pumps use onsite energy from underground temperature differentials to heat and cool buildings with rewarding reductions in energy use. They are also known as ground source heat pumps.

Water Source Heat Pumps

9

Water source heat pumps extract or reject heat from large water bodies to heat and cool buildings. This term is also used for heat capture systems that utilize water loops within buildings and districts (see heat capture).

cooling networks. Microgrids are small-scale electric grids that connect more than one building to a power source and can integrate DERs—including renewables, fuel cells, and CHP units. When combined with energy storage and demand management strategies to reduce peak demand (see Buildings chapter), microgrids produce clean electricity that also improve the reliability of energy services for customers. Following the devastation of Hurricane Sandy, the City and State have supported the evaluation and installation of new microgrids in the city that can function independently from the central electric grid and can support critical loads in the event of a power outage. District heating and cooling networks provide similar benefits for buildings that are connected to a shared source of heating and cooling.

Prices have fallen for many DERs that can be deployed as part of a microgrid or a district heating and cooling network. The current low cost of natural gas in particular creates favorable economics for CHP deployment. Natural gas-fired CHP installations have increased over the last decade, with more than 230 MW of distributed CHP generation now installed in New York City. Based on the carbon intensity of today's grid, CHP units reduce GHG emissions relative to electricity from the grid due to their effective usage of waste heat. They can also serve as a reliable and cost-effective anchor for district heating and cooling networks (refer to box at left) and could be used to establish a platform for clean localized energy solutions in the future that integrate more renewable energy sources.

However, as the electric grid continues to become cleaner, the GHG emissions associated with natural gas-fired CHP will eventually reach a "breakeven" point at which the electricity generated by CHP is no longer less carbon intensive than the grid. Globally, there are examples of CHP installations that incorporate renewable fuel sources, such as biomass and synthetic natural gas. Biomass is a fuel created from organic matter, such as food waste and construction and demolition (C&D) waste. The City has a long tradition of using biomass at its wastewater treatment plants by harnessing methane gas produced during the treatment process and using it to produce electricity and heat for use on-site. However, transitioning from natural gas to biomass throughout New York City would require a major new supply chain in the region. Anaerobic digestion is one option for expanding this supply, which has the potential to play an increasingly prominent role in helping to divert the landfilling of organic waste while also creating a low carbon source of energy (see Waste chapter).

Smart grids. Utilities are adapting to increased installations of DERs, but these resources create new technical and economic challenges. Utilities must rethink their business models and introduce a new set of technologies to enable the transition to an electric grid with greater penetration of DERs, including smart grid technologies. Smart grid technologies use communications, remote control, and automation software to enhance reliability and energy efficiency of the electric grid and to integrate a growing proportion of DERs. Smart grid technologies include smart meters, controls, computers, and equipment that enable utilities to quickly scale up or scale back power output to address real-time swings in electric supply and demand.[2] By providing two-way communication between the utility and its customers, this also allows customers to reduce energy use when it is most beneficial, such as during times of peak energy demand when prices are highest. The emergence of smart grid technologies helps grid operators to better match supply with demand and manage power quality, resulting in a more flexible, efficient, and reliable grid.

Another key to integrating renewable energy into the electric grid will be enhancing the flexibility of existing generators to meet changes in electric demand. Many fossil-fuel based generators have a minimum generation level and are unable to increase or decrease output quickly enough to match potentially rapid shifts in renewable generation. Fast-ramping natural gas generators, such as combustion turbines, are designed to start and stop quickly. Improving the efficiency of these generators and linking them with dispatchable renewable energy, energy storage, and smart grid technologies is a key component of a more flexible grid that can incorporate large-scale renewable energy sources and DERs.

80 x 50 Roadmap: Energy

Achieving 80 x 50 will require aggressive action on all fronts. Based on the City's analysis, the New York State electric generation mix will need to move beyond the BAU grid to become 70 to 80 percent renewable. This will include significant volumes of offshore wind, expansive land-side solar and wind installations, hydropower, and new transmission that will allow access to these renewable energy sources from outside the city. This is in line with the City's low carbon intensity grid scenario, and is increasingly feasible as renewable energy sources become more economically viable and as a

Understanding and Prioritizing the Potential of Community Energy

New York City cannot reach 80 x 50 without community energy solutions. Deploying electricity and heating resources at a community scale also creates opportunities to advance growth, equity, sustainability, and resiliency. Specifically, the deployment of energy resources can create local jobs and strengthen local businesses, potentially reduce energy costs, contribute to cleaner air quality and reduced greenhouse gas emissions, and help communities and buildings keep the lights on during a power outage.

The City conducted a geospatial analysis to inform priority areas where the City can support the deployment of community energy resources. The study identified the feasibility of implementing a range of technologies to meet demand and reduce greenhouse gas emissions at the community scale, including combined heat and power (CHP), ground source heat pumps, water source heat pumps, combined cooling, heating and power (CCHP), wind, solar, and heat recovery.

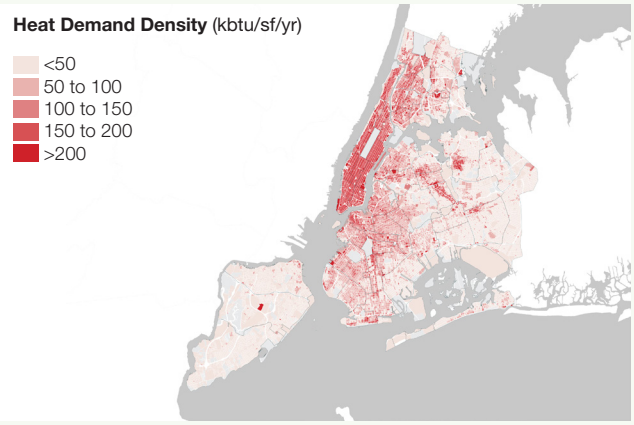
These technologies deliver power, heating and cooling to buildings through district heating and cooling networks and microgrids (Refer to Community Energy Solutions call out box). District heating and cooling networks consist of pipes in the ground connected to energy sources that can provide heating and cooling needs to more than one building. A microgrid connects more than one building to one or more power sources. With the appropriate controls and design, buildings connected to the microgrid can maintain power even when isolated from the utility grid. These platforms for energy delivery can reduce greenhouse gas emissions by taking advantage of renewable sources locally and avoid energy that is lost in the delivery of energy from large-scale centralized systems. The community energy analysis evaluated the technical potential of each technology and their potential to reduce greenhouse gas emissions.

To better understand which locations in the city would most benefit from these installations beyond greenhouse gas emission reductions, the City overlaid several other parameters to this analysis, including climate risks and environmental and economic factors at the community district level. This work is ongoing and additional data will be integrated into the analysis going forward.

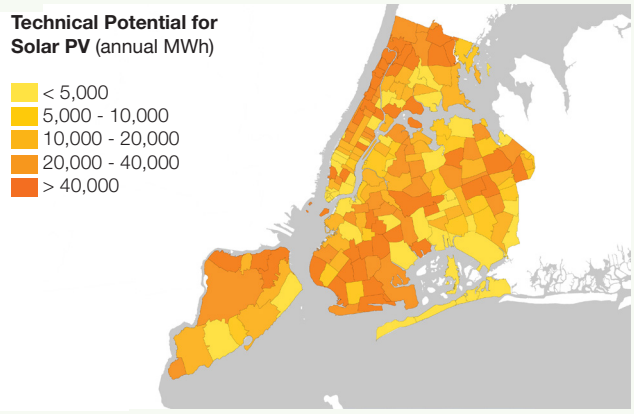
Distributed energy resources can achieve goals that both mitigate emissions and advance objectives across growth, equity, sustainability and resiliency.

Approach and Sample Outputs

As a first step, the City mapped current demands for heating, cooling, and power across the city in order to match up potential new supply with existing needs to identify opportunities for district heating and cooling systems that could capture economies and efficiencies of scale. This map shows heating demand at the block level across the City. The demand for heating, cooling, and power is greatest in areas of the city with a high density of buildings, which includes much of the Bronx, Brooklyn, and Manhattan. While building density provides assurance that there is sufficient energy and heating and cooling demand for a local district system (e.g., as described above and please also refer to Community Energy Solutions call out box), it leaves limited space for the installation of some distributed energy resources.

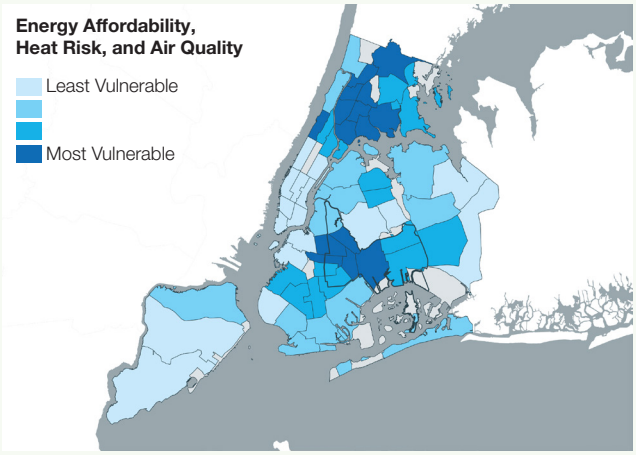


Once heating, cooling and power demand was examined, the analysis assessed the energy supply potential of different distributed heating, cooling and power technologies, including solar PV, solar thermal, wind, combined heat and power systems, combined cooling, heating and power systems, and heat pumps (water source and ground source) at the block level. Technologies were prioritized based on their emissions reduction potential. The map above focuses on one type of technology—solar PV—and shows that there is clear potential for solar PV across the five boroughs.



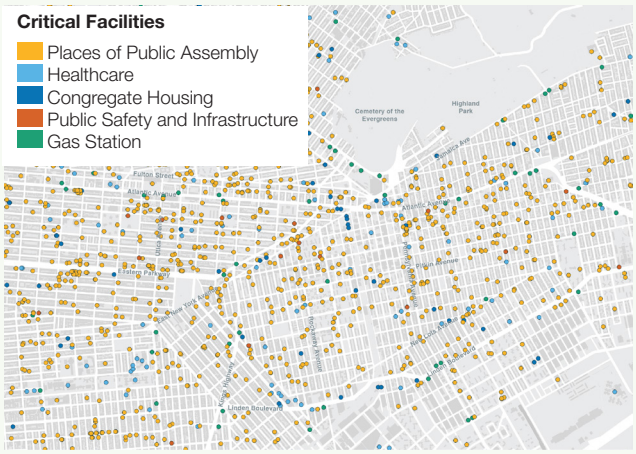
Data source: City University of New York - New York Solar Map

In addition to assessing the technical supply potential, understanding which communities are most vulnerable to climate risks and high energy costs helps inform where the



deployment of community energy solutions can provide the broadest set of co-benefits in terms of equitable economic development, sustainability and resiliency. This map above shows the results—at a community district level—of a composite risk index made up of three different factors that community energy projects may help address: energy affordability, air quality, and heat risk. The City is also examining individual risk indicators and how they overlap with each other.[3] These analyses are ongoing and will help inform where the City will prioritize its facilitation efforts for community energy projects, including bringing together community non-profits, project developers, financing and funding entities and state and federal partners. This map shows that the east Bronx and central Brooklyn are priority areas for community energy.

The map above identifies potential critical facilities ranging



from City-owned assets such as firehouses, police stations and schools, to community-based critical facilities such as cooling centers and shelters. Churches and community centers can also serve as community-defined critical facilities, by providing important services to vulnerable populations during an outage and/or serving as a designated place to shelter during an extreme weather or evacuation event. Community energy projects should seek to include alternate or backup power at these types of facilities if feasible. This map zooms in on neighborhoods in Central Brooklyn which host a variety of different potential critical facilities that could be candidates for inclusion in a potential community energy project.

Relevant Projects

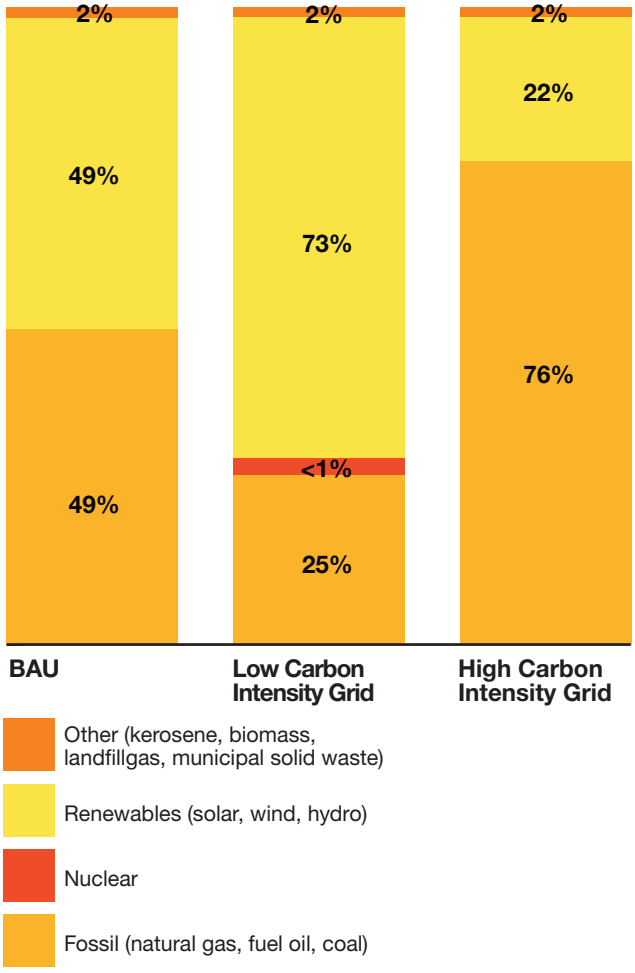
Developing a district heating system and microgrid for the NYCHA Red Hook East Houses and Red Hook West Houses. To meet heating needs and provide energy resiliency benefits to over 6,250 residents, many of whom are elderly, disabled, or children, across 28 buildings and 2,873 apartments, NYCHA issued an RFP in June 2016 for the development of a district heating system and resilient microgrid for its Red Hook Houses. The eight existing steam plants, which provide heat to these residents, were severely damaged by flooding from Sandy, and the buildings are currently receiving heat and hot water from temporary boilers. NYCHA hopes to enter contract negotiations by end of 2016.

Piloting an energy resiliency project for the Hunts Point in Southeast Bronx. Home to a strong residential community and a major industrial job hub for food distribution, Hunts Point is vulnerable to infrastructure outages and flooding. The Hunts Point Resiliency Project will result in the implementation of an energy pilot project that will enhance the resiliency of the area and decrease its vulnerability to extended power outages. Guided by an extensive stakeholder engagement process that includes over 45 local community organizations, businesses, residents, and elected officials, the project aims to build resiliency, strengthen the community, and provide workforce opportunities in the peninsula.

result of both policy decisions and technological innovation. Deploying these resources for New York City's grid will also require adequate transmission capacity to the city.

Reducing demand on the electric grid by maximizing energy efficiency in buildings, scaling up distributed solar PV, and installing energy storage would increase the ability to meet energy demand with renewable energy sources. At the same time, we must also shift away from fossil fuels for heating, cooling, and hot water production in buildings. When combined with efficiency improvements, transitioning these systems to high efficiency electric technologies, such as air source or ground source heat pumps, could achieve significant GHG reductions by tapping into a clean future electric grid (see Buildings chapter). Similarly, transitioning to electric vehicles will contribute further GHG reductions by reducing the use of petroleum in on-road vehicles (see Transportation chapter).

2050 Electric Grid Fuel Mix by Scenario



The City can also deploy low-carbon district heating and cooling networks at strategic locations to reduce energy consumption and provide resiliency benefits by capturing wasted heat from power plants, substations, and building cooling systems and installing district-scale ground source and water source heat pumps.

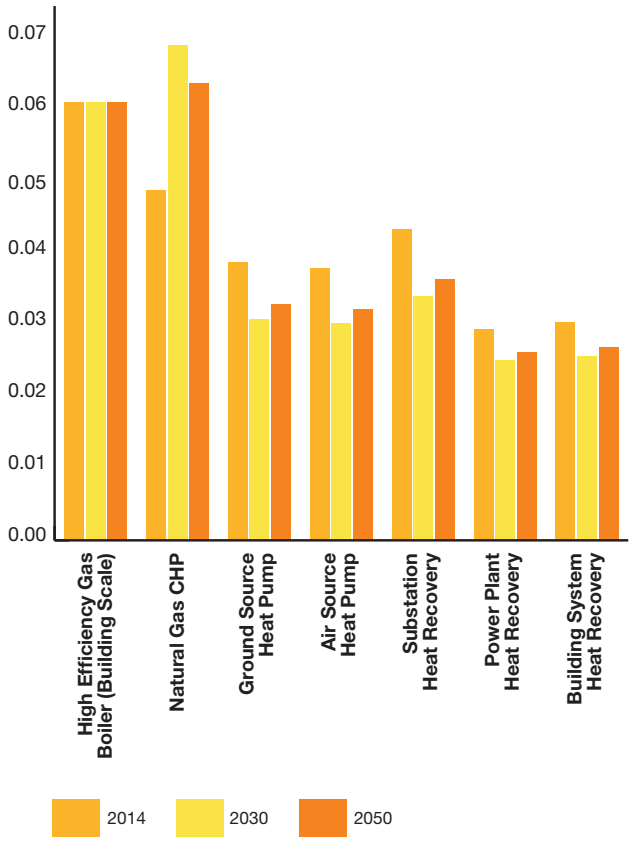
To better understand the opportunities for supplying local energy sources, the City is developing a Community Energy Map to analyze the technical potential of a range of distributed energy resources throughout all five boroughs of the city, block by block. The Community Energy Map will consider the current demands for heating, cooling, and power across different building typologies, the physical characteristics of each block, the technical potential for several technology types, and the business case for these technologies. The analysis will further prioritize opportunities based on their potential for GHG reductions and several geographically-based indicators of social vulnerability.

The analysis found that CHP is a promising technology for community energy today because its beneficial use of waste heat from electricity generation makes it economical and reduces GHG emissions relative to the current electric grid. However, when paired with the City's low carbon intensity grid scenario, natural gas-fired CHP will cease to provide a GHG reduction benefit. Still, CHP is an important part of the 80 x 50 roadmap because it can be the primary source of heat for district heating networks in the near term. In the long run, natural gas CHP could transition to renewable fuel sources or be phased out in favor of low-carbon heat sources such as biogas to reduce GHG emissions. This strategy allows CHP to play an important role in establishing district heating and cooling networks in New York City that will ultimately be necessary to achieve 80 x 50.

Challenges to address

While the adoption of DERs bears promise for the City's GHG reduction, air quality, and resiliency goals, high levels of DER adoption are hampered by regulatory, technical, and financial challenges. DERs are subject to various permitting and interconnection requirements that can add time and expense to project planning. Once completed, the value proposition for several types of DERs

Carbon Intensity of District Heating Sources
(tCO_2e/MMBtu)



depends on factors such as the compensation received from utilities for energy that is not consumed on-site, but is rather exported to the grid (currently governed by a "net metering" tariff that allows on-site energy production to offset energy consumption) and the cost of maintaining utility service as a backup to the DER when it is out of service (known as a "standby tariff"). With State-level regulatory activities taking these tariffs under review as part of REV, there is an opportunity for the City and others to advocate for the more holistic valuation of the benefits DERs provide to the grid, the environment, and society. Failure to adjust these tariffs to recognize the full value they provide will continue to hinder significant DER uptake.

Given the above hurdles to DER adoption in addition to space constraints, the City will need to look beyond its own borders for the provision of large-scale renewables. While the high density of New York City's built environment is conducive to public transit and provides opportunities for community energy solutions, it also means that the city has little available land for large-scale renewables. With the exception of the Bronx, New York City is a city of islands, meaning that there are a limited number of transmission lines that connect the city to the regional electric grid, which has greater access to land and natural resources for large-scale renewables. Much like other infrastructure investments, adding new transmission capacity will require major capital investments and years to develop. Still, the City can engage the State and the New York Independent System Operator (NYISO) regarding the need for transmission investments to bring economic renewables from upstate into New York City.

Policies that are set at the state, regional, and federal level are the main drivers of future GHG reductions from the electric grid. Statewide policies are helping to increase the role of renewable energy in the grid mix, but additional regulatory changes are necessary to support market conditions for existing power plants to transition to cleaner, more flexible technologies that support a renewables-based grid. The lack of direct City control over its electricity supply makes it more critical for the City to leverage its purchasing power where possible to invest in renewable energy resources.

State and regional entities have also helped to address economic challenges to low-carbon electricity generation through RGGI, which is an interstate emissions trading scheme among northeastern states that places a cost on GHG emissions from power plants. Putting a price on carbon allows market forces to drive down demand for high-carbon fossil fuels and make renewable energy more economically competitive, although current prices still do not reflect the true cost to society from the environmental and public health impacts associated with GHG emissions and emissions of criteria pollutants, including particulate matter, ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead, and as a result, have not had a significant impact on the market. Moreover, our modeling indicates that more electricity will be imported from outside the RGGI-participating states by 2050. Accordingly, the City must advocate for state, regional, and federal policies that better reflect the social costs of energy production to ensure future supplies come from clean and renewable sources.

The price of natural gas can also partly determine the feasibility of a sufficiently renewables-based grid to achieve 80 x 50. Natural gas prices have been relatively low in recent years due to an increase in supply ex-

plained in part by the widescale use of hydraulic fracturing, or "fracking," to extract natural gas from shale formations. Fracking is a controversial method of natural gas extraction, with opponents pointing to adverse effects on local water quality among other impacts. The transition from oil and coal to natural gas, which burns cleaner than other fossil fuels, has contributed to lower GHG emissions to date in power plants. However, sustained low natural gas prices could increase our reliance on gas and delay the uptake of large-scale renewables.

The transition to a renewables-based grid will also heighten challenges of intermittency. In order to provide reliable service, the grid will need to become increasingly flexible, incorporating energy from centralized or decentralized plants that can ramp up and down quickly. This will need to be combined with utility-scale storage to respond to the daily fluctuations of solar and wind generation. Making this transition will require technological solutions as well as price signals that provide incentives for supply balancing resources and load management.

Simultaneously, as building systems and vehicles shift from heating fuels and petroleum to efficient, electric-based technologies, increased electricity demand may affect grid performance and resiliency as we become more dependent on the grid to support more of our daily activities. An increased dependence on reliable electricity, coupled with increasingly intermittent supply to the electric grid, make it imperative that decisive steps are taken to develop the necessary market and regulatory environment to enable emerging grid management technologies to flourish.

Near-term actions to reduce GHG emissions

Increase direct and indirect investments in large-scale renewable energy and energy storage

New large-scale renewable energy systems are one of the most critical investments for achieving 80 x 50. The CES will build upon existing renewables in the state, realizing more of the potential for on-land wind turbines and large-scale solar farms upstate. New York City's ambitious 80 x 50 goal will require going beyond full implementation of the CES. This includes fostering a new regional market for offshore wind, similar to those along European coastlines.

To help catalyze the market for large-scale renewable energy, in July of 2015, the City issued a Request for Information to identify projects that would meet 100 percent of City government electricity needs from new renewable energy while maintaining reliability and affordability. After responses were received in September 2015, and no single project met all of the requirements. The City has met with various respondents and other stakeholders, including project developers, regulatory agencies, utilities, and environmental advocates, to explore options in greater detail and to identify opportunities to further spur private-sector investment.

From these collaborations, the City has identified several near-term opportunities and continues to work with a broad base of stakeholders to accelerate and ensure longer-term opportunities have the greatest potential to be realized. The City is engaged in discussions with offshore wind developers on ways the City could facilitate the development of this resource around the metro area. This will signal the City's interest in offshore wind, help attract components of the supply chain to the local area and boost economic activity, and provide valuable lessons for larger offshore wind farms off of New York City that are further out on the horizon.

In addition, the City has been speaking with a number of developers who are looking to bring larger volumes of renewable energy from outside of New York City into the local system via high voltage direct current (HVDC) transmission lines. These types of projects have the ability to tap into numerous renewable energy technologies, including solar, land-based wind, and hydroelectric power, in locations that are more suitable to their development and transmit the energy long distances, often underground, with less energy lost along the way.

Along with GHG emission reductions, future offshore wind farms along with underground HVDC lines that connect directly into the local grid afford New York City an increased level of reliability and resiliency that will help keep the power on and restore it more quickly when there are major interruptions from natural or human induced events. They also bring the added benefit of reducing reliance on older, less efficient in-city generators, resulting in improved air quality and public health. The City will continue to assess how it can leverage its purchasing power and work with utilities, regulators, transmission owners, grid operators, generators, environmental advocates and developers to bring about legislative and rule changes that will facilitate the delivery of 70 to 80 percent of the citywide electrical load from renewable

energy sources.

Increase efficiency and emissions requirements for in-city generators

The in-city generation stock is expected to transition from providing roughly 50 percent of generation today to less than one-third in 2050. It will need to play a supporting role to the renewables-based grid, shoring up the reliability of electricity supply within the five boroughs. The City will continue to support the repowering or replacement of the most inefficient power plants. Those remaining will need to be efficient natural gas turbines that can ramp up and down quickly to complement the ebb and flow of a grid highly reliant on intermittent renewable energy resources.

The City will work with the New York State Public Service Commission (PSC) to create a long-term vision for the future of the grid and will advocate for NYISO to develop standards that will guide this transition. One such example is the development of a ramping tariff that would allow NYISO to procure ramping capability to address the intermittency challenges associated with a renewables-based grid. The City will continue to play an active role in NYISO discussions that impact the investments in and operations of in-city generators. We will also advocate for investment in programs and products that improve grid flexibility and ensure power quality.

The City will pursue the expansion of the transmission network that connects the city to the regional grid, in order to access clean regional resources and reduce the need for in-city generating capacity to satisfy the city's reliability requirement. In turn, this will facilitate the retirement of older, less efficient plants and reduce costs for ratepayers in the long run. The City will also support measures to expand the in-city transmission and distribution network to address acute stresses, such as local transmission constraints near load pockets, in order to further decrease reliance on in-city generators.

Make an unprecedented commitment to promote clean, distributed energy resources

DERs, including rooftop and community solar, energy efficiency, and energy storage, will play an important role in increasing the amount of clean energy in the city, especially in the near term. They also play a critical role in reducing demand on the grid and providing resiliency benefits. Therefore, building on efforts over the last few years, the City is bolstering its commitment to support their deployment.

Community energy solutions can support both climate mitigation and adaptation needs. The development of the Community Energy Map allows the City and project developers to identify which locations provide the opportunities to both reduce GHG emissions and enhance the resiliency of vulnerable neighborhoods with community energy systems.

In addition to evaluating the technical potential of different distributed generation sources, the Community Energy Map incorporates dimensions of climate change vulnerability—including energy affordability, air quality, heat risk, and flood risk—so that investments in clean, resilient energy investments can be prioritized to address these challenges. The findings from this analysis could facilitate potential partnerships for community energy projects. The City will explore developing the map into an online resource that will help communities and project developers identify potential sites for community energy projects.

The City can lead by example by deploying DERs on our own buildings and can leverage our own assets to foster community energy solutions. The City owns thousands of public facilities, including 14 wastewater treatment plants, throughout the five boroughs, and has committed to retrofit every municipal building with significant energy use to improve energy efficiency and to install 100 MW of distributed solar energy on City-owned property by 2025 (see Buildings chapter). NYCHA has an additional 328 developments and has committed to reduce energy intensity per square foot from these properties by 20 percent by 2025 though energy efficiency upgrades and the development of 25 MW of renewable energy capacity by the same year.

From hospitals and office buildings to neighborhood schools and libraries, larger public facilities offer an opportunity to serve as host sites or power and heating off-takers for community-scale energy projects. As densely developed as the city is, there are opportunities to consider brownfields, landfills, other open spaces, and public rights-of-way for community-scale energy resources. The Department of Citywide Administrative Services (DCAS) already identifies any City-owned properties that may be candidates for rooftop solar. DCAS is now exploring the expansion of this program to identify vacant City properties that could be used to host community shared solar arrays. The City will explore ways to facilitate the beneficial use of such sites through a variety of mechanisms, such as through low- or no-cost land

leases.

To promote greater penetration of DERs, the City is working to address regulatory and market barriers to deployment. "Soft" costs due to permitting and interconnection requirements have impeded the growth of building- and community-scale DERs. The City is actively engaged in reviewing regulatory barriers and encouraging modifications to existing utility tariffs to support their more efficient deployment. For example, the City has continually advocated for changes to utility standby rates, which are designed to recover the utility's costs of "standing by" with a reliable supply of power in the event that a DG unit fails and the customer requires full electricity supply from the utility grid.

The City has successfully advocated for modifications to existing standby rates to make them more attractive for DG project developers. Examples include encouraging the PSC to create a "campus-style" standby rate that allows a customer to offset load at multiple buildings from a single DG unit. The City also successfully argued for an incentive for standby customers that rewards DG units for reliable performance and petitioned for modifications to the steam standby rates to reduce onerous steam standby charges that can make DG project economics challenging.

The City has also played a key role in shaping discussions around net metering, which has been a critical driver in smaller-scale DG development throughout the City. The City is actively participating in the statewide effort to develop a successor tariff to net metering with the objective of encouraging significant new investment in renewable energy over the next several years. In addition, the City has been a leading proponent for community DG, which, through projects such as community shared solar arrays, is designed to extend the benefits of smaller-scale DG to a much greater number of participants—particularly customer segments like low-to-moderate income customers that have been historically underserved by renewable energy development. The City recently joined a coalition of solar industry and environmental advocates in petitioning the PSC to remove, for certain building arrangements, the 10-member requirement currently in the community DG rules, with the goal of expanding opportunities for on-site community DG to the many smaller, multifamily buildings located throughout New York City.

Furthermore, the City has been an active voice in reforms to utility interconnection procedures, which are routinely cited as one of the largest barriers to increased DG deployment. As a result, the City advocated for changes to New York's standardized interconnection requirements that are designed to, among other things: (1) expedite the interconnection process for projects that will have minimal impact on the utility grid; (2) reduce the upfront costs that project developers are required to bear; and (3) expand the project size limit (from 2 MW to 5 MW) for eligibility under standardized interconnection treatment. In addition, the City is a participant in the PSC's ongoing Interconnection Policy Working Group, which is tasked with identifying and resolving major barriers to DG interconnection with the utility grid, such as uncertain allocation among developers of required utility upgrade costs. All of these efforts are designed to reduce the time and expense associated with utility interconnection, while ensuring that interconnections continue to be completed in a safe and reliable manner.

These measures serve to benefit various forms of clean DG and will support the City's ambitious solar deployment goals. In 2014, the City committed to install 100 MW of solar PV capacity on City-owned property by 2025 and to support the development of 250 MW of solar PV on private property by 2025, in part through group purchasing and community shared solar projects. The City is over a third of the way toward achieving its 250 MW private-sector solar target (combining the 69 MW in operation with the 17 MW in development) and on track to be a quarter of the way toward its 100 MW goal by the end of 2018.

As we continue progressing towards the OneNYC solar goal, the City is expanding the citywide installation target (for both private and publicly-owned properties) to 1,000 MW by 2030. The City's efforts to streamline the permitting and review process have reduced the average turnaround time for solar PV plan reviews at the Department of Buildings (DOB) to less than a day (see Buildings chapter) and provide significant support for this new stretch goal. In addition, this new target builds on the impressive recent growth of the city's solar market, which is projected to continue its upward trajectory, on the strength of emerging technologies and market structures. With over 2,700 solar jobs already in New York City, this expanded solar deployment target solidifies the city's position as a major clean energy jobs hub in the northeast.

Through the New York City Solar Partnership, a joint

effort of the City University of New York (CUNY), the New York City Economic Development Corporation (NYCEDC), and the Mayor's Office of Sustainability, the City will support programs that accelerate rooftop solar installations and efforts to facilitate community shared solar installations. The Solar Partnership recently launched Solarize NYC, which supports community-led group purchasing campaigns that lower the costs of installing rooftop solar PV, as well as Shared Solar NYC, a program to match developers with rooftop owners that can host large "shared solar" installations. Under Shared Solar NYC, rooftop owners can offer subscriptions to shares of the project's energy output to renters and homeowners without suitable roofs. The City is taking additional policy measures to ensure that community shared solar can flourish in New York City, where its initial uptake has lagged relative to other areas of New York State with greater land availability for substantial solar installations. For instance, the City has submitted a joint petition with other stakeholders throughout the state to the PSC to enable small multifamily properties to structure their own community shared solar projects.

We are also establishing the city's first-ever energy storage deployment target—100 MWh by 2020. Energy storage can enhance the economic viability of solar PV installations while also helping to manage peak electricity demand and provide a resiliency benefit by providing backup power. Energy storage systems also power electric vehicles and can be used to help manage their electricity consumption from the grid in high-voltage charging applications.

Battery technology needs a streamlined pathway through regulatory agencies and into the marketplace. CUNY's Smart DG Hub Resilient Solar Project has been coordinating this process in partnership with City agencies and utilities. For example, fire safety is a key issue that must be addressed before certain types of energy storage systems, in particular lithium-ion batteries, can become widely deployed. The Fire Department of the City of New York (FDNY) is actively engaged in an energy storage testing study commissioned by Con Edison and the New York State Energy Research and Development Authority (NYSERDA) to assess safety and suppression measures required for various types of energy storage systems. This work will inform the development of improved permitting guidelines to streamline FDNY's review process for technologies deemed sufficiently safe in testing. In order to accelerate the safe deployment of emerging technologies, including energy storage systems, the City will make investments to reduce permitting times, develop standards for design and installation of safety measures, and continue to incorporate new technologies into the City's building and fire safety codes.

In addition to solar, the City is exploring opportunities to scale up the use of ground source heat pumps. The City is conducting a cost-benefit analysis that includes the social cost of carbon when comparing ground source heat pumps to traditional heating systems for City-owned buildings. The City is also developing a publicly available online screening tool to assess whether ground source heat pumps can be a cost-effective low-carbon solution for providing heating and cooling to both City-owned and private buildings (see Buildings chapter).

To encourage the further development and adoption of new and emerging technologies, the City, led by EDC, will continue its support for clean technologies and smart cities entrepreneurs and innovation through the Applied Sciences NYC initiative to build or expand world-class applied sciences and engineering campuses in New York City, and UrbanTech NYC—a comprehensive program offering incubation and step-out spaces, prototyping equipment and commercialization programming, demonstration opportunities, and shared re-

Solar installation in NYC
Photo credit: NYC Deparment of Citywide Administrative Services

sources to companies working to solve New York City's urban challenges.

Laying the Foundation for the Future

The challenge of achieving 80 x 50 goes beyond New York City. Regulatory action is needed at the state, regional, and federal levels to enable large-scale renewables to become the dominant sources in the electric grid. As technologies evolve and distributed energy resources become increasingly cost competitive, the institutional and regulatory framework must evolve to allow for these solutions to be integrated into the energy supply system and to allow for customers to have the ability to play a more active role in determining their energy supply. Public policy must also continue to guide decisions made in the private sector in order for the City to achieve its goals—namely, the City will continue to advocate at the NYISO and PSC for increased transmission that connects the city directly to other areas in the region that are near large-scale renewable energy production facilities.

Con Edison has implemented interconnection and other infrastructure improvements to support DER integration, enhance the resiliency of the grid, and reduce emissions from its steam system. The City will continue to look to Con Edison as a partner in achieving 80 x 50 and will also continue to advocate for utilities to build upon these improvements and accelerate the transformation necessary for a 2050 grid that is renewables-based, affordable, and reliable.

It takes time for new technologies and business models to mature and become competitive with existing systems. Researchers and project developers must also be able to test and refine the technologies in real-world settings to give them ample opportunity to mature. New York City will continue to foster and support innovation by offering public sites to test new technologies and strategies and encouraging private sites to host pilot projects, such as through the DCAS Innovative Demonstrations for Energy Adaptability (IDEA) program (see Buildings chapter). The City and NYCEDC will also continue to invest in emerging technologies and private sector innovation for DERs, DG, energy storage, and other opportunities through its joint initiatives.

The NYISO and the State will have to continue to lead the way in defining the vision for a renewables-based grid, ensuring the NYISO market structures result in the fleet of in-city generators, energy storage, and smart grid technologies necessary to help balance the grid and ensure reliable service. In terms of DERs, New York State's Reforming the Energy Vision (REV) is laying the groundwork for a transition to future energy systems that feature distributed energy resources more prominently, and the City will continue to advocate for utilities to implement REV in a way that allows clean energy to be prioritized based on a variety of social and environmental considerations without sacrificing energy reliability or resiliency.

Energy Strategies	Energy	Buildings	Transportation	Waste
Increase direct and indirect investments in large-scale renewable energy and energy storage	●			
Reduce greenhouse gas emissions of in-city energy systems	●			
Make an unprecedented commitment to promote clean, distributed energy resources	●	●	●	●

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Buildings

In 2050...

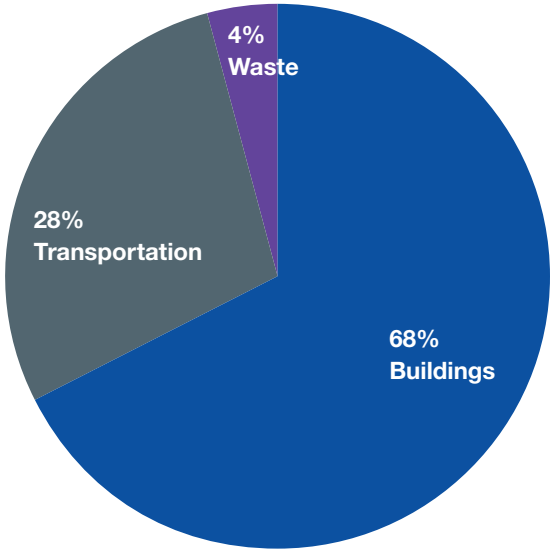
We envision that nearly all of our existing buildings will be upgraded to use significantly less energy, and many will have transitioned away from fossil fuels to clean and renewable energy sources. As a result, the air will be cleaner, New Yorkers will have greater control over their energy bills, and residents will have more comfortable homes—there will no longer be a need to open a window in the dead of winter to cool an overheated apartment. New buildings will be built to the best energy performance standards, and New York City will boast an expanded industry of world class architects, engineers, and contractors who are in high demand locally and globally to design and construct ultra-low energy buildings. Developers, owners, and residents will have access to a wide array of financial resources and highly qualified service providers to design the next generation of new buildings and retrofit existing properties. Building operators and staff, the critical link to maintaining these deep energy reductions, will have the tools and expertise to run building systems at the highest level of performance, while building tenants and residents will be empowered with smart ways to control energy use and comfort in their spaces.

Achieving 80 x 50: Buildings

New York City has over one million buildings that make up more than five billion square feet of built area. More than 90 percent of these buildings will still exist in 2050. The energy used in the city's diverse building stock is the largest contributor of greenhouse gas (GHG) emissions, responsible for 68 percent of the citywide total in 2014. [1]

Commercial and multifamily buildings make up a majority of built floor area and GHG emissions from energy used in buildings. One- to four-family homes represent the largest number of buildings, but the total built floor area and GHG emissions from these buildings are proportionally less.

New York City GHG Emissions by Sector (2014)



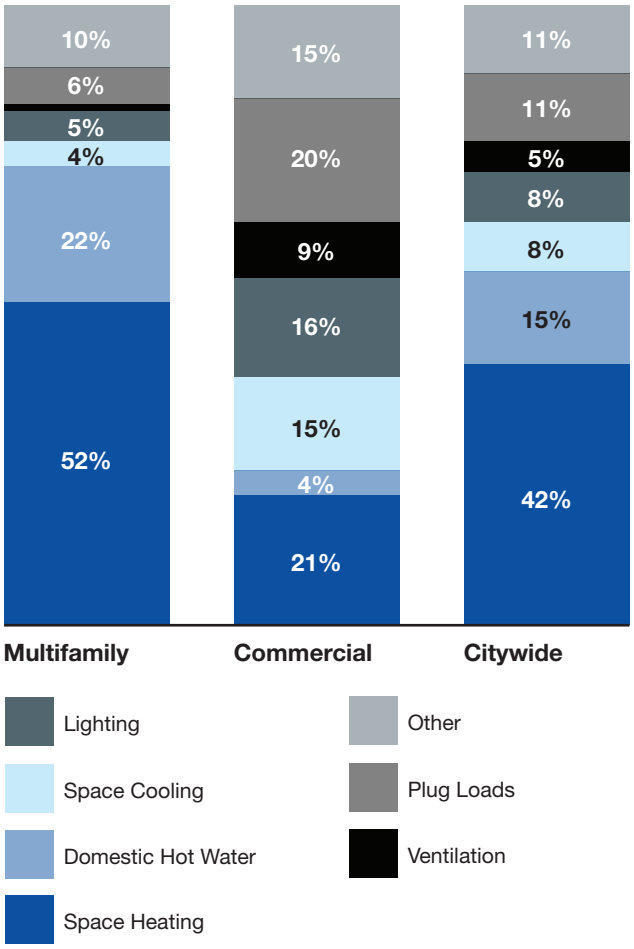
Since 2005, GHG emissions from the energy use in buildings have decreased by 12 percent, even as the city's built area has increased. The decrease is a result of reduction in GHG emissions from the electricity supply, conversion from heavy heating oil to cleaner fuels, and increased energy efficiency and conservation.

Many of the initiatives to reduce GHG emissions from buildings launched to date are aimed at the city's largest buildings. Going forward, all buildings will play a role in the path to 80 x 50. New buildings will need to meet ultra-low energy standards, and nearly every existing building will need to implement deep energy retrofits that holistically address heating, cooling, and building envelopes. To realize the full extent of potential GHG reductions, buildings must transition away from fossil fuels for certain systems, maximize on-site renewable energy, improve operations and maintenance, and empower residents to reduce energy use.

Drivers of GHG emissions

Fossil fuels that are burned in New York City's buildings, primarily to produce heat and hot water, account for 60 percent of the GHG emissions from buildings and almost 30 percent of total citywide emissions. Natural gas burned on-site accounts for more than half of building-based energy use and over 45 percent of GHG emissions. The share of heating oil has decreased significantly since 2005 as a result of the City's efforts to phase out No. 6 and No. 4 fuel oils, but still accounts for 11 percent of building-based emissions. Electricity, used mostly for lighting, plug loads, and cooling, accounts for almost

GHG Emissions from Large Buildings by End Use (2014)



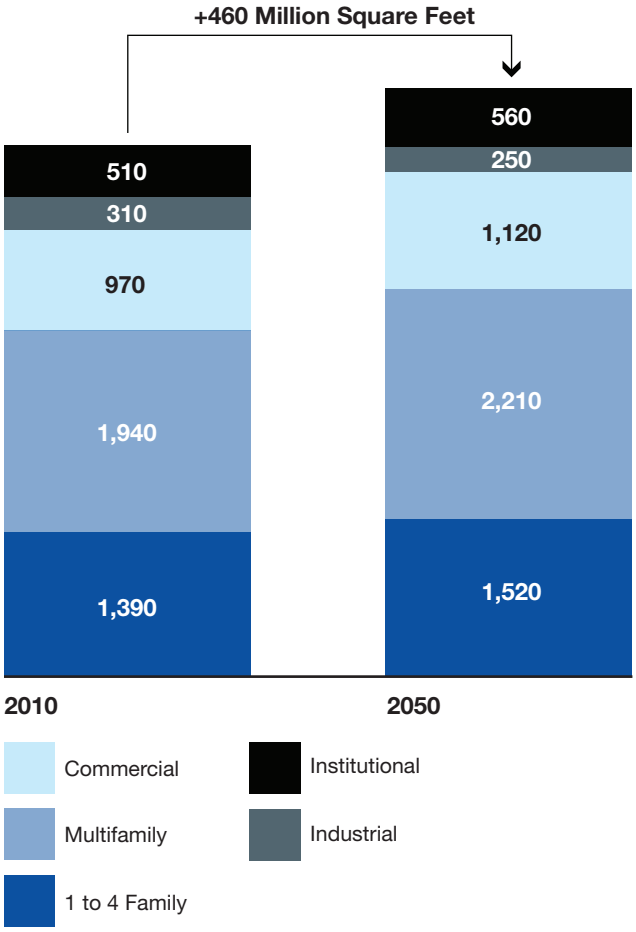
one-third of the energy use and 40 percent of GHG emissions from buildings. District stream use in buildings accounts for three percent of GHG emissions.

The energy used for heating—typically natural gas or heating oil—accounts for more than half of all building-based GHG emissions. In multifamily buildings, the energy used for the combination of heating and domestic hot water (DHW) production account for nearly three-quarters of their GHG emissions. In commercial buildings, emissions sources are more evenly distributed across heating, plug loads, and lighting.

Business as usual findings

In order to understand what it will take to achieve 80 x 50 citywide, the City first modeled projected GHG reductions under a business as usual (BAU) scenario for each sector through 2050. The BAU scenario includes GHG reductions achieved to date and the impacts from projected population growth, existing state and federal policies, and local policies enacted prior to 2014.

Projected Growth in Built Area by Building Use 2010-2050 (millions of square feet)



By 2050, New York City's population is anticipated to grow to nearly 9.2 million people and the city's workforce is estimated to grow to 4.8 million people.[2] This growth is expected to result in nearly 100,000 new buildings, which equates to roughly 460 million square feet of new built area. This includes a 12 percent increase in residential and six percent increase in commercial space.[3]

Under the BAU scenario, total building-based GHG emissions are expected to decrease by 24 percent from 2005 levels by 2050, which is largely due to GHG reductions from the electricity supply, fuel switching away from heavy heating oil, and efficiency improvements in buildings as a result of previously enacted policies.[4] Existing buildings continue to be the largest contributor of GHG emissions, representing over 90 percent of the total built square footage and building-based emissions. New building growth is expected to increase these emissions by nine percent.

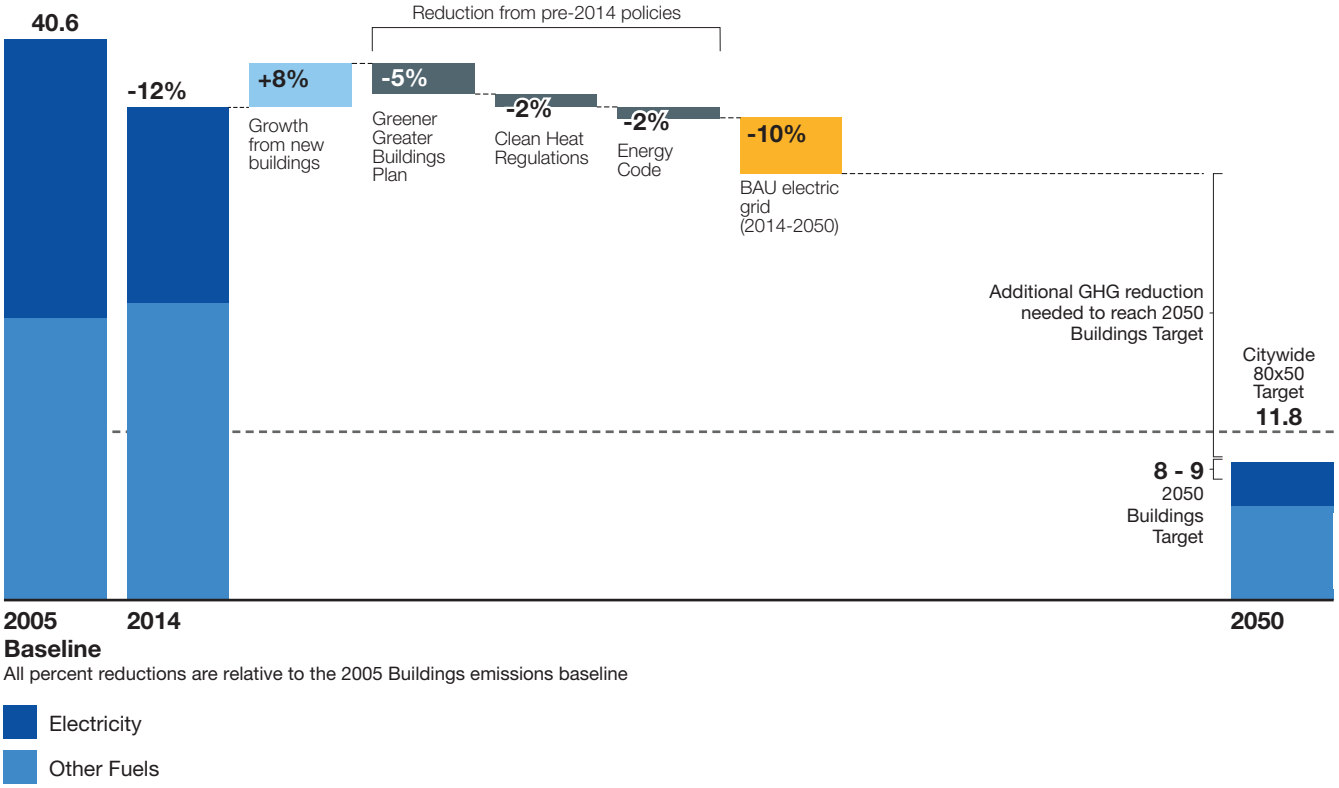
GHG emissions from on-site natural gas and heating oil use are expected to remain roughly constant from today's levels. As our electricity supply becomes cleaner, fossil fuel-based energy sources will account for a larger proportion of building-based GHG emissions, increasing from roughly half of building-based emissions in 2005 to over two-thirds in 2050.

Emerging Trends

The future electric grid. The potential for significant reductions in building-based GHG emissions depends largely on the carbon intensity of the electricity supply, or the amount of carbon dioxide equivalent emitted per unit of energy. If future electricity generation is dominated by fossil fuel-based power plants, the GHG emissions associated with electricity use in buildings will be higher than in a scenario in which renewable energy plays a major role in the electricity supply. Therefore, efforts to green the electric grid are essential to achieving significant GHG reductions from buildings.

Community-scale energy. Distributed renewable energy located on-site in buildings or as part of community-scale energy systems will reduce building-based GHG emissions. The largest potential for distributed renewable energy comes from solar PV installed on building rooftops. The technical potential for on-site solar in New York City is increasing as technologies advance, efficien-

Buildings Business as Usual Scenario 2005-2050, in Million Metric Tons in Carbon Dioxide Equivalent ($MtCO_2e$)

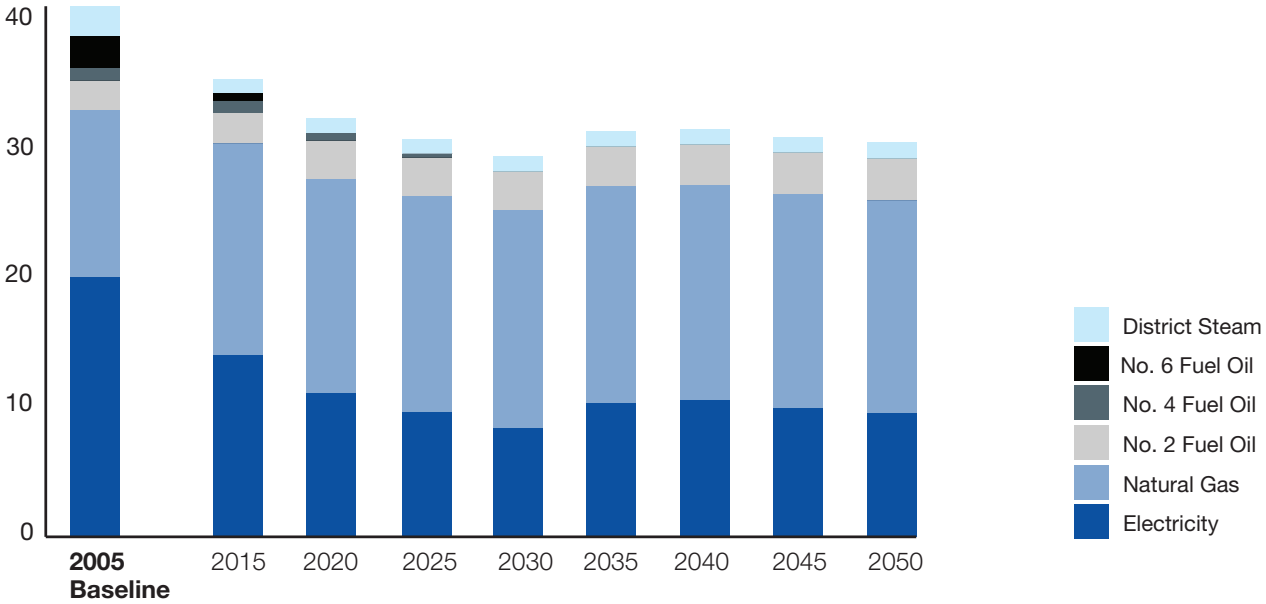


All percent reductions are relative to the 2005 Buildings emissions baseline

Electricity

Other Fuels

Buildings Business as Usual Scenario by Fuel Type 2005-2050 ($MtCO_2e$)



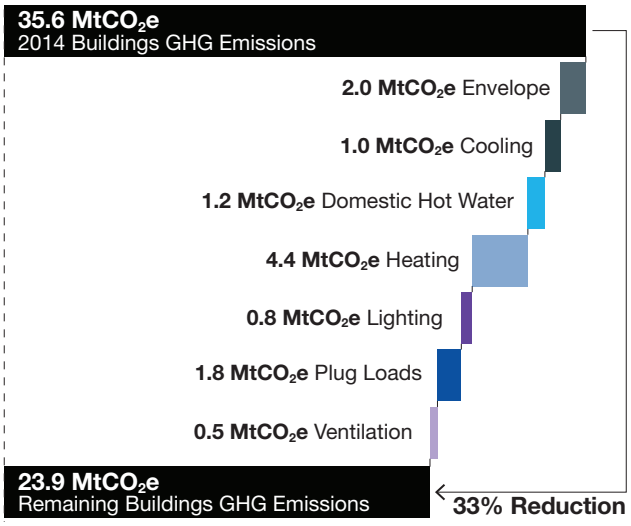
cies improve, and as the City, State, and federal government work to remove regulatory barriers.

The City also assessed district heating and cooling options, including solar thermal, combined heat and power (CHP), combined cooling heat and power (CCHP), wind, ground source heat pumps (GSHP), water source heat pumps (WSHP), and heat recovery (see Energy chapter). New York City is already home to Con Edison's district steam system, the nation's largest district heating network. These localized energy solutions hold the potential to meet clean energy demand and to provide health and resiliency benefits.

Energy efficiency. Improving energy efficiency of buildings will continue to be the most important strategy to reduce building-based GHG emissions even as the electric grid becomes cleaner. Many of today's buildings use more electricity for equipment, cooling, and plug loads than ever before, but the on-site energy used for heating and hot water production will continue to be the major driver of the city's building-based emissions.

To identify opportunities to transform the building stock for a low-carbon future, Mayor de Blasio convened the Buildings Technical Working Group (TWG) in 2015. The TWG analyzed nearly 100 low- and medium-difficulty energy conservation measures (ECMs) in existing buildings (typically with paybacks of 10 years or less) and found that these measures could reduce current building-based GHG emissions by up to 33 percent. Implementing these measures would lead to $2.7 billion in energy cost savings and 15,000 direct construction-related jobs.

Potential GHG Reductions from Low- and Medium-Difficulty ECMs



Technical Working Group ECMs Underway

ECMs within the 2016 Energy Code	Decrease window u-values for punched openings
	Increase wall insulation for one- to four-family homes
	Replace PTAC units with those with a higher energy efficiency rating
	Install an environmental monitoring systems for tenant HVAC equipment
	Install A/C and lighting controls in dormitories and hotels
	Reduce lighting power density and improve lighting controls
	Air seal one- to four-family homes
ECMs Identified for Immediate Action	Seal roof vents in elevator shafts
	Install digital controls for boilers
	Install thermal de-stratification fans in heated industrial spaces
	Improve tenant lighting controls
	Expand LL88 to residential building common areas
	Upgrade exterior lighting to current Energy Code standards
	Restrict open refrigerators in retail stores
ECMs to be Incorporated into Local Law 87 Requirements	Comprehensive upgrade for one-pipe steam heating distribution system
	Comprehensive upgrade for two-pipe steam heating distribution system
	Comprehensive upgrade for PTAC distribution system

Deep energy retrofit strategies. The TWG also analyzed deep energy retrofit strategies that holistically address heating systems, cooling systems, and the building envelope. The analysis showed that deep energy retrofits could achieve energy reductions of 40-60 percent in typical New York City buildings using existing technologies. At a minimum, these deep energy retrofits include repairing or replacing heating distribution systems, upgrading heating equipment to higher efficiency models, properly sizing equipment to building energy loads, and installing better controls and sensors. These measures must be paired with improvements to the building envelope, which includes improved insulation and air tightness, in order to realize their full potential. For some buildings, this will require reconfiguring room air conditioning or installing central cooling systems or mini-splits for combined heating and cooling to reduce through-wall and

On-Site Building Heat Pump Systems

Residential heat pump installation
Photo credit: 51% Studios Architecture, https://www.flickr.com/photos/51pct/

Air source and ground source heat pump systems represent two promising opportunities to reduce GHG emissions from buildings and tap into a cleaner future grid.

Air source heat pumps are essentially high efficiency air conditioning systems that are able to run in reverse to provide heat during the winter. These systems use electricity to extract heat from cold outdoor air to heat buildings, and extract heat from indoor spaces to meet cooling needs in the summer. By providing cooling without large window or wall penetrations, heat pump systems also reduce energy waste associated with air leaks around traditional window or through-wall air conditioning units.

Modern centralized air source heat pump systems are often referred to as Variable Refrigerant Flow (VRF) systems, which have the ability to modulate and meet a building's heating and cooling needs to different zones within a building. Decentralized air source heat pump models, called "mini-splits," allow a single outdoor unit to be connected to multiple indoor units in several rooms. Current air source heat pump technologies may need supplemental heating on days when the temperature drops below zero, although the technology is improving.[16]

Ground source heat pumps use the relatively stable temperature of the earth to provide heating and cooling. On-site ground source heat pump systems consist of a heat pump installed within the building and a ground coupling system that consists of piping or wells to transfer heat to and from the ground. Ground source heat pumps can be more efficient than air source heat pumps when the outdoor air temperature is very hot or cold, although implementation can be disruptive in a dense urban environment and land availability may limit their feasibility.[17]

For heat pump systems that use refrigerants, it is important that they are properly operated and maintained to avoid leakage of hydrofluorocarbons (HFCs), which are common refrigerants, and the associated fugitive GHG emissions. Federal and international efforts are underway to phase out the use of HFCs in support of refrigerant alternatives.[18]

window penetrations that lead to air leakage. These systems must be consistently maintained to sustain energy reductions, and tenants and residents must also be empowered to reduce their energy use. Many of the retrofit paths would be costly today, but replicability could lead to cost reductions. Testing these modeled strategies in real buildings will be critical.

Transitioning away from fossil fuels in buildings. As part of the analysis, the TWG explored options to transition from fossil-fuel based heating, cooling, and hot water systems to renewable energy sources. High efficiency electric technologies for heating, cooling, and hot water production, such as air source heat pumps (ASHPs) paired with variable refrigerant flow (VRF) or mini-splits, would benefit from a future renewables-based electric grid. The TWG found that even with today's electric grid, the deep energy retrofit strategies that include these high efficiency electric technologies and building envelope improvements currently reduce GHG emissions. Citywide electricity use could increase moderately as a result of the use of efficient electric heating technologies and the adoption of electric vehicles, but this would not significantly impact the carbon intensity of the city's electricity supply (see Energy chapter).

On-site combined heat and power (CHP) systems cogenerate electricity and useful heat. While these systems realize significant efficiencies, they typically rely on the combustion of fossil fuels, most often natural gas. CHP

deployed today reduces GHG emissions, but as the electric grid becomes cleaner, these systems will eventually emit more greenhouse gases than the grid emits.

Biofuels. Biofuels are types of fuels that are sourced from natural materials, such as agricultural waste or anaerobic digestion of wastewater. Biodiesel is a type of biofuel that is made from a variety of resources including agricultural residue, recycled cooking oil, and animal fats, and can be used in place of heating oil. Biodiesel reduces the on-site GHG emissions from heating oil use in a building, and is estimated to reduce lifecycle[5] GHG emissions by 50 to 80 percent relative to the heating oil it replaces.[6,7] Currently, all heating oil used in New York City buildings is a minimum two percent biodiesel blend (B2). For buildings that already use fuel oil, switching to biodiesel blends of up to 20 percent (B20) would reduce GHG emissions and can be achieved in existing building systems with little to no equipment modification.[8] Biodiesel blends greater than 20 percent have the potential to further reduce emissions, but introduce potential reliability challenges with equipment manufactured today and supply chain constraints based on current production levels. Expanding local and sustainable sourcing of biodiesel inputs from city waste streams could be a promising opportunity to increase the supply of biodiesel while reducing waste and recovering resources such as recycled cooking oil, trap grease, and animal fats.

Biogas, which is methane recovered from organic waste streams, could be another opportunity to reduce GHG emissions. Natural gas-dependent systems, including CHP systems, would benefit from sourcing renewable fuels such as biogas. The City is working to optimize the production, collection, and use of biogas at in-city wastewater treatment plants. The City is also seeking to support small scale anaerobic digestion to both increase the production of renewable energy and the capacity to process organics citywide (see Waste chapter).

Demand management. Demand management strategies in buildings include energy efficiency, demand response (in which energy use is curtailed during peak electricity demand), and energy storage (in which energy is produced during off-peak hours and stored in batteries or ice storage for later use). These strategies serve to manage total energy consumption and peak electricity demand and are an increasingly important component of GHG reduction strategies for buildings. Annual peak demand is expected to grow throughout New York State, although the estimated rate of growth has been declining as a result of increased energy efficiency and on-site renewable energy generation.[9] Demand management strategies can also reduce electricity demand charges and provide resiliency benefits to building occupants.

High efficiency electric heating and cooling can support efficient operations of the electric grid. Annual electric peak demand in New York City currently takes place in summer months. By using these technologies to increase winter electric loads and decrease summer electric loads, the annual load curve will be more level, allowing for more efficient and less costly electricity supply throughout the year.

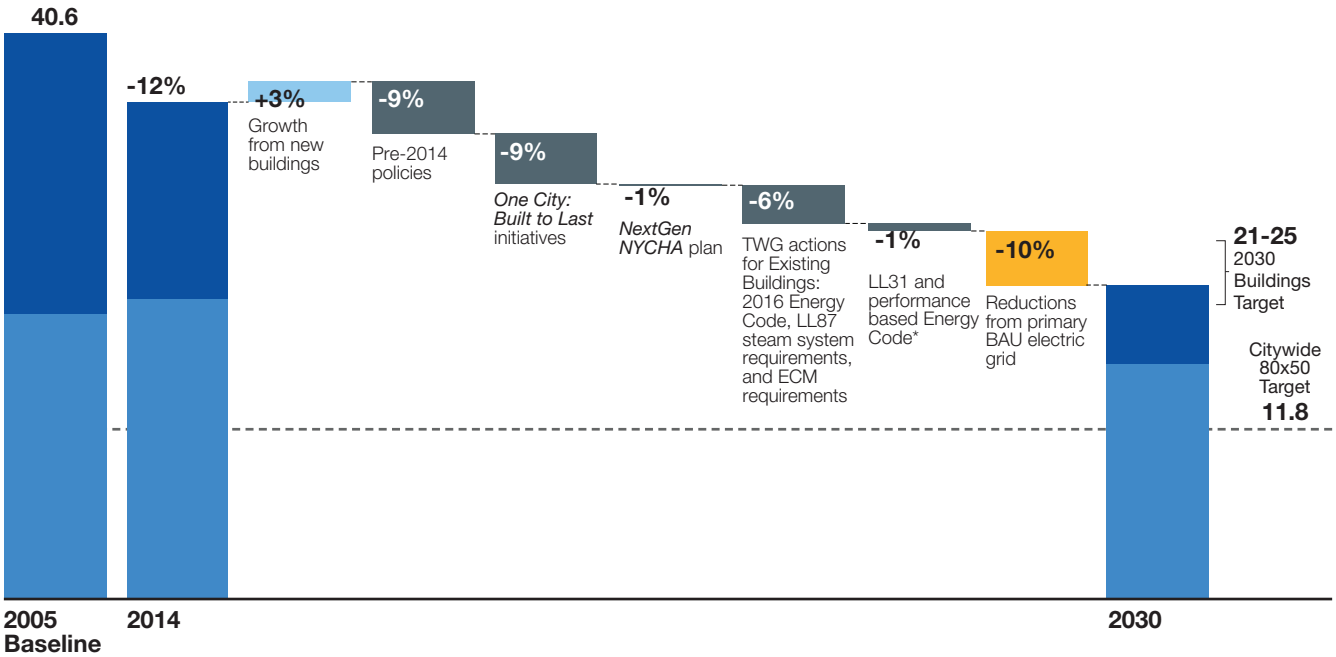
Holistic energy performance design. New buildings have a critical role to play to reduce GHG emissions. The buildings that are constructed today will still be here in 2050. Requiring new and substantially renovated buildings to meet the highest possible energy performance standards will prevent the need for future retrofits in these buildings.[10] The City has made incremental updates to the Energy Code that have improved the energy efficiency of our new and substantially renovated buildings. However, continuing these improvements at the same rate will eventually encounter diminishing returns for energy and GHG reductions.

A more cost-effective approach would require a paradigm shift towards design for holistic energy performance. The incremental approach to updating the Energy Code increases efficiency requirements on a system-by-system level. A "performance-based" approach considers the whole building as an integrated system. Whole building design standards that set a low-energy performance target, for example an energy use intensity (EUI) per square foot, can achieve significantly greater energy reductions than incremental Code updates and allow for greater design flexibility. This typically results in very well-insulated buildings that have minimal air leakage and are heated, cooled, and ventilated with very little energy.[11] Moreover, implementing a performance-based Energy Code would benefit efforts to implement deep energy retrofits in the city's existing building stock as new technologies and strategies emerge to achieve holistic energy performance and design professionals and contractors develop new skills.

80 x 50 Roadmap: Buildings

To reach 80 x 50, GHG emissions from buildings must be reduced from more than 35 million metric tons of carbon dioxide equivalent ($MtCO_2e$) in 2014 to between eight

Buildings Trajectory to 40 x 30 with Current Policies 2005-2030 ($MtCO_2e$)



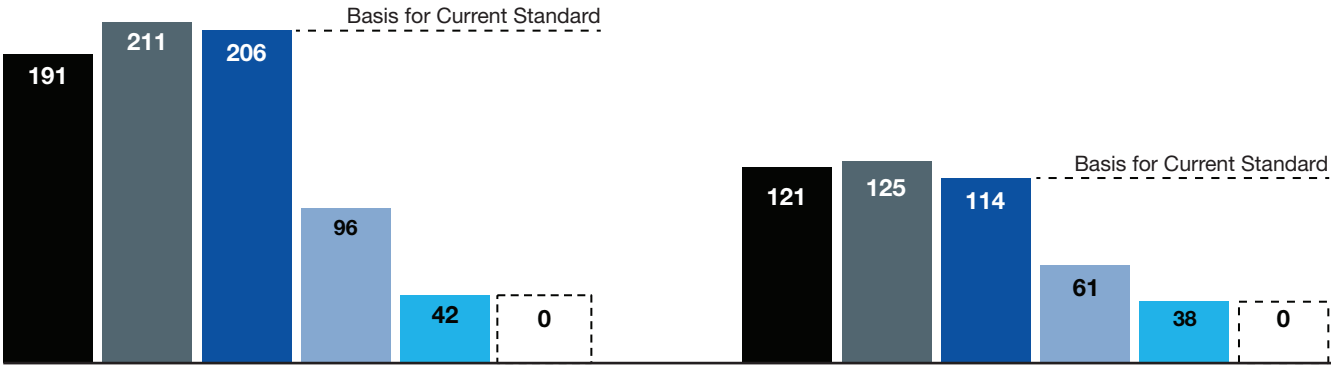
All percent reductions are relative to the 2005 Buildings emissions baseline

Electricity

Other Fuels

* Assumes a 50% reduction from ASHRAE 2013 standards for new construction and substantial renovations implemented in 2017 for public buildings and 2022 for private buildings

Potential GHG Reductions from a Performance-Based Energy Code (Energy Use Intensity in kbtu/sq.ft.)



NYC Existing Median

50% below NYC median (Basis of LL31)

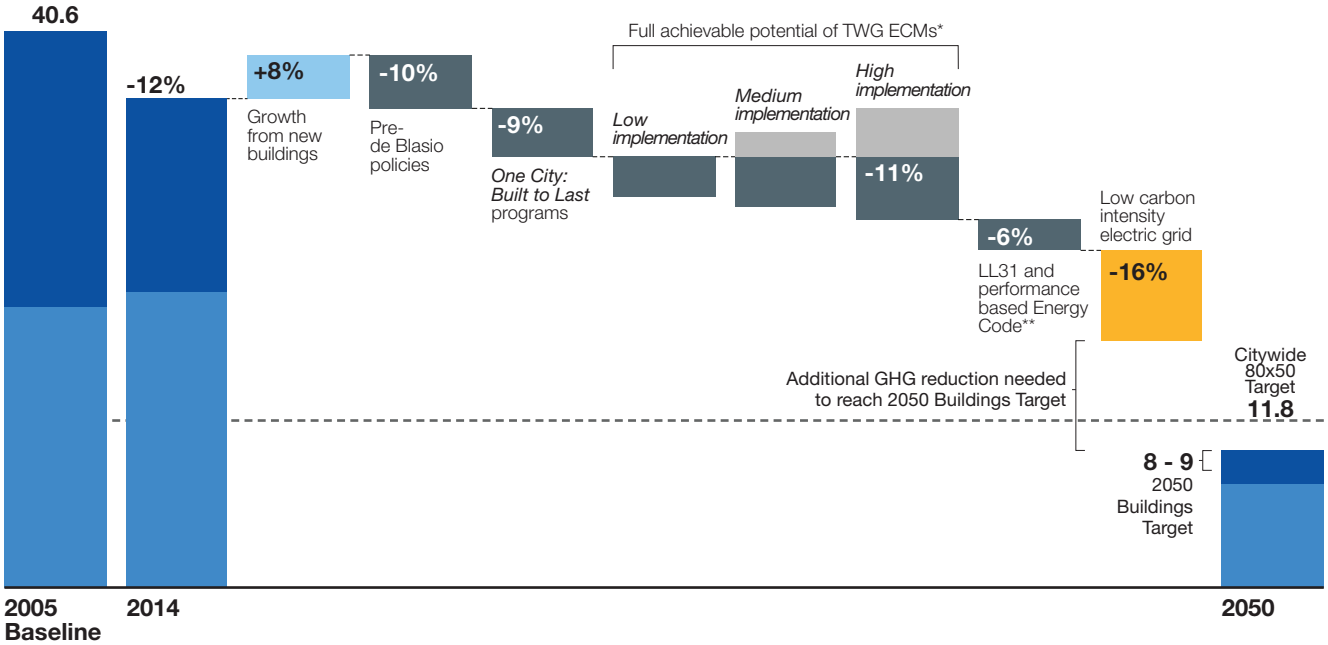
ASHRAE 90.1 - 2010 (Basis of 2014 NYC Energy Code)

Passive House

ASHRAE 90.1 - 2013 (Basis of 2016 NYC Energy Code)

Net Zero

Buildings Trajectory to 80 x 50 with Low- and Medium-Difficulty ECMs 2005-2050 ($MtCO_2e$)



All percent reductions are relative to the 2005 Buildings emissions baseline

Electricity
Other Fuels
One City Built to Last Overlap

* Full implementation of TWG ECMs includes 100% overlap with One City: Built to Last initiatives

** Assumes a 50% reduction from ASHRAE 2013 standards for new construction and substantial renovations in public buildings beginning in 2017, and a 70% reduction from ASHRAE 2013 standards implemented in 2022 for both public and private buildings.

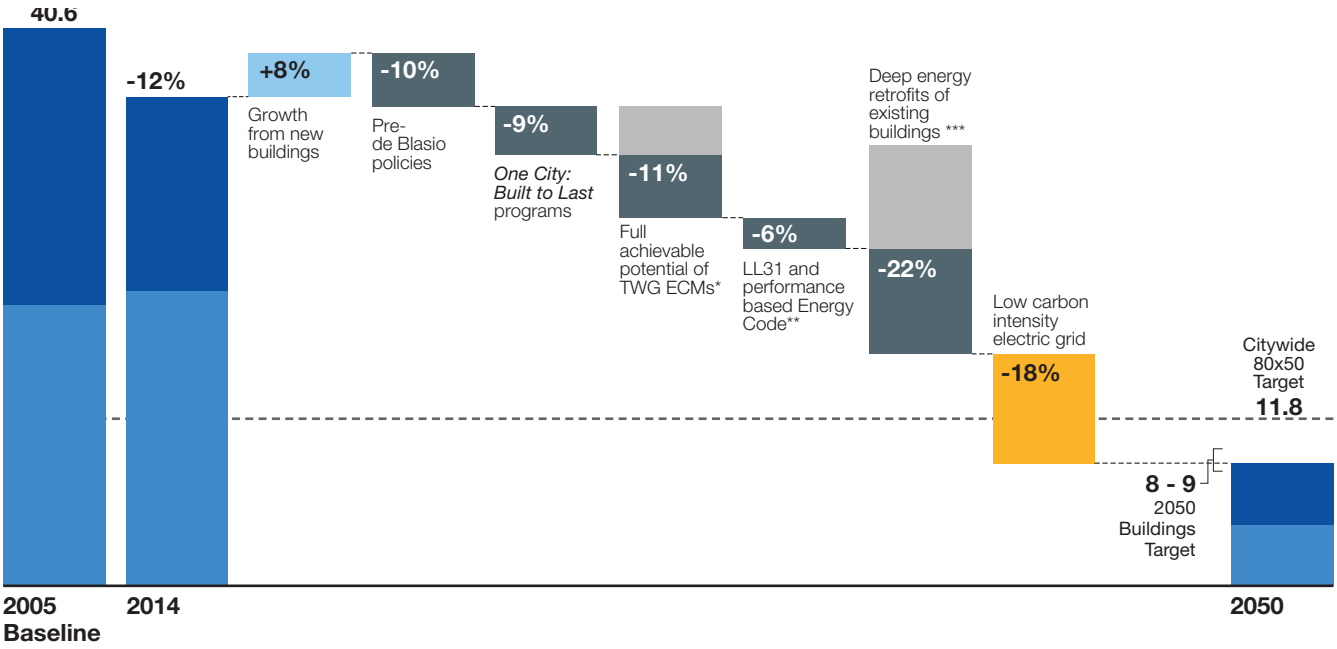
and nine $MtCO_2e$ annually by 2050. This target includes the potential GHG reductions from energy efficiency and clean energy upgrades in buildings, as well as the expected building-based GHG reductions from transitioning towards a renewables-based electricity supply.

Since 2014, the City has launched new policies and programs to reduce GHG emissions through *One City: Built to Last (Built to Last)*, the City's ten-year plan to improve energy efficiency in buildings, and the *One City: Built to Last Technical Working Group Report* (the *TWG Report*). These policies and programs are projected to reduce building-based GHG emissions by 45 percent from 2005 levels by 2030, with GHG reductions from the electric grid expected to account for a large portion of these reductions.

Additional projected GHG reductions will come from implementing low- and medium-difficulty energy conservation measures (ECMs) identified by the TWG, many of which have been incorporated into the 2016 Energy Code. Combined with the City's initiatives across the waste, transportation, and energy supply sectors, these measures will place New York City on track to achieve the interim goal of a 40 percent reduction in citywide GHG emissions by 2030 (40 x 30).

Ultimately, low- and medium-difficulty efficiency measures alone will not be sufficient to achieve 80 x 50. Even when combined with the City's low carbon intensity grid scenario (see Energy chapter) and a performance-based Energy Code that achieves a 70 percent reduction in energy use from current standards, implementing all of the low- and medium-difficulty ECMs identified by the TWG results in a projected 56 percent reduction in building-based emissions from 2005 levels. This scenario would require buildings to reduce GHG emissions by an additional nine to ten $MtCO_2e$ to achieve the final target of between eight to nine $MtCO_2e$ annually by 2050.

Buildings Trajectory to 80 x 50 with Deep Energy Retrofits 2005-2050 ($MtCO_2e$)



All percent reductions are relative to the 2005 Buildings emissions baseline

- Electricity
- Other Fuels
- *One City Built to Last* Overlap

* Full implementation of TWG ECMs includes 100% overlap with One City: Built to Last initiatives

** Assumes a 50% reduction from ASHRAE 2013 standards for new construction and substantial renovations in public buildings beginning in 2017, and a 70% reduction from ASHRAE 2013 standards implemented in 2022 for both public and private buildings.

*** Includes 100% overlap with *One City Built to Last initiatives* and TWG ECMs. 50-60% of buildings implement strategies that include high efficiency electric technologies for heat and hot water.

In order to assess opportunities for additional reductions, the City analyzed deep energy retrofit strategies based on the retrofit paths developed by the TWG, which have the potential to reduce energy use in existing buildings by 40-60 percent. Recognizing the potential to tap into a cleaner future electric grid, these included retrofit strategies that incorporate high efficiency electric technologies for heating paired with building envelope improvements.

The City also analyzed the impacts of a performance-based energy code that achieves between 50-70 percent reductions from current standards beginning in 2022 for new buildings and substantial renovations. In addition, the City assessed the impacts of wide-scale adoption of up to roughly seven GW of distributed solar PV, which includes projected improvements to panel efficiencies, and the introduction of district heating and cooling networks in key areas across the city.

The full implementation of these strategies, when combined with the City's low carbon intensity grid scenario (see Energy chapter), is projected to reduce building-based GHG emissions to roughly eight MtCO2e annually—achieving the GHG reductions that are necessary from buildings to meet 80 x 50 at a citywide level.

The most significant driver of these reductions is the implementation of the deep energy retrofit strategies that holistically address heating, cooling, and the building envelope across all existing buildings in the city. Based on the analysis, between 50 and 60 percent of these buildings must pursue strategies that include a transition to efficient electric technologies for heating systems, tapping into a significantly cleaner future electric grid. Under this scenario, significant solar penetration of roughly seven GW is installed on building rooftops and open lots, and district heating and cooling networks are adopted in key areas of opportunity. New buildings are built to a performance-based Energy Code beginning in

Brussels Exemplary Buildings Program

The City can look to the example of Brussels in Belgium as a model for its path forward. In 2015, Brussels became the first European city to enact regulations that require all new construction to be built to very-low energy standards following its successful Brussels Exemplary Buildings Program. The program awarded the design and construction or renovation of nearly 250 very-low energy buildings over six years and trained thousands of design professionals and contractors in best practices drawn from the experience of the awarded buildings to prepare the industry for the new regulations. This accelerated the shift towards holistic energy performance in Brussels' design and construction industry.

2022 and consume 70 percent less energy than buildings that are constructed today.

Challenges to address

The technology and strategies that exist today are capable of reducing GHG emissions from buildings to the levels that are needed to place the city on a pathway to 80 x 50. To realize this potential, the city must both achieve ultra-low energy performance from new buildings and substantial renovations in the next several years while at the same time facilitating deep energy retrofits in nearly all existing buildings over the longer term.

For new and substantially renovated buildings, the most promising opportunity to achieve significant GHG reductions is to require holistic energy performance. A small but growing number of buildings in New York City have been constructed to performance standards that significantly reduce energy use and GHG emissions, such as the Passive House standard, which uses 60-70 percent less energy than current standards. These have tended to be smaller buildings, although the new residential tower at Cornell Tech will become the largest Passive House structure in the world once complete. Still, there are a limited number of design professionals and contractors in the city have experience in this type of construction.

Facilitating implementation of a performance-based Energy Code will require significant education and training to prepare the industry for a paradigm shift. Industry professionals, developers, and contractors across the city must be trained on new design concepts, energy modeling, and construction methods. The City and its partners in the private sector will need to develop and provide proof of concept details and resource libraries for the industry. Many more buildings that are designed to ultra-low energy standards must be constructed and replicated across a broad array of building types, uses, and classes to test new solutions and inform the City's requirements.

For existing buildings, New York City has yet to implement retrofit strategies that show promise in delivering deep energy reductions on a wide scale. The development of the TWG deep energy retrofit paths is a significant step, demonstrating that it is possible to reduce energy use between 40-60 percent in New York

Residential Tower at Cornell Technion Campus
Photo credit: BuroHappold Engineering

The Dutch Energiesprong Initiative

The Energiesprong model in the Netherlands is an innovative program that has streamlined the retrofit process. In 2010, the Netherlands piloted a competition for local manufacturers to standardize retrofits for eligible building types to achieve "Net-Zero Energy" performance. After several rounds of the competition, Energiesprong retrofit packages are now completed in less than 10 days and come with a 30-year energy performance warranty. The costs of these retrofits, while still high, have decreased by 40 percent in the last six years. The New York State Energy Resource and Development Authority (NYSERDA) is now replicating this program model in New York State to bring these opportunities to the local market.

City buildings, but these strategies will need to be tested in the real world. Buildings must shift away from fossil fuels for heat and hot water production and toward renewable sources or high efficiency electric technologies and while making improvements to the building envelope to reduce heating loads. However, the costs of these improvements remain high and there are few examples in New York City today. These technologies will need to be supported with programs to generate demand and supply chain solutions to help bring down costs. Contractors, installers, and building operators will also need to be trained on their installation and use. Additionally, many buildings will need to install on-site renewable energy sources such as solar PV, but costs of these systems can still be out of reach for some New Yorkers, and many buildings have space and shading restraints.

Deep energy retrofits and on-site renewable energy installations can reduce energy costs in buildings and improve resident comfort, but these upgrades will require investments. Building owners and decision-makers also face competing needs to ensure their buildings are safe, comfortable, and desirable for tenants, which limits the amount of capital that can be spent on energy efficiency and clean energy upgrades. Financing can be a major barrier, particularly for those who may lack the capital reserves or creditworthiness to access commercial financing options, and lending for these projects can require specialized technical analysis, while traditional loan products do not recognize energy savings in the underwriting process. Moreover, the current prices of natural gas and other fossil fuels are inexpensive relative to electricity and renewable sources of energy, which poses a major obstacle to transitioning away from these fuels—although the costs do not take into account the environmental and public health costs associated with the impacts of using fossil fuels.

The public and private sector will need to work together to develop the appropriate financing mechanisms to assist building owners in making energy efficiency and renewable energy investments. The City must also work to help bring down costs through programs to support the market as well as direct financing and incentives for building owners. Building owners will also need clear guidance on options for achieving deep energy savings and incorporating retrofit strategies into long-term capital planning. Moving forward, the City and private sector leaders will need to test the applicability of deep energy retrofit strategies and explore new technologies and solutions that can both ease implementation and lower the potential costs.

Some of New York City's buildings will also need to become part of community-scale energy systems, such as community shared solar PV or district heating and cooling networks (see Energy chapter). Community-scale energy can maximize system efficiencies and has the potential to bring down the costs of energy production. Because of limited space and shading of buildings due to the city's density and other factors, community-scale energy sources can offer greater efficiency and flexibility than building-scale solutions. Still, coordination challenges exist between private building owners and regulatory hurdles will need to be addressed to encourage adoption of these solutions.

Another challenge is that tenant energy use makes up a sizeable portion of building energy consumption, and much of it is currently not subject to State or federal regulations. Commercial tenant spaces can account for 40-60 percent or more of a building's overall energy use and present a significant opportunity to reduce GHG emissions. Realizing the opportunities to reduce energy use from commercial tenant spaces would require better alignment between landlords and tenants, while the lack

of transparency of energy use information can create a significant obstacle to identifying and implementing efficiency opportunities. The successes of the commercial tenants participating in the NYC Carbon Challenge demonstrate that strategies are available and have the potential to be replicated to reduce energy use and GHG emissions from tenant spaces.

The full potential for GHG reductions in buildings will also require a workforce that is trained and knowledgeable about energy efficient operations of building systems. Whether a building owner is investing in state of the art technologies or upgrading existing systems to reduce energy costs, the proper installation, operations, and maintenance is essential to achieving optimal energy performance. This will require training thousands of workers on new technologies and construction methods, which would also help bring down potential costs of both new construction and deep energy retrofit strategies.

While the challenges to charting the path to 80 x 50 are significant, they are not insurmountable. Over the next three decades, technologies, markets, and State and federal policies will change that will alter the landscape for achieving deep GHG reductions. The City will continue to play an active role to identify and address new and evolving challenges to make the necessary improvements to buildings. The City will work closely with the State, federal government, and its private sector partners to ensure that new policies are tailored to industry needs and any new requirements provide the industry with time to prepare. As a result of these actions, New Yorkers will enjoy more comfortable living spaces, more productive workspaces, more control over their energy costs, cleaner air, and a more sustainable future.

Near-term actions to reduce GHG emissions

The City has long been a leader in efforts to reduce GHG emissions from buildings. The building codes have improved sustainability and energy performance. The landmark Greener, Greater Buildings Plan (GGBP) requires building owners to make cost-effective efficiency upgrades and provides transparent energy use information at an unprecedented scale. A mandated phase-out of heavy heating oil use in large buildings has lowered GHG emissions and improved air quality across the city, contributing to the cleanest air that New Yorkers have enjoyed in more than 50 years. The NYC Carbon Challenge has promoted progress with private sector leaders, demonstrating best practices in achieving deep GHG reductions across a range of building types. Meanwhile, the City has led by example by implementing energy efficiency retrofits and piloting new technologies across the large portfolio of City-owned and City-operated buildings. These efforts have resulted in reduced GHG emissions from buildings, improved energy efficiency, and lower energy costs for New Yorkers.

In 2014, with Mayor Bill de Blasio's commitment to 80 x 50, the City released *Built to Last*, a 10-year plan to catalyze the market for energy efficiency and clean energy services and reduce building-based emissions 30 percent by 2025. The City also pledged to continue leading by example by committing to retrofit every City-owned building with significant energy use and installing 100 MW of solar power by 2025. Altogether, *Built to Last i*ncludes 22 initiatives that the City is now implementing.

To identify the steps necessary to place buildings on the pathway to achieving 80 x 50 citywide, the City convened the TWG as a group of experts to identify leading edge standards for new construction and substantial renovations and the systems-specific opportunities for existing buildings that are necessary to transform the City's building stock. The TWG also evaluated financial and regulatory structures and assessed the operations, maintenance, and training that are necessary to enable this transformation. In April 2016, the City released the *TWG Report*, which included additional policies and programs to help place buildings on a pathway to 2050.

Building on this progress, the City will pursue the following eleven strategies to transform new and existing buildings for a low-carbon future.

Implement cost-effective upgrades in existing buildings to improve energy efficiency in the near-term

Cost-effective efficiency upgrades in existing buildings today are essential to begin reducing energy use and GHG emissions in the near-term. Buildings owners must install high efficiency equipment at the time of replacement and begin implementing other common sense efficiency measures to save energy costs quickly.

The GGBP requires owners of large buildings over 50,000 square feet in floor area to make common sense upgrades to building systems, including lighting upgrades to meet current codes (Local Law 88 of 2009, or LL88), sub-metering to measure tenant energy use

(LL88), and retro-commissioning to bring existing energy-using systems to optimal efficiency (Local Law 87 of 2009, or LL87). The GGBP also requires energy and water use benchmarking (Local Law 84 of 2009, or LL84) and energy auditing to provide energy use transparency (LL87). The City has committed to expanding the GGBP benchmarking, lighting upgrade, and sub-metering requirements to owners of mid-sized buildings that are 25,000 to 50,000 square feet in floor area. The City also committed to improving compliance and enforcement of the GGBP laws by enhancing staff capacity at the NYC Department of Buildings (DOB).

The City completed the phase-out of No. 6 heavy heating oil in June 2015 and set the deadline for No. 4 oil phase-out by 2030. In addition, the City has enacted more than 50 recommendations from the Green Codes Task Force and 16 recommendations from the Building Resiliency Task Force to improve the city's building codes and increase the sustainability and resiliency of our buildings. With the release of the *TWG Report* in April 2016, the City will implement the most cost-effective efficiency measures identified by the TWG as soon as possible through new codes and programs. The TWG found that upgrades to buildings' steam heating distribution systems represent one of the single largest potential reductions in GHG emissions of all cost-effective efficiency measures. As such, the City will enhance the requirements for retro-commissioning to ensure better heating distribution system performance for large buildings over 50,000 square feet in floor area. The City will also pursue a similar requirement for mid-sized buildings between 25,000 and 50,000 square feet.

Finally, recognizing that buildings with federal or State historic designations are exempt from the Energy Code because of New York State law, the City has also committed to tailoring energy standards for appropriate application to historic buildings.

Scale up deep energy retrofits that holistically address heating systems, cooling systems, and building envelopes and transition buildings away from fossil fuels

In the long-term, the City will need to develop pathways to implement deep energy retrofits in existing buildings and transition away from fossil fuels. This will include helping building owners and decision-makers to implement these strategies and incorporate them into long-term planning, while working to bring down the potential costs.

In the *TWG Report,* the City committed to requiring large building owners to assess deep energy retrofit strategies as part of their required LL87 energy audit through a simple template developed by the City. To facilitate the voluntary adoption of deep energy retrofits, the City will launch a "High Performance Retrofit Track" of the NYC Retrofit Accelerator program to assist early adopters as they implement these retrofit strategies.

The City will advance efficient electric forms of heating, cooling, and hot water production, such as air source heat pumps with VRF or mini-splits and ground source heat pumps. To develop the market for these technologies, the City is collaborating with other leading U.S. cities, New York State, and manufacturers to educate building owners and remove barriers to installations.

In addition, as part of Local Law 6 of 2016, the City's Department of Design and Construction (DDC) is developing a GIS-driven online screening tool to determine feasibility and cost-effectiveness of installing a ground source heat pump system at any location in the city. The tool will be open to the public and will provide relevant data for building owners and developers across the city.

Expand distributed solar energy and install 1,000 MW of solar capacity by 2030

In *Built to Last,* the City set a goal to install 250 MW of solar on the rooftops of privately-owned buildings, in addition to 100 MW of solar power on City-owned facilities. The City has supported this goal by working with the New York City Solar Partnership to make the city a friendlier market for solar.

In 2006, the Solar Partnership was formed by Sustainable CUNY of the City University of New York (CUNY), the City, and the NYC Economic Development Corporation (NYCEDC) to reduce market barriers for investing in solar, attract solar energy companies to the city, and increase solar energy production capacity. The City has supported the Solar Partnership to extend solar energy to communities that have historically lacked access to clean energy, allowing the Partnership to scale up two new and innovative solar programs. Shared Solar NYC supports community shared solar projects, where multiple customers can invest in a solar installation, providing opportunities for New Yorkers to invest in solar regardless of home ownership (see Energy chapter). Solarize NYC is a citywide group purchasing program that can reduce solar costs for homeowners by 10-20 percent. The Solar Partnership is also working to increase the

Solarize CB6

The NYC Solar Partnership developed a pilot Solarize campaign in Brooklyn Community Board 6 (Solarize CB6) in 2015. The Partnership and community representatives selected two solar installers through a competitive process. Solarize CB6 held public educational workshops and participated in community events, ultimately reaching more than 660 residents and businesses. more than 350 people signed up for solar siting assessments, representing over 400 buildings. As a result, over 140 kW of solar capacity was installed at 25 percent less than the average cost for residential installations in the area.

resiliency of communities by incorporating energy storage with solar installations through Sustainable CUNY's Smart Distributed Generation (DG) Hub.

The Solar Partnership has worked with City agencies to reduce many of the barriers faced by property owners and installers by helping to develop streamlined City permit applications and other process improvements. DOB has reduced the average turnaround time for solar PV plan reviews from four to eight weeks to less than a day. Process improvements at the Fire Department of the City of New York (FDNY) have also improved the outlook for solar, including lowering the pitched-roof threshold that has allowed for larger solar PV projects to be safely installed on an additional 5,000 New York City buildings. The NYC Department of City Planning (DCP) has also successfully introduced changes to zoning that established parameters to allow rooftop solar installations on buildings throughout the city.

Building on this progress, the City is now expanding the citywide installation target for private and public properties to 1,000 MW by 2030. The new target builds on the success of existing programs and the impressive recent growth of the solar market in the city, as well as the introduction of promising technologies such as solar canopies and new market structures such as community shared solar. The City's expanded solar target will also complement the City's new goal to install 100 MWh of energy storage by 2020 (see Energy chapter).

The City will pursue new programs and initiatives to support its expanded solar target. The City has increased its investment in Solarize NYC to serve up to eight communities each year through 2025 to enable greater solar adoption on individual buildings. The City has also advocated to the State for the extension of the property tax abatement for solar PV systems that expires at the end of 2016. Finally, the City will continue its engagement with the State to help shape policies to support community shared solar programs to facilitate adoption in New York City (see Energy chapter).

Ensure building decision-makers have access to building energy use information

Building energy use information is essential for building owners, decision-makers, and occupants to understand energy consumption and prioritize investments. The GGBP requires large building owners to complete energy and water use benchmarking once a year (LL84) and to complete an energy audit and retro-commissioning once every 10 years to repair equipment deficiencies and identify efficiency opportunities (LL87). The City has committed to bringing all mid-sized buildings over 25,000 square feet in floor area under the requirements of the GGBP. As part of this anticipated expansion, the City launched the NYC Benchmarking Help Center in 2015 to provide technical assistance and support for all covered buildings in the benchmarking process.

To facilitate access to energy information in City-financed affordable housing, the NYC Housing Preservation and Development (HPD) and the NYC Housing Development Corporation (HDC) now require owners and managers of buildings that enter their financing programs to benchmark their energy and water use. Pre-qualified vendors will provide automatic utility uploads into an accessible platform that displays utility usage. This will allow property owners and managers to control and reduce utility costs through targeted efficiency improvements.

The City continues to push for energy use information to become more accessible and transparent for building occupants and tenants. In the *TWG Report*, the City committed to develop a comparative metric for commercial tenant energy use and a voluntary benchmarking program for commercial tenants to record and share building energy use information. The City will also seek to require sub-metering in non-residential tenant spaces that are larger than 5,000 square feet in area and require the disclosure of energy use and cost information for all real estate transactions.

Provide assistance to the private sector to accelerate adoption of energy efficiency and clean energy
It is challenging to implement energy efficiency and clean energy upgrades in buildings. There is a range of financing, incentive, and educational resources to help, but these can be difficult for building owners and decision-makers to navigate. The City has created multiple programs to assist the private sector and accelerate the implementation of these upgrades.

In September 2015, the City launched the NYC Retrofit Accelerator, a free program that offers advisory services to building owners and operators during all of the steps required to successfully complete water and energy efficiency projects. In 2016, the City launched Community Retrofit NYC as a complementary program specifically for small and mid-sized multifamily building owners in central and northern Brooklyn and southern Queens. Community Retrofit NYC also serves to create a pipeline for HPD's new Green Housing Preservation Program that provides low- and no-cost financing for efficiency upgrades as part of a broader scope of work in exchange for an affordable housing agreement. By 2025, these programs are projected to reach up to 20,000 buildings and reduce the city's GHG emissions by nearly one million metric tons. Through the NYC Retrofit Accelerator and Community Retrofit NYC, the City also works closely with the New York State Energy Resource and Development Authority (NYSERDA) and the local utilities to deliver financial incentives for efficiency measures and ensure they are tailored to industry needs.

Going forward, these programs will provide guidance to implement key efficiency measures on a voluntary basis. This includes an outreach and assistance campaign to be launched through the NYC Retrofit Accelerator in the fall of 2016 that is dedicated to helping building owners and decision-makers upgrade their steam heating distribution systems.

The City also continues to collaborate with private sector leaders. The NYC Carbon Challenge is the City's voluntary leadership program for private and institutional organizations to reduce their building-based GHG emissions by 30 percent or more over ten years. Since 2007, more than 75 participants have accepted the NYC Carbon Challenge, representing over 265 million square feet of real estate and accounting for seven percent of the city's building-based emissions. Participants have reduced their carbon intensity by an average of 19 percent and ten participants have already achieved the GHG reduction target. In addition, twelve participants have now extended their commitments to a 50 percent reduction in GHG emissions by 2025—paving the way with innovative strategies and best practices to achieve these deep carbon reductions.

NYC Retrofit Accelerator Assistance for Steam Heating System Upgrades

More than 70 percent of large buildings in New York City use steam heating distribution systems, and these systems are rarely replaced and are often not regularly maintained. This can result in energy waste, clanging pipes, and uncomfortably cold spaces and overheated rooms in the same building. To help address this major source of the city's GHG emissions, the NYC Retrofit Accelerator is developing outreach and assistance to encourage and streamline upgrades to steam heating systems. This will build demand for these upgrades to help building decision-makers successfully complete the steps required to implement holistic, common-sense solutions. To ensure program participants have access to trusted contractors, the City has qualified and trained staff from the city's major heating service firms to implement this work. As a result, building owners and residents will save on heating costs and will no longer need to open a window in the dead of winter to cool an overheated apartment.

Streamline regulatory processes for building energy efficiency and clean energy
In April 2012, New York City Council adopted the Zone Green Text Amendment to the Zoning Resolution. The Amendment allows for external insulation of existing buildings, in conjunction with related changes to the State Multiple Dwelling Law; removes floor area penalties for thicker, highly efficient exterior walls when new buildings outperform City Energy Code; allows greater flexibility for the location of efficient air conditioning equipment; allows shading of windows to reduce summer cooling needs; and allows solar electric and hot wa-

ter systems to be added on the rooftops of any building, new or existing, in the city.

To further remove barriers to implementing efficiency projects, the City will work with the NYC Landmarks Preservation Commission (LPC) to update its rules and procedures for implementing efficiency and clean energy upgrades in landmarked buildings and neighborhoods, such as restrictions on size, height, and visibility, and addressing areas of uncertainty. The LPC recently provided additional guidance for solar installations on landmarked buildings, to clarify the standards for "minimally visible." On a state level, the City will pursue amendments to the State Multiple Dwelling Law to remove requirements in conflict with energy efficiency standards.

Ensure building owners can finance energy efficiency projects

In 2009, the City created the New York City Energy Efficiency Corporation (NYCEEC) as a non-profit finance company that provides loans and alternative financing solutions for energy efficiency and clean energy projects. NYCEEC finances projects across all building types and neighborhoods for energy efficiency and clean energy technologies.

In the City's *Housing New York* plan, the City committed to financing energy and water efficiency measures in affordable housing as part of a moderate rehabilitation scope of work financed by the HPD or HDC. The Green Physical Needs Assessment (GPNA), released by HDC in 2015, integrates energy and water audit protocols into a physical needs assessment to ensure that the holistic needs of a property are addressed. HPD also launched the Green Housing Preservation Program in 2015, which provides no- and low-cost financing for efficiency improvements along with moderate rehabilitation work for small- to mid-sized multifamily buildings. In 2016, HPD closed the first six projects in this program.
In 2012, HDC launched the Program for Energy Retrofit Loans (PERL) to help finance energy efficiency projects in large affordable properties that must comply with the City's heating oil regulations and energy auditing and retro-commissioning requirements. HDC is now redesigning PERL and is working with NYCEEC on an energy services agreement model that fits with HDC projects and will allow loans to be underwritten to projected savings.

In addition to these options, there are numerous energy efficiency financing and incentive programs available in New York City through NYSERDA and the local utilities. The City created the NYC Retrofit Accelerator and Community Retrofit NYC to help building owners and decision-makers to identify and navigate these resources and examine opportunities to lower hard and soft costs of completing projects. The City will continue to work with NYSERDA and the utilities to identify new financing and incentives and will expand NYCEEC, which is a formal partner for the NYC Retrofit Accelerator, to provide increased financing and guidance to a greater number of buildings.

Achieve exceptional energy performance for new buildings and substantial renovations

The City first established a local Energy Conservation Code in 2009 (the Energy Code), providing the City with the ability to enact standards that are more stringent than State requirements. Since 2009, the City has consistently updated the Energy Code. Most recently, the City enacted the 2016 Energy Code which exceeds the State standards and achieves at least an 8.5 percent reduction in energy use in new commercial buildings and at least a 25 percent reduction in energy use in new residential buildings as compared to the current standards. The City's affordable housing agencies require additional energy and sustainability standards for all new buildings and substantial renovations financed by the City by requiring a tailored version of the Enterprise Green Communities Criteria (EGCC), a comprehensive green building framework designed for affordable housing. The City has also expanded enforcement of the Energy Code to ensure that new buildings realize the necessary energy use reductions

Despite these advancements, the TWG found that a holistic approach to the Energy Code is necessary to significantly reduce GHG emissions from new buildings and substantial renovations while also potentially reducing construction costs.[12] New York City will initiate a fundamental change to the Energy Code by working together with industry and City Council to introduce requirements for new buildings and substantial renovations to be designed to a whole building energy performance standard. The performance-based Energy Code will include an effective metric by building type that defines an energy performance target and accounts for the varying uses and occupancy intensities, allowing for variation across building types. Because the market needs time and resources to adjust, the City will phase

in this change by first requiring new and substantially renovated buildings to report on this new metric in 2019 and then requiring energy performance design targets beginning in 2022.

Building on the success of the Brussels Exemplary Buildings Program, the City must develop proof of concept and allow the industry time to adapt. The City can launch a large-scale program to award the design and construction of very-low energy buildings and provide education, training, marketing, and other incentives for competition participants, as well as additional market support to help reduce the costs of related products and services. The data and industry experience from the program can help inform the development of the metric and targets for the new performance-based Energy Code.

The City's affordable housing agencies are leading the charge towards high performance new construction and substantial renovations. In May 2016, HPD released SustaiNYC, a request for proposal for a site in East Harlem, which includes the requirement for achieving Passive House standards and will deliver housing affordability critical to the community. In addition, at least five other affordable housing developments in the city are pursuing Passive House certification in various stages of development. The City sees this as the new frontier of all residential design and construction and will learn from SustaiNYC to scale up this type of construction across its affordable housing stock.

Lead by example in City-owned buildings

The City has the opportunity to lead innovation and industry experience by using the thousands of buildings it owns and operates as laboratories for energy efficiency and sustainability. Since 2005, all City-owned developments receiving a certain amount of City funding have been required to achieve a Leadership in Energy and Environmental Design (LEED®) rating level of Certified or Silver. DDC and the City's School Construction Authority (SCA) have pursued even more ambitious energy design in their new projects, such as the Kathleen Grimm School for Leadership and Sustainability at Sandy Ground that was built to net-zero energy standards. DDC also recently expanded the scope of its commissioning contracts to include energy auditing and identify more opportunities to improve energy performance at the outset of its projects. This will include building envelope commissioning to optimize the thermal performance and airtightness of building exteriors and ensure that they are built and tested to specifications.

Kathleen Grimm School for Leadership and Sustainability at Sandy Ground

The Kathleen Grimm School for Leadership and Sustainability at Sandy Ground (Public School 62) is the first "net-zero energy" school constructed in New York City and one of the first of its kind worldwide. The two-story school is 68,000 square feet and serves 444 pre-kindergarten through fifth grade students. The design reduces energy use by roughly 50 percent as compared to a standard new NYC public school by using an ultra-tight high performance building envelop, daylit corridors, energy recovery, a geothermal well field, and demand-control ventilation. The building offsets the rest of the energy use with wrap-around solar PV panels that are placed on the entire roof area and the south façade, giving the building its iconic skin, and includes solar thermal panels to provide domestic hot water and supplement the heating system.

Photo credit: NYC School Construction Authority

In March 2016, the City enacted Local Law 31, requiring all new capital projects for City-owned properties to be constructed to consume at least 50 percent less energy than buildings constructed to today's standards. As part of this initiative, DDC is also conducting a study to demonstrate how all new City-owned buildings can be designed to achieve Passive House standards by 2030.

Solar PV Installation at DCAS Facility
Photo credit: NYC Department of Citywide Administrative Services

The City's experience will help generate data and industry expertise that will be helpful when developing the new performance-based Energy Code for all buildings. The City's efforts will also provide a training ground for the skills that will be necessary for local professionals and contractors to develop and construct very–low energy buildings.

In 2014, the City committed to investing over $1 billion to complete efficiency improvements in every municipal building with significant energy use and installing 100 MW of on-site renewable power by 2025. As part of this commitment, the City announced a major expansion of programs administered by the Department of Citywide Administrative Services (DCAS) to accelerate efficiency improvements in City-owned properties.

DCAS invests in high-value energy efficiency projects through its Accelerated Conservation & Efficiency (ACE) program, which it has recently expanded to reach additional City agencies. The City is also developing new contracting mechanisms to implement deep retrofits in key City-owned facilities, prioritizing buildings with the greatest opportunity for energy savings through a comprehensive retrofit, and pursuing pilots for clean energy technology on selected properties. To date, DCAS has completed over 1,000 energy efficiency and clean energy projects across 675 buildings, which have reduced GHG emissions from City-owned buildings by an estimated 120,000 metric tons of carbon dioxide equivalent (tCO2e) annually. The City collects and shares energy use information about its buildings through regular benchmarking, energy audits, and retro-commissioning for buildings 10,000 square feet and larger.

The City is also investing in renewable energy and energy storage technologies. The City has installed 8.8 MW of solar PV across 52 buildings, and is on track to reach a quarter of its 100 MW goal by the end of 2018. This includes a 15 MW Power Purchase Agreement (PPA) to install rooftop solar on 88 additional public buildings, including 66 schools. Wherever possible, solar PV installations will be paired with energy storage systems to provide peak load shaving and emergency backup power, which will be prioritized for schools serving as emergency shelters, fire houses, homeless shelters and community centers. To support expanded solar installations, the City passed Local Law 24 of 2016, requiring DCAS to assess the solar PV potential of public buildings' rooftops to inform a citywide strategy for the siting and procurement of solar PV systems at municipal facilities.

The City has also established a solar curriculum that is being incorporated into classroom learning in public schools to help bring the benefits of solar energy to life. DCAS and the City's Department of Education (DOE) partnered with Solar One, a non-profit organization, to provide curriculum, classroom supplies, and professional development training to teachers whose schools received solar PV installations.

The New York City Housing Authority (NYCHA), which provides housing for more than 400,000 New Yorkers in its public housing portfolio, has pledged to reduce the energy used per square foot in its buildings by 20 percent by 2025. NYCHA's 10-year NextGen NYCHA Sustainability Agenda includes strategies for portfolio-wide energy efficiency upgrades, smart buildings technologies, and deep energy, whole-building retrofits for specific buildings.[13] NYCHA plans to attract $300 million in private capital through energy performance contracts, which will fund upgrades for large scale retrofits. For small buildings and scattered sites, NYCHA will leverage New York State and utility-run efficiency programs to reduce energy use and secure $30 million in public and private incentives by 2025.[14] All new NYCHA construction projects will be required to conform to the New York City-specific requirements outlined as Enterprise Green Communities Criteria, while substantial and moderate rehabilitation projects will also be required to meet new energy standards. NYCHA will also work with HPD and HDC to require or encourage ultra-low energy buildings in requests for proposals to develop housing on unused NYCHA properties.

DCAS and DDC have partnered to implement a new Low Energy Pilot Program to optimize energy performance in capital projects and support the integration of energy efficiency into the City's design guidelines and capital planning. The City will complete an Energy Master Plan on all new DDC-initiated capital projects, which will include site-specific recommendations for deep energy reduction measures that will be selected based on a holistic cost-benefit analysis. The pilot will next be expanded to the SCA.

DCAS and DDC are also partnering on a pilot to incorporate solar PV as part of DDC capital construction projects, which could include solar canopies on municipal parking lots, electric vehicle charging stations, and extended life of the parking lot surface. In addition, the City is assessing wastewater treatment plants and other properties for their solar PV potential to offset public building energy loads.

Prepare New York City's workforce to deliver high performance buildings

The tens of thousands of architects, engineers, developers, building operators, energy service providers, contractors, manufacturers, and tradespeople in New York City are a critical link to achieving and maintaining energy and GHG reductions from across the city's buildings.

The City created the Building Energy Exchange (BEEx) in 2010 as an independent non-profit organization to drive energy efficiency in the built environment through a first-of-its-kind resource center in downtown Manhattan. BEEx provides educational resources, exhibits, and targeted research for the industry on energy efficiency technologies and strategies. The resource center serves as a hub for the NYC Retrofit Accelerator and for activities that help building owners, operators, and designers understand and implement energy efficiency and clean energy upgrades.

New Yorkers currently have access to a range of external trainings in energy efficiency best practices through organizations such as the Real Estate Board of New York (REBNY), Buildings Operators Management Association NY (BOMA NY), Urban Green Council, and others. A key service provided by the NYC Retrofit Accelerator is to connect building decision-makers, staff, and industry professionals with these trainings and provide additional trainings where there are gaps. This will help reach new segments of building decision-makers, including property managers and real estate professionals.

The City is committed to expanding access to these trainings for the next generation of building operators and decision-makers to ensure better building performance and provide new pathways for career advancement. The City has committed to creating a new building operator training program that will be practical and tailored to the needs of staff in underrepresented building types, including small, mid-sized, and affordable buildings.

The City has expanded operations and maintenance training for its municipal-owned buildings staff. These include the Preventative Maintenance Collaborative, which strategically funds skilled staff, tools, and materials for agencies to better manage and maintain municipal buildings, and the Expenses for Conservation and Efficiency Leadership (ExCEL) program, which provides City agencies with an additional opportunity to apply for non-capital specific funding to further support operations and maintenance improvements on a competitive basis. In addition, as part of its NextGen NYCHA Sustainability Agenda, NYCHA will begin implementing training and retro-commissioning initiatives to address over- and under-heating problems common throughout NYCHA properties.

To ease compliance with New York City's existing operations and maintenance laws and regulations, the City will aggregate the relevant laws and regulations into one central resource to make requirements accessible. The City will also include lessons learned from the Preventative Maintenance Collaborative in City-owned buildings and best practices from NYC Carbon Challenge participants to develop guides that assist owners of various building types to develop their own building-specific operations and maintenance plans.

Position New York City as a global hub for energy efficiency and clean energy technology

NYCEDC supports clean technology entrepreneurship and urban innovation through a program called Urbantech NYC. The initiative offers to emerging companies incubation and "step-out" spaces, prototyping equipment, commercialization support, and shared resources such as mentorship and demonstration opportunities. Since 2014, the Urban Future Lab, including the ACRE Incubator, has helped dozens of early-stage clean tech companies, stimulating innovation and economic growth while generating new jobs for New Yorkers. In 2016, NYCEDC activated two new Urban Technology Growth Hubs at Grand Central Tech in Midtown Manhattan and the Brooklyn Navy Yard.

IDEA Program Demonstrates Innovative Energy Storage Systems for Buildings

Recognizing the importance of energy storage technologies to improve resiliency for public facilities and scale up renewable technologies, DCAS and NYC Health + Hospitals are advancing two energy storage demonstration projects as part of the City's IDEA program. Through this program, the City is piloting the Uni Energy Technologies (UET) ReFlex vanadium flow battery at Jacobi Hospital and the Encell Technology, Inc. fused ion battery at Queens Hospital. These projects will contribute to the City's new goal to create 100 MWh of energy storage by 2020, demonstrate energy savings through peak load reduction, and inform applications in future projects, such as pairing storage with solar PV to enhance building resiliency.

The City is also building on NYCEDC's Applied Sciences NYC initiative to expand world-class applied sciences and engineering campuses. In 2011, the City announced the Cornell Techn on campus on Roosevelt Island, which will nearly double the number of full-time engineering students enrolled in New York City Masters and Ph.D. programs. The new campus itself will also pave the way for high performance buildings, with the construction of the tallest Passive House building in the world underway. The Applied Sciences NYC initiative also includes Columbia University's Data Science Institute and New York University's Center for Urban Science and Progress (CUSP). CUSP is now a recognized leader in building energy analysis, most recently partnering with the City to release New York City's Energy and Water Use 2013 Report analyzing the City's 2013 benchmarking and energy auditing data.

The CUNY Institute for Urban Systems Building Performance Lab (BPL), founded in 2006, is another initiative to advance high-performance building operations and practices. The BPL provides continuing education programs for facility managers, building operators, and energy professionals; internships for CUNY students; and building systems research and development. The BPL has also created training curriculums used across the City.

The City has continued to advance investment in emerging entrepreneurs through its own purchasing power. DCAS's Innovative Demonstrations for Energy Adaptability (IDEA) program engages vendors of new or under-utilized energy technologies to test their solutions in City-owned buildings. DCAS has advanced four phases of the IDEA program, focusing on building controls, energy storage, heating and cooling system optimization, and innovative renewable energy technologies. DCAS will share results from the successful technologies with the private sector and other City agencies through a central clearinghouse of case studies, performance data, and analytics.

Laying the Foundation for the Future

To achieve 80 x 50, nearly every building in NYC will need to complete a deep energy retrofit that holistically addresses heating, cooling, and the building envelope. There will also need to be a significant shift away from fossil fuel-based heating and hot water systems towards renewable energy sources and efficient electric technologies. Building owners and decision-makers will need to improve operations and maintenance and empower tenants and residents to manage their energy use. The City must also move as quickly as possible towards a performance-based Energy Code in new construction and substantial renovations that will achieve ultra-low energy buildings. Buildings can also play an important role in scaling up distributed renewable energy resources, such as solar PV, and community-scale solutions, such as district heating and cooling networks, but coordination barriers and regulatory hurdles will need to be addressed.

The City must support the implementation of deep energy retrofit strategies in private sector buildings and lead by example by testing these strategies and emerging technologies in City buildings. Renewable and efficient electric technologies for heat and hot water production are viable today, but they will need to be supported by policies and programs to encourage wide-scale adoption. Building owners and decision-makers will need clear guidance on how to phase in retrofits and provided sufficient time for capital planning. Building tenants and residents will also need to do their part to save energy and will need to be empowered with smart ways to control their energy use and costs.

Buildings have a critical role to play to achieve our solar and energy storage targets, and the City will need to support these efforts. Solar PV technologies are rapidly improving in terms of both efficiencies and design. Energy storage technologies are also improving, which increase the usable energy from renewable technologies. Continued efforts to overcome market barriers, streamline permitting, and alleviate other regulatory impediments will be important to scale these evolving technologies and realize the full potential for energy efficiency and distributed renewable energy. As a result, the City will create new jobs and expand the industry of building professionals in high demand both locally and globally.

Building owners, decision-makers, and residents will need educational, financial, and technical resources to make informed investments. This includes information about their building energy use, new financing products and incentives to cover the costs, more streamlined regulatory processes, and assistance navigating these resources. Wide-scale training for industry professionals, contractors, and building staff will be necessary to implement a performance-based Energy Code, as well as to achieve and maintain energy savings in existing buildings.

The City can and will continue to be a leader in the effort to improve the efficiency, affordability, and resiliency of its building stock. The City will continue to lead by example in its own buildings, and will develop new programs and policies over the next three decades to transform the city's buildings to ultra-low energy structures that are comfortable and affordable. As always, the City will work closely with the State and federal government and its private sector partners to ensure that these policies are adapted to the needs of the industry while also realizing our ambitious climate goals.

Buildings Strategies	Energy	Buildings	Transportation	Waste
Implement cost-effective upgrades in existing buildings to improve energy efficiency in the near-term		●		
Scale up deep energy retrofits in existing buildings that holistically address heating systems, cooling systems, and building envelopes and transition buildings away from fossil fuels	●	●		
Expand distributed solar energy and install 1,000 MW of solar capacity by 2030	●	●		●
Ensure building owners and decision-makers have access to building energy use information		●		
Provide assistance to the private sector to accelerate adoption of energy efficiency and clean energy	●	●		
Streamline regulatory processes for building energy efficiency	●	●		
Ensure building owners can finance energy efficiency projects	●	●		
Achieve exceptional energy performance for new buildings and substantial renovations	●	●		
Lead by example in City-owned buildings	●	●	●	●
Prepare New York City's workforce to deliver high performance buildings	●	●		
Position New York City as a global hub for energy efficiency and clean energy technology	●	●	●	●

Transportation

In 2050...

We envision that getting around the city will have become dramatically safer, cleaner, and more convenient. Mobility will have largely become an on-demand service with mobile applications allowing New Yorkers to plan the most efficient route from Point A to Point B, optimizing among available options such as the subway, bus, bike share, ferry, or a shared mini-bus, with seamless payment within the entire region and across all modes.

Sustainable modes of transportation—walking, biking, and transit—will comprise 80 percent of all trips taken in the city, with the transit system remaining New York's workhorse for moving residents and visitors around, and new development focused around high-capacity transit hubs. Meanwhile, the share of trips taken by automobile will have dropped from 33 to 20 percent with travelers instead relying on app-based shared mobility services. Remaining vehicles will be cleaner and more efficient than today's vehicles. Roughly half of new car purchases will be zero-emission vehicles, and low-carbon fuels will have largely replaced petroleum-based gasoline and diesel. Additionally, the proliferation of autonomous vehicles will have dramatically reduced the need for parking and personal car ownership.

Additionally, by 2050, the City and industry partners will have reshaped the freight network. Goods movement within the city will have shifted somewhat from trucks toward inherently lower-carbon modes, such as maritime and rail freight. Heavy trucks, locomotives, marine vessels, and freight yard equipment will run on lower-carbon fuels, and mini-distribution hubs served by trains and marine vessels will allow consumer goods to be transferred to low- or zero-emission vehicles and delivery bikes to reach their final destinations. Most significantly of all, the City's sustained efforts towards Vision Zero combined with reductions in harmful air pollution from fewer and cleaner vehicles on the road will have greatly reduced public health impacts from transportation.

Achieving 80 x 50: Transportation

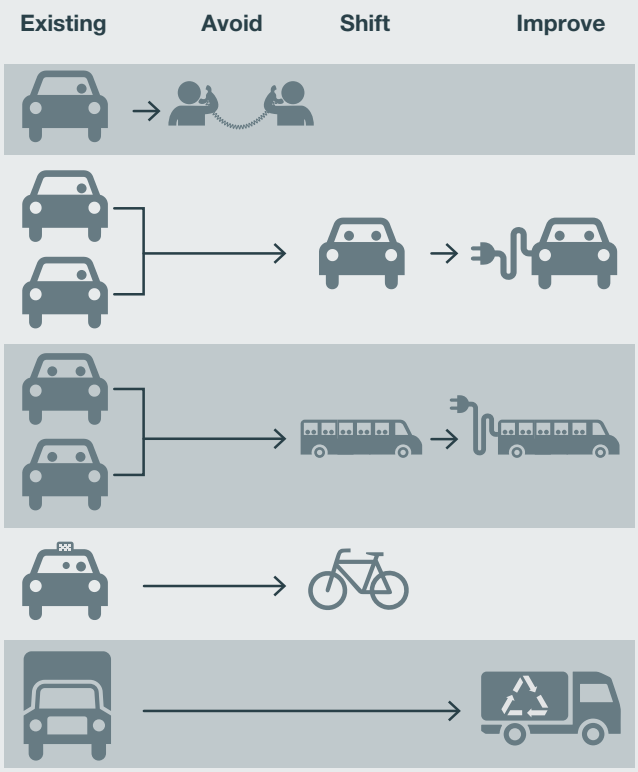
New York City has the highest proportion of trips by modes other than private vehicles—walking, biking, and public transit—of any large U.S. city.[1] Achieving deep emission reductions from this already low base in the transportation sector, therefore, entails even more dramatic changes than might be required in a more car-dependent system. It will also require a holistic approach given the maturity and diversity of the New York metro region's transportation network. There is no "silver bullet."

Reducing transportation-related greenhouse gas (GHG) emissions is rooted in an "avoid/shift/improve" approach. Some trips can be avoided entirely through better integration of transportation and land-use decisions, transportation demand management and better use of data and technology—for example, locating affordable housing units in closer proximity to job centers is an effective way to avoid the need for longer trips. Of the remaining trips, many can be shifted from high-carbon modes (such as single-occupancy private cars or taxis) to lower-carbon modes (transit, biking, walking, shared rides)—this is known as "mode shift." In addition, the technology and fuel mix of all vehicles can be improved through a dramatic shift to electric and other zero-emission vehicles, as well as greater use of renewable or low-carbon fuels and improved vehicle designs. Long-term success in embracing this "avoid/shift/improve" framework will depend on our ability to leverage advances in technology, respond to market signals, influence travel behavior through smart planning and infrastructure investment, engage in fruitful collaboration with State and regional partners, and ultimately, embrace a wholesale change in our transportation culture. These changes will have the added benefits of reducing trip travel time, expanding options for getting around, and improving overall public health through better air quality and increased physical activity.

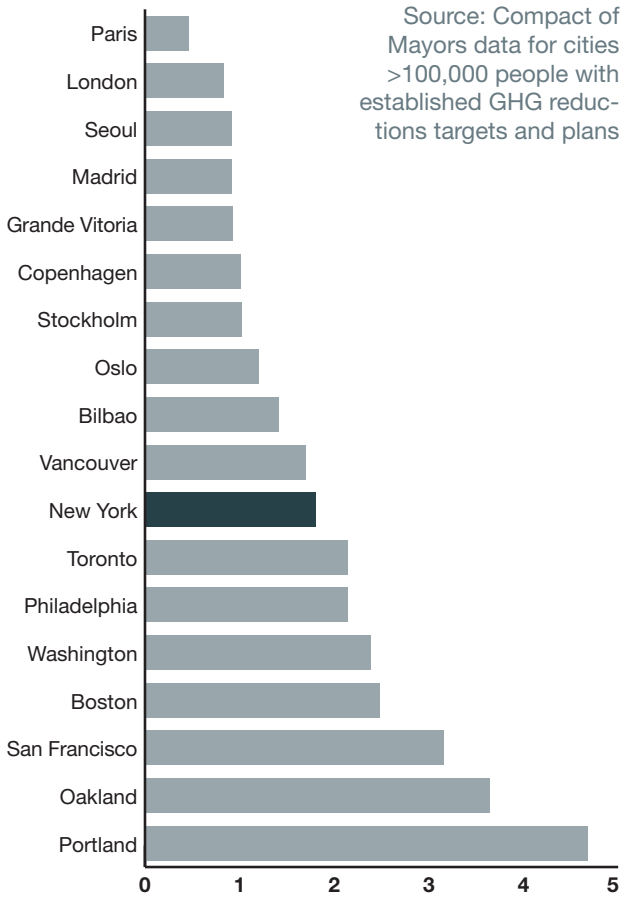
"Avoid/shift/improve" strategies also support the City's OneNYC growth, equity, and resiliency visions. Beyond

Avoid/Shift/Improve

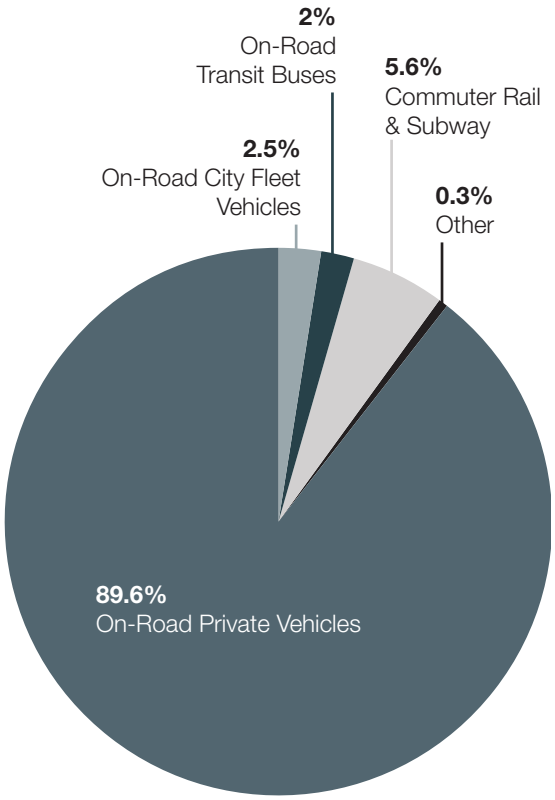
The approaches outlined in this chapter will alter travel patterns in the city between today and 2050 in three fundamental ways. Some trips will be avoided, no longer needed because of improvements in land-use or technology (such as teleconferencing instead of driving to an off-site meeting). Others will be shifted to lower-carbon modes as walking and biking, in particular, become increasingly safe and convenient. Still others will be improved through a transition to cleaner technologies, such as electric powertrains or renewable forms of common fuels like diesel and compressed natural gas. Certain trips will be impacted by more than one element of this paradigm, as when multiple current single-occupancy vehicle trips in gasoline-powered cars that transition to a single shared ride trip powered by electricity.



Transportation GHG Emissions With Peer Cities
(tCO_2e per Capita)



Drivers of Transportation GHG Emissions



climate action, sustainable transportation planning boosts the economy by cutting down on congestion caused by single occupancy vehicles, promotes healthy, active modes of transport such as walking and biking that can reduce the prevalence of chronic diseases, and creates a safer transportation system that leads us toward realizing the "zero" in Vision Zero. Expanding travel choices for New Yorkers who do not have easy access to a vehicle through smart transit investments will also strengthen the critical link between transportation and access to jobs and economic opportunity. In addition, reducing the number of trips and shifting to cleaner vehicle technologies and fuels can reduce emissions of fine particulate matter (PM2.5) and other air pollutants.

Drivers of Transportation GHG emissions

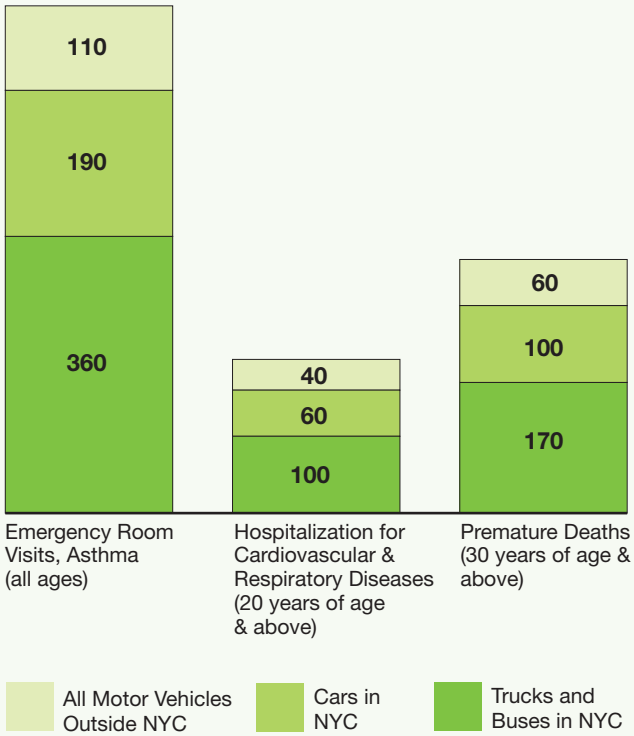
The transportation sector is responsible for 28 percent of citywide GHG emissions. On-road transportation (vehicles, transit and long-distance buses, trucks, taxis, and for-hire vehicles) comprises 94 percent of transportation-related GHG emissions in New York City from the more than 21 billion annual vehicle miles traveled (VMT) on the city's streets. Private on-road light-duty vehicles (i.e., cars) alone account for 78 percent of all transportation GHG emissions.

A majority of VMT in the city (90%) is generated from trips that neither begin nor end in the central business district (CBD, or Manhattan below 60th Street) but rather in upper Manhattan, the Bronx, Brooklyn, Queens, and Staten Island. Some of these miles are associated with trips that begin or end outside the city (36%), but most are contained within the city (54%). Trips that begin and end outside the city ("transboundary trips") make up a small percentage of in-city VMT (6%). Trips associated with travel to, from, or within the CBD are also relatively limited (10%).

Public Health Impacts due to Vehicle Emissions

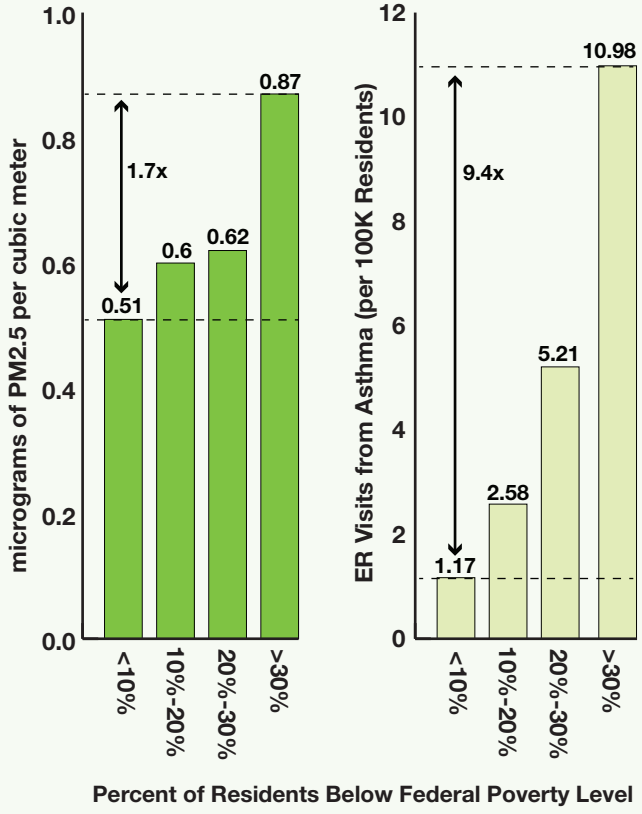
Reducing emissions from traffic in and around New York City can improve public health – especially among our most vulnerable residents. Vehicles emit fine particulate matter (PM2.5), which contributes to multiple adverse health outcomes. The City's Department of Health and Mental Hygiene recently released a study which found that traffic-related PM2.5 causes 320 premature deaths and 870 emergency department visits and hospitalizations each year among City residents. The largest adverse health outcomes came from trucks and buses traveling the City's streets, which account for over half of traffic PM2.5-related health outcomes.

Annual Health Events due to PM2.5 Exposure from Vehicle Emissions (Number of Cases per Year by Source)



PM2.5 Exposure due to Trucks & Buses

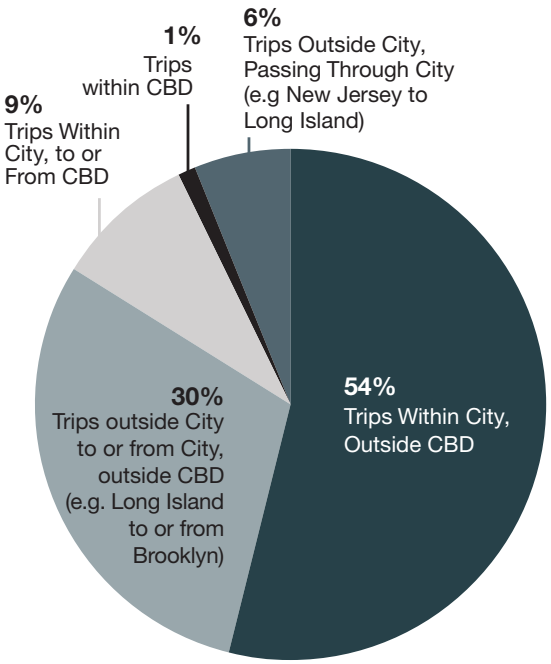
PM2.5-Attributable Health Impacts due to Trucks & Buses



The study also found that traffic-related PM2.5 pollution and its health impacts were greater in the City's poorer neighborhoods. Relative to more affluent neighborhoods, high-poverty neighborhoods had 1.7 times the PM2.5 exposure and 9.3 times the rate of emergency department visits for asthma due to emissions from trucks and buses. By prioritizing attention to the most polluting vehicles and the most burdened neighborhoods, we can help to reduce health inequities in New York City.

Study reference: http://ehjournal.biomedcentral.com/articles/10.1186/s12940-016-0172-6

Share of Total NYC Vehicle Miles Traveled by Trip Origins and Destinations



Business as usual findings

To better understand what it will take to achieve 80 x 50 citywide, the City modeled projected emissions through 2050 from the transportation se ctor under a business as usual (BAU) scenario. This analysis took into account general background growth in the city's population and transportation activity as well as the emissions impacts of relevant previously committed and funded initiatives and regulations at the city, state and federal levels and assumes no further intervention by the City. Under this scenario, transportation-related GHG emissions are expected to decline 36 percent by 2030 and 40 percent by 2050 compared to 2005. These reductions are largely the result of federal fuel economy standards, such as the Corporate Average Fuel Economy (CAFE) standards, as vehicle fleets turn over, as well as prior investments over the last decade that were intended to encourage mode shift. These include the rollout of the first wave of Select Bus Service (SBS) routes, which feature several benefits over standard bus service including traffic signal priority and dedicated bus lanes.

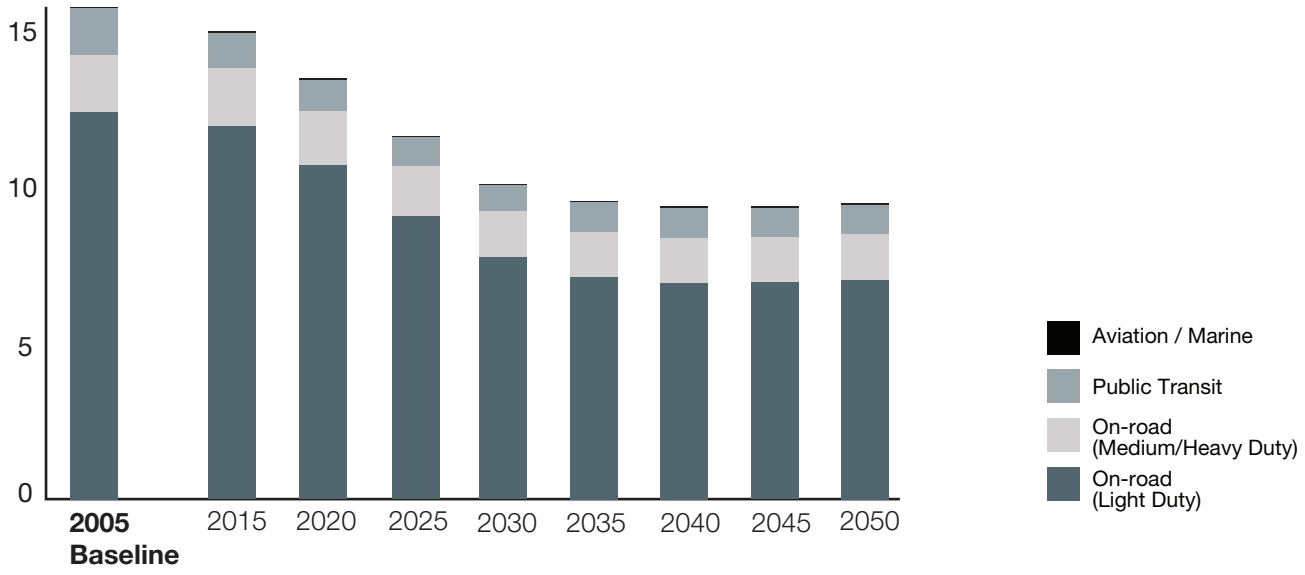
Mobility as a Service

New York has a vast and growing array of transportation options: buses and subways, taxis and ridesharing, commuter vans and on-demand shared rides, bike share and car share. We want to get around in whatever way makes the most sense, whether in terms of cost, time or enjoyment. What if we did not have to worry about how we made our trip and paid for it, but rather could rely on technology to help us get where we need to go using whichever modes work best for a given trip?

Shared mobility, which encompasses any transportation mode outside of driving your own car, presents new opportunities for New Yorkers who currently own personal vehicles to reconsider these major purchases. Shared mobility can mean many things, from point-to-point car share, filling empty seats in on-demand for-hire vehicles, or making what could have been a slow, congestion-filled vehicle trip on a more flexible (and healthy) bike share ride. The common theme is a widening spectrum of choice regarding travel options that blend modes together and provide only the necessary level of service for a given trip. By removing the vehicle ownership element from the travel equation, the number of cars on the road—and parked on the curb—may decrease.

If done right, shared mobility services, along with technology-enabled trip planning and universal fare payment, offer the potential to be even more convenient than today's numerous but mostly separate systems, providing more ubiquitous and affordable mobility to more of the population. Mobility as a service will create a dynamic marketplace of travel options, allowing New Yorkers to more fluidly choose a customized "basket" of transportation modes depending on their needs.

Business as Usual GHG Emissions: Transportation, in Million Metric Tons of Carbon Dioxide Equivalent ($MtCO_2e$)



Therefore, without further action, the City is almost on track to achieve 40 x 30, but is well short of the citywide 80 percent reduction goal for 2050. Private on-road light-duty vehicles are expected to account for 51 percent of transportation GHG emissions in 2030 and 46 percent in 2050, demonstrating the need for additional effort to facilitate the avoidance of certain types of trips,shift others to lower-carbon modes, and expedite the improvement of all vehicle trips to cleaner and more efficient technologies and fuels.

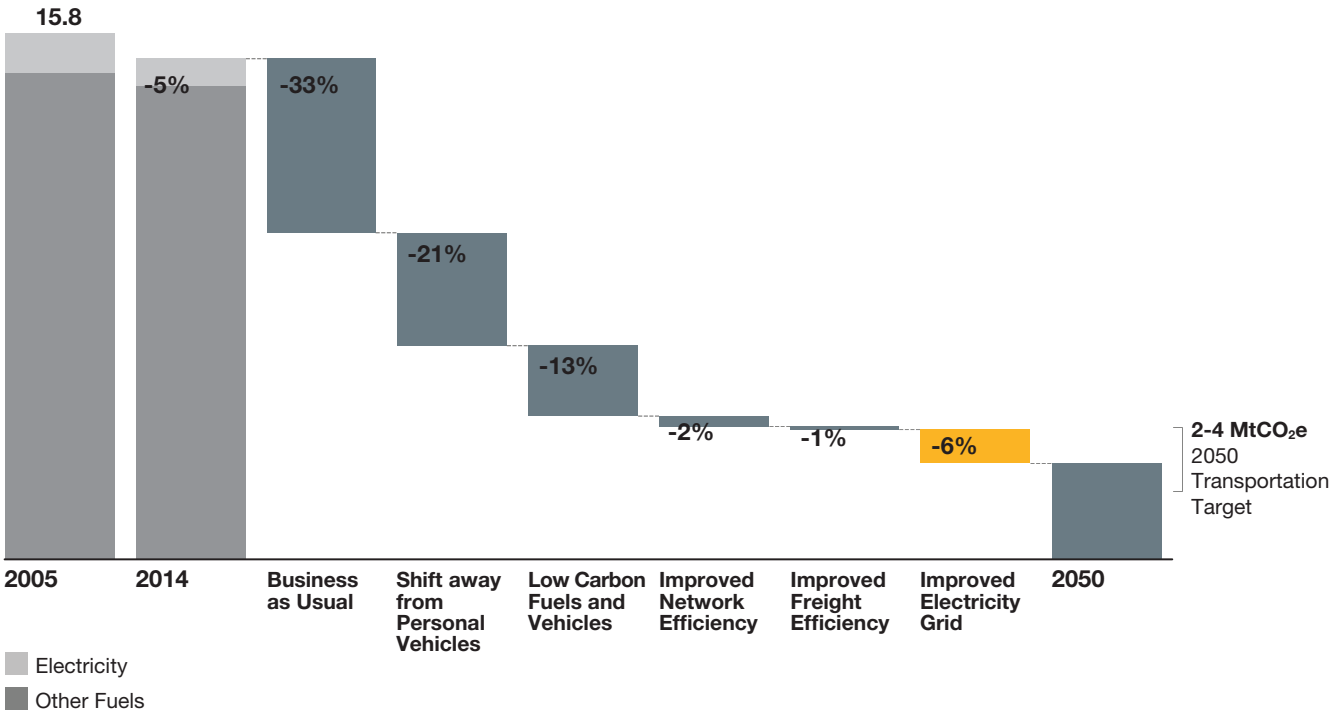
Emerging trends

Shared mobility. The transportation sector is on the verge of more dramatic changes than at any point since the advent of the automobile. Our society is shifting towards a more blended mix of mobility options than has traditionally been the case. These shifts include more shared mobility models, more low-emission vehicles that operate on renewable or low-carbon fuels, and the impending introduction of autonomous vehicles. These shifts have the potential to work in support of GHG reduction and other City goals, such as improving traffic safety, job access, and air quality.

Electric vehicles. In addition to changes in the way New Yorkers get around, a growing recognition of the dangers of climate change and supportive policies are expected to continue to impact purchasing decisions, especially as cleaner vehicle technologies mature. While battery electric, plug-in hybrid, and fuel cell vehicles comprise a very small share of today's car market, these zero-emission vehicles are projected to comprise 15 percent of new car purchases in 2030 and will be roughly half of all new cars sold in 2050. The trend toward electrification will extend beyond cars, reaching medium- and heavy-duty vehicles as well as non-road equipment and maritime vessels in more limited applications. For instance, shore power (also called "cold-ironing"), or the use of land-side electricity to power onboard systems for ships while at port, has already been deployed for cruise ships in Brooklyn and can greatly reduce idling emissions and improve local air quality.

Renewable and low-carbon fuels. Where no electric alternative is feasible, vehicles will increasingly use renewable or lower-carbon versions of today's petroleum-based fuels. For heavy-duty vehicles, ferries, and other large non-road engines, natural gas is likely to continue its recent market growth. Renewable natural gas from landfill, agriculture, or other non-fossil feedstocks offer an opportunity to provide low-carbon replacements for today's natural gas in the future, and renewable diesel can replace the use of petroleum in any remaining diesel engines.

Transportation 80 x 50 Roadmap ($MtCO_2e$)



E-commerce. A final trend that relates to transportation is the way in which we purchase and consume. The growing popularity of e-commerce has the potential to place additional strain on our street network, even as it reduces consumer vehicle trips and as fleets become more efficient.

80 x 50 Roadmap: Transportation

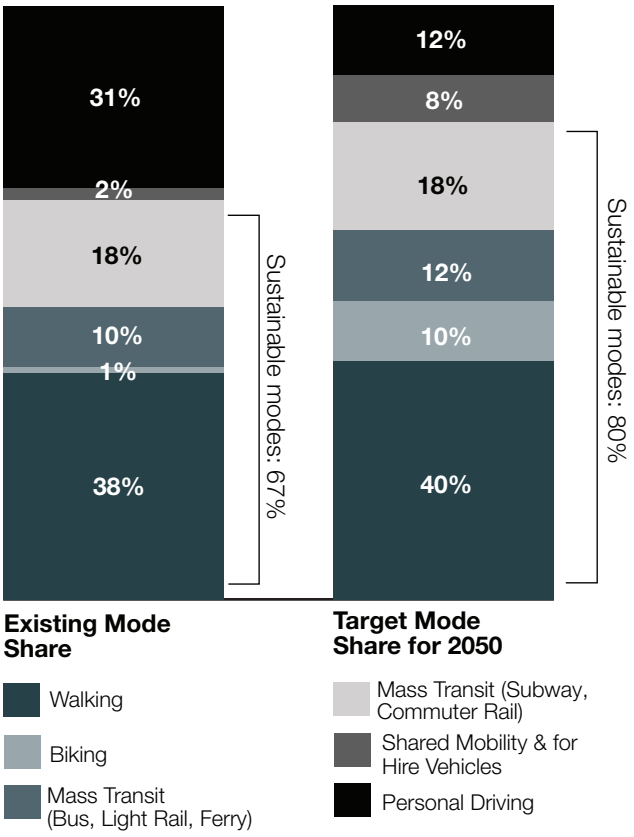
Beyond those initiatives included in the BAU analysis, the City has recently launched or expanded many programs and initiatives that will help the city move closer to 80 x 50. OneNYC includes several programs related to transportation that will result in future emissions reduction, including Vision Zero. The NYC Department of Transportation's (DOT) *Strategic Plan 2016: Safe·Green·Smart·Equitable* (*Strategic Plan 2016*), provides more specificity and additional commitments that will help pave the way towards significant emissions reductions, including increasing the efficiency of freight movement in New York City, dramatically expanding bike infrastructure, and planning for the next generation of SBS and light rail routes.

These recently launched programs are expected to reduce GHG emissions below the BAU trajectory by an additional 6 percent by 2030 and 9 percent by 2050. These programs set New York City on a track to achieve an anticipated 42 percent reduction in transportation-related GHG emissions relative to 2005 by 2030, exceeding the City's 40 x 30 goal. By 2050, these recently launched and expanded efforts are projected to get the City to an estimated 49 percent reduction in transportation-related GHG emissions below 2005 levels.

Since existing initiatives alone will not get us to 80 x 50, the City assessed additional scenarios to understand the level of reductions in VMT and uptake of cleaner vehicles necessary to achieve the goal. The analysis showed that significant adoption of zero-emission vehicle (ZEV) technologies—those that have either zero or near-zero tailpipe emissions and very low lifecycle GHG emissions—and low-carbon fuels such as compressed natural gas (CNG), combined with existing initiatives, could achieve a 51 percent reduction by 2030 and a 71 percent reduction in transportation-related GHG emissions by 2050.

To estimate potential GHG emissions reduction associated with lower VMT, the City tested several scenarios using the New York Metropolitan Transportation Council's (NYMTC) regional travel demand model (the Best Practice Model, or BPM). The results showed that

Mode Shift Targets for In-City Trips



reaching 80 x 50 citywide will require a wide variety of transportation strategies to incentivize a shift away from single-occupancy driving towards lower-carbon modes. BPM simulations also revealed that enhancements to make transit service more convenient are a necessary complement to provide an attractive alternative to single-occupancy vehicle (SOV) use.

Altogether, the analysis found that expanding current commitments and supplementing them with strategies to reduce the number of trips made by personal driving and to shift new vehicle purchases to cleaner technologies can result in GHG emissions reduction of 58 percent by 2030 and 82 percent by 2050 relative to the 2005 baseline. Importantly, this portfolio of actions translates to a mode share of 80 percent for walking, biking, or public transit, whereas these sustainable modes comprise only 67 percent of trips today.

Challenges to address

The efficiency of New York City's transportation system is largely the result of plans and investments made over the past 150 years. The systems that exist today are not easily changed, and the interrelated challenges posed by regulatory and operational jurisdictions are deeply institutionalized.

For many of the strategies necessary to achieve 80 x 50, New York State government including the Metropolitan Transportation Authority (MTA) and New York State Department of Transportation (NYSDOT), regional partners such as the Port Authority of New York and New Jersey and NJ Transit, and federally regulated entities like Amtrak are critical for implementation. Addressing certain transportation needs in the city is complicated due to the City's lack of control over key elements of the system, such as the improvement and expansion of the core transit network, setting of fares, pricing to manage the city's busiest roads and bridges, and the use of cameras for enforcement (e.g., of bus lane restrictions, speeding, and red lights). In order to reach 80 x 50, these partnerships with outside stakeholders will be essential in implementing an "all of the above" basket of strategies that facilitates the necessary transitions.

Another significant challenge to improving the transit network in particular is the magnitude of the funding needed simply to maintain a state of good repair for existing assets, let alone to upgrade and expand the system. New York's infrastructure is aging, and major new funding is required to make the investments necessary to simply keep pace with our global peer cities. This task is all the more difficult because of less dependable federal funding: the federal gas tax, the primary revenue source for the Highway Trust Fund, has not been increased since 1992. There is a need to find innovative ways to fund new investments and, just as importantly, to maintain existing assets.

There are also many challenges associated with wide-scale adoption of new vehicle technologies and low-carbon fuels. Primarily, there is the "chicken-and-egg" problem: investments in electric vehicles are hampered by uncertainty regarding charging capacity throughout the city, while investments in publicly available charging infrastructure are uncertain to pay off as long as demand for charging remains low. In addition to this coordination barrier, the prospect of wide-scale adoption of ZEVs poses its own challenges. Namely, the

charging and fueling infrastructure required to support the level of ZEV adoption necessary to achieve 80 x 50 would place significant demands on the local electricity system and would introduce the challenge of siting infrastructure in a dense urban setting where parking is already at a premium.

Finally, the potential increase in truck trips associated with the growth of internet-based commerce and home deliveries could worsen congestion on our streets and along our curbs. This issue is exacerbated by the city's current lack of significant freight rail connections, which further increases our reliance on trucks to move our goods throughout the city.

Near-term actions to reduce greenhouse gas emissions

The following strategies include a mix of existing and expanded City initiatives along with several new City strategies intended to provide reductions in GHG emissions. The City can implement many of these approaches directly; others will require partnerships with regional stakeholders, New York State government, or others. Taken together, these strategies seek to encourage travel by lower-carbon modes over personal vehicles; minimize congestion and total miles driven through technology, market signals, and new mobility service models; transition towards more efficient vehicles that run on cleaner and renewable fuel sources; and re-envision freight policies to reduce congestion, emissions, and costs. These strategies are also intended to improve the health and quality of life of our communities.

Modernize, expand, and reduce crowding on the city's transit system

New York City already has the most comprehensive transit system in the U.S. To achieve 80 x 50, many more New Yorkers and visitors will need to opt for lower-carbon modes over vehicles, which requires these modes to be safe, convenient, and enjoyable.

In partnership with the MTA, the City continues to launch new SBS lines throughout the five boroughs and has committed to launch ten additional routes by 2021, including two new routes by the end of 2016. The City has also begun a detailed feasibility analysis for the Brooklyn-Queens Connector (BQX), a modern streetcar line planned to connect residents to burgeoning job centers along the Brooklyn and Queens waterfronts that currently lack robust transit access. In addition, the launch of Citywide Ferry Service in 2017 will better meet the transportation needs of growing neighborhoods and provide redundancy for the existing transit system.

The City is also committed to improving critical first- and last-mile trips to and from transit hubs, and is currently exploring the potential for ride-sharing services to meet these travel needs in areas underserved by the subway system. As stated in DOT's recently released Strategic Plan 2016, the agency, in partnership with the MTA, will conduct a study of unmet transit needs in communities across the five boroughs and develop a set of recommendations to meet these needs. Possible recommendations include expansions of Select Bus Service (SBS), the rail system, and streetcars.

Speeding up bus service is critical to reversing the decline in bus ridership and making the bus an attractive alternative to driving. The introduction of paperless all-door boarding on all buses (not just those branded as SBS) would enable buses to spend less time waiting for passengers to board and would have a significant

Image credit: NYC Economic Development Corporation

Protected bike lane at Clinton St. in Manhattan
Photo credit: NYC Department of Transportation

impact on bus service quality and the efficiency of bus travel. The City will continue to advocate for paperless all-door boarding on the MTA's local bus routes as part of the MTA's new fare payment system, in addition to working with the State Legislature to expand the City's authorization to use bus lane enforcement cameras, which are essential to providing more reliable and faster bus service.

The City will also continue to support the expansion of the transit system through its historic $2.5 billion contribution to the MTA's 2015-2019 capital plan, which funds the second phase of the Second Avenue Subway, the Penn Station Access project to bring Metro North trains into Penn Station, and expansion of communications-based train control, which enables more frequent subway service. Working with the Port Authority, Amtrak, and others, the City will also support key investments in the regional transit network, including the Gateway project to expand and enhance trans-Hudson rail service through a new tunnel, station, and track expansion. This support will extend to smaller but equally crucial investments that improve the subway system such as the rollout of the new MTA fare payment system (which will replace MetroCard) and investments in open gangway subway cars to increase capacity. Finally, through a 2017 citywide transit needs study, the City will communicate its priorities for the next generation of major regional capital investments.

Since most improvements in the subway and commuter rail system are the responsibility of State and regional partners, the City will continue to engage with them to plan for major expansions of the transit network. The goal of these improvements is to increase transit use, which could be achieved through reduced fares for commuter rail trips within the five boroughs and more frequent service at commuter rail stations within the city, among other strategies. These improvements will enable more New Yorkers, especially those who live beyond the reach of the subway system, to use the commuter rail network to get around.

Make walking and biking safer, more convenient options for all New Yorkers

Walking and biking are carbon-free modes of transportation that support an active lifestyle, promote public health, and reinforce New York's role as a leader in sustainability among American cities. It is critical to make walking and biking even safer, more convenient, and more enjoyable in order to promote them over car trips, both as primary modes and as first- and last-mile connections to the core transit network.

Consistent with Vision Zero and DOT's Strategic Plan 2016, the City will continue to implement record numbers of Vision Zero street safety projects, including new markings, pedestrian refuge islands, and shortened pedestrian crossing distances, and will invest in the Great Streets program to transform major corridors across the city. DOT will continue to make pedestrian improvements around schools and in neighborhoods with high numbers of senior citizens, create neighborhood open spaces through pedestrian plaza projects using underutilized street space, and improve the streetscape with benches and wayfinding signs, among other enhancements. DOT will also improve accessibility for New Yorkers with disabilities by upgrading the Street Design Manual and capital project standards to reflect the principles of universal access, installing accessible pedestrian signals, investing in an expansion of curb ramps, and conducting new wayfinding technology pilots for visually impaired pedestrians.

DOT is also currently testing new design treatments to reduce left turn conflicts—one of the leading causes of crashes involving pedestrians—and is seeking State authorization to expand the use of speed cameras, which have been shown to reduce dangerous speeding by as much as 50 percent. DOT will also explore how new tools, including stationary and mobile traffic cameras and video processing software, may help DOT to better understand and manage the street network and improve safety, such as by helping the agency diagnose potential safety problems before a serious crash occurs.

While New York remains a walking city, more New Yorkers are biking now than ever before. The City will continue its expansion of a growing bicycle network, with a record 75 miles of bike network to be added in 2016, including 18 miles of protected lanes, and an accelerated annual target of at least 10 miles of protected lanes to build out a more robust protected network. DOT is also expanding its efforts to create bicycle connections across bridges and is advancing efforts to create a continuous greenway loop around the entirety of Manhattan In partnership with Motivate, the parent company of Citi Bike, the City has committed to expand Citi Bike to over 12,000 bikes in over 700 stations by the end of 2017, and is exploring a phase three expansion to bring Citi Bike to all five boroughs. DOT is also developing secure, high-capacity bicycle parking facilities near transit hubs and expanding the popular bicycle corral program for on-street bicycle parking. The City will continue to work with the State Legislature to create a sensible legal framework to regulate pedal-assist bicycles (e-bikes) to improve safety and allow more New Yorkers to travel by this environmentally friendly mode. Finally, DOT will complete a Bicycle Safety Study and Action Plan, along with new measures to assess bicycling progress, improve data collection, and understand travel decisions.

Despite the rapid growth in the city's bicycle network, there are still many areas that lack sufficient bike connections. In addition to planned expansions, the City will emphasize an all-ages and abilities core network of protected bike lanes throughout the five boroughs, and the build-out of key connectors linking neighborhoods to transit hubs. The City will explore opportunities to provide high-capacity bicycle parking facilities near transit stops across the city so that more people can readily access the subway and commuter rail systems. The City will work with the State Legislature and at the federal level to expand commuter benefits for bicyclists and bike share users to encourage the mainstream adoption of cycling.

Ensure that the City's policies prioritize walking, biking, and transit

The strategies to encourage surface transit use, walking, and biking will only be successful if the City prioritizes street space for these modes and makes them attractive alternatives to driving. To do so, the City is expanding sidewalks and pedestrian plazas in areas of pedestrian crowding; hosting events that open up streets for public recreation such as Summer Streets, Weekend Walks, and Shared Streets; building on the Lower Manhattan Shared Streets pilot project; and exploring similar projects in other neighborhoods. In tandem with an improved curbside management strategy, the City will also continue to repurpose on-street parking into space for other uses such as commercial loading, bus lanes, bike lanes, public plazas, bicycle parking, and bike share stations.

Moving forward, the City will continue to encourage walking, biking, and transit and will integrate planning for these modes into the design and operation of streets and into the City's enforcement efforts. Doing so will justify, underpin, and tie together all future efforts to reallocate street space, manage demand, and ultimately reduce emissions from transportation.

As part of this policy, the City aspires to a sustainable mode share of 80 percent by 2050, an increase from 67 percent today and a figure indicated by our analysis to be consistent with an 80 x 50 transportation system. Of this 80 percent sustainable mode share, 40 percent of trips will be made by foot, 10 percent by bike, and 30 percent by transit. The remaining 20 percent of trips in 2050 will still involve vehicles, but a significant number of those trips will shift towards shared rides that more effectively utilize the network by filling empty seats to reduce the total number of vehicles on New York City's streets. The City will also continue to construct bus lanes and protected bike lanes on major streets and explore the expansion of shared streets, based on a successful pilot in lower Manhattan. Additionally, the City will begin planning for opportunities to create car-free or shared streets in dense areas of the city, in the vein of the downtowns of many global peer cities.

Land-use decisions and rules can also influence how New Yorkers live and travel, and the City is committed to promoting growth that supports sustainable, mixed-use, mixed-income communities. Housing New York includes targeted initiatives that identify specific opportunities for new housing in transit-accessible areas, supported by infrastructure and services, with a level of density and mix of uses that supports and encourages walking and bicycling for neighborhood trips.

Leverage technology and data to expand travel options and optimize the transportation network

New York City is experiencing record levels of employment, population, tourism, and economic activity, all of which contribute to added congestion on city streets. The City is making efforts to improve real-time traffic

Autonomous Vehicles: What Does the Future Hold?

Autonomous vehicles ("AVs" or "driverless cars") are coming, and may completely transform the driving experience as we know it, by smoothing vehicular traffic patterns and greatly improving roadway safety. However, the impact of AVs on greenhouse gas emissions is uncertain. While AVs will almost certainly feature cleaner technology than today's vehicle stock, they may still result in more emissions if vehicle miles traveled skyrockets as a product of the increased convenience and safety of driving. On the other hand, if we guide implementation of this emerging technology correctly, we could see truly remarkable societal benefits and still manage to reduce transportation emissions.

Potential advantages of AVs:

- Mobility options increase for those unable to drive
- Crashes, serious injuries and traffic deaths plummet, and we reach Vision Zero
- AVs are managed by transportation network companies and become integrated with an overall shift toward Mobility as a Service
- Most AVs are actually a form of on-demand shared ride, and we see improved efficiency compared to today's typical auto occupancy of under two people per vehicle
- Parking demand plummets, and we reclaim a vast amount of curbside space and repurpose it for more sustainable and public uses
- Vehicles themselves are completely redesigned and become new social spaces in their own right

Potential challenges from AVs:

- Many AVs fall short of coping all of the time with the city's complex traffic environment and thus require distracted drivers to suddenly take over vehicle operation, leading to road crashes, injuries, and fatalities
- Driving becomes so easy that everyone wants to own an AV, and overall VMT skyrockets
- We mainly continue to drive alone, and we see no improvement and in fact worsening traffic congestion
- Demand for curbside space dramatically increases as pick-ups and drop-offs become much more common for both people and packages
- Many AVs are roaming our streets with no occupants as they return from dropping off their owners at work, leading to empty vehicles stuck in their own congestion
- We cater to this new technology and redesign our streets for the benefit of AVs, to the detriment of walking, cycling, and high-capacity public transport
- The City, led by DOT and TLC is currently working to evaluate the potential safety, congestion, social, environmental, and economic impacts of autonomous vehicles and develop a set of policies for federal and state advocacy and to guide future pilot projects.

operations management, but more needs to be done to improve traffic data collection, monitoring, and enforcement. Meanwhile, new mobility services, such as ridesharing, e-hail taxi services, and car sharing offer the potential to reduce the demand for private motor vehicle ownership and use, but also could spur a move away from more GHG-efficient public transportation. The City will continue to explore how these emerging mobility services might best be regulated and guided to support sustainability goals.

The City will continue to make transportation data available to third-party mobile application developers, and generally encourage an open-data environment. We will continue to support MTA's work to update its transit payment technology. There may also be opportunities for the City to explore partnerships with the private sector to foster a seamless "mobility as a service" experience that empowers New Yorkers to plan trips across all modes—transit, bike share, rideshare, and others—in real-time and on-demand. We will study examples from other cities that have implemented formal car-sharing

policies and programs, and will adapt them to our current transportation system, as appropriate, in light of our sustainability goals. The City will likewise explore other opportunities to manage travel demand, such as partnerships with large employers or linking lower-carbon travel choices to the Electronic Benefit Transfer (EBT) program.

In addition, the City and the U.S. Department of Transportation have begun a "connected vehicle" pilot project to test safety applications and vehicle-to-vehicle communication systems. As part of this effort, DOT is developing an Intelligent Transportation System (ITS) strategic plan and is expanding transit signal priority systems for SBS. The City will also continue to expand the use of data analytics to support real-time traffic operations management and encourage compliance with traffic laws. In addition to saving lives, automated speed enforcement and red light camera programs promote good driving behavior and have a significant impact on keeping the network flowing at a steady pace, which reduces congestion and emissions. The City will also continue to work with the State Legislature to expand the use of speed and red-light camera enforcement at high-crash areas and near schools, which will also enhance the efficiency of the roadway network.

Better manage and price parking to encourage efficient travel choices

Through the PARK SMART program, the City has already begun to price curbside parking in commercial areas at variable rates, encouraging efficient levels of turnover and enabling drivers to more easily find parking spaces. Following the success of the PARK SMART program, DOT will begin a more comprehensive analysis of the use of metered parking spaces in commercial districts across the five boroughs. The analysis will inform the development of a 21st-century parking management strategy to increase curb availability for deliveries, customer parking, and eventually pick-up and drop-off of

NYC Clean Fleet

NYC Clean Fleet is the most comprehensive and ambitious blueprint for municipal fleet sustainability in the nation. Unveiled by Mayor de Blasio in December 2015, Clean Fleet expands on NYC Fleet's substantial strides in sustainability by setting concrete targets to reduce its consumption of greenhouse gas-emitting petroleum-based fuels—50 percent by 2025 and 80 percent by 2035.

In the near term, Clean Fleet committed New York City to add 2,000 electric vehicles (EVs) to its sedan fleet by 2025—the largest such commitment of any U.S. city. In less than a year since the announcement of Clean Fleet, the City has increased the size of its EV fleet by more than 60 percent with more than 500 total EVs. In April 2016, the City reinforced its EV commitment by announcing it would only purchase plug-in vehicles for all non-emergency sedan orders beginning in fiscal year 2017. This should bring NYC Fleet near 1,000 total EVs by the end of 2017. The Department of Citywide Administrative Services (DCAS) is exploring innovative channels to ensure that its sizable EV fleet can charge up, including a solicitation for standalone solar canopies that can charge fleet EVs with renewable power without relying on the electricity grid. DCAS is also exploring an interagency EV carshare pilot to address congestion in Downtown Brooklyn, where several agencies have active vehicle fleets.

NYC Clean Fleet also set forth a vision of displacing petroleum diesel with alternative fuels for use in medium- and heavy-duty fleets. With a requirement that diesel vehicles use biodiesel blends of at least 5 percent (B5) year-round, many agencies were already using B20 during warmer months for their fleets. In support of Clean Fleet, nonemergency vehicles are now beginning trials of B20 during colder months and B50 during warmer months. The New York City Police Department (NYPD) has also begun using B10 in its heavy-duty vehicles during summer months. The City is also actively investigating the supply chain, fire safety, and permitting steps that would be required to run portions of the heavy-duty fleet on renewable diesel, which can completely replace petroleum diesel in existing diesel engines from the same feedstocks that produce biodiesel.

Sustainable Freight

New Yorkers want what they want, when they want it. As a result, local trucks carry goods to residents and businesses all day long. As a city of islands, with the exception of the Bronx, we have limited rail and marine connections to the mainland, and therefore most freight moving through the city is carried on trucks, rather than by rail or ship.

New York City needs a reliable and efficient freight network to support our economy as well as the needs of our residents, businesses, and visitors. But the current system is not sustainable—goods movement contributes roughly ten percent of the City's transportation-related GHG emissions, exacerbates particulate and ozone pollution, adds to congestion on our streets, increases wear-and-tear on our pavements, and increases risk of vehicle crashes.

Many of the foundational elements to the 2050 sustainable freight system are already in place. Here's a snapshot of some of the steps already or soon to be underway at City agencies and in collaboration with regional partners:

- Expand the Hunts Point Truck Replacement Program to new fleets and locations—and, if possible, citywide
- Expand off-hour delivery programs to shift truck deliveries away from peak hours
- Use technology to expand the enforcement of truck parking and delivery zones in congested areas
- Evaluate the feasibility of zero-emission truck refrigeration units (TRUs)
- Expand the use of weigh-in-motion sensors and cameras to detect overweight trucks and develop strategies to foster a culture of compliance with traffic rules and regulations to mitigate infrastructure deterioration and safety challenges caused by overweight trucks
- Reactivate the South Brooklyn Marine Terminal to connect the City to the national rail network, which will create 300,000 square feet of shed space for warehousing, and provide more than 1,000 feet of berthing space for ocean-going vessels
- Expand the transload facility at 65th Street rail yard in Sunset Park to enhance rail-to-truck cargo movements and reduce "last-mile" truck congestion, costs, and pollution
- Coordinate with the private railroads through the Metropolitan Rail Freight Council to increase rail freight; the Council has identified 18 projects that preserve and expand rail freight, such as the preservation and development of the Bay Ridge Branch in Brooklyn and Queens
- Study ways to unlock the value of NYC's smaller, secondary waterways (e.g., Newtown Creek, Gowanus, and Eastchester Creek) that are home to many maritime industrial businesses that move over 4.4 million tons of aggregate, fuel, and recyclables each year
- Study feasibility of Low-Emission Zones to reduce truck emissions in congested areas or in communities that bear a disproportionate impact of truck traffic
- mplement safety improvements at the at-grade rail crossings in the Maspeth Industrial Business Zone, which will enhance both mobility and safety
- Work with our regional partners to advance implementation of the Cross Harbor Freight Program

Freight Movement
Photo credit: NYC Department of Transportation

passengers from shared rides and autonomous vehicles. Adding to these improvements, drivers will soon be able to pay meter fees with their smartphones. Additionally, the City is assessing an expanded off-peak commercial delivery program to decrease the competition for scarce curb space, and exploring the potential for automated enforcement of curb regulations. Looking beyond commercial districts, we will also assess how parking policy can encourage emissions reductions citywide.

Support new mobility options that reduce GHG emissions and prepare for autonomous vehicles

Shared mobility services such as car share, bike share and shared taxi and for-hire vehicle (FHV) trips are changing how New Yorkers get around. To prepare for continued changes and ensure that they reduce transportation emissions, DOT will undertake a shared-use mobility plan to identify the opportunities and challenges posed by new transportation services and models. The plan may include evaluating the potential for ridesharing services to meet travel needs in areas underserved by the subway, the ability for carsharing to reduce car ownership and improve parking availability, and strategies to promote the adoption of low-emission vehicles.

The NYC Taxi and Limousine Commission (TLC) will continue to support the modernization of yellow and green taxis through the licensing of e-hail applications that help match passengers and drivers, including those that support the sharing of rides among passengers. DOT will consider dedicating more curbside parking to carshare and shared mobility services to facilitate a shift away from traditional private vehicle ownership. The City will also continue to work with the Port Authority to accommodate the expanding interest in and potential for ride sharing from the airports.

The City has already started to prepare for the significant technological and cultural shift that may be ahead as technology for autonomous vehicles advances. DOT and TLC are examining the potential safety, congestion, social, environmental, and economic impacts of autonomous vehicles, and will advocate to State and federal lawmakers for policies that reinforce these considerations. This assessment will also guide pilot projects, including the use of the municipal fleet to test self-braking and potentially other automated features as an introduction to this technology. The City will focus on the potentially transformative safety and mobility benefits of these technologies, while seeking to mitigate the possible unintended consequence of increasing GHG emissions that could result if the emergence of autonomous vehicles generates a spike in vehicle trips.

Accelerate purchases of zero-emission vehicles

NYC Clean Fleet outlines how City agencies will lead by example and cut vehicle emissions while meeting their operating needs. With more than 29,000 vehicles, the City's procurement decisions can accelerate the development of the ZEV market and catalyze similar investments by other cities and large fleets.

To accelerate the use of ZEV technologies into high-mileage fleets, such as taxis and FHVs, the City will partner with private sector stakeholders to provide high-value electric vehicle (EV) charging, and will advocate for State legislation to reduce or waive the existing rental car tax for short-term ZEV FHV rental services.

A lack of a robust public infrastructure network to support ZEVs is a major reason their uptake has lagged in New York City.[1] While Local Law 130 of 2013 requires that new parking garages and open lots be equipped to accommodate electric vehicle charging equipment for at least 20 percent of parking spaces (thus making them "charger-ready"), it does not require the installation of chargers. To begin addressing this barrier, the City is installing additional EV charging stations at its municipal parking lots and fields over the next year. The City will also develop a deployment roadmap that identifies advantageous locations for ZEV-enabling infrastructure based on factors including likelihood for use by high-utilization fleets, locations of charger-ready parking spaces, and proximity to existing electric distribution infrastructure. We will integrate this analysis into the Community Energy Mapping effort, detailed in the Energy chapter. Additionally, the City will continue to advocate for EV charging rate structures to encourage the deployment of EVs and enabling infrastructure in a manner that increases the efficiency of the electric distribution system.

In collaboration with stakeholders participating in the New York City Electric Vehicle Advisory Committee, formed by DOT pursuant to Local Law 122 of 2013, the City will enhance these efforts to accelerate the adoption of ZEVs, and in particular EVs. The advisory committee is composed of representatives from DOT, the NYC Department of Environmental Protection (DEP), the NYC Department of Buildings (DOB), the Mayor's Office of Sustainability, City Council, the five Borough Presidents' offices, the EV industry, and transportation

and environmental advocates. The City will ask the advisory committee to lead the necessary stakeholder discussions that will lead to an EV implementation roadmap to drive investment and regulatory reform to support the private sector's transition to ZEVs, and will continue to work with the City Council on these recommended measures.

Exploration is also underway on the potential for a hydrogen fueling station pilot in the city to provide access to fuel cell vehicles. For both the electric charging and hydrogen fueling stations, City agencies are working with the Fire Department of the City of New York (FDNY) to address energy storage technologies, charging issues, and any other safety concerns related to the introduction of these new low-carbon vehicles and fuels.

Encourage the use of renewable and low-carbon fuels where electric vehicles are not an option

Electric vehicles are presently not an option for most heavy-duty vehicles. Therefore, the City will increase its use of renewable and low-carbon fuels in its own heavy-duty fleet. The City already blends biodiesel into the diesel fuel it uses in trucks and buses. In 2015, 93 percent of the diesel fuel used by nearly 10,000 City trucks and buses ran on biodiesel blends ranging from 5 to 20 percent (B5 to B20). The City also uses alternative fuels such as compressed natural gas (CNG) in some of its trucks and buses where it makes operational sense to do so; roughly 250 heavy-duty vehicles operate on either CNG or propane, including 44 NYC Department of Sanitation (DSNY) collection trucks. The use of CNG and biodiesel, depending on the source, in vehicles reduces emissions of GHGs as well as particulate matter and other criteria air pollutants relative to petroleum diesel, providing air quality and public health benefits citywide.

As a major component of NYC Clean Fleet, the City will expand its focus from biodiesel and CNG to increasing the use of renewable and low-carbon versions of all of the fuels the municipal fleet uses. Where renewable diesel or natural gas can replace conventional fossil fuels, we will do so. To accelerate the private market for renewable and low-carbon fuels, the City will advocate for a state or regional low-carbon fuel standard, based on the success of the low-carbon fuel standard in California. In that state, more than half of the natural gas used in transportation comes from renewable sources, including landfills, water treatment facilities, and agriculture, rather than from fracked fossil sources.

Encourage increased efficiency of local and "last-mile" freight delivery

The City has taken steps to increase the efficiency of local and "last-mile" freight delivery. This includes pilot projects to incentivize off-peak deliveries, steps to improve curb management and truck parking, and innovative funding incentives to reduce truck emissions. In particular, the Hunts Point Truck Replacement Program has funded the replacement of 500 pre-2007, inefficient trucks with newer, cleaner models.

Looking ahead, DOT's recently released *Strategic Plan 2016* will guide the City's investments and planning for future freight policy. The plan considers a range of measures to increase the efficiency and reduce the carbon footprint of freight movement, including expanded camera enforcement of curb loading, an expanded off-hour delivery program, expanded enforcement of anti-idling laws, and increased enforcement of truck weight, size, emissions limits through GPS and other technology innovations.

The City will help transition local truck deliveries to the cleanest, most efficient technologies to address long-standing concerns about truck pollution and congestion. In particular, the City will study the potential for Low-Emission Zones (LEZs) that limit traditional truck traffic in overburdened neighborhoods and incentivize or require zero- or low-emission "last mile" deliveries. LEZs exist in more than 400 European cities, but have not been implemented in the U.S. By adapting European strategies such as variable emissions-based charges, time-of-day restrictions, and prohibition of the oldest, dirtiest trucks to the New York City context, LEZs could provide both GHG reductions and public health benefits to communities that have borne the disproportionate burden of our current system.

The City will also seek funding to extend the Hunts Point Truck Replacement Program into new fleets and locations, expanding this program to address the dirtiest diesel trucks citywide. The City will consider the suitability of new ZEV and other vehicle technologies for trucks (e.g., electric, hybrid, natural gas, stop-start, and others); new procurement policies to reduce GHGs from municipal government-related deliveries; incentives to reduce partial load shipments from private sector deliveries; and strategies to reduce emissions from truck refrigeration unit equipment.

Invest in rail, maritime, and other infrastructure to increase the efficiency of freight movement

DOT, the New York City Economic Development Corporation (NYCEDC), and other agencies are advancing a number of approaches to increase freight efficiency using new or existing investments in rail, maritime, and other infrastructure as alternatives to long-haul truck freight. These investments will take trucks off New York City's limited bridge crossings and add valuable options for bulk cargo transportation. NYCEDC and DOT have also increased opportunities to capture new air cargo markets by allowing trucks carrying industry-standard 53' trailers to access JFK's air cargo facilities, supporting approximately 60,000 jobs in Queens. We will continue to explore opportunities to divert progressively greater shares of freight from trucks to rail, barge, or air through targeted investments and interventions such as those outlined above. To improve the efficiency of air freight, the City will coordinate closely with the Port Authority, including on a demonstration project of zero- and low-emissions ground support equipment, and will undertake a Phase 2 study to identify new opportunities for air cargo.

Until now, the City has focused most of its marine and non-road equipment interventions on the reduction of criteria pollutants, such as particulate matter and nitrogen oxides. Local Law 77 of 2004 requires the use of ultra-low sulfur diesel for any non-road equipment used on City construction projects. Earlier this year, the City's new contract for Citywide Ferry Service requires that vessels be powered by engines meeting or exceeding EPA's Tier 3 marine diesel engine emissions standard. Opportunities to reduce GHG emissions from marine and non-road equipment are limited, but the City will take several exploratory steps. We will continue to evaluate the potential to convert marine and non-road equipment to low-emission technologies, such as natural gas, hybrid, electric, and fuel cell powertrains. For example, the City will assess the ongoing implementation of NYCEDC's shore power collaboration with the Port Authority at Brooklyn Cruise Terminal to guide future prospects for providing alternative power to marine vessels at terminals in New York City. The City will also work to develop a program to implement and enforce anti-idling regulations for all non-road equipment operating in the City.

Laying the foundation for the future

Emissions reductions of 80 percent citywide will require significant action beyond the above initiatives between now and 2050. Building on existing projects and studies, 80 x 50 will require major investments in expanding and improving low-carbon transportation networks under the City's control (i.e., those for surface transit, walking, and bicycling) and those under the control of others. Therefore, the City will continue working with State, regional, and federal partners to fund and invest in expansions of the core transit network.

We will need to leverage technological shifts that influence mode decisions, optimize the transportation network, and increase uptake of low-emission vehicles. The use of cameras, sensors, vehicle monitors, and other devices can provide rich data and analytics to perform real-time traffic management and promote network efficiency. However, the City cannot promote technological adoption on its own. Developing the market for electric vehicles in New York City, for example, will require working with utilities, building owners, and others to deploy the necessary charging infrastructure to support these vehicles.

Changes to the transportation landscape to enable deep GHG emissions reduction, supported by a wholesale shift to mobility as a service, will also require institutional changes that increase cooperation and commitment between the City and State, regional, and federal partners. The City will work to break down barriers between jurisdictions and agencies in pursuit of its emissions reduction goals as well as seek greater control over the funding, regulation, and enforcement of its transportation system. Stronger mechanisms for regional planning among these entities are critical, and the City stands ready to take the lead on a comprehensive regional agenda for GHG emissions reduction.

Regulatory changes will also play a role in reaching 80 x 50 in the transportation sector. The City will need to evaluate the level of regulation needed for shared mobility services and autonomous vehicles in order to ensure that they reduce GHGs and supplement, rather than replace, the transit network. The City will also need to work with the State and the federal government to establish fair, transparent, and practical regulatory environments to guide the deployment of emerging technologies to ensure that they operate safely, efficiently, and reduce overall VMT.

Cross-jurisdictional regulatory programs like a low-carbon fuel standard will have to be adopted to enable the rapid deployment of renewable and low-carbon fuels. Widespread adoption of cleaner vehicle technologies and fuel types will require substantial market changes; until the auto and truck industries see a market for a wide selection of ZEV offerings in every vehicle type, the options will be limited. The City will also need to help the industry create a common approach towards EV charging, which will overcome the current trend of different companies using different charging standards for their vehicles.

Similarly, bringing about the sustainable freight system that we will need in 2050 will require the City and its regional partners to invest in a diversity of strategic approaches. These include:

- New or rehabilitated rail and marine infrastructure to provide an alternative to trucking along congested roadways and river crossings;
- New strategies for local freight deliveries that meet businesses' and residents' desire for timely and on-demand goods delivery without adding stress to neighborhood streets;
- New approaches to freight distribution centers, waste transfer stations, and other centrally-located facilities to reduce impacts of heavy vehicle emissions, particularly in low-income communities; and
- Cleaner, more efficient engines to power the trucks, locomotives, and marine vessels that carry our goods where they need to go.

Many governments around the world are grappling with similar institutional, regulatory, and market challenges. To spur the scale of transformation needed to achieve global GHG reduction goals, New York City will continually strive to be a model of sustainable transportation governance for other cities to emulate.

Transportation Strategies	Energy	Buildings	Transportation	Waste
Modernize, expand, and reduce crowding on the city's transit system			●	
Make walking and biking safer, more convenient options for all New Yorkers			●	
Ensure that the City's policies prioritize walking, biking, and transit			●	
Leverage technology and data to expand travel options and optimize the transportation network			●	
Better manage and price parking to encourage efficient travel choices			●	
Support new mobility options that reduce GHG emissions and prepare for autonomous vehicles			●	
Accelerate purchases of zero-emission vehicles	●	●	●	
Encourage the use of renewable and low-carbon fuels where electric vehicles are not an option	●		●	●
Encourage increased efficiency of local and "last-mile" freight delivery			●	
Invest in rail, maritime, and other infrastructure to increase the efficiency of freight movement			●	●

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Waste

In 2050…

We envision that New York City will have already achieved its 2030 Zero Waste goals, eliminating the landfilling of waste from residential buildings as well as commercial establishments and industrial and institutional operations. It will be easy and convenient for New Yorkers to minimize the amount of waste they generate and reuse or recycle products. The collection of recyclables and organic materials such as food scraps and yard waste, along with the expansion of energy and material recovery from waste, will have spurred economic activity and catalyzed the development of a citywide circular economy. Smart collection routes, cleaner vehicles, and new technologies will also have helped minimize emissions from the transport and processing of waste.

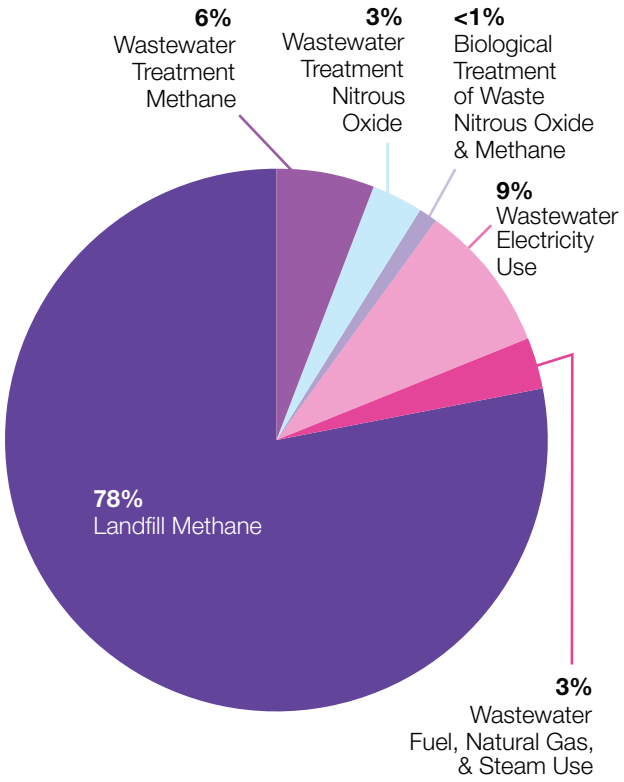
Achieving 80 x 50: Waste

For the waste sector, achieving 80 x 50 requires the City to fully implement its existing commitments to divert all waste from landfills and to produce enough renewable energy at its wastewater treatment sites to meet its on-site energy needs. Consistent with the City's Zero Waste goals, reducing GHG emissions from the solid waste sector involves reducing the volume of waste generated, collecting food waste (the largest source of waste-related GHG emissions) to make compost or energy, and increasing reuse and recycling of remaining materials. Achieving net-zero energy at the City's wastewater treatment plants requires retrofitting or replacing systems for increased efficiency, capturing methane emissions for energy use, and installing new renewable energy systems on its facilities and land.

Drivers of GHG emissions

Among the four sectors that contribute to GHG emissions in NYC, waste is the smallest contributor, making up four percent of citywide GHG emissions. These emissions are primarily the result of the decay of waste disposed of in landfills and wastewater treatment processes.

Sources of Emissions: Waste



Organic waste is the most significant generator of waste-related greenhouse gas emissions. This includes food and yard waste as well as the plant-based materials in paper products. When organic materials are landfilled, methane gas is generated as organic materials decay in the absence of oxygen. This is significant given that the U.S. Environmental Protection Agency (EPA) estimates that methane has a global warming potential 28 to 36 times greater than carbon dioxide.[1]

Approximately 78 percent of the total emissions attributed to the waste sector are the result of methane generated by New York City's landfilled waste. Another 22 percent of total waste-related emissions are from the treatment of wastewater, including the methane generated from the treatment process and the carbon dioxide emissions from the energy used to operate the City's 14 wastewater treatment plants (WWTPs). For the City's 80 x 50 analysis, GHG emissions related to WWTPs are included in the Waste chapter; however, in the City's GHG Inventory, per the Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories, the GHG emissions resulting from WWTPs are captured in stationary energy.

In addition to waste processing, the local collection and transport of materials to recyclers and end disposal points also contributes to citywide GHG emissions. The NYC Department of Sanitation (DSNY) is responsible for managing residential waste, and private carters collect, transport, process and landfill waste for the commercial sector. Together, these fleets are responsible for approximately 69,000 $MtCO_2e$; while this is a small contribution to overall citywide emissions (0.13 percent); waste hauling operations also impact local air quality, traffic congestion, and overall quality of life. Consistent with the Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories, the GHG emissions resulting from the collection and transportation of waste are captured in the transportation analysis.

Business as usual findings

In order to understand what it will take to achieve 80 x 50 citywide, the City first modeled projected GHG reductions under a business as usual (BAU) scenario for each sector through 2050. The BAU scenario includes GHG reductions achieved from existing state and federal policies, and local policies and initiatives enacted prior to 2014. Taking into consideration population growth, economic development, waste composition trends, and the implementation of the New York City Solid Waste

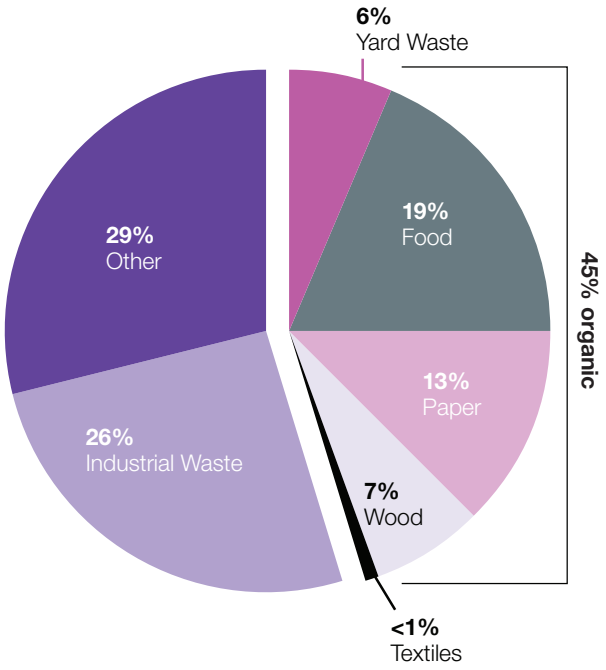
Management Plan (SWMP), the City expects that emissions from waste will be fairly constant between now and 2050, with the majority (78 percent) attributed to landfilled waste.

The largest category of New York City's waste stream is organic matter, which includes food, garden waste and plant debris, paper, wood, and textiles. These categories together make up 45 percent of the current waste stream and represent a significant opportunity to reduce emissions from landfilled waste by diverting these materials for resource recovery including anaerobic digestion and composting, or—for certain materials—reuse.

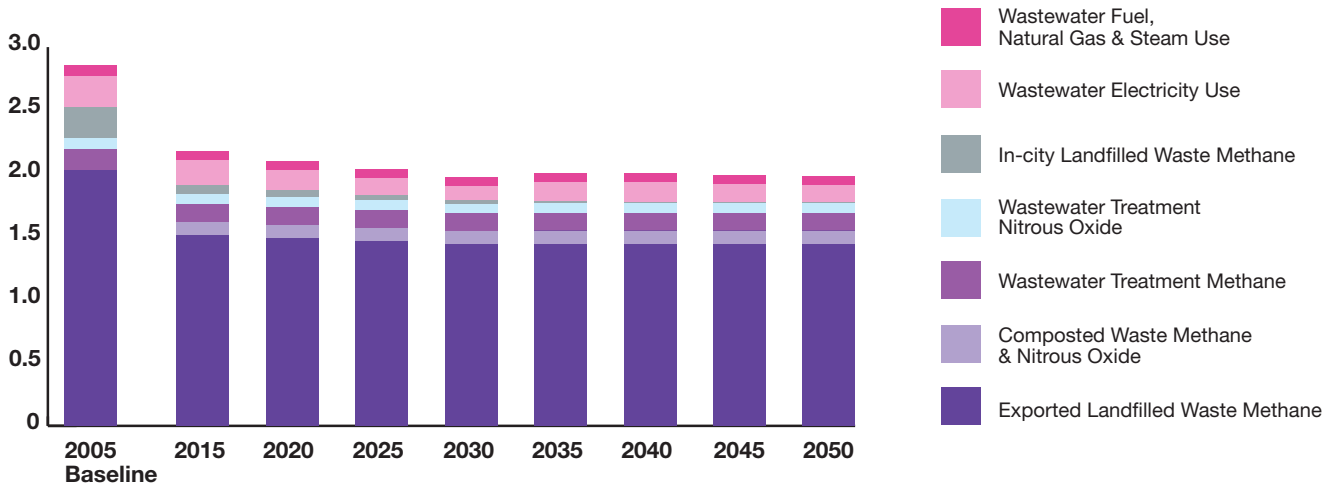
Since organic material is the most significant generator of greenhouse gases among all waste categories, and since food makes up the largest portion of organic waste, minimizing food waste at the source and reducing the landfilling of food waste through composting and other beneficial disposal methods, such as anaerobic digestion, will have a significant effect on reducing the total GHG emissions attributed to waste. Anaerobic digestion of food scraps has the potential to provide a biological, non-fossil fuel energy source for district heating systems throughout the city. As described in the Energy chapter, district heating and community energy are priorities for New York City.

Citywide emissions projections also reflect the impact of regulations that govern vehicles, including those that transport watste, and their related emissions as discussed in the Transportation chapter. Federal policies that govern air emissions from vehicles will drive transportation related emissions reductions. However, locally the full implementation of the SWMP, which emphasizes the use of rail and barge transport, rather than long-haul trucking, and compliance with Local Law 145 of 2013, which requires all heavy trade waste vehicles to meet 2007 EPA emissions standards by 2020, will also

Current Composition of NYC's Waste Stream

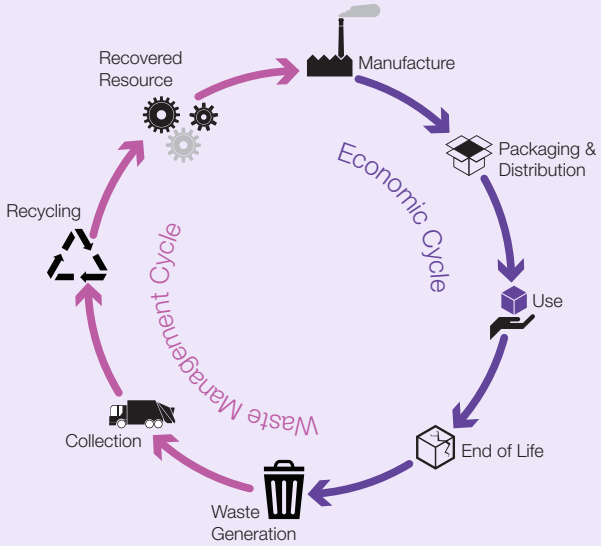


Business as Usual Scenario: Projected Waste-Related GHG Emissions Through 2050, in Million Metric Tons of Carbon Dioxide Equivalent ($MtCO_2e$)



Circular Economy

A circular economy turns away from a "make-use-dispose" approach toward initiatives that keep resources in use for as long as possible, extracting the maximum value from them while in use, then recovering and regenerating products and materials at the end of each service life. Achieving this requires focus on innovations in product design and technology, source reduction, reuse, recycling and organics diversion, and advanced efforts to extract materials and value from any remaining waste – returning these resources to market as inputs to new products and services.



contribute to reducing GHG emissions. Additionally, these policies will result in fewer air polluting emissions, helping to improve air quality in New York City's neighborhoods and supporting improved public health.

Emerging trends

In the future, potential increases in waste associated with growth are expected to be offset by waste reduction trends over the past 20 years that are rapidly changing the way New Yorkers purchase products and the types of waste they generate. Particularly, the rise of the new economies (digital, sharing, and circular) are changing the way New Yorkers purchase products, and trends in improved packaging are leading to decreased waste related to the products that New Yorkers buy. Together, these trends are expected to continue to reduce waste generation volumes per person. With the addition of improved waste collection and disposal processes, emissions from the waste sector will further decrease.

Changing consumption patterns, largely attributed to the digital and sharing economies, are leading to a decrease in per-person waste generation volumes. The adoption of digital media and the use of the internet for the consumption of news, media and online learning has been a strong contributor to decreasing paper waste. Paperless transactions also contribute to reducing the volume of newspaper and office paper discarded.

Not only are we changing what we consume, we are also changing how we acquire things that we consume. The growth of the sharing economy is enabling individuals to borrow a product instead of owning it directly. For example, with a few smart phone clicks, consumers can now rent a car, tools, and clothing for a certain amount of time. This reduces the need to produce and dispose of new products.

When we do purchase things for consuption, we are increasingly seeing a shift from the use of virgin materials for producing products to reuse and the use of recycled materials. This circular economy reduces the amount of waste for disposal as products that were once disposed at the end of life can now be reused or repurposed into something new.

Finally, advances in packaging materials have resulted in the use of lighter-weight materials like plastics and aluminum in place of glass and steel, which reduces the amount of waste generated per person. More recently, even rigid plastic packaging materials have started to be displaced by the rapidly growing use of flexible packaging materials.

Beyond shifts in consumption patterns, there are also opportunities to shift the way that New York collects, treats, and disposes of its waste and discarded material. While not a new trend, the use of pressurized vacuum tubes (i.e. pneumatic tubes) for waste collection is becoming increasingly present in global cities. Pneumatic tube technology has been in use at Roosevelt Island for the past forty years. Waste collection tubes connect the Island's numerous buildings to DSNY's Roosevelt Island

Promising solutions for organic waste management

Solution	Description	Market Challanges
Breakthroughs in Existing Solutions		
Centralized Anaerobic Digestion	Large-scale system that uses micro-organisms to break down organic material in the absence of oxygen that can control and harness production of biogas, allowing for the production of energy, while also optimizing biosolids treatment and beneficial use.	• Separation and collection of organic materials from the waste stream • Contamination of feedstock • Siting of digesters due to perception, land availability, zoning, and permitting
Composting	The breakdown of organic material which can be done at a range of scales, from household to commercially-viable city-scale. Common types of composting include in-vessel composting where organic material is bulked together and confined within a building or a container, and windrow composting where organic material is piled together in long rows.	• Collection of organic material • Elimination of food packaging and other contaminants • Location and space requirements • Resale of final product
Emerging Technology		
Small-Scale Anaerobic Digestion	Building-scale and even household-scale anaerobic digesters are becoming more prevalent in the market.	• Economic feasibility of small-scale biogas cleaning and electricity conversion • On-site handling of digestate (i.e., remaining, high nutrient liquid)

Collections and Compaction Plant, which minimizes the transportation component of waste collection. Advance pneumatic systems allow waste to be separated by type (organics, recycling, and refuse) at the source for direct transfer via underground pipes to waste transfer stations (see next page).

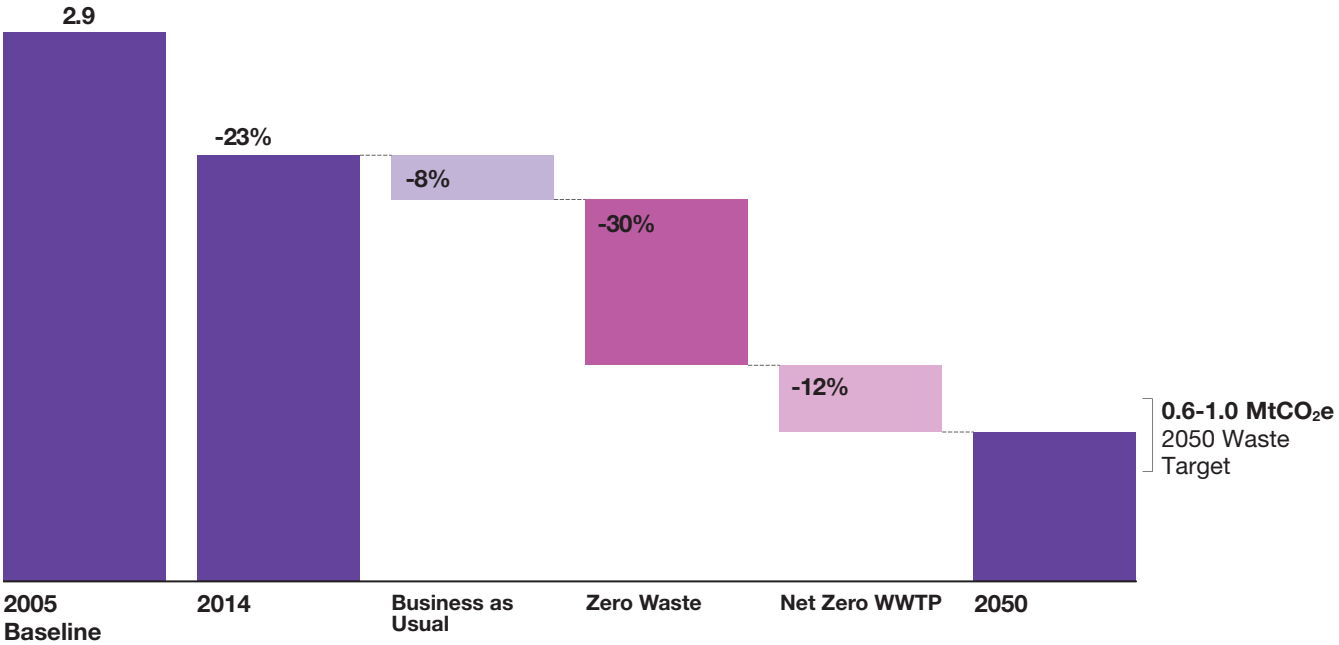
Wastewater treatment plants have long been considered locations for treatment and disposal; however, they are now being viewed as resource recovery facilities, providing a critical opportunity to recover energy, heat, and nutrients. The opportunity for heat utilization, nutrient recovery, and renewable energy production is expected to expand the role of these facilities beyond public health protection and environmental compliance. Specific technologies are emerging that could efficiently mine latent heat, energy, nutrients, and other resources that make up the wastewater stream. The move toward energy neutrality at the City's wastewater plants will include the increased application of these recovery technologies, in order to mine and return these valuable resources within the City and outside its borders. For example, utilization of biogas (i.e., methane) produced from the digestion processes of wastewater will be expanded to generate additional heat and power at the City's plants, displacing a significant portion of fuel oil, natural gas, and grid electricity currently used to run these plants. Biogas can also be scrubbed and injected into the local distribution networks to help supply the surrounding communities with biogas for residential and commercial use. In addition, biosolids, the nutrient-rich solid waste that remains after the dewatering of the sludge in the wastewater treatment processes, can be treated and used as fertilizer materials or for other beneficial uses.

80 x 50 Roadmap: Waste

In the April 2015 release of *OneNYC*, the City committed to sending zero waste to landfills by 2030 (Zero Waste). To achieve Zero Waste, DSNY is implementing programs that target all sectors—residential, institutional, commercial—and all waste streams, including recyclables, organics, plastic bags and Styrofoam, electronics, textiles, and other non-recyclable waste. Once implemented, these initiatives are expected to reduce waste emissions by 850 $MtCO_2e$, which is more than a 55 percent reduction from the 2030 business as usual scenario and accounts for a 30 percent decrease from 2005 baseline waste emissions.

OneNYC also includes a City commitment to achieve net-zero energy at all fourteen of the Department of Environment Protection's (DEP) wastewater treatment plants within New York City. Implementing this initiative will include expansive integration of energy conservation measures into capital improvement projects, as well as management of biogas collection and utiliza-

An 80 x 50 Roadmap: Projected GHG Reductions from the Waste Sector by 2050 ($MtCO_2e$)



All percent reductions are relative to the 2005 Waste emissions baseline

tion, biosolids treatment and beneficial use, and growth of on-site power generation. Anaerobic digestion of food scraps has the potential to provide a biological, non-fossil fuel energy source for district heating systems throughout the city. The City has already begun a three-year pilot program to process food waste through anaerobic digestion at the Newtown Creek Wastewater Treatment Plant. As part of this project, the methane gas from this process will be refined into natural gas and pumped into the National Grid system. The City will continue to evaluate opportunities and investments needed to expand food co-digestion at DEP's wastewater treatment plants beyond the Newtown Creek facility.

DEP investments to achieve net-zero energy are projected to reduce GHG emissions associated with its wastewater treatment plants by 35 percent by 2030 and almost 80 percent by 2050, compared to the business as usual scenario. This reduction accounts for a 12 percent citywide decrease from 2005 baseline waste emissions.

The reductions attributed to implementing Zero Waste and net-zero energy at the City's wastewater treatment plants chart a clear path for the waste sector's role in achieving 80 x 50 citywide.

Challenges to address

Achieving Zero Waste and shifting to a thriving circular economy depends on high recycling rates; however, New Yorkers currently recycle less than half of the metal, glass, paper, and plastic in their household waste stream. Resident confusion over how to recycle and current requirements to separate recyclables into multiple bins are among the main barriers to greater participation. While recycling rates have been improving thanks in part to DSNY outreach efforts, the city still has a long way to go. Best practices around the world have demonstrated the success of a combination of outreach, financial incentives, and infrastructure that allows recycling to be simple, easy, and convenient. Given the city's dense built environment, including its older building stock, and brimming residential neighborhoods, this is easier said than done.

Near-term actions to reduce GHG emissions

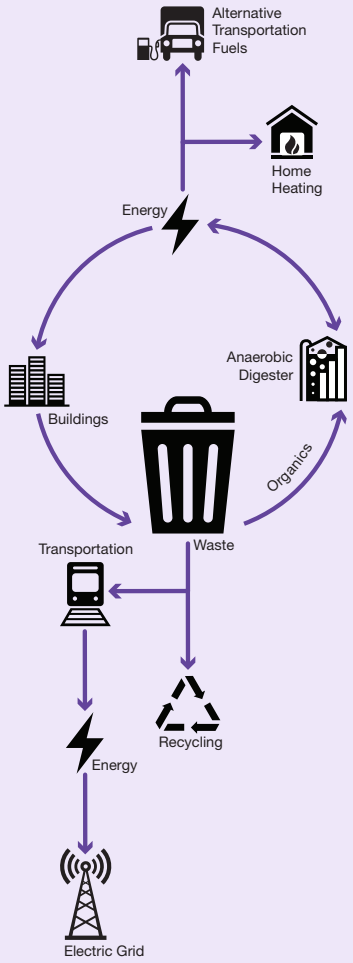
As part of the implementation of Zero Waste, the City is evaluating efforts to minimize the amount of all waste material generated within the city, advance the citywide circular economy, expand energy and material recovery

Pneumatic Waste Management Systems

A pneumatic waste collection system is a sustainable waste management system that connects buildings, transportation, solid waste and energy. These systems can collect source-separated refuse from residential and commercial establishments and allow for:

- processes that treat organics locally through anaerobic digestion to produce renewable energy in the form of electricity or natural gas which can be used:
  - to power the treatment process
  - as energy for buildings
  - to heat homes
  - for the production of alternative transportation fuels
- diverting recyclables to local reuse opportunities, and
- connecting the remaining waste to rail yards for transportation to facilities that have the technology to cleanly and efficiently convert the refuse into beneficial by-products.

These systems demonstrate the successful integration of new technologies and existing infrastructure to capture resources that have traditionally been underutilized. They also provide a model for improving the management of source-separated waste in dense urban areas, and enhance fuel security and diversity by providing community-scale renewable energy while also reducing GHG emissions and criteria air pollutants through more efficient movement of materials.



from waste to reduce the impact of waste processing, and reduce emissions from all modes of transportation for all waste streams.

Engage all New Yorkers in reducing waste disposal to landfills

While it is critical to take steps to make recycling easier and organics collection available to more New Yorkers, it is also critical to reduce the components of the waste stream that cannot be readily diverted.

GreeNYC, a program of the Mayor's Office of Sustainability, leads multiple campaigns to reduce waste, including the Stop Junk Mail and B.Y.O. campaigns to reduce waste from paper, single-use shopping bags, coffee mugs, and water bottles. The Stop Junk Mail campaign has successfully reduced paper waste by over seven million pounds since 2011. The B.Y.O. campaign is also a success, averting 300 million plastic bags in NYC from landfill, increasing plastic water bottle recycling by 28 percent, and having over 15,000 New Yorkers pledge to carry reusable bags, mugs, and water bottles provided by GreeNYC. This program has resulted in a financial savings of over two million dollars to the City and DEP has already provided additional funds to support the campaign.

Despite the significant progress from GreeNYC's B.Y.O. campaign, more than 10 billion plastic bags still show up in the waste stream annually. These bags contaminate the recyclable and organic waste streams, and often end up in local waterways. As part of Zero Waste, City Council adopted legislation that will reduce waste and encourage New Yorkers to bring their own bags by placing a five-cent fee on carryout bags at stores. Based on the experience of other cities, DSNY projects that

GreeNYC BYO campaign poster

this fee could reduce plastic and paper bag waste by approximately 60 percent. The City is working with retail associations and retailers to provide free reusable bags to New Yorkers in advance of this fee going into effect, and periodically in the years to come. Additionally, DEP received a grant to support The Bag Challenge, which will encourage retailers and customers to switch from using single-use bags to reusable bags while also studying changes in behavior for more targeted outreach.

To reduce marine debris from plastic bags and other waste that often ends up in local waterways, DEP launched the Trash Free NYC Waters Initiative. Early efforts included partnering with GreeNYC's B.Y.O. campaign and the Clean Streets = Clean Beaches campaign. Additional outreach highlighting the impact of plastic waste and litter on local waterways is planned for 2017.

Minimize waste generated by all City agencies

All city agencies are encouraged to take part in efforts to reduce waste and purchase sustainable products. City-wide employees are encouraged to recycle and separate food scraps and organic material for composting. Further, agency purchases are subject to the City's Environmentally Preferable Purchasing program, which started in 2005. Environmentally Preferable Purchasing (EPP) focuses on the human health and environmental impact of goods and products purchased by selecting products that are more environmentally preferable to others. EPP takes into account many factors, such as waste production, energy and water use, greenhouse gas emissions, indoor air quality, recycled and reused content, and the presence of hazardous substances. The EPP laws consist of Local Laws 118, 119, 120, 121, and 123 of 2005. The EPP program also includes packaging reduction guidelines (Local Law 51 of 2011) and green building standards for certain types of capital projects (Local Law 86 of 2005). Pursuant to the EPP laws, the City developed minimum standards for certain goods and construction products based on their human health and environmental impact. Any City agency procuring one of these goods or products must include specifications in their procurement package that meet or exceed these standards. As part of 80 x 50, this program will continue to be a lever where the City can exert its market power to reduce its waste-related GHG footprint.

Giving all New Yorkers the tools for waste prevention and reduction extends to educating the next generation of recyclers in the classroom. In 2015, DSNY, the Department of Education (DOE), and GrowNYC built a strong interagency team to create a zero waste culture

NYC students source-separating cafeteria waste at a Zero Waste School
Photo credit: NYC Department of Education

in our schools. Now, in accordance with the OneNYC commitment, DOE in partnership with DSNY, is rolling out the Zero Waste program at more than 100 schools in fall 2016. Following operational assessments and broad stakeholder engagement this past spring and summer, students and staff at the Zero Waste Schools will implement a strategy that demonstrates how, when recyclables and organics are fully separated out of the waste stream, there is really very little left to go in the trash.

Launch outreach campaigns to reduce food waste

DSNY uses a variety of media to educate New Yorkers on how to properly dispose of their waste materials, including flyers, stickers, and an interactive website. In addition to providing information about curbside organics collection, DSNY provides tips and schedules for organizations that accept donations of canned and packaged food, and for food scrap drop-off sites. In collaboration with non-profit partners and NYC Service Corps, DSNY also provides ongoing outreach to the neighborhoods that receive curbside organics collection and will continue to expand this outreach as more neighborhoods are added.

While diverting organic waste from landfill is essential to reducing waste and GHG emissions, preventing the flow of wasted food is also essential to meeting the City's goals. An efficient, equitable food distribution system, with adequate infrastructure, ensures that all New Yorkers have access to affordable, healthy food. The food system is deeply connected with public health, economic development, and community wellbeing. The Mayor's Office works with partners, including food recovery organizations to recapture edible food for donation and encourage New Yorkers to reduce food waste as part of nutrition and environmental education initiatives.

Implement proven incentive-based systems to minimize waste generation

In *OneNYC*, the City committed to developing an equitable blueprint for Save-as-You-Throw. Such a program would create financial incentives to reduce waste. New Yorkers that produce less waste and recycle more would save money. In 2015, DSNY convened a group of community development, property management, environmental justice, labor, and other stakeholders to discuss a potential proposal. In 2016, these stakeholders participated in focused-topic working groups. Cities such as San Francisco, California, and Seoul, Korea have implemented similar strategies that require residents to pay

Zero Waste

In *OneNYC*, the City committed to the ambitious goal of sending Zero Waste to landfill by 2030. In conjunction with this goal, the following initiatives were developed. These initiatives not only help the City achieve Zero Waste, but also improve air quality and reduce greenhouse gas emissions.

1. Expand the New York City organics program to serve all New Yorkers by the end of 2018
2. Enhance the City's curbside recycling program by offering single-stream recycling by 2020
3. Reduce the use of plastic bags and other non-compostable waste
4. Give every New Yorker the opportunity to recycle and reduce waste, including at NYCHA housing
5. Make all schools Zero Waste Schools
6. Expand opportunities to reuse and recycle textiles and electronic waste
7. Develop an equitable blueprint for a Save-As-You-Throw program to reduce waste
8. Reduce commercial waste disposal by 90 percent by 2030

Photo credit: NYC Department of Sanitation

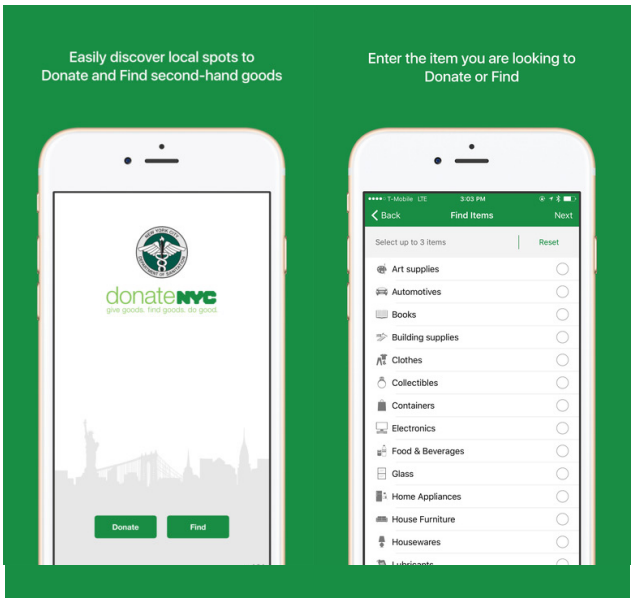
for their bins and garbage bags of trash; the bigger the bin and the number of garbage bags, the more residents pay. Over the next several years, DSNY will continue to work with stakeholders to develop this program.

Support increasing citywide reuse and donation

In June 2016, DSNY launched donateNYC, a program designed to make finding and giving second-hand goods easier for New Yorkers. DonateNYC provides residents with a website and a mobile app to help them search by material and location to find the most convenient place to give or find reusable goods. For local nonprofit organizations in need of donated goods, or businesses looking to donate, donateNYC offers an online materials exchange where they can connect, donate and receive reusable goods.

The donateNYC partnership program also supports New York City's nonprofit reuse sector. Partner organizations include thrift stores, clothing banks, social service providers, creative arts programs, and community-based reuse programs. Formerly known as ReuseNYC, this partnership is designed as a trade network for local nonprofit donation and reuse programs that accept and locally distribute second-hand items.

As the City continues towards its goal of sending zero waste to landfills by 2030, donateNYC partners will help the City reach its goal by providing verifiable data needed to assess progress. In 2015, partner organizations diverted more than 40 million pounds of material from landfills — creating a reduction of over 60,000 tons of carbon emissions. Partner organizations also served more than 1.3 million New Yorkers last year through family services, housing/sheltering, healthcare, workforce development and food bank programs.



donateNYC mobile app
Source: NYC Department of Sanitation

Accelerate diversion of recyclable materials from landfills

As part of Zero Waste, the City committed to enhance its curbside recycling program by offering single-steam recycling by 2020 to make recycling easier for every New Yorker. New York City already has the largest curbside recycling program of any U.S. municipality, but currently New Yorkers separate only half of all recyclable materials from their trash. Since 2015, DSNY has worked closely with its recycling vendors to develop a plan to convert curbside collection from dual stream to single stream—so paper, metal, glass, and plastic recyclables are all collected together in the same bin or bag. The City is on track to achieve this initiative and anticipates that significant modifications will be made to vendor recycling facilities in the next few years. This effort goes hand in hand with the City's efforts to identify opportunities to expand markets for recyclables and move toward a circular economy in partnership with the New York City Economic Development Corporation (NYCEDC) and industry groups.

NYCHA is also working to give every New Yorker the opportunity to recycle and reduce waste. DSNY, NYCHA, and the Mayor's Office have partnered to launch NYCHA Recycles! In just over a year, more than 1,600 NYCHA buildings now participate in the program, which includes installation of recycling bins, staff training and resident outreach, and ramp up of collection service. All NYCHA buildings will actively participate in the NYCHA Recycles! program by the end of 2016. GrowNYC is training all NYCHA residents on separating recyclables and putting materials in the correct bins. GrowNYC also launched the Environmental Ambassadors Program, a program that trains volunteer NYCHA residents to become community recycling experts who will continue recycling education at NYCHA moving forward.

In further support of the City's *OneNYC* and Zero Waste goals, the City is launching a public-private partnership that unleashes the emerging economic potential of New York City's circular economy through collabora-

tions that foster new approaches to policy, design, and practice. NYCEDC, DSNY, and the NYC Mayor's Office of Sustainability (MOS) are partnering with the Ellen MacArthur Foundation, a non-profit organization devoted to advancing circular economy solutions for industry and government, to explore opportunities for innovation and new enterprises across multiple New York City industries. The partnership will support design innovation and commercialization through coordinated efforts with City agencies, local universities, and the private sector to address urban challenges and develop circular economy solutions for New York City.

Capture organics and ensure sufficient capacity to facilitate beneficial reuse in both the residential and commercial sectors

The City has been expanding its organics program to reach the *OneNYC* goal to serve all New Yorkers by the end of 2018. In 2015, DSNY expanded curbside organics collection by more than 50,000 households and is now serving more than 700,000 residents. By the end of 2016, New York City will have the largest curbside organics collection program in the country. At the same time, DSNY is introducing curbside organics collection in high-rise buildings throughout Manhattan, continuing annual collection of Christmas trees for diversion, and will resume the seasonal leaf collection program in the fall of 2016. To date, the public interest and participation in the curbside program are encouraging signals to the City that New Yorkers are willing to adopt this practice.

Ensuring capacity to process the city's organic waste is central to the program's rollout. In 2017, DSNY will upgrade its Staten Island Compost Facility to improve capacity to compost food scraps and yard waste collected in the borough. DSNY has also signed new contracts with regional processors to ensure adequate organics processing capacity as the program grows. In addition, DEP, in partnership with Waste Management, has begun a three-year demonstration project that will co-digest up to 250 tons of organic waste per day at the Newtown Creek Wastewater Treatment Plant, to be converted to renewable biogas and biosolids. Construction of the project is complete and initial testing and processing has begun.

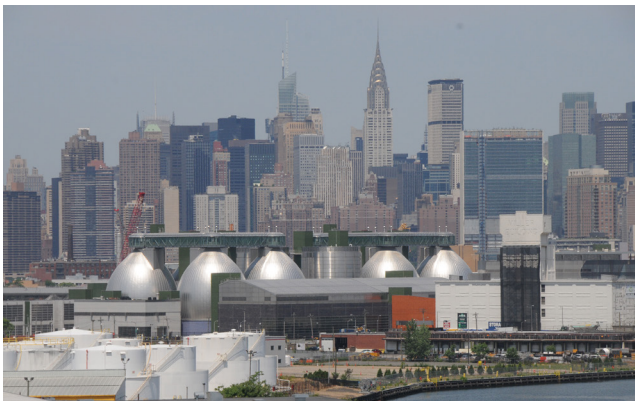
In 2015, DSNY adopted rules that designate the first set of covered establishments that must comply with the commercial organics mandate, Local Law 146 of 2013. Beginning August 2016, all stadiums and arenas, large

NYC organics collection bins ready for DSNY curbside pickup
Photo credit: NYC Department of Sanitation

food manufacturers and wholesalers, and hotels with more than 150 rooms are required to source separate and divert their food waste for beneficial use. Enforcement will commence in early 2017. Analysis is underway to determine whether there is adequate processing capacity to expand the subset of businesses that need to comply with the law going forward.

In addition, the City has more than 225 community compost sites across all five boroughs, and the NYC Compost Project offers annual courses for individuals interested in composting at home or in community gardens. This year, the Business Integrity Commission (BIC) announced a pilot program to allow acceptable entities to use non-motorized vehicles to divert organic waste for local businesses and to waive carter license fees for small community composting organizations that collect organic material from commercial establishments for the purposes of composting it locally.

Local Law 146 of 2013 covers businesses that account for about half of all commercial food waste in New York City. After DSNY completes phasing-in all of the establishments covered by that law, the City will work with City Council to expand the law to require other types of food service establishments to beneficially use their organic waste.



Anaerobic digestion facility at Newtown Creek WWTP
Photo credit: NYC Department of Environmental Protection

To support the expansion of organics processing citywide, the City needs to develop additional organics sorting and processing capacity in NYC and the metropolitan region. While some of this may occur centrally, the City is also seeking to support safe, smaller-scale anaerobic digestion. Therefore, DEP will develop specifications for grease interceptors and other potential pretreatment equipment required to treat the discharge from on-site waste systems. DEP will also conduct inspections to ensure that grease interceptors are properly operated and maintained, and it will develop discharge characteristics and requirements for these systems. If needed, DEP will also develop discharge characteristics and requirements for community-scale anaerobic digestion projects to integrate into district heating and electric generation.

Expand energy recovery from wastewater processing operations

DEP has been moving forward its commitment to achieve net-zero energy at the City's fourteen wastewater treatment plants. The agency will develop a strategic energy plan to continue to move toward net-zero energy. This will include the commencement and completion of an Energy Neutrality Study, integration of state of good repair and energy conservation measures analysis, and pursuit of cost effective renewable energy projects, among other studies, initiatives, and improvements. DEP has completed energy audits at each wastewater treatment plant to determine how much energy must be generated to close the energy gap and is developing a plan to reduce energy consumption and generate renewable energy on-site. Design is underway at the North River Wastewater Treatment Plant to install a 12MW cogeneration system. This system will use a combination of digester gas produced on site and natural gas to generate electricity to meet the plant's base electrical demand, while recovering enough heat for the plant's heating needs. This project will optimize use of biogas, natural gas, and electricity to run plant operations and offset over 1.7 million gallons of fuel oil annually. DEP is also evaluating additional energy efficiency, GHG reduction, electric generation, and renewable energy options at all DEP facilities.

DEP's central policies and strategies related to managing water demand, restoring wetlands, installing green infrastructure, and protecting forested lands also have GHG benefits. To quantify the benefit to the City, DEP developed a model that provides project-specific GHG impacts that result from lower electrical and fuel usage for system operation and maintenance, decreased flow to treatment facilities, reductions in leakage, and direct carbon sequestration. The tool, developed as part of the 2016 Water-Energy Nexus Study, demonstrates which current and planned programs will provide the greatest GHG and energy demand reductions and will be integrated into capital project planning and prioritization.

Reduce emissions from the collection and disposal of commercial waste

In August 2016, DSNY and BIC released the results of a study of the city's private carting industry. Private carting companies, licensed by BIC, collect more than three million tons of waste and recyclables per year from the city's restaurants, hotels, offices, and other commercial establishments. The Private Carting Study, first committed to in OneNYC, found that establishing commercial waste collection zones could reduce truck traffic associated with commercial waste collection by 49 to 68 percent and reduce GHG emissions by 42 to 64 percent.

Over the next two years, DSNY and BIC will work with a broad group of stakeholders including businesses, the private carting industry, and environmental justice advocates to develop an implementation plan for commercial waste reform in New York City. The plan will layout a framework for establishing commercial waste collection zones that will improve customer service standards, achieve the City's environmental goals, set clear standards for worker safety, and allow for new investments in recycling infrastructure and cleaner trucks, thereby dramatically reducing GHG emissions and improving air quality.[2]

Laying the foundation for the future

Our analysis shows that the Zero Waste program, together with DEP's net-zero energy commitment, provides a clear path for significantly reducing waste-related GHG emissions. DSNY is already growing its organics collection program and working to increase recycling, which addresses the key materials that generate the majority of waste-related GHG emissions. In support of these efforts, the City also has a number of initiatives underway to facilitate the adoption of technologies and solutions that support 80 x 50, including the pilots and studies described above. However, additional work lies ahead to understand the economic, environmental, and social costs and benefits as well as to develop the regulatory framework that will guide safe and equitable installation of the most promising technologies.

Greater adoption of GHG-reducing waste management solutions also requires education and partnership with community organizations, property owners, and the general public to change perceptions. For example, technologies associated with the use of waste to generate energy are equated with outdated incineration technologies that have been banned in the city since the 1980s. Today's waste-to-energy technologies are far more advanced and must meet strict health and safety requirements. Regulators need to work together with industry leaders and communities to understand the appropriate conditions for installing safe technologies and use these guidelines to create clear, streamlined regulations and processes to guide their deployment.

Finally, the private sector needs to play a role in greater deployment of GHG-reducing waste strategies, including anaerobic digestion and composting, and implementing more sustainable practices. Clear regulations will support investment of additional organics processing and supporting infrastructure for the city's waste, but private waste management companies can also adopt route optimization strategies, vehicle upgrades, and other strategies to further reduce their GHG footprints. These efforts must be supported by waste reduction and better source separation efforts by businesses and individuals citywide.

Waste Strategies	Energy	Buildings	Transportation	Waste
Engage all sectors in reducing waste disposal to landfills				●
Minimize waste generated by all City agencies				●
Launch outreach campaigns to reduce food waste				●
Implement proven incentive-based systems to minimize waste generation				●
Support increasing citywide reuse and donation				●
Accelerate diversion of recyclable materials from landfills				●
Capture organics and ensure sufficient capacity to facilitate beneficial reuse in both the residential and commercial sectors				●
Expand energy recovery from wastewater processing operations	●			●
Reduce emissions from all modes of transportation for all waste streams			●	●

greeNYC

The Role of New Yorkers

One of the most valuable assets the city has in reaching our 80 x 50 goal is our residents. The everyday choices New Yorkers make, like whether to weatherize, drive, take public transit, recycle, or adjust their thermostat, add up—and fast. Through voluntary action, the city's residents can drive significant reductions in greenhouse gas emissions. GreeNYC is dedicated to engaging New Yorkers in adopting these high-impact actions.

GreeNYC is a sophisticated marketing and data-driven program that aims to change the behaviors and thought processes of New Yorkers over time through strategic, multi-media education campaigns, events and partnerships. With a strong brand supported by the recognizable and accessible "Birdie" mascot, initiatives have included encouraging residents to stop car engine idling, using air conditioners more efficiently in summer months, using energy efficient lighting, drinking tap water, biking to work, reducing paper consumption by opting out of unwanted catalogs and increasing the use of reusable bottles, mugs and shopping bags.

GreeNYC uses a multi-disciplinary approach, combining marketing, behavioral research, climate psychology and behavioral economics to engage residents to change behavior to reduce GHG

B.Y.O. BOTTLE

emissions from the city's largest emitting sectors--buildings, energy supply, transportation, waste--and other environmental topics. It measures environmental impacts of campaigns in addition to more traditional measures of engagement, and relies on thriving partnerships with corporate partners, non-governmental institutions, and a diverse range of small businesses to achieve its goals. This, coupled with a strong brand adopted across multiple City agencies, allows GreeNYC to not only connect with the public to achieve meaningful results, but to arm New Yorkers with the right tools to make a difference.

The GreeNYC Brand

The GreeNYC brand was conceived with the intention to shift away from using the shaming, guilt, and fear-inducing approaches that have been commonly used to drive environmental behavior change, and thereby increase engagement and appeal beyond those already inclined toward green behavior. To increase the accessibility of the brand, the mascot "Birdie" was created. Birdie is designed not as an authority on all things environmental, but instead as a New Yorker, engaging in the behaviors he is encouraging. In addition to being featured graphically in GreeNYC materials, Birdie also represents GreeNYC at events in the city to build awareness and participation. New Yorkers have had an overwhelming positive response to the brand. A 2015 survey found that 70 percent of New Yorkers who saw the "B.Y.O." campaign reported it made them feel "informed," "happy" and "grateful." That same survey found that almost half of all New Yorkers were familiar with the mascot's image, a demonstration of Birdie's success as representative of GreeNYC.

The Environmental Impact of Everyday New Yorkers

GreeNYC has pioneered a data-driven approach to public education that is coupled with the successful GreeNYC brand and strategy. This has enabled the city to effectively engage New Yorkers in taking on actions that have had measurable impacts on our environment, emphasizing the idea that New Yorkers' actions can help realize policy goals or fill in the gaps created by absent or recently initiated policies. Moreover, GreeNYC's efforts have highlighted that individual actions can generate impact quickly and at a lower cost than technological or infrastructure interventions. The fact that New Yorkers already view themselves as leading agents of change along with local government demonstrates the need to continue and grow the effort to engage and support New Yorkers in living more sustainably.

Early on, the Mayor's Office recognized that decisions the city's 8.5+ million residents make about how they consume and discard goods, move around the city, use energy and water have a tremendous impact on citywide GHG emissions and environmental quality. In some cases, the City can mandate residents to change behaviors, but many of the steps New Yorkers can adopt to improve the environment of the city are voluntary. Through residents' participation, GreeNYC has achieved gains that complement strategies in policy, infrastructure and law enforcement. Multiple surveys have shown New Yorkers see themselves and local government as the entities most responsible for improving the city's environment. GreeNYC exists at this intersection and deploys an accessible and positive brand coupled with compelling data-driven messaging to engage residents and achieve measurable environmental benefits.

Moving Forward Towards 80x50

Moving forward, GreeNYC will continue to research, plan, implement and measure the impacts of strategic behavior change campaigns. GreeNYC will continue to collaborate with City agencies and outside partners to educate and influence the public on their ability to change the behaviors. GreeNYC will continue to do behavioral impact research to identify high-impact target actions, messaging strategies, engagement strategies and tools for environmental impact assessment.

GreeNYC has distributed over 30,000 reusable bags to New Yorkers who pledge to consume fewer plastic bags. Photo credit: Stacy Lee

Next Steps

The path forward

Achieving 80 x 50 presents a unique opportunity for New York City to continue our global leadership on environmental action. The City is hard at work implementing the climate policies and programs will that put us on the path to 80 x 50. Our roadmap highlights the challenges to reaching 80 x 50, particularly in a dense, urban environment, as well as the opportunities that exist to transform our city in the face of climate change. To guide our next steps, the City will work to ensure that all New Yorkers will benefit from the economic opportunities that will come with the transition to a low-carbon future. By: (1) supporting the development of the workforce, (2) fostering emerging technologies, (3) spurring the expansion of new industries locally, and (4) working together, we can ensure that we reach 80 x 50 and create a strong and just future for New York City.

1. We will create new green job opportunities

80 x 50 is an opportunity to grow a dynamic and inclusive economy and to make the city more resilient against climate change. We will ensure New York City's workforce can support and participate in our low-carbon future. We will work with partners to ensure that architects, engineers, and design professionals are trained to design for holistic building energy performance and contractors and tradespeople can construct high performance buildings. We will also support emerging clean energy entrepreneurs and facilitate training to develop a workforce to install and maintain clean energy technologies. As new technologies take hold, including solar PV, anaerobic digesters, and electric vehicles, a high-skilled workforce will be in increasing demand. We will continue to work with partners to leverage the creation of training and job opportunities to improve wages and increase skills among New Yorkers most in need of economic opportunity.

2. We will adopt promising technologies

Since we cannot predict future innovations, New York City's Roadmap to 80 x 50 is based on technologies available today. However, the City plays a key role in the adoption of new and emerging technologies and helps to guide deployment through thoughtful regulations. We will continue to test these technologies on our own assets, including our buildings, fleet, and land. The City will also look to expand innovative new strategies including carbon sequestration, which has the potential to create net-negative emissions. We are committed to catalyzing the market by sharing the results of studies, supporting local clean tech entrepreneurs, and using our own purchasing power for technology with proven cost and energy efficiency benefits.

3. We will spur new local industries

New York City will continue to be a global hub for energy efficiency and clean energy technology through NYCEDC initiatives, such as UrbanTech NYC and Applied Sciences NYC. These initiatives will support the creation of thousands of new jobs and bring a cadre of highly skilled professionals, further establishing New York City as a global leader in sustainable urban innovation.

4. We will work together

We can all make simple changes in our homes and lifestyles that will help us achieve 80 x 50. The decisions we make about goods we consume, and how we dispose of them, how we purchase and use appliances, and the

Grand Central Tech
Photo credit: NYC Economic Development Corporation

Shared Streets at Bowling Green
Photo credit: NYC Department of Transportation

temperature at which we keep our homes can have a significant impact. Through strategic and data-driven marketing efforts, GreeNYC empowers New Yorkers to make smart decisions that will achieve meaningful impacts. GreeNYC is the City's public education program that empowers New Yorkers to take actions to live more sustainably, which can save residents money, improve personal comfort, and help the City's overall GHG reduction goals. GreeNYC uses a data-driven approach to identify target audiences, create messaging and artwork, design media plans, develop partnerships, and measure results. Future GreeNYC campaigns will help New Yorkers reduce waste from food, paper, and plastics; take simple steps to weatherize their homes; use appliances more efficiently; switch to more efficient light bulbs; adjust thermostats; unplug chargers and electronics when not in use; and purchase more energy efficient appliances.

The City will also continue to make changes to its own buildings and operations to reduce its GHG impact and encourage its employees to take actions in the office and at home. For example, employees are encouraged to "burn calories, not energy" by taking the stairs as often as possible instead of the elevators and to recycle and compost their waste.

The City will evaluate and prioritize strategies and policy options necessary for 80 x 50 by their ability to achieve cobenefits across all four lenses of *OneNYC*. Cobenefits will include affordability, health and wellbeing, reliability of utilities and services, adaptation, economic opportunity, diversification and flexibility of services, and access for all New Yorkers.

To encourage continued engagement with New York City residents and start a conversation about the challenges and opportunities to achieving 80 x 50, the City will develop an interactive, online educational tool. Once built, the interactive tool will enable residents and the general public to create their own roadmap to 80 x 50 for New York City. Drawing on the City's 80 x 50 analysis, users will be able to create different combinations of strategies to reduce GHG emissions from the city's energy supply, buildings, transportation, and waste and visualize the projected outcomes of their choices.

We will continue to update this roadmap as part of OneNYC

Technologies, regulations, and markets are rapidly changing. To ensure the roadmap remains relevant, it must be dynamic. Therefore, progress toward 80 x 50 will be captured in the annual *OneNYC* progress reports and our analysis and assumptions will be updated every four years as part of the *OneNYC* update. By driving our progress as part of *OneNYC*, we will create a more sustainable, more resilient, and more equitable city.
New Yorkers deserve nothing less.

Rooftop garden at Brooklyn Navy Yard
Photo credit: NYC Economic Development Corporation

80
50

Glossary

Term	Definition
80 x 50	An 80 percent reduction in citywide greenhouse gas emissions by 2050 from a 2005 baseline. New York City made a commitment to 80 x 50 in September 2014. To reach 80 x 50, over 43 million metric tons of carbon dioxide-equivalent (CO_2e) emissions reductions relative to business as usual trends will need to come from cleaner power generation, fossil-fuel-free modes of transportation, a reduction of solid waste and improved waste management, as well as improvements to the energy efficiency of buildings across New York City.
Carbon Dioxide Equivalent (CO_2e)	A measure for describing how much global warming a given type and amount of greenhouse gas may cause, using the equivalent amount or concentration of carbon dioxide (CO_2) as a reference. CO_2e is commonly expressed as million metric tons of carbon dioxide equivalent ($MtCO_2e$).
Accelerated Conservation & Efficiency (ACE) Program	Launched by DCAS Energy Management in 2013, this program provides funds on a competitive basis for capital projects identified by City agencies that improve energy efficiency and reduce greenhouse gas (GHG) emissions from municipal buildings.
Air Source Heat Pump (ASHP)	A system that uses electricity to extract heat from cold outdoor air during the winter in order to provide heat indoors, or to extract heat from indoor spaces to provide cooling. An ASHP uses a refrigerant system involving a compressor and a condenser to absorb heat from one place and release it at another. They can be used as a space heater or cooler, and are sometimes called "reverse-cycle air conditioners."
Anaerobic Digestion	A process by which organic matter, such as food waste or sewage, is broken down in the absence of oxygen to produce biogas and biofertilizer.
Autonomous Vehicles (AVs)	Also known as self-driving vehicles, vehicles in which at least some aspects of a safety-critical control function (e.g., steering, acceleration, or braking) occur without direct driver input.
Base Load	The minimum level of demand on the electric grid over a period of time.
Battery Electric Vehicles (BEV)	A type of electric vehicle that uses rechargeable battery packs to store chemical energy. Electric motors and motor controls use the stored chemical energy to propel the vehicle in lieu of a traditional internal combustion engine.
Battery Storage System	A method of storing electricity on site for use as an alternative to electricity supplied from the electrical grid. It can be used during periods of high demand on the electrical grid or during emergencies as backup power.
Best Practice Model (BPM)	A regional travel demand model employed by the New York Metropolitan Transportation Council (NYMTC) to predict changes in future travel patterns based on expectations for demographic profiles and transportation systems in the region.
Biodiesel	A renewable alternative to petroleum diesel fuel (petrodiesel) used as heating fuel and in standard diesel engines. It can be used alone or blended with petrodiesel in various proportions to reduce GHG and particulate matter (PM) emissions, and to improve lubricity. The main sources for biodiesel are agricultural products such as soybeans and grapeseed (virgin oils), or waste products such as used cooking oil and unwanted animal fats (nonvirgin oils).
Biodigester	See *Liquifiers*.

Biofuels	Fuels, such as biomass, biogas, biodiesel, or ethanol, that are produced from biological processes, such as agriculture and anaerobic digestion.
Biogas	A source of renewable energy, specifically methane, that is derived from the process of bacterial decomposition of sewage, manure, waste, plant crops, or other organic waste products.
Biomass	Any plant-derived organic matter available on a renewable basis, including agricultural and feed crops, agricultural crop wastes and residues, wood wastes and residues, aquatic plants, animal wastes, municipal wastes, and other waste materials. As an energy source, biomass can either be used directly via combustion to produce heat or converted into various forms of biofuel.
Building Retrofit	Changes to the structure or systems of an existing building. Building retrofits allow for reductions in energy and water consumption with the use of more efficient technologies, products, and designs, and can improve amenities for the building's occupants.
Buildings Technical Working Group (TWG)	A group of architects, engineers, academics, environmental advocates, labor unions, and real estate leaders convened by the City of New York to identify the leading edge standards for new construction and substantial renovations and the systems-specific opportunities for existing buildings to place buildings on the pathway to achieve 80 x 50 at a citywide level. The TWG also evaluated financial and regulatory structures and assessed the operations, maintenance, and training necessary to enable this transformation.
Business as Usual (BAU)	A methodological framework that incorporates expected conditions from all policies and programs enacted by the State and federal government or from local policies and programs enacted prior to the de Blasio administration. This serves as a baseline against which proposed policy measures and programs will be evaluated towards achieving the 80 x 50 goal.
Carbon Intensity	The amount of carbon dioxide equivalent emitted per unit of energy.
Combined Cooling Heating and Power (CCHP)	Also known as trigeneration, this form of combined heat and power includes the production of cooling through the use of absorption chillers that use steam produced by combined heat and power (CHP) engines.
Combined Heat and Power (CHP)	Also known as cogeneration, CHP is the simultaneous production of two or more useful forms of energy from a single device, typically electricity and useful heat. A CHP system will take fuel, most commonly natural gas, to generate electricity. Excess heat from this process is then used to provide space or hot water heating to buildings, or process heat for manufacturing.
Community Energy	Refers to technologies that are used to produce and distribute energy for two or more buildings. This can include distributed generation, district heating and cooling, microgrids, and/or energy storage.
Community Wind	A system of locally-owned wind turbines which convert wind into electricity. These commercial-scale wind turbines can help communities save energy costs and reduce the need to purchase electricity from a utility.

Corporate Average Fuel Economy (CAFE) Standards	First enacted by Congress in 1975, CAFE standards are designed to improve the average fuel economy, based on miles per gallon, of cars and light trucks produced for sale in the United States. Each automaker is required to sell a mix of vehicles that meet each year's CAFE standard or pay penalties. In 2012, the most recent CAFE standards were adopted, setting new regulations for model years 2017-2025 that yield an average fuel economy of 54.5 miles per gallon by model year 2025.
Criteria Air Pollutants	Six common air pollutants that are assigned specific National Ambient Air Quality Standards (NAAQS) through the Clean Air Act: particle pollution, also referred to as particulate matter (PM), photochemical oxidants and ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead.
Dehydrators	Equipment used to heat and agitate waste in order to separate the liquid and solid portions as a means to reduce food waste weight and volume. Byproducts of this process are a residual mulch-like material—which can be disposed of via landfill, composting, soil amendment, or fertilizer—and condensate water, which is drained to the sewer.
Demand Management Strategies	Also known as demand-side management (DSM), demand management strategies reduce and/or shift customer energy demand and can help relieve stress on the central electric grid.
Distributed Energy Resources (DER)	Sources of energy that are smaller than utility-scale energy sources and can be aggregated to provide the power necessary to meet regular demand.
Distributed Generation (DG)	Technologies that allow consumers to generate electricity on site through solar photovoltaic (PV) systems, combined heat and power (CHP), and other technologies. DG can serve one or more buildings and can bolster resiliency by adding redundancy to the supply of energy and reducing strains on the electrical grid.
District Energy	See *District Heating and Cooling*
District Heating and Cooling	Also referred to as "district energy," systems that produce steam, hot water, or chilled water at a central plant that is piped underground to multiple buildings.
Domestic Hot Water (DHW)	Potable water for use within a building. DHW is typically heated in a boiler or a tankless electric coil system and distributed to buildings' water fixtures and water-consuming appliances, such as washing machines, for occupants' use.
E-Bikes / Electric Bicycles	Bicycles with an electric motor that assist with user mobility. The current regulatory environment creates uncertainty on which types of "e-bikes" are legal for use.
Electric Vehicles (EVs)	An umbrella term to describe a variety of vehicle types that use electricity as their primary fuel source for propulsion or as a means to improve the efficiency of conventional internal combustion engine. These generally include battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), and fuel cell electric vehicles (FCEV).
Energy Conservation Measure (ECM)	Systems that are installed within a building or maintenance activities to existing systems that are implemented to reduce building energy consumption. An ECM may also be referred to as a building retrofit.

Energy Audit	An assessment of the energy-using systems and processes within a building that consume energy. The audit process produces a list of recommended energy conservation measures (ECM) and operational changes that will result in energy reductions if implemented.
Energy Benchmarking	The measurement of energy consumed by a building or group of buildings over a set amount of time. Energy benchmarking be used to observe changes in building energy use over time and track the effect of building improvements on energy use.
Energy Efficiency	The use of less energy to provide the same service. A building, machine, or other energy consuming object is more energy efficient if it delivers more functions or services for the same energy input, or the same function or service for less energy input.
Energy Storage	Technologies that save generated energy and use it at another time. Energy storage includes electric systems such as batteries as well as thermal systems such as hot and cold water storage tanks. Energy storage can enhance the technical and economic viability of distributed generation, and it can operate critical systems during grid outages.
Energy Use Intensity (EUI)	The "amount of energy consumed over a set period of time and normalized by another factor, such as per square foot or per person. EUI is most commonly calculated by dividing the total energy consumed by the building in one year (typically measured in kBtu) by the total gross floor area of the building," allowing for comparison of building performance across buildings of different sizes.
Environmentally Preferable Purchasing (EPP)	Governmental purchasing program that focuses on human health and the environmental impact of goods and products purchased by selecting products that are more environmentally preferable to others. NYC's environmental purchasing program takes into account several factors, such as waste production, energy and water use, greenhouse gas emissions, indoor air quality, recycled and reused content and the presence of hazardous substances.
Fine Particulate Matter (PM2.5)	Refers to fine particles or droplets in the air that are two and one half microns or less in width, or thirty or more times smaller than that of a typical human hair. PM2.5 travel deeply into the human respiratory tract, reaching the lungs. Exposure to fine particles can cause short-term health effects such as eye, nose, throat and lung irritation, coughing, sneezing, runny nose, and shortness of breath. Exposure to fine particles can also affect long-term lung function and worsen medical conditions such as asthma and heart disease.
For-hire Vehicles (FHVs)	Vehicles that provide prearranged services for passengers to contact companies that have networks of licensed drivers and vehicles that can pick them up, as licensed through the NYC Taxi and Limousine Commission.
Fuel Cell Vehicles (FCV) / Fuel Cell Electric Vehicles (FCEVs)	Vehicles that use a fuel cell and an on-board energy storage device to power an electric motor. The "fuel cell combines oxygen from the air with compressed hydrogen stored on-board to generate electricity for the motor. Most emit only water and heat, which results in their classification as a zero-emission vehicle.

Gateway Program	A proposed set of strategic rail infrastructure improvements designed to improve current services and create new capacity that will allow the doubling of passenger trains running under the Hudson River. It would involve constructing a new two-track tunnel under the Hudson River.
Geothermal Energy	Heat from the earth that can be used as a renewable source of energy.
Geothermal Heat Pumps	Systems that use the relatively stable temperature of the earth to provide heating and cooling for buildings. These systems consist of a heat pump installed within the building and a ground coupling system that consists of piping or wells to transfer heat to and from the ground. This term is interchangeable with "ground source heat pumps."
Gigawatt (GW)	A unit of electric power equal to one thousand megawatts (MW) or one billion watts .
Greener, Greater Buildings Plan (GGBP)	New York City's comprehensive plan to target energy efficiency in large existing buildings released in 2009. It includes job training opportunities, a financing entity called the New York City Energy Efficiency Corporation (NYCEEC), and Local Laws 84, 85, 87, and 88 of 2009.
Greenhouse Gas (GHG) Emissions	Gases that trap heat in the atmosphere by absorbing and emitting solar radiation within the atmosphere, causing a greenhouse effect that warms the atmosphere and leads to global climate change. The main GHGs are water vapor, carbon dioxide, methane, nitrous oxide, and ozone.
GreeNYC	A City-run program dedicated to educating, engaging, and mobilizing New Yorkers to help New York City meet its ambitious sustainability goals of generating zero waste and reducing GHG emissions 80 percent by 2050.
Ground Source Heat Pumps	Systems that use the relatively stable temperature of the earth to provide heating and cooling for buildings. These systems consist of a heat pump installed within the building and a ground coupling system that consists of piping or wells to transfer heat to and from the ground. This term is interchangeable with "geothermal heat pumps."
Heat Capture	A suite of technologies that recover waste heat, often from commercial and industrial activities such as power plants, electrical substations, and pumping stations or from building cooling systems. The waste heat can be used when there is a simultaneous demand for heating or it can be stored for future use.
International Existing Building Code (IEBC)	A model code developed by the International Code Council that establishes minimum regulations for existing buildings intended to encourage the use and reuse of existing buildings, while requiring reasonable upgrades and improvements .
kBtu	One thousand British thermal units. Often used to calculate the energy use intensity (EUI) per square foot of buildings.
Kilowatt (kW)	A unit of electric power equal to 1,000 watts.
Kilowatt Hour (kWh)	A measurement of the amount of kW of electrical power used in one hour.
Lifecycle GHG Emission	The full range of GHG emissions associated with the raw materials extraction, manufacturing or processing, transportation, use and end-of-life management of a good or service. Includes all GHG emission scopes (1, 2, and 3) per the Global Protocol for Community-Scale GHG Emissions.

Light-emitting Diode (LED) A technology that produces light efficiently by passing electrical currents through semiconductor material. LED light bulbs emit more visible light using less electrical power and have a longer lifespan than traditional incandescent light bulbs or compact fluorescent lamps.

Liquefiers Biological liquefaction systems, also known as "biodigesters" or "liquid composters" that break down organic waste in the absence of oxygen to produce biogas and biofertilizer. The process produces only grey water as a by-product, which is discharged to the sewer.

Liquid Composter See *Liquifiers*.

Load Pocket A geographic area that does not have sufficient transmission for electricity to reliably supply its total demand for electricity, and must have generation capacity located within that area.

Local Law 84 of 2009 (LL84): Benchmarking A local New York City law that requires owners of buildings over 50,000 gross square feet to measure their energy and water consumption annually in a process called benchmarking.

Local Law 87 of 2009 (LL87): Energy Audits & Retro-commissioning A local New York City law that requires buildings over 50,000 gross square feet to conduct an energy audit and perform retro-commissioning once every 10 years.

Local Law 88 of 2009 (LL88): Lighting & Sub-metering A local New York City law that requires owners of large non-residential buildings to upgrade lighting to meet current New York City Energy Conservation Code standards and to install electrical sub-meters for each large non-residential tenant space, and provide monthly energy statements.

Low-Carbon Fuel Standard (LCFS) A regulation administered by the California Air Resources Board (CARB). The LCFS requires producers of petroleum-based fuels to reduce the carbon intensity of their products. Petroleum importers, refiners, and wholesalers may develop their own low carbon fuel products or buy LCFS credits from other companies that develop and sell low carbon alternative fuels, such as biofuels, electricity, natural gas or hydrogen.

Low-Carbon Fuels (LCFs) A general classification of fuel types that may be used by the transportation sector to lower the greenhouse gas emissions from petroleum-based fuels, such as gasoline or diesel. Fuels that are currently subject to California's regulation of low carbon fuels include gasoline, diesel, compressed and liquefied natural gas (from either fossil or bio-based sources), electricity, hydrogen, ethanol, and biomass-based diesel.

Megawatt (MW) A unit of electric power equal to one million watts.

Microgrid An electrical distribution network that is connected to two or more buildings in a local area. With the appropriate controls and design, some microgrids can enter into "island mode" and provide power to buildings without using the central grid.

Mini-Split A ductless air source heat pump (ASHP) system that allows a single outdoor unit to be connected to indoor units in several rooms.

Million Metric Tons of Carbon Dioxide Equivalent ($MtCO_2e$) A measure for describing how much global warming a given type and amount of greenhouse gas may cause, using the equivalent amount or concentration of carbon dioxide (CO_2) as a reference.

Net-zero Energy	A concept to describe structures and systems that produce enough renewable energy to meet their own annual energy consumption requirements.
New York City Solid Waste Management Plan (SWMP)	A program adopted in 2006 to switch the export of NYC residential waste from truck-based methods to an equitable network of marine and rail transfer stations located in all five boroughs.
New York State Multiple Dwelling Law	A state law that protects against intensive occupation of multiple dwelling sites, overcrowding of multiple dwelling rooms, inadequate provision for light and air, insufficient protection against the defective provision for escape from fire, and improper sanitation of multiple dwellings in certain areas of the state.
NYC Solar Partnership	A collaboration between the Mayor's Office of Sustainability, the New York City Economic Development Corporation, and Sustainable CUNY that supports the goal to install 1 GW of solar on roofs citywide by 2030.
On-Site Renewable Power	Energy that is generated on-site in a building that comes from renewable resources, including sunlight, wind, and geothermal heat.
Packaged Terminal Air Conditioner (PTAC)	A self-contained air conditioning and heating unit that is installed through a wall and designed to cool or heat a single space.
Passive House	A rigorous standard for energy efficiency in a building that uses less than 10 kBtu per square foot per year for heating and cooling, resulting in a 60-70 percent reduction in energy use from New York City's existing required building standards. Passive house standards result in a very well insulated, virtually air-tight building that minimizes heating and cooling needs, and therefore also reduces energy usage. A significant portion of heat is provided externally via solar energy and internally from building occupants and electrical equipment, while balanced fresh air is constantly supplied.
Peak Demand	The maximum level of demand on the electric grid during a given time frame.
Peak Periods	Periods of time during which energy use and the costs to produce energy are highest. For electricity, peak periods are typically during the hottest hours of the summer. For natural gas, they are usually during the coldest periods of winter.
Performance-Based Energy Code	An energy code that requires a whole-building energy performance target, for example energy use intensity (EUI) per square foot, as opposed to requiring efficiency standards for individual pieces of equipment.
Plug Load	Building energy consumption attributed to appliances or devices that draw electricity from a standard electricity socket.
Plug-in Hybrid Electric Vehicles (PHEV)	Vehicles that use on-board rechargeable batteries that can be recharged from an external source of electric power. These vehicles have both an electric motor and an internal combustion engine, thus sharing similarities with conventional hybrid vehicles.
Power Purchase Agreement (PPA)	A contract between a seller who generates electricity and a buyer looking to purchase electricity, often used for purchases of renewable sources of energy separate from the utility.
Public Service Commission (PSC)	New York State's public utilities commission that regulates and oversees electric, gas, steam, telecommunication, and water services.

Renewable Energy	Energy that comes from resources which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat.
Shared or Sharing Economy	A trend toward renting or borrowing assets for specific services rather than owning the asset outright. In transportation, this can mean using car share services to replace traditional car ownership.
Site Energy Use	The amount of on-site heat and electricity consumed by a building as reflected in utility bills.
Smart Grid Technologies	Technologies that use communications, remote control, and automation software to enhance reliability and energy efficiency of the electric grid and to respond to the growth of distributed energy resources. Smart grid technologies include smart meters, controls, computers, and equipment that enable automated demand response for utilities to address real time swings in electric supply and demand, and enable two-way communication between the utility and its customers to allow customers to also reduce demand.
Solar Canopies	Structures that elevate solar photovoltaic systems above building roofs, allowing the systems to avoid conflicts with other rooftop uses, including fire access areas.
Solar Photovoltaic (PV)	Also known as solar electric systems or solar panels, these are systems that convert sunlight into electricity. Any excess electricity produced that a building does not use can be sold to the utility through a process called net-metering.
Solar Thermal	Systems that use solar energy to generate hot water that can be used for domestic hot water and/or space heating in buildings. The system can be paired with thermal energy storage that can store heat until it is needed to meet demand.
Solarize NYC	A program that provides resources and assistance for communities to run solar group purchasing campaigns that lower the costs of installations by aggregating demand.
Source Energy Use	The amount of heat and electricity consumed by a building accounting for transmission or distribution losses.
Space Heating	Mechanical systems that deliver heating, and sometimes humidification, to a building's internal spaces. Heat is typically delivered through air ducts, hot water (referred to as hydronic systems), or steam from a central furnace or boiler.
Sustainable Modes	Walking, bicycling, and traditional "fixed-route" transit services (subway, bus, commuter rail, and ferry). Sustainable modes currently account for 67 percent of trips within New York City.
Thermal Energy Storage (TES)	Technologies that make it possible to store thermal energy for consumption at a later time. By creating a delay between the production and consumption of heating and/or cooling, TES allows renewable sources of heat to be accessed at the optimal time for production.
Transportation Network Companies (TNCs)	Companies that provide a platform to connect customers with drivers via websites and/or mobile apps.

Variable Refrigerant Flow (VRF)	A centralized air source heat pump (ASHP) system that has the ability to modulate and meet a building's heating and cooling needs by different zones within a building. This prevents the common, but inefficient, practice of reheating chilled air.
Vision Zero	A citywide commitment to reduce and ultimately eliminate all traffic-related injuries and deaths that occur on city streets. This ambitious goal is being met through expanded enforcement against dangerous moving violations like speeding and failing to yield to pedestrians, new street designs and configurations to improve safety, broad public outreach and communications, and a sweeping legislative agenda to increase penalties for dangerous drivers and give New York City control over the safety of its streets.
Vehicle Miles Traveled (VMT)	A measurement of miles traveled by vehicles within a specified region for a specified time period.
Water Benchmarking	The measurement of water consumed by a building or group of buildings over a set amount of time.
Water Source Heat Pumps	Systems that use the relatively stable temperature from large bodies of water to provide heating and cooling for buildings. This term is also used to refer to heat capture systems that utilize water loops that circulate through buildings and districts. Water source heat pumps can also be deployed as a hybrid system in a building using a central boiler to heat water and a heat pump system tapping into the boiler's hot water supply.
Watt	A watt is used to express the rate of energy conversion or transfer with respect to time. A watt is defined as one joule of energy per second.
Watt-hours	A measurement of energy describing the total amount of electricity used over time. Watt-hours are a combination of how fast the electricity is used (watts) and the length of time it is used (hours).

Directory of Abbreviations

BEEx	Building Energy Exchange
BIC	City of New York Business Integrity Commission
BOMA NY	Building Operators Management Association NY
BPL	CUNY Institute for Urban Systems Building Performance Lab
Con Edison	Consolidated Edison, Inc.
CUNY	City University of New York
DCAS	New York City Department of Citywide Administrative Services
DCP	New York City Department of City Planning
DDC	New York City Department of Design and Construction
DEP	New York City Department of Environmental Protection
DOB	New York City Department of Buildings
DOE	New York City Department of Education
DOHMH	New York City Department of Health and Mental Hygiene
DOT	New York City Department of Transportation
DSNY	New York City Department of Sanitation
FDNY	Fire Department of the City of New York
HDC	New York City Housing Development Corporation
HPD	New York City Department of Housing Preservation and Development
LPC	New York City Landmarks Preservation Commission
MOS	New York City Mayor's Office of Sustainability
MTA	Metropolitan Transportation Authority
NYCEDC	New York City Economic Development Corporation
NYCEEC	New York City Energy Efficiency Corporation
NYCHA	New York City Housing Authority
NYISO	New York Independent System Operator
NYMTC	New York Metropolitan Transportation Council
NYPA	New York Power Authority
NYSDOT	New York State Department of Transportation
NYSERDA	New York State Energy Research and Development Authority
NYSRC	New York State Reliability Council
ORR	New York City Mayor's Office of Recovery and Resiliency
PANYNJ	Port Authority of New York and New Jersey
PSC	New York State Public Service Commission
REBNY	Real Estate Board of New York
RGGI	Regional Greenhouse Gas Initiative
SCA	New York City School Construction Authority
TLC	New York City Taxi and Limousine Commission
TWG	Buildings Technical Working Group
U.S. EPA	U.S. Environmental Protection Agency

End Notes

Introduction

1. Based on updated 2014 GHG emissions, originally reported in the Inventory of New York City Greenhouse Gas Emissions in 2014 (published April 2016). Through the 80 x 50 analysis, more rigorous methodologies for representing transportation and waste emissions were identified. These methodologies were applied to both the 2005 baseline and 2014 data for the Transportation and Waste sectors, and formed the basis of the 80 x 50 analysis. These changes reduced the share of citywide GHG emissions attributable to energy use in buildings, while the total magnitude of building-based GHG emissions remained the same.

Methodology

1. NYC DSNY (2013). NYC Curbside Waste Characterization Study, retrieved from: http://www1.nyc.gov/assets/dsny/docs/2013-Waste-Characterization-Study.pdf

Energy

1. National Renewable Energy Laboratory (NREL). Annual Technology Baseline – 2015 Final.
2. Smartgrid.gov, retrieved from: https://www.smartgrid.gov/the_smart_grid/smart_grid.html
3. To evaluate energy affordability, a composite index was developed that includes the NYC-adjusted poverty rate, rent-burden, and energy-cost burden, from the NYC Center for Economic Opportunity, NYU Furman Center, and an analysis of US Census Bureau data, respectively. For air quality, data sources include annual average PM2.5 and rate of asthma hospitalizations from the NYC Department of Health and Mental Hygiene (DOHMH). For heat vulnerability, data sources include the Heat Vulnerability Index developed by DOHMH, as well as the number of nursing homes and adult care facilities per community district, from the NYC Department of City Planning's PLUTO dataset. As noted in the introduction, additional data is being integrated into the analysis and work is ongoing. Due to data privacy concerns, results of the analysis are shown at the community-district scale.

Buildings:

1. Based on updated 2014 GHG emissions, originally reported in the Inventory of New York City Greenhouse Gas Emissions in 2014 (published April 2016). Through the 80 x 50 analysis, more rigorous methodologies for representing transportation and waste emissions were identified. These methodologies were applied to both the 2005 baseline and 2014 data for the Transportation and Waste sectors, and formed the basis of the 80 x 50 analysis. These changes reduced the share of citywide GHG emissions attributable to energy use in buildings, while the total magnitude of building-based GHG emissions remained the same.
2. New York Metropolitan Transportation Council (NYMTC) projection for 2015 population growth based on 2010 enumeration.
3. City of New York (2016). One City Built to Last: Technical Working Group Report and NYU Furman Center (2014) State of New York City's Housing and Neighborhoods, retrieved from: http://furmancenter.org/research/sonychan/2014-report
4. "Business as usual" (BAU) projections are different from those cited in the One City: Built to Last Technical Working Group Report (the TWG Report) due to: 1) Updated BAU projections in this report include changes to the carbon intensity of the electric grid as part of the projected GHG reductions from buildings, and 2) One City: Built to Last policies were included as existing initiatives in the TWG Report, but have been excluded from BAU in this report.
5. Lifecycle GHG emissions include Scopes 1, 2, and 3 per the Global Protocol for Community-Scale GHG Emissions.

6. EPA, Renewable Fuel Standard.
7. California Air Resources Board (2015). Low Carbon Fuels Standard, retrieved from: https://www.arb.ca.gov/fuels/lcfs/peerreview/peerreview.htm
8. New York City Mayor's Office of Sustainability (2014).
9. New York Independent System Operator, Inc., 2015 Load & Capacity Data Report (Gold Book).
10. The NYC Building Code defines a substantial improvement as "any repair, reconstruction, rehabilitation, addition or improvement of a building or structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the improvement or repair is started. If the structure has sustained substantial damage, any repairs are considered substantial improvement regardless of the actual repair work performed." The term does not, however, include either:
    A. Any project for improvement of a building required to correct pre-FIRM health, sanitary or safety code violations identified by the commissioner, the Fire Commissioner, the Commissioner of Housing Preservation and Development, or the Commissioner of Health and Mental Hygiene, and that are the minimum necessary to assure safe living conditions; or
    B. Any alteration of a historic structure provided that the alteration will not preclude the structure's continued designation as a historic structure.
11. Lovins, A., Lovins, H., Hawken, P. Rocky Mountain Institute (1999). Tunneling through the Cost Barrier, retrieved from: http://www.rmi.org/Knowledge-Center/Library/NC99-06_TunnelingThroughCostBarrier
12. Ibid.
13. New York City (2016). The NextGeneration NYCHA Sustainability Agenda, retrieved from: http://www1.nyc.gov/site/nycha/about/sustainability.page
14. Ibid.
15. U.S. Department of Energy (2016). Heat Pump Systems: Air-Source Heat Pumps, retrieved from: http://energy.gov/energysaver/air-source-heat-pumps
16. New York City Mayor's Office (2015). Geothermal Systems and their Application in New York City, retrieved from: http://www.nyc.gov/html/planyc/downloads/pdf/publications/2015_Geothermal.pdf
17. U.S. Environmental Protection Agency (2016).
18. US Department of Energy (2015). A Common Definition for Zero Energy Buildings, retrieved from: http://energy.gov/sites/prod/files/2015/09/f26/A%20Common%20Definition%20for%20Zero%20Energy%20Buildings.pdf

Transportation

1. Institute for Quality Communities (2013). Biking, Walking, and Transit Use Across the US, retrieved from: http://iqc.ou.edu/2015/01/27/modeshare2013/
2. The International Council on Clean Transportation (2015). Assessment of Leading Electric Vehicle Promotion Activities in United States Cities, retrieved from: http://www.theicct.org/leading-us-city-electric-vehicle-activities

Waste

1. EPA (2016). Understanding Global Warming Potentials, retrieved from: https://www.epa.gov/ghgemissions/understanding-global-warming-potentials
2. NYC DSNY and BIC (2016). Private Carting Study Executive Summary, retrieved from: http://www1.nyc.gov/assets/dsny/downloads/pdf/studies-and-reports/Private_Carting_Study_Executive_Summary.pdf

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