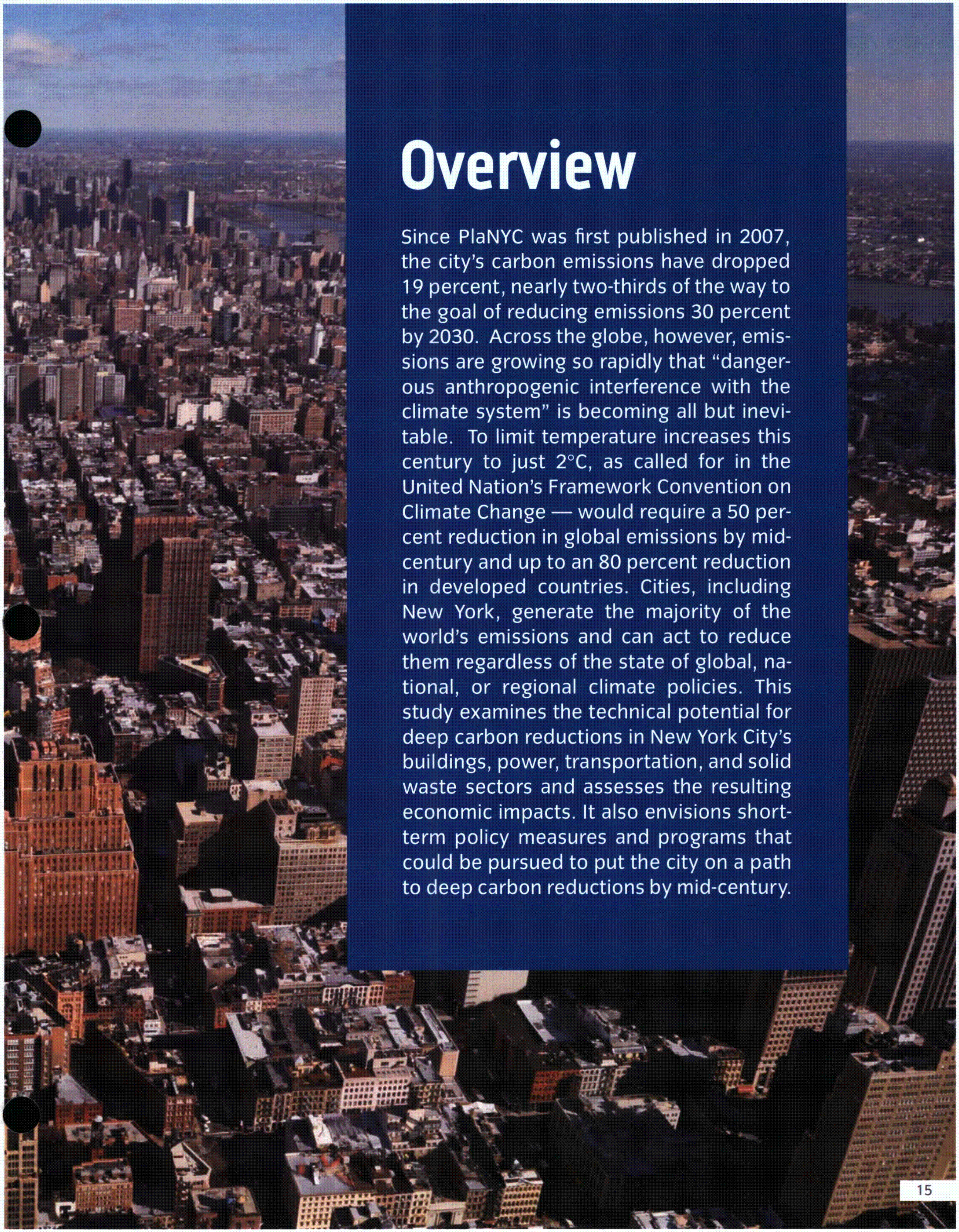


Overview

Since PlaNYC was first published in 2007, the city's carbon emissions have dropped 19 percent, nearly two-thirds of the way to the goal of reducing emissions 30 percent by 2030. Across the globe, however, emissions are growing so rapidly that "dangerous anthropogenic interference with the climate system" is becoming all but inevitable. To limit temperature increases this century to just 2°C, as called for in the United Nation's Framework Convention on Climate Change — would require a 50 percent reduction in global emissions by mid-century and up to an 80 percent reduction in developed countries. Cities, including New York, generate the majority of the world's emissions and can act to reduce them regardless of the state of global, national, or regional climate policies. This study examines the technical potential for deep carbon reductions in New York City's buildings, power, transportation, and solid waste sectors and assesses the resulting economic impacts. It also envisions short-term policy measures and programs that could be pursued to put the city on a path to deep carbon reductions by mid-century.

Why 80 by 50?

New Construction in Long Island City, Queens

New York City committed to reducing citywide greenhouse gas emissions by 30 percent before 2030 as part of its comprehensive sustainability agenda, PlaNYC, in 2007.[1] Six years later, the city's emissions have fallen by over 19 percent. The City's power supply is cleaner, its buildings are more energy efficient, and residents drive less and generate less waste. If the city is able to reduce its emissions by one percent each year over the next 16 years — only half the rate of annual reductions since 2005 — it will reach the 30 percent goal by 2030.

Despite this local progress, global emissions are rapidly accelerating: in the past five years, they have outpaced the highest of the four scenarios that the Intergovernmental Panel on Climate Change (IPCC) developed. If emissions continue on this trajectory, temperatures could rise by 4 to 6°C by 2100 and yield up to six feet of global sea level rise. (See chart: *Emissions and Temperature Rise Under Different Scenarios*).[2]

To limit the increase in temperatures to 2°C in the next century — a limit that the United Nations Framework Convention on Climate Change (UNFCCC) says is necessary to "prevent dangerous anthropogenic interference with the climate system" — global emissions would have to be reduced by at least 50 percent below 1990 levels by mid-century. Because developed countries have contributed the majority of atmospheric emissions to date and have high per-capita emissions rates compared to the global average, they would need to reduce their emissions even more aggressively, by up to 80 percent by 2050 — hence "80 by 50."

Adoption of the 80 by 50 goal is growing at the national and sub-national level. The European Union adopted the 80 by 50 goal in 2005; the United Kingdom followed in 2008. Several U.S. states including New York and California have also adopted non-binding commitments to 80 by 50, but on a national level, the United States has committed to reduce its emissions by only 17 percent from 2005 levels by 2020. Some regional efforts such as the Regional Greenhouse Gas Initiative (RGGI) in the Northeast have set more aggressive targets but have experienced political challenges in implementing programs to reduce emissions.

Cities, too, can act – both because they produce the majority of global emissions, and because they often have the tools to curb emissions even in the absence of national or regional action. New York City is responsible for close to half a percent of total global emissions if consumption is taken into account – and City government has substantial tools to promote emissions reduction. These include its ability to regulate buildings and land use, collect taxes and offer incentives, create public-private partnerships, offer technical assistance, and develop and operate major infrastructure as well as thousands of public facilities.

Study Objectives

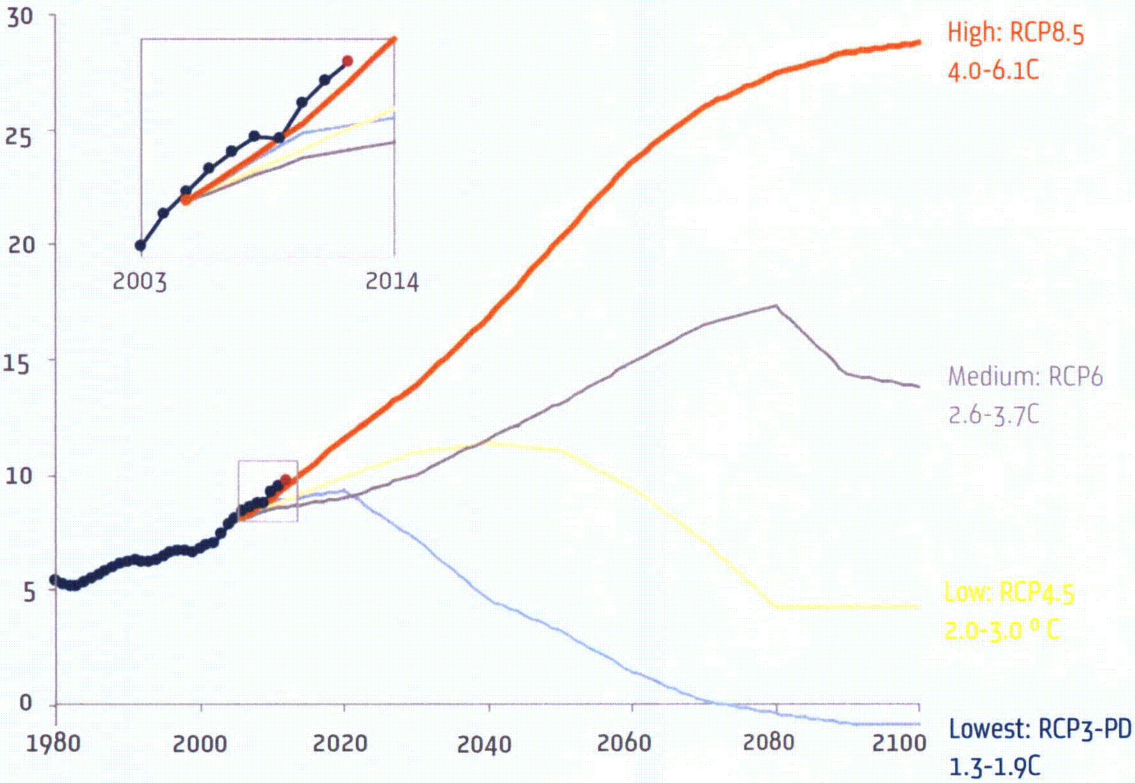
The 2011 update to PlaNYC called on the Mayor's Office of Long-Term Planning and Sustainability (OLTPS) to examine the feasibility of achieving 80 by 50 in New York City. The ensuing research was informed by other long-term studies conducted locally and abroad.[3] This resulting document is a research study, however, and should not be misinterpreted as an endorsement of the 80 by 50 target. The appropriate long-term reduction target for a city like New York — which has already reduced emissions aggressively and is far below the U.S. national average in per capita emissions — might well be lower and policy makers' focus may be better suited to shorter timeframes. Still, it is important to pose long-term questions, diagnose problems, and assemble possible solutions with a level of rigor that the seriousness of the challenge requires. This report does not advance specific policy proposals, but instead examines how New York City could move towards 80 by 50, or a more near-term accelerated goal, if it chooses to.

Study Approach

Because the city's carbon emissions come from four very different sectors – buildings, power generation, transportation, and solid waste – the study examines strategies in each one individually at first. The study analyzes over 70 individual carbon reduction measures in all four of the sectors, building on both city data and expert- and experience-driven assumptions about the kind of actions that realistically could be accomplished.

It is also important to consider how the four sectors interact and function as a whole. For example, making

Emissions and Temperature Rise Under Different Scenarios
Billions tons of CO_2e per year from fossil fuels, cement production, and gas flaring



Source: NYC Mayor's Office

buildings more energy efficient reduces the amount of clean power that is necessary, while electric vehicles are only as clean as the electric grid is. The study accounts for these interactions so that changes in one sector are reflected in all others. A collective "package" of least cost measures across the four sectors is then assembled based on both the technical potential and economic analysis. This package, or pathway, to 80 by 50 is then evaluated for its impacts on jobs and the economy.

Converting technical potential into real emissions reductions can be extremely challenging. The economics of a carbon abatement measure might be attractive in theory, but any number of barriers may arise — financing may not be readily available, regulations might be too complex, or the opportunity cost, may simply be too high. Furthermore, actions to reduce carbon would lie in the hands of millions of people making countless daily and long-term decisions.

With this in mind, the study carefully evaluates the barriers to implementing carbon abatement measures in each sector and then proposes potential ways to overcome those obstacles.

GHG Accounting Scopes

New York City's GHG inventory follows standard international conventions for municipal GHG emissions reporting. The City's inventory includes Scope 1 emissions from buildings and industrial facilities within the city, vehicle operated within the city, and solid waste and wastewater managed within the city; Scope 2 emissions from electricity and steam used in buildings, industrial facilities, streetlights, and transit systems within the city; and Scope 3 emissions from solid waste generated within the city but disposed of outside of the city's boundary.

GHG accounting practice has historically classified emissions by "Scopes" per the World Resources Institute/World Business Council for Sustainable Development's Greenhouse Gas Protocol, the world's corporate GHG accounting standard and the standard upon which many other GHG accounting protocols are based. Following the WRI/WBCSD guidance, New York City defines Scopes as:

Scope 1: Direct emissions from on-site fossil fuel combustion or fugitive emissions from within the city's boundary

Scope 2: Indirect emissions from energy generated in one location, but used in another, such as district electricity and district steam

Scope 3: Indirect emissions that occur outside the city's boundary as a result of activities within the city's boundary, e.g. emissions from exported solid waste. Examples of Scope 3 emissions that are not included in New York City's inventory include emissions from extraction and production of purchased materials, transportation of purchased fuels, and use of sold products and services.

New York City's current GHG inventory includes all Scope 1 and Scope 2 emissions, and includes Scope 3 emissions from solid waste generated within the city's boundary but disposed of outside of the city. The City may revise its GHG reporting approach to include additional sources (including consumption-based emissions) as applicable GHG protocols evolve.

New York City's Emissions Profile

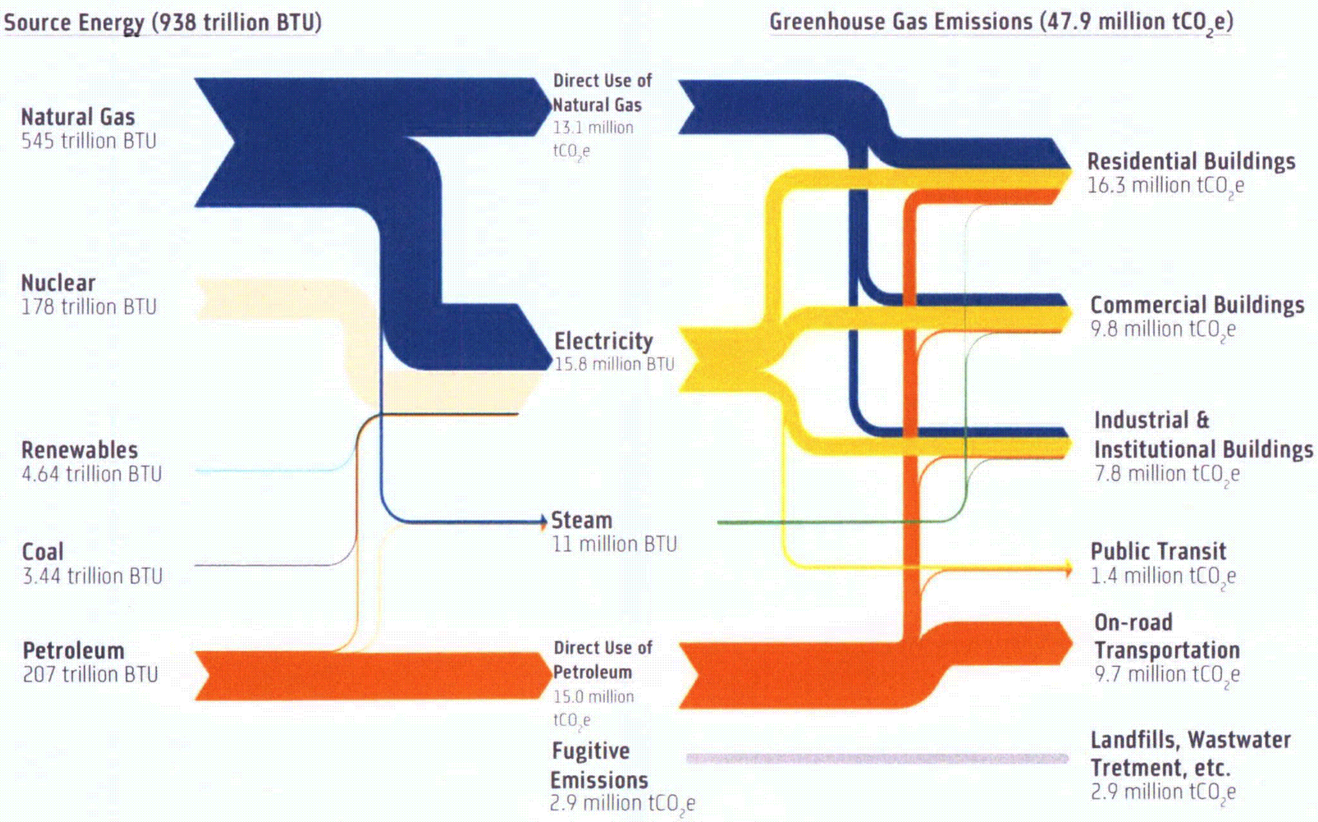
Energy and GHG Fundamentals

New York City consumes enormous amounts of energy, and most of it — 81 percent — comes from the combustion of fossil fuels. This combustion occurs on a centralized basis — at power plants to create electricity and steam — and on a distributed basis — in countless buildings and vehicles to provide basic services and mobility.

Energy use in buildings accounts for 71 percent of the city's total emissions footprint. Of these emissions, roughly 55 percent come from the on-site combustion of natural gas and liquid fuels to produce heat and hot water, and to cook; while the remaining 45 percent of emissions stem from electricity production and consumption. The transportation sector contributes another 23 percent of the city's total emissions. Of these emissions, liquid fuel consumption in vehicles accounts for 85 percent, while the remainder stem from electricity used to power subways. Fugitive emissions from landfills, the wastewater treatment process, and the energy sector account for the remaining 5 percent of the city's emissions.[4]

In total, the city emitted nearly 48 million metric tons of carbon dioxide equivalent (CO2e) in 2012. The City's emissions methodology only includes Scope 1 and Scope 2 emissions; emissions from aviation are not included (though strategies to reduce emissions from planes while they are on the runway are part of this report); neither are consumption-based emissions, which would capture the emissions embedded in the goods that New Yorkers consume. The methodology for capturing consumption-based emissions is evolving, and future GHG inventories are likely to include at least some of them. (See sidebar: *GHG Accounting Scopes*)

Energy and GHG Emissions Flows
Petajoules and $MtCO_2e$

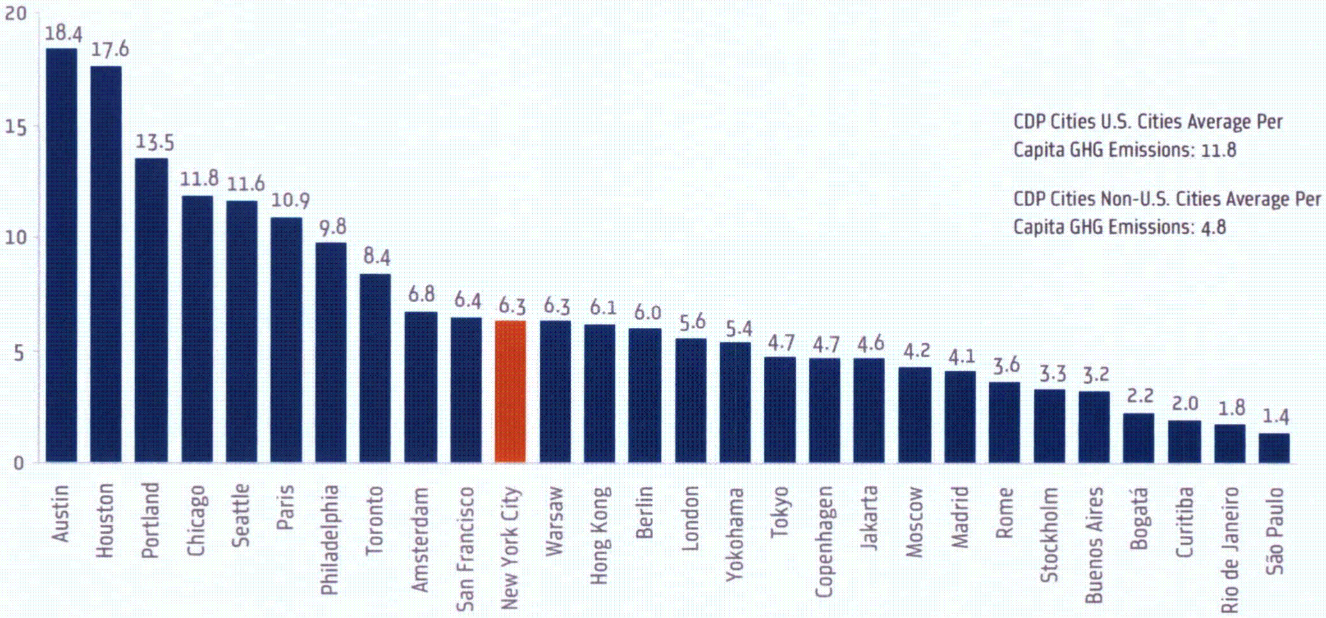


Source: NYC Mayor's Office

New York City's Emissions Relative to Other Cities

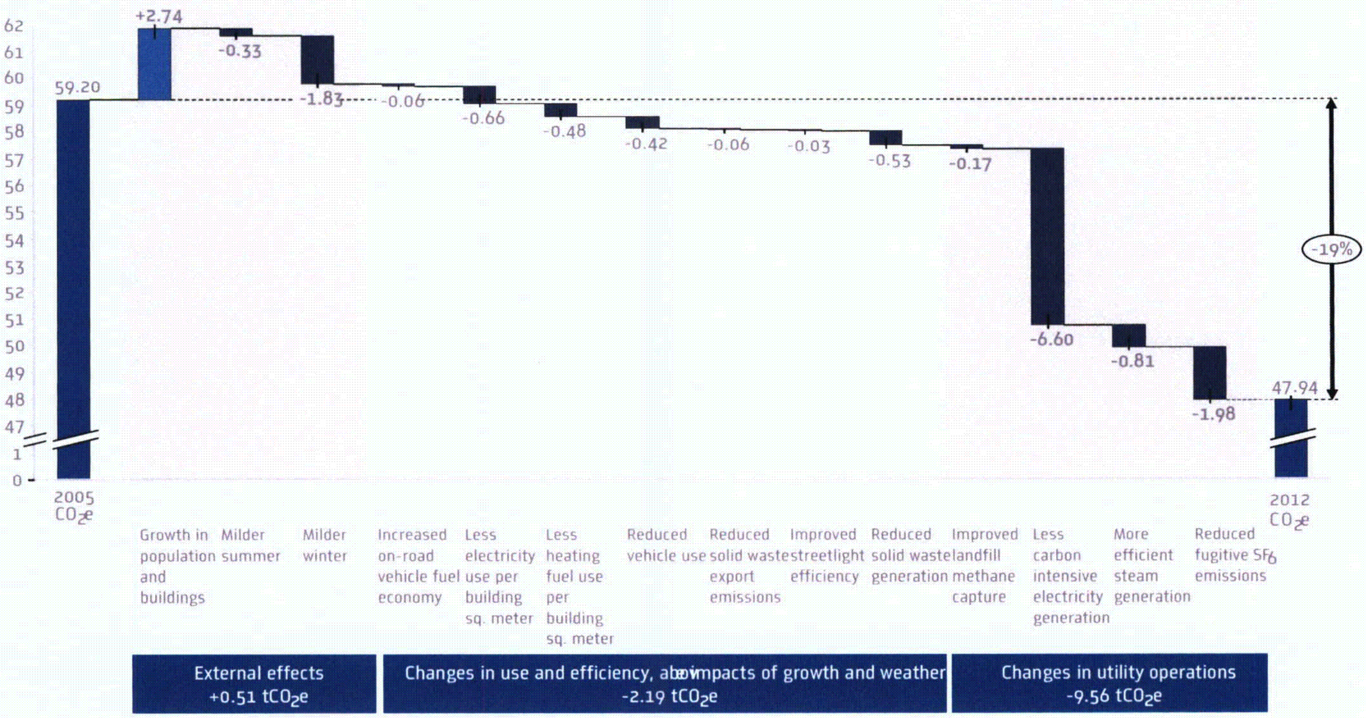
New York City uses large amounts of energy – but per capita, its dense built environment and extensive mass transit system make it one of the most energy efficient cities in the U.S. In a recent study of urban emissions done by the Carbon Disclosure Project (CDP), the average New Yorker was responsible for 44 percent less carbon pollution than the average US urban dweller. On the international level, New York City is competitive but a number of global city's have even lower per capita emissions levels. (See chart: *Per Capita GHG Emissions for Selected U.S. and Global Cities*)

Per Capita GHG Gas Emissions for Selected U.S. and Global Cities[5]
Emissions in $MtCO_2e$



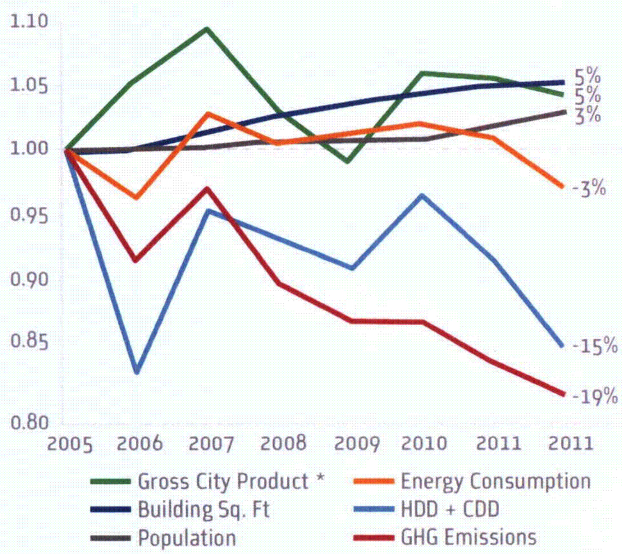
Source: Carbon Disclosure Project

2005 to 2012 GHG Emissions Reduction Drivers
$MtCO_2e$



Source: NYC Mayor's Office

Energy, Emissions, and Economic Indicators
Indexed to 2005



Source: NYC Mayor's Office

Emissions Reduction Since 2005

New York City's emissions fell by 19 percent between 2005 and 2012, and the city is now nearly two-thirds of the way to meeting the 30 by 30 goal. The majority of reductions stemmed from cleaner power as a result of fuel switching from coal and oil to less carbon intensive natural gas, as well as the introduction of state-of-the-art power plants that replaced old, inefficient units. Improved energy efficiency in buildings and automobiles, fewer car trips and less waste have also contributed to the reductions. Emissions and energy use fell even as the city's population, building area, and economy all grew compared to 2005. If this trend continues, it would represent a significant structural change, as energy use has closely mirrored economic growth throughout history. (See charts: *2005 to 2012 GHG Emissions Reduction Drivers* and *Energy, Emissions, and Economic Indictators*)

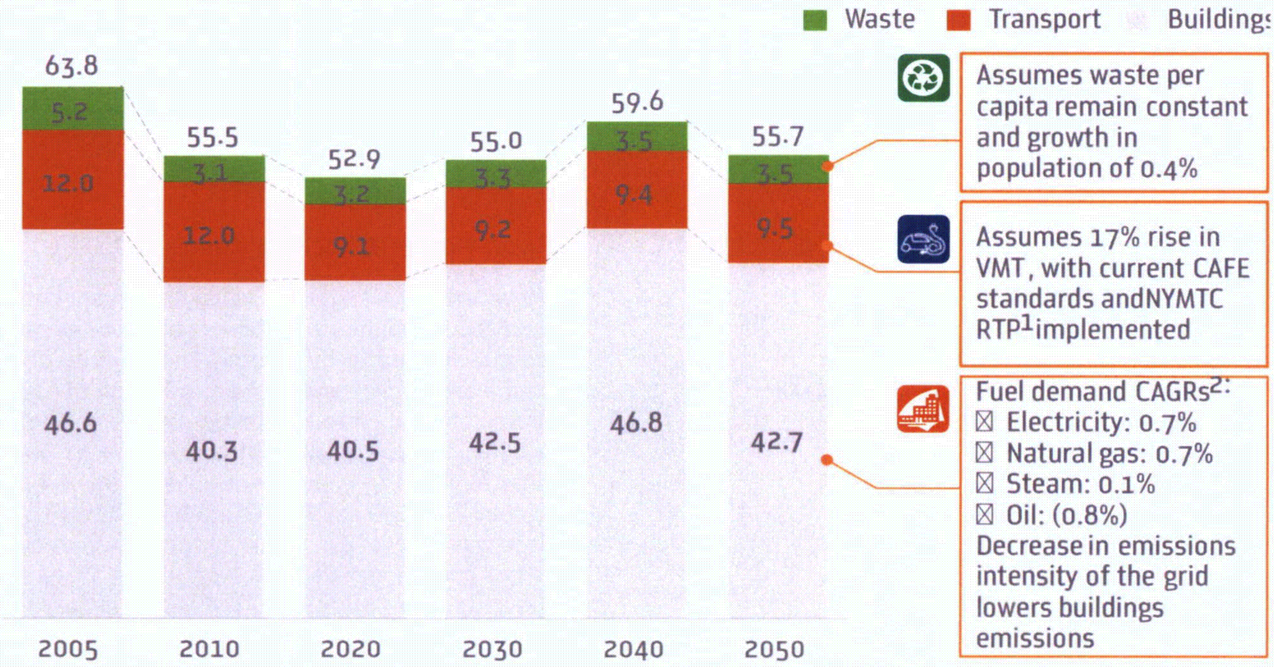
Technical Methodology

The analysis informing this report began with developing projections for the growth of greenhouse gas emissions between today and 2050, assuming that no aggressive action is taken to reduce emissions. Once these projections – the "business as usual" scenario — were developed, quantitative models helped estimate the technical potential for reductions in four key sectors--buildings, power, transportation, and solid waste — and to assess the cost-effectiveness of each individual action as well as impacts to the economy.

Under the 'business as usual' scenario (BAU), 2050 GHG emissions would stand at 55.7 MtCO2e – roughly similar to emissions today and far above the 12.7 million ton cap that the city would need to abide by in order to achieve 80 by 50. Conservative assumptions about economic growth and energy prices underlie the BAU projections. With these assumptions, emissions would fall between now and 2020 due to a continued switch from coal to natural gas in the power sector; then increase for two decades after that in line with growing population; and ultimately fall as renewables become economically viable in 2040-2050 and displace fossil fuel generation. The relative contribution of sectors to carbon emissions remains relatively constant: in the 2050 BAU, buildings would contribute 77 percent of emissions, while transport would contribute 17 percent, with the balance coming from solid waste and fugitive emissions (See chart: *Carbon Emissions Under the BAU Scenario*).

With the business as usual scenario in place, the technical potential for carbon reduction was evaluated using three different models: a Marginal Abatement Cost Curve (MACC), the North American Energy and Environment Model (NEEM) from the consulting firm Charles River Associates, and the REMI Policy Insight model, run by AECOM.

Carbon Emissions Under the BAU Scenario



Source: NYC Mayor's Office

The first model, the MACC, estimates the potential for emissions reduction in the buildings, transportation, and solid waste sectors by evaluating over 70 different carbon abatement measures. This bundle of potential measures focuses on existing technologies and makes the following conservative assumptions:

- **Learning curves are ambitious but achievable,** based on historical factors and expert insight about the pace of advancement that improves technology or lowers costs.
- **Equipment is replaced at the end of useful life to minimize costs,** rather than replacing it on an accelerated basis to achieve energy savings or carbon reductions.
- **No carbon price exists,** or any other significant Federal or regional action to reduce carbon that would lead to a price signal in the marketplace.

For each measure, the model calculates its annualized capital cost and operational savings, estimates the resulting carbon reduction, and computes the societal cost of abatement in dollars per ton. The calculations are completed for a point in time every 5 years and the results are displayed on a graph — a so called "marginal abatement cost curve". On the curve, the lowest-cost measures are on the left, the highest-cost ones are on the right; the width of the bar indicates each measure's carbon abatement potential in millions of metric tons, and its height indicates its societal cost of abatement per ton – whether positive or negative. (See chart: *2050 Marginal Cost Curve for Building Sector*)

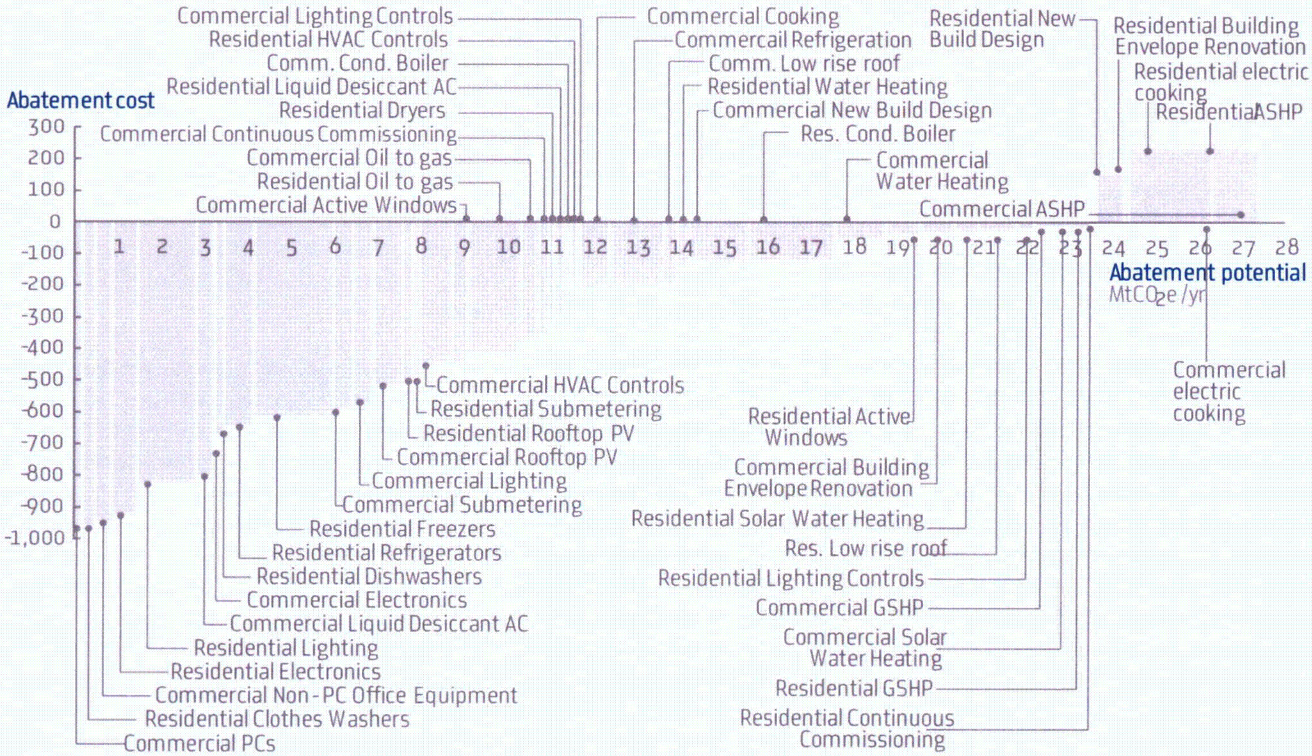
The purpose of introducing the concept of societal cost is to be able to quickly compare the relative cost-effectiveness of different carbon abatement measures without going into the details of each potential decision-maker's constraints and preferences. Its main simplifying assumption is that all measures can be financed at a 4 percent discount rate — roughly equivalent to a long-term government bond. The concept is helpful – but it also has important limitations. For one, it does not differentiate between winners and losers for any given measure. If, for example, a landlord pays for better lighting, but tenant captures the savings that outweigh the capital investment, the model would consider the measure to have a negative societal cost (e.g. a societal benefit), however the landlord would experience it as a loss. Likewise, if an investor can only access financing at a 10 percent interest rate, he or she would be unlikely to undertake an energy efficiency measure that only achieves a reasonable payback if lending is done at 4 percent. The cost curve would not capture either of these nuances.

A second proprietary model developed by the power sector consulting firm Charles River Associates, was used to find the least-cost solutions to supplying power to the marketplace while complying with the carbon reduction trajectory. The Charles River NEEM model North American Energy and Environment Model (NEEM) assumes a carbon cap for New York City that declines linearly from 2012 to 2050. This serves as a simplified modeling tool and effective proxy for the power sector subsidies that would be required to achieve 80 by 50 — it does not indicate that the City is advocating for a city-level carbon cap. As the modeled cap declines each year, the model determines the lowest cost mix of providing electricity using existing conventional generation and new, lower carbon resources while remaining below the carbon cap. The model incorporates the demand projections produced by the MACC for the buildings, transportation, and solid waste sector. In turn, it supplies the MACC with power price calculations for the 80 by 50 pathway, which the MACC then uses to adjust demand projections again based on assumptions about the elasticity of power demand. This iterative approach brings the two models to near-convergence and ensures consistency across all four sectors.

Once the calculations are completed for all sectors, a model called REMI Policy Insight was used to estimate the jobs and economic impact of the 80 by 50 pathway. The REMI model is a standard tool of economic analysis that integrates features of econometric, input/output and computable general equilibrium models to estimate the impact of policy measures on local economies throughout the U.S. A New York City specific version of the REMI model looked separately at 150 different local sub-sectors and analyzed the impacts of undertaking each individual carbon abatement measure — as well as decarbonization in the power sector — on jobs, gross regional product, and personal income through 2030[6]. The model accounted for one-time capital outlays, the opportunity cost of local spending, operational savings, and changes to long-term regional competitiveness.

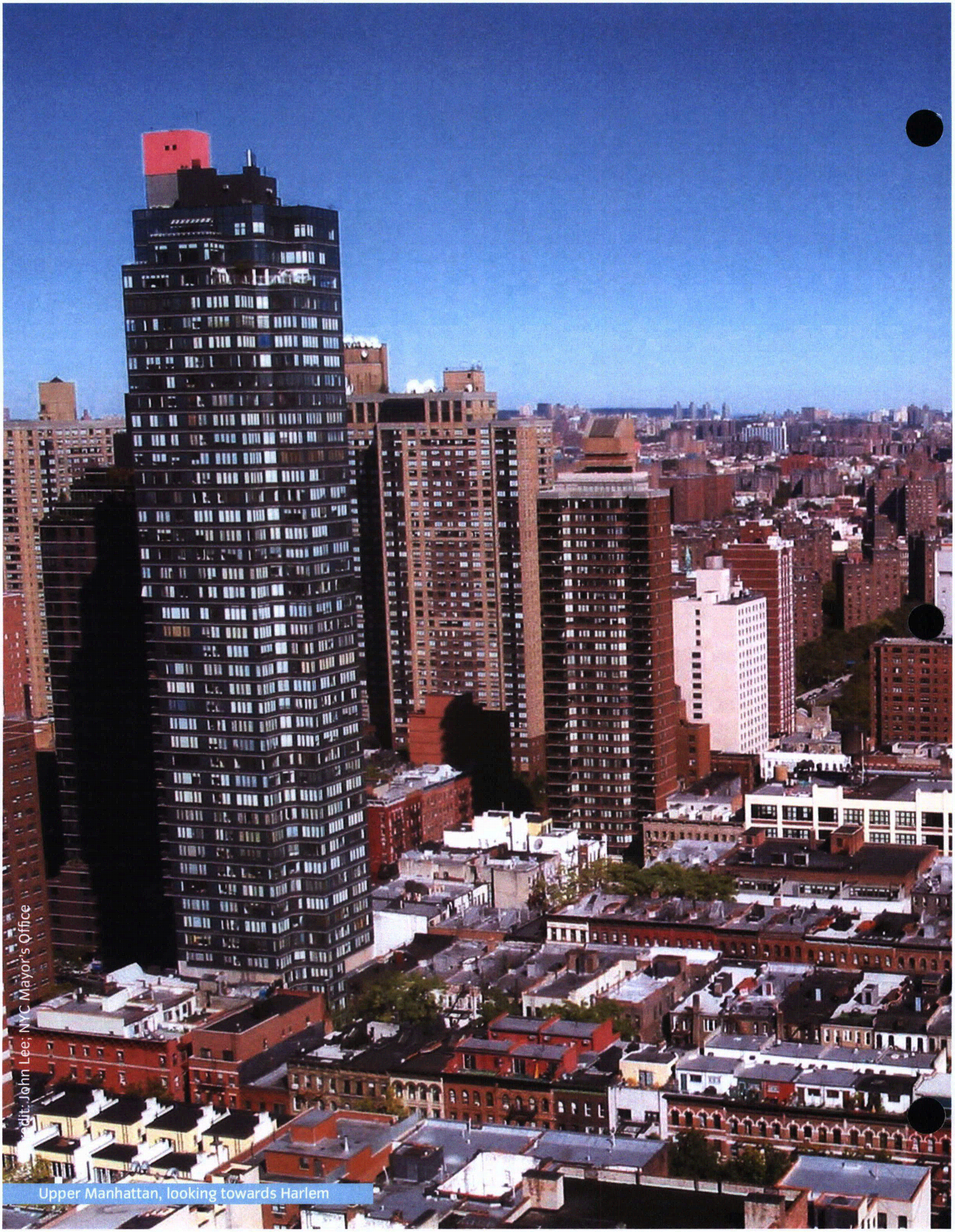
Together the three models showed what is technically feasible, how much it would cost and how the economy would benefit, and what the theoretical timeline for achieving an 80 percent reduction would be. This theoretical analysis then needed to be turned into concrete policies and initiatives that the City could undertake if it chooses to pursue 80 by 50. A broad range of stakeholders from the buildings, power, transportation, waste, and environmental sectors advised on possible approaches. This then became the basis for a range of public policy initiatives, programs, pilots, and research studies that together could unlock near-term investments and position the City along the pathway to deep carbon reductions by mid-century.

2050 Marginal Abatement Cost Curve for Buildings Sector
$/tCO$_2$e

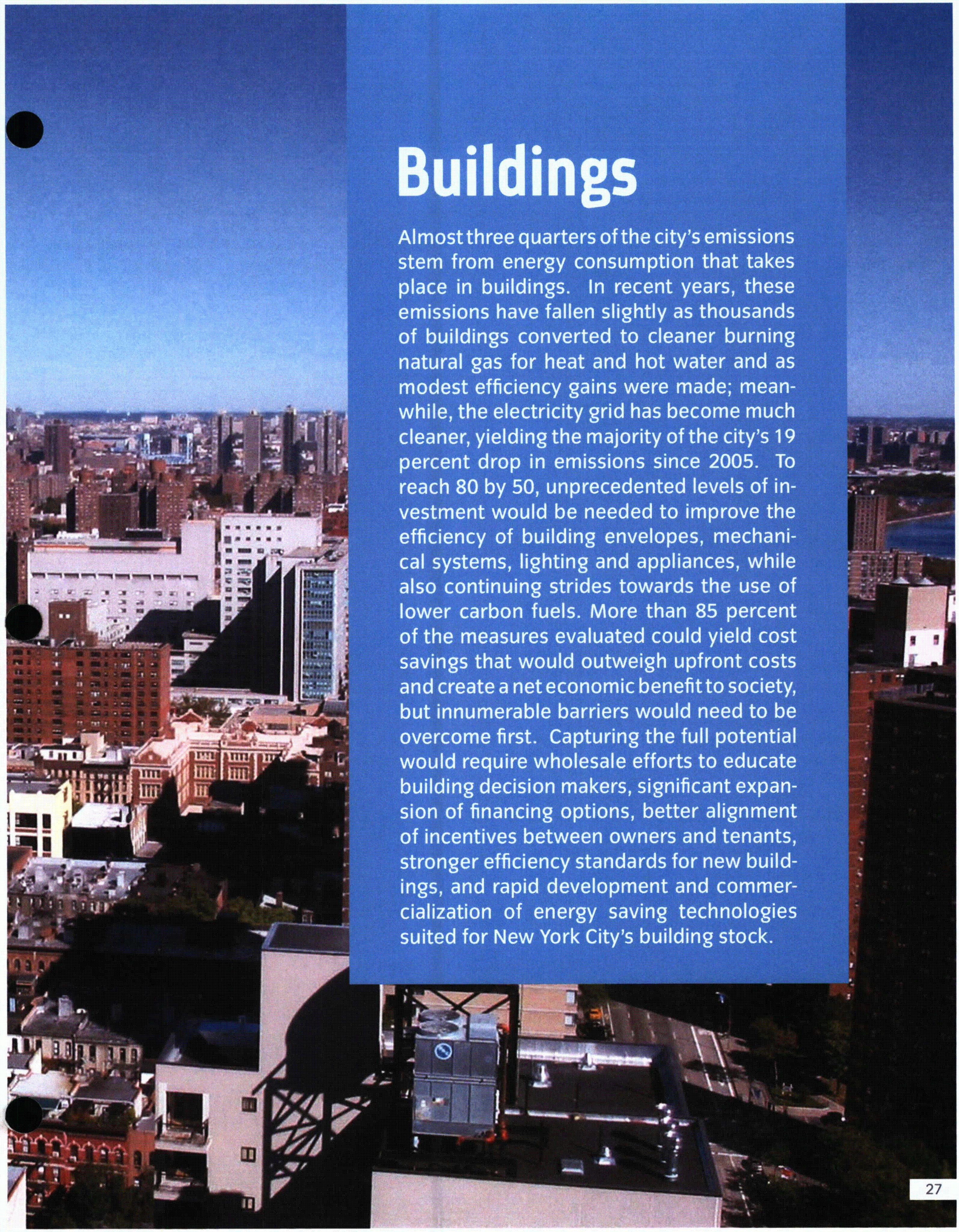


Source: NYC Mayor's Office


Credit: NYC Mayor's Office


Credit: John Lee; NYC Mayor's Office

Upper Manhattan, looking towards Harlem



Buildings

Almost three quarters of the city's emissions stem from energy consumption that takes place in buildings. In recent years, these emissions have fallen slightly as thousands of buildings converted to cleaner burning natural gas for heat and hot water and as modest efficiency gains were made; meanwhile, the electricity grid has become much cleaner, yielding the majority of the city's 19 percent drop in emissions since 2005. To reach 80 by 50, unprecedented levels of investment would be needed to improve the efficiency of building envelopes, mechanical systems, lighting and appliances, while also continuing strides towards the use of lower carbon fuels. More than 85 percent of the measures evaluated could yield cost savings that would outweigh upfront costs and create a net economic benefit to society, but innumerable barriers would need to be overcome first. Capturing the full potential would require wholesale efforts to educate building decision makers, significant expansion of financing options, better alignment of incentives between owners and tenants, stronger efficiency standards for new buildings, and rapid development and commercialization of energy saving technologies suited for New York City's building stock.

Overview

Retrofit of the United Nations headquarters in Manhattan

From single-family homes to fifty-story skyscrapers, the city's buildings number nearly a million. They provide homes to families and places to conduct business – but they also consume most of the City's energy and account for the majority of its emissions. All together, the electricity that powers lighting, mechanical equipment and plug loads in buildings and the fuels that are burned to produce heat and hot water are responsible for 33.9 million tons of emissions – approximately 71 percent of New York City's total. These emissions dropped slightly in recent years as thousands of buildings took advantage of low natural gas prices and moved away from relatively more expensive fuel oils for heating — but significant potential for emissions reductions remain.

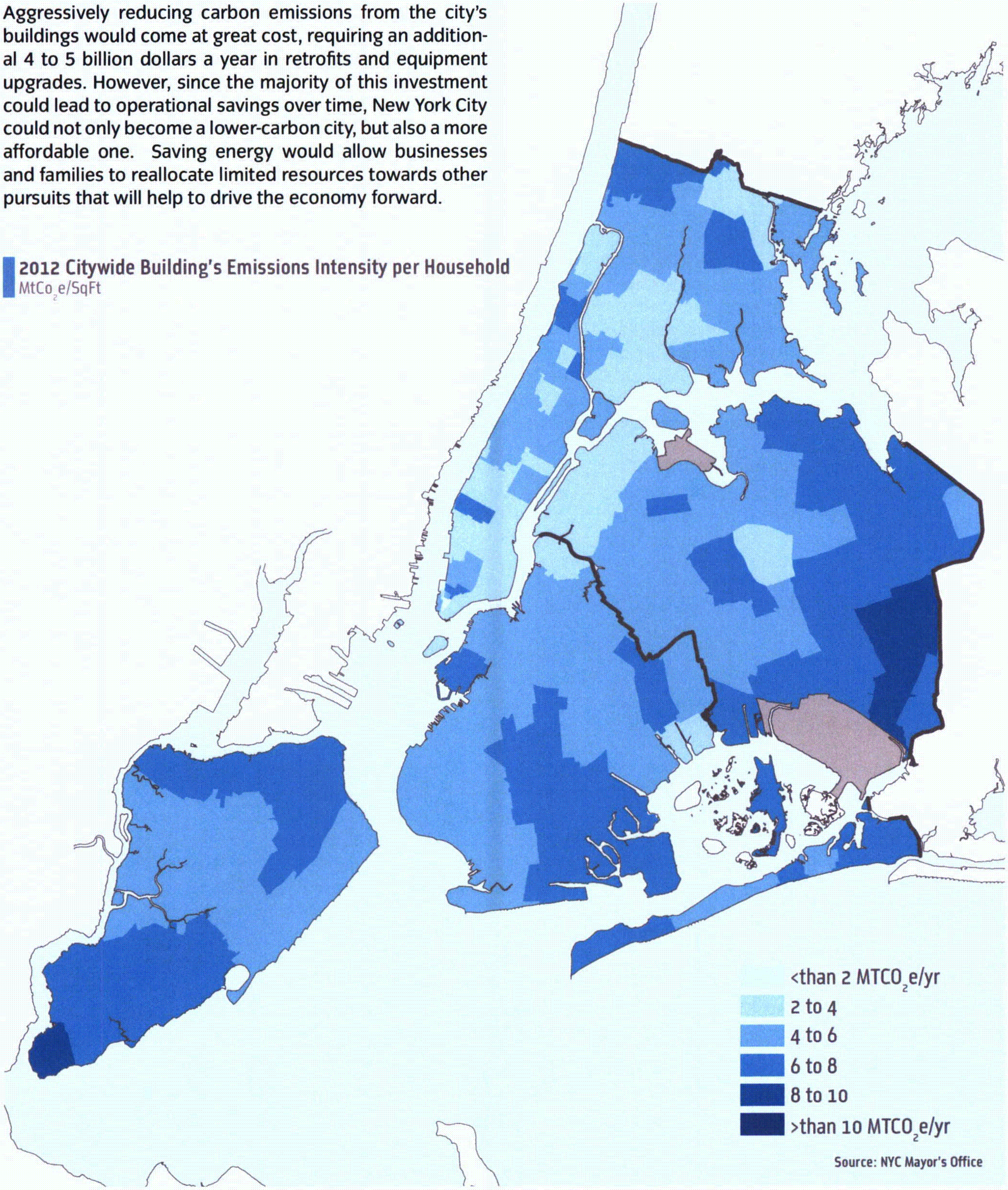
In the future, in both new and existing buildings, envelopes could be built tighter, building systems could be more efficient and intelligent, and renewable energy sources could replace fossil fuels for heating, hot water, and cooking. Taken together, these strategies could produce sufficient emissions reductions to put New York City on a pathway to 80 by 50.

More than 85 percent of the potential measures analyzed for the building sector could yield cost savings that would outweigh upfront costs. But that does not necessarily mean that they would be implemented. Even for measures that make economic sense for an individual decision-maker, multiple obstacles may stand in the way, including limited access to financing, the need for technical assistance, misalignment of interests with tenants, or simply the lack of interest.

The City has already begun to address these obstacles. The Greener, Greater Buildings Plan, a package of laws passed in 2009, laid the groundwork by requiring the city's largest buildings — those greater than 50,000 square feet — to assess, or "benchmark," their energy and water consumption on an annual basis, and also to undertake audits, retro-commissioning and some mandatory upgrades to building systems over a longer term horizon. These laws provide the city's largest buildings with the basic information they need to take advantage of energy efficiency opportunities and begin realizing the resultant cost-savings. However, broader efforts would be needed to put the city on the pathway to 80 by 50.

Aggressively reducing carbon emissions from the city's buildings would come at great cost, requiring an additional 4 to 5 billion dollars a year in retrofits and equipment upgrades. However, since the majority of this investment could lead to operational savings over time, New York City could not only become a lower-carbon city, but also a more affordable one. Saving energy would allow businesses and families to reallocate limited resources towards other pursuits that will help to drive the economy forward.

2012 Citywide Building's Emissions Intensity per Household
$MtCo_2e/SqFt$



Source: NYC Mayor's Office

Buildings Fundamentals

Building Stock

New York City's one million buildings together add up to more than 5 billion square feet of real estate. The building stock varies significantly by age, ownership structure, use, and construction type.

Residential buildings dominate the building sector: they represent 92 percent of the number of buildings and 70 percent of total built area. Residential building types vary greatly, ranging from five-story Victorian era walk-ups, turn-of-the-twentieth century brownstones, pre- and post-war elevator buildings, newly built curtain-wall high-rises, and single-family homes. Ownership types vary as well: the majority of the city's multifamily housing units are rentals, with the remainder primarily cooperatives and condominiums, and there is an overlay off affordable housing regulations that can lead create variation even within individual buildings. Single-family homes are primarily directly owned.

Commercial and institutional buildings — primarily offices, but also hospitals, universities, and municipal facilities — represent 5 percent of the number of buildings, but a disproportionate 22 percent of the built area. They are also some of the city's largest buildings; properties exceeding 1 million square feet in built area are not uncommon. Large real estate companies often control tens of millions of square feet of commercial space and contain a multitude of tenants in their portfolios. However, owner-occupied buildings also occur with frequency among the largest corporations and institutions.

Industrial buildings only represent a small share of the city's space, accounting for 3 percent of the number of buildings and 6 percent of built area. Most are low-rise structures with flat roofs located in the city's industrial areas such as the South Bronx, or Newtown Creek and Sunset Park in Brooklyn.

The overall building stock is old relative to the national norm. The average New York City building was built around 1940 and is 73 years old. Buildings turn over at approximately 0.5 percent a year, with the pace increasing in boom times, such as the years leading up to the Great Depression, during the 1960s, and in the early 2000's. The average lifespan of buildings in New York City tends to exceed the national average, and as a result, over 80 percentof the buildings we have today will still exist in 2050.

Regulatory Framework

New York City government has a broad degree of control over how buildings are designed and built. The City's building codes set criteria for structural integrity, the design of mechanical systems, building envelope, and a whole range of life and safety issues for new buildings and major renovations. The City's Energy Code, which was first adopted in 2009, establishes the minimum energy performance standards for building envelopes, heating and air-conditioning systems, and lighting. In addition, the City's extensive zoning system governs land use, building density and massing, and other criteria at both the individual building lot and neighborhood levels.

A number of recent regulatory efforts that grew out of PlaNYC are beginning to impact the design, construction, renovation, and operation of the city's buildings.

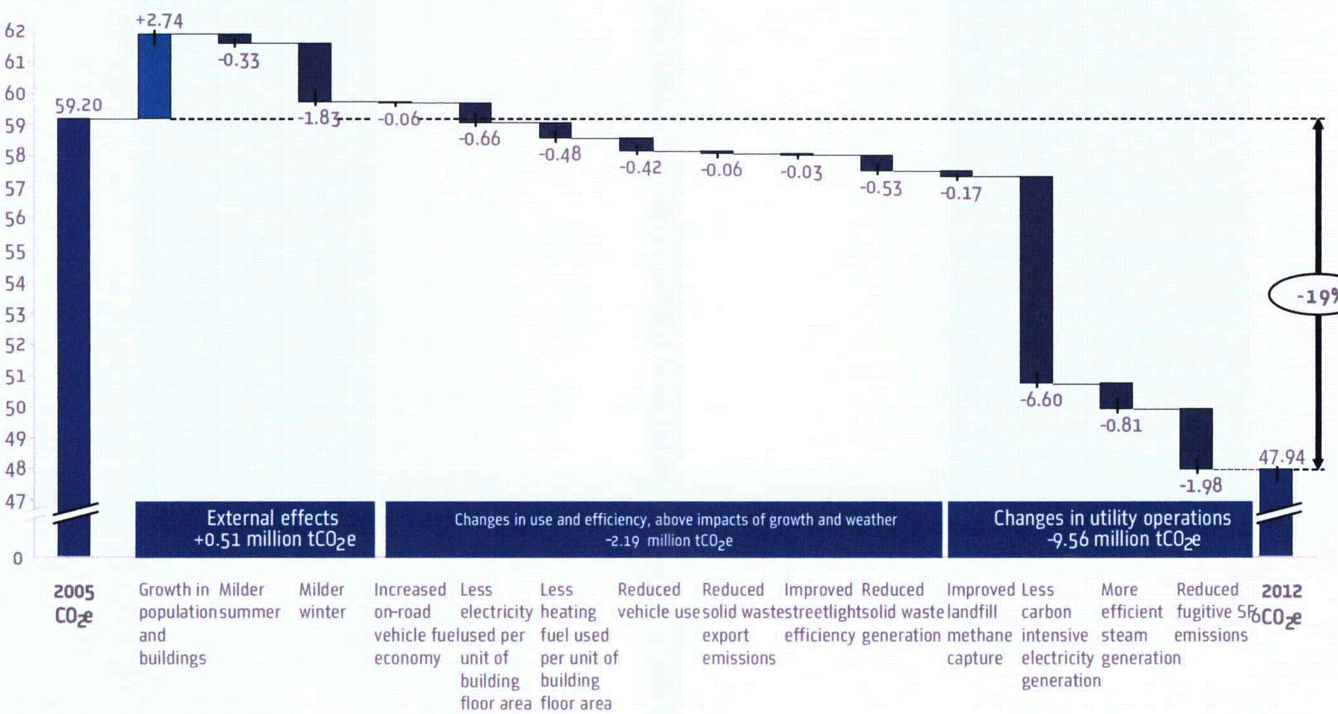
The Greener, Greater Buildings Plan (2009) requires the city's largest buildings – those above 50,000 square feet – to measure and report, or benchmark, their energy and water use every year; to complete energy audits and retro-commissioning of building systems every ten years; and to install sub-meters and upgrade lighting in commercial buildings. The City has implemented almost half of the 111 proposals developed by the Green Codes Task Force (2010), a panel of leading architects, engineers, construction, and real estate professionals that was tasked by Mayor Bloomberg and City Council Speaker Christine Quinn to recommend code changes to promote sustainable construction and operational practices. The City's regulations to phase out the use of heavily polluting No. 6 and No. 4 heating oils and the accompanying NYC Clean Heat program have led to over 3,000 large city buildings converting to cleaner heating fuels such as ultra-low sulfur (ULS) No. 2 fuel, biodiesel, or natural gas. Finally, the City's Zone Green proposal (2012), modified the zoning regulations to remove barriers to energy efficiency and renewable energy technologies both new and existing buildings.

Sources of GHG Emissions

In 2012, buildings were responsible for 33.9 million tons of emissions — or roughly 71 percent of the city's total. Fifty-three percent of these emissions came from fossil fuels — largely natural gas and fuel oil for heating, cooking, and hot water — while the remainder came from electricity consumption. Emissions from electricity consumption fell in recent years as power grid became cleaner; in 2005, electricity consumption was responsible for 50 percent of all building emissions, but in 2012, that number dropped to 44 percent. (See charts: *2005 to 2012 Changes to Citywide Buildings GHG Emissions* and *Citywide Buildings and Streetlight Emissions by Source*)

Residential buildings contribute the greatest share of emissions, accounting for 48 percent of all building-based emissions in 2012. Commercial buildings account for the second largest share, with 29 percent of emissions; and industrial and institutional buildings accounted for the remainder. (See chart: *Building Emissions by Building Type*)

2005 to 2012 Changes to Citywide Buildings GHG Emissions
GHG Emissions $MtCO_2e$

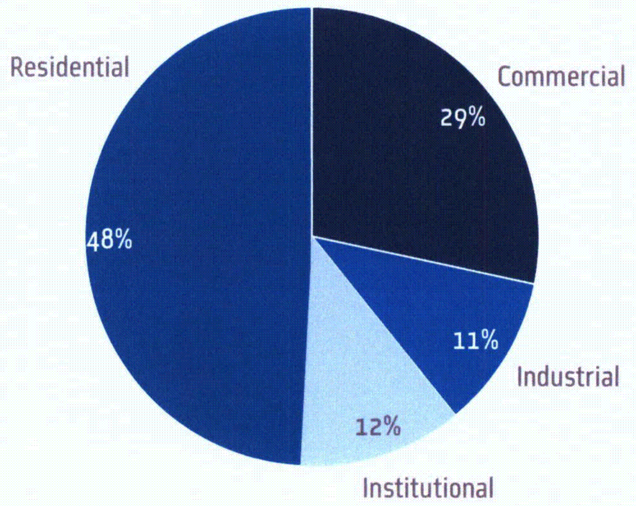


Source: NYC Mayor's Office

Building Emissions by Type

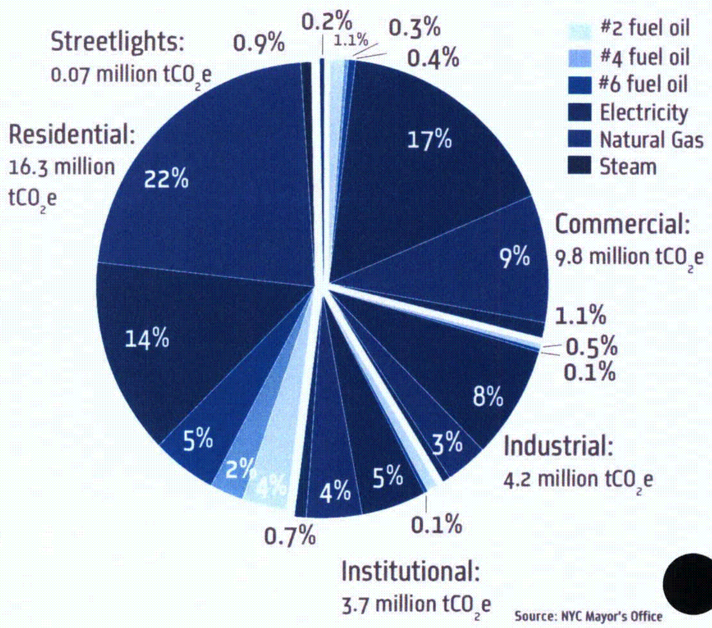
The 2 percent of buildings that are greater than 50,000 square feet in area — those subject to the Greener Greater Buildings Plan — have an outsized impact by consuming nearly 45 percent of the city's energy and producing nearly 45 percent of its emissions. The City's analysis of benchmarking data collected through Local Law 84 revealed wide variations in energy use in these buildings. The per-square-foot energy use intensity within each of the five main building sectors varies between 4 and 8 times between the lowest and highest energy users, suggesting significant potential for efficiency gains. Additionally, analysis of the relationship between building age and energy use reveals that many of the city's least energy-intensive buildings were built before 1930, while a large number of the most energy-intensive buildings were built after 1991. While differences in building usage patterns may account for some of the variation, the evolution of construction methods over time, as well as the changing demands for certain space configurations, also play a role. (See charts: *Variation in Median ENERGY STAR Score and Median EUI by Building Age* and *Variation in Source Energy Use Intensity (EUI) by Sector*)

Building Emissions by Building Type
Percentage of $MtCo_2e$; 2012



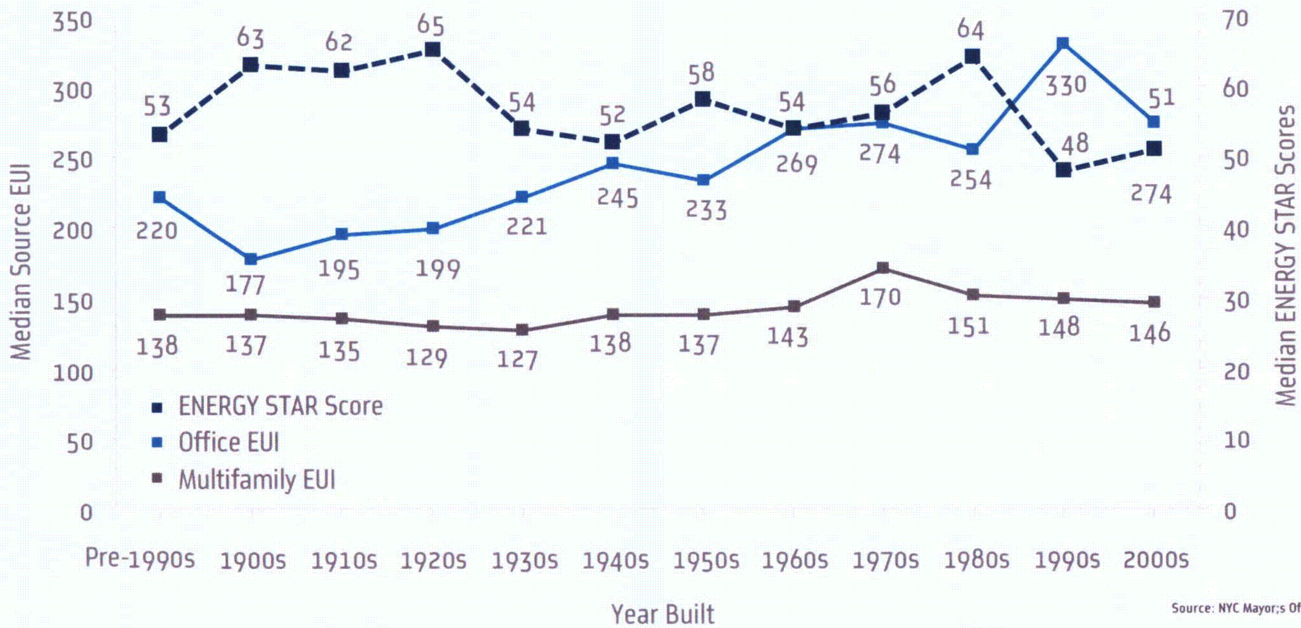
Source: NYC Mayor's Office

Citywide Buildings and Streetlight Emissions by Source
$MtCo_2e$ by source



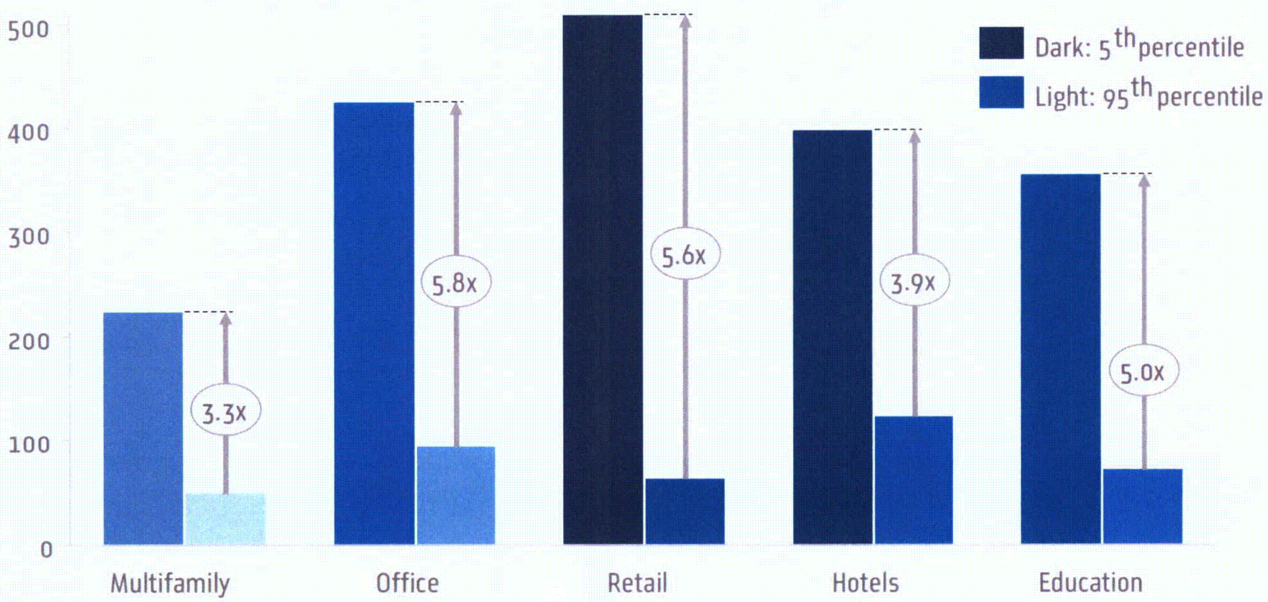
Source: NYC Mayor's Office

Variation in Median ENERGY STAR Score and Median EUI by Building Age
Source EUI (Annual kbtu / sq ft)



Source: NYC Mayor;s Office

Variation in Source Energy Use Intensity (EUI) by Sector
Source EUI (Annual kbtu / sq ft)



Source: NYC Mayor's Office

Technical Potential of GHG Reduction Measures

As % of total 2005 emissions

Measure	%
Building Exteriors	**11.1%**
Roof and envelope renovations	4.7%
Better windows	2.4%
Efficient designs for new buildings	4.0%
Building Systems, Lighting, Submetering, and Endpoint Controls:	**15.0%**
Thermal equipment efficiency and sizing	2.6%
Advanced air conditioning	2.8%
Lighting efficiency and controls	4.2%
HVAC controls	0.6%
Continuous Commissioning	2.6%
Submetering	2.2%
Plug Loads	**2.6%**
Better electronics and appliances	2.6%
Sources of Energy for Heating, Hot Water and Cooking	**13.2%**
Conversion to gas	1.8%
Solar water heating	2.8%
Ground source heat pumps	2.6%
Air source heat pumps	4.8%
Cooking	1.2%
Biogas	--
Biomass district CHP	--
Advanced biodiesel	--

Credit: John Mayor's Office

Emissions Abatement Potential

The carbon abatement potential from building efficiency measures is significant, but the potential must be understood relative to the costs. Improved building systems and reductions from plug loads have large potential to reduce emissions at relatively low costs, and could result in significant paybacks over time. Upgrades to the thermal performance of walls, windows, and roofs are similarly important, although higher costs require longer periods of time to realize a payback through energy savings. Improvements in building operations and the monitoring and control of building systems offer practical solutions to saving energy that can be immediately realized with little cost. Despite the significant saving potential from energy efficiency, 80 by 50 cannot be reached without reducing fossil fuel consumption in buildings and switching to renewable energy sources. This transition to cleaner fuels on-site can be expensive, technically complex, and challenged by a range of regulatory, financing, and construction obstacles.

Building Exteriors

Building exteriors – roofs, walls, windows – are the first point of energy losses. Renovating and maintaining the exteriors of existing buildings and improving building codes that govern new construction could abate up to 7.0 million tons of emissions.

Roof and envelope renovations

4.7%[a]
3.0 million tons [b]
-$80 per ton [c]

Building envelopes and roofs separate the interior environment from conditions outside. While new buildings are designed to minimize thermal exchange between indoors and outdoors — making it easier to maintain comfortable temperatures indoors — many existing buildings have envelopes that do not meet current standards. Opportunities abound to improve building envelopes, whether through simple measures like weatherization and air-sealing, or through comprehensive façade retrofits. Across the city, there is the potential to eliminate 4.2 million tons of emissions through four types of measures. The greatest reductions could come from renovations to commercial envelope (2.0 million tons at -$110/ton, assuming 50 percent of existing floor space is covered) and low-rise residential roof insulation (0.8 million tons at -$10/ton assuming 50 percent of roofs are targeted). Renovating residential envelopes and low-rise commercial roofs could each reduce emissions by 0.1 million tons (at -$210/ton and -$20/ton, respectively, assuming renovation of single-family homes and high-rise curtain wall residential buildings and targeting of 5 percent of commercial floor space). The blended 2030 cost per ton from building envelops and roofs stands at -$80/ton.[7]

Better windows

2.4%
1.5 million tons
-$120 per ton

All across the city, leaky and inefficient windows degrade overall building energy performance. Improving windows can save significant amounts of energy and in some cases may be as simple as sealing holes around window-mounted air-conditioning units. For new buildings, using triple-paned glass instead of double-paned glass is an easy way to save energy over the lifespan of the building, and a relatively recent technology called "active windows" that dynamically respond to minimize heat gains in warm months and heat losses in cold months could reduce energy losses by up to 30 percent. Improving the performance of windows citywide could lead to reductions of 1.5 million tons —90 percent of this potential is within residential buildings at -$80/ton and the remainder is in commercial buildings at -$400/ton. The blended cost of this abatement measure is -$120/ton in 2030.

Efficient designs for new buildings

4.0%
2.6 million tons
-$30 per ton

The City's energy code sets minimum standards for thermal performance but many buildings still use excessive amounts of energy, particularly those with high window-to-wall ratios (e.g. glass curtain wall buildings), which offer limited protection from solar gain and have many thermal loss points. A highly efficient new design paradigm known as Passive House can yield well-insulated, virtually airtight buildings that require little additional mechanical energy to keep indoor air comfortable. Utilizing high-performance design standards to reduce non-plug load energy use by up to 70 percent

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

on the majority of new construction could abate up to 2.6 million tons of emissions, with roughly half of this potential coming from residential buildings. Measures in residential buildings would carry a 2030 cost of $60/ton (assuming 70 percent penetration), but measures in non-residential buildings would be cost-saving at -$110/ton. The blended 2030 average would stand at -$30/ton, falling to -$120/ton by 2050 as costs go down with technological maturation and the economies of scale.

Building Systems, Lighting, Submetering, and Endpoint Controls

Building systems consume vast amounts of energy to provide heating, cooling, and lighting of spaces, particularly if the systems are older and inefficient, or poorly operated. Replacing equipment with more efficient technologies and improving operations could reduce emissions by up to 9.5 million tons at negative costs.

Thermal equipment efficiency and sizing

2.6%

1.6 million tons

-$190 per ton

Thermal equipment in buildings – boilers used for heating, hot water, and cooking – typically rely on the combustion of fossil fuels. Oversizing of equipment often occurs when specifications are based on rules of thumb or taken from equipment manufacturers' generic recommendations, instead of the results of detailed analysis of the required loads. Replacing inefficient equipment with the best available models at naturally occurring retrofit times and conducting proper calculations to "right-size" equipment could abate up to 1.6 million tons of emissions. More efficient boilers – including condensing types – could yield 1.5 million tons of reductions, with two thirds coming from residential buildings. Improved commercial cooking equipment could abate an additional 0.1 million tons. The blended average cost would stand at -$190/ton in 2030.

Advanced air conditioning

2.8%

1.8 million tons

-$400 per ton

Air conditioning is essential to maintain comfort during hot summer days and in densely occupied spaces, but it is a major drain on the city's energy resources. On hot summer days, the increase in air conditioning use can cause electricity demand to spike by 1.4 GW by late afternoon (approximately 20 percent of the night-time load level), which is equivalent to the output of three large gas-fired power plants. Larger and newer commercial and residential buildings can be air conditioned through central HVAC systems; smaller or older buildings use split systems mounted in walls or windows that provide air conditioning for individual apartments or offices. More efficient technologies are available, but they have not yet been adopted commercially at scale. For example, in the early stages of commercialization are air conditioning systems that utilize liquid desiccants, which are able to dehumidify and cool incoming air simultaneously, thus reducing the need to overcool to control humidity and yielding energy savings of up to 30 percent. Adopting similarly efficient air conditioning systems could reduce emissions by up to 1.8 million tons, of which nearly 80 percent would come from large commercial buildings where they would prove to be most economical at -$600/ton in 2030. Costs for residential buildings would be high in 2030, at $370/ton, but they could drop to -$300/ton by 2050. The blended cost for 2030 would stand at -$400/ton.

Lighting efficiency and controls

4.2%

2.7 million tons

-$610 per ton

Lighting in non-residential buildings accounts for almost 14 percent of the city's carbon emissions, and there is great potential for reducing this share both through more efficient lights and through better lighting controls. Most of the potential would come from adopting the most efficient Light Emitting Diode or LED lights, which are becoming more and more affordable and accepted but have not yet been adopted en masse. Replacing 50 percent of existing CFL and incandescent lights with LEDs by 2030 and 90 percent by 2050 could abate up to 2.4 million tons of emissions at the cost of -$670/ton assuming that. Over that time period, costs of LED lighting is expected to fall by 50 percent. Lighting controls would play a smaller, but still prominent role: installing dimmers and occupancy sensors that shut off lights when a room is not in use could reduce emissions by 0.3 million tons, with almost 90 percent of the potential in commercial buildings due (-$200/ton). The blended cost for all measures would stand at -$610/ton.

HVAC controls

Existing HVAC systems are often equipped with inadequate controls. For example, building tenants can find it impossible to control heating or cooling directly, and resort to opening windows to manage temperatures. Installing better endpoint thermal controls like thermostats and electrostatic microvalves could allow better managed space conditioning. This could lead to 0.4 million tons of GHG reductions that would be split evenly between commercial and residential at an average cost of -$330/ton.

0.6%

0.4 million tons

-$330 per ton

Continuous commissioning

HVAC systems require careful tuning and frequent monitoring of building performance data to run at optimal efficiencies. However, building operators often neglect to undertake this important maintenance measure, forgoing opportunities to capture an average of 12 percent energy savings from HVAC operations. Capturing these available reductions through "continuous commissioning" could abate as much as 1.6 million tons of emissions, with 75% coming from commercial buildings at a cost of -$280/ton and the rest from residential, at the 2030 cost of $50/ton, for a blended cost of -$190.

2.6%

1.6 million tons

-$190 per ton

Submetering

Commercial tenants and residents of multifamily buildings often have no ability to understand or control how much energy they use – instead, energy is included in their overall rental bill. Electric submetering of individual spaces changes this by allowing tenants to obtain direct consumption and billing data, which could potentially enable them to undertake energy efficiency measures. Because this action can reduce energy use by an average of 10 percent, implementing submetering citywide – already required of the largest buildings by 2025 – could lead to GHG reductions of as much as 1.4 million tons, split equally between residential and commercial properties at a 2030 cost of -$460/ton.

2.2%

2.2 million tons

-$460 per ton

Plug Loads

Efficient devices and appliances are available today - but they are not universally installed. Deploying the most efficient technologies at the point of equipment turnover could abate up to 1.7 million tons of emissions highly cost-effectively.

Better electronics and appliances

Computers, personal electronics, refrigerators, washers and dryers and other appliances continuously draw power in homes and businesses whether they are being used or not. Although many appliances and electronics have become more efficient thanks to federal Energy Star requirements, usage rates have also increased and many older devices have not yet been replaced. Furthermore, consumers may not opt for the most efficient models available even if they are cost-effective. Making sure that the most efficient appliances and devices are installed at the point of equipment turnover could reduce emissions by up to 1.7 million tons. Commercial and residential electronics are two of the biggest opportunities, at 0.4 million tons each; and with costs below -$700/ton. Replacing commercial computer systems, commercial refrigeration, and residential freezers could yield 0.2 million tons of reduction each at costs below -$570/ton. Average 2030 costs for plug load reductions stand at -$720/ton.

2.6%

1.7 million tons

-$720 per ton

Sources of Energy for Heating, Hot Water, and Cooking

Fuel switching from refined petroleum products to natural gas can reduce but not eliminate greenhouse gas emissions, so while fuel-switching is an effective near-term measure, it is insufficient to reach 80 by 50. Several options are available to further decarbonize heating including solar hot water heating, ground and air-source heat pumps, and biofuels, but marketplace penetration is still very limited. The city could abate up to 7.2 million tons of emissions through a combination of highly cost-effective measures like switching to natural gas from fuel oil and costly ones like solar thermal and electric heat pumps.

Conversion to gas

1.8%

1.1 million tons

-$730 per ton

The City's regulations to phase out the use of heavy heating oil and its Clean Heat program to accelerate the transition to cleaner fuels has coincided with historically low natural gas prices and the availability of new supply in the region. In just two years, over 2,000 buildings have converted from heavy oil to natural gas. Future conversions from oil to gas could contribute up to 1.1 million tons of GHG reductions. Natural gas prices may increase as demand rises, but even then, the 2030 cost of abatement would be hugely negative at -$730/ton.

Solar water heating

2.8%

1.8 million tons

-$140 per ton

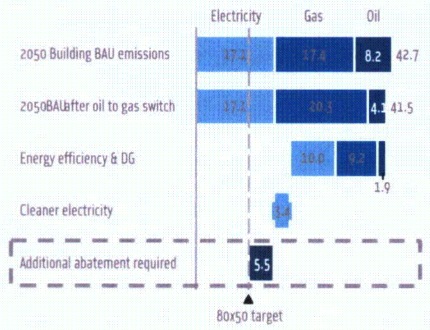
Solar hot water heating (SWH) systems heat water through solar energy collected on a rooftop – though it requires a supplemental heat source when temperatures are below freezing and its efficiency drops to near zero. On a cost per ton basis, SWH systems are expected to be more cost effective than photovoltaic solar power (PV) systems through 2030—at which point high electricity prices and technological advancements would give solar PV the edge. However, SWH will likely prevail in terms of abatement potential on a per square foot basis: by 2030, SWH could abate 15 tons of carbon per 1,000 square feet of roof space, while PV could only abate 7, even with performance improvements. SWH systems could abate up to 1.8 million tons of emissions at a 2030 cost of $140/ton, potentially falling to -$50/ton in 2050 as technologies improve.

Gap to 80 by 50

Fuel-switching from oil to gas, energy efficiency improvements, distributed generation, and cleaner grid electricity may together reduce building emissions from 42.7 million tons in the business-as-usual case to 17 million tons by 2050 — but that is still not enough to reach the 80 by 50 goal. An additional reduction of 5.5 million tons would be required. (See chart: *Drivers of Change to Building Sector Emissions*)

Several technologies discussed in this chapter – ground source heat pumps, air source heat pumps, biogas, biomass CHP, and advanced biodiesel – could potentially cover the gap, though questions about costs and feasibility must be addressed.

Drivers of Change to Building Sector Emissions
Metric Ton Co_2e



Source: NYC Mayor's Office

Ground source heat pumps

2.6%

1.7 million tons

-$30 per ton[8]

Ground source heat pumps (GSHP) use electricity to cycle fluid between a building and underground wells to transfer heat. The ground maintains a stable temperature of approximately 55°F year round, which makes it possible to use it as a heat source (in the winter) or a heat sink (in the summer) through transferring heat from the ground to the building or vice-versa.[9] Three major types of ground source systems are available and their applicability depends on the geology of a given location within the city. (See graphic: *Ground Source Heat Pump Feasibility by System Type*)

Actual penetration of these systems would be limited by the high cost of drilling wells under existing buildings, space requirements, and the complexities of integrating with existing heating systems. GSHPs could abate emissions by up to 1.7 million tons. The assumptions for the proportion of heating load (160 trillion BTU, down from 300 trillion BTU today) that these systems would serve differ by borough.[10] Citywide, the 2050 cost of abatement would stand at -$30/ton.

Air source heat pumps

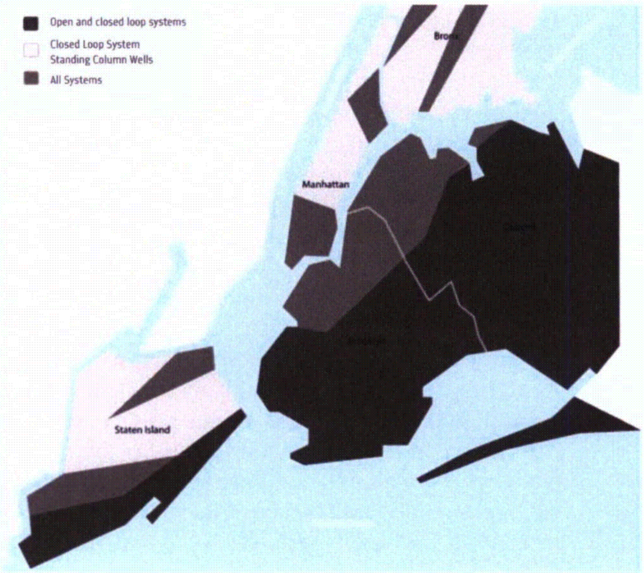
4.8%

3.1 million tons

$140 per ton[8]

Air source heat pumps (ASHP) work similarly to a GSHP, but they use outside air as the heat sink, which is less efficient given the seasonal variation in air temperature. They are easier to install than GSHP because they do not require subsurface construction work,[11] but the lower efficiency levels mean that they are less cost-effective overall, costing $140/ton in 2050 compared to -$30/ton for GSHP. ASHP's could abate up to 3.1 million tons if deployed at scale but their ultimate role will depend on the cost and feasibility of other technologies for decarbonizing building fuels.

Ground Source Heat Pump Feasibility by System Type
System Types



Source: NYC DDC, NYC Mayor's Office

Cooking

1.2%

0.8 million tons

$160 per ton[12]

Most cooking in New York City relies on natural gas stoves. Emissions from cooking would not be the first priority for abatement since they are a relatively small source overall. However, on the 80 by 50 pathway, alternatives like induction stoves, which heat up more quickly but cost more than conventional equipment, would eventually need to be considered. If induction stoves were to become the method of choice, the abatement potential would add up to 0.8 million tons at a cost in 2050 of $160/ton.

Biogas

Biogas production through wood gasification, relying on sustainably harvested wood from regional forests could potentially satisfy the city's entire remaining heating load. Although biogas is not carbon-free because its production requires energy, it still offers a 70 percent reduction in lifecycle GHG emissions compared to conventional natural gas. It is unclear if there is sufficient sustainable biomass located near regional ports to be transported economically, especially given the risk of long-term competition for supply amongst other cities that follow suit with their own biogas demands. Still, the technology is worth exploring – in Europe, at least three biogas power plants are currently in various phases of completion.[13] Abatement costs of biogas are very sensitive to future natural gas and biomass prices, but conservative assumptions based on current prices of coal gasification plants being built at scale suggest that $16 billion in capital investment would be required to satisfy all of the city's remaining heating needs in 2050 and that abatement costs could run at above $250/ton.

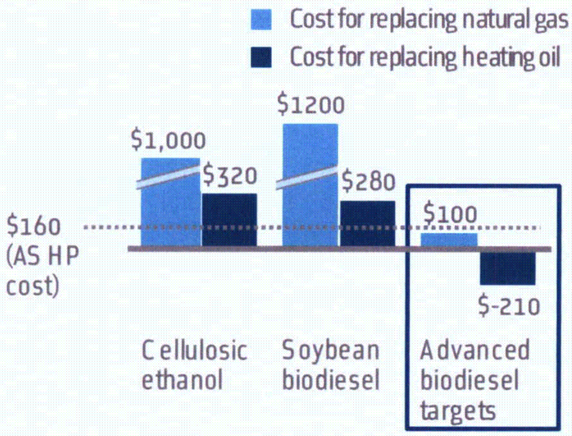
Biomass district CHP

CHP systems use a heat engine to generate electricity and then capture and reuse the waste heat to supply space heating, cooling, or hot water. As a result, CHP systems offer an efficiency improvement over the alternative combination of electricity from New York City's current grid and heat from a natural gas boiler – but the improvement is not high enough to make it a viable large-scale solution on the 80 by 50 pathway (see Power chapter for additional discussion of CHP's electricity production potential). If biomass were used instead of natural gas, however, CHP systems constructed at a district level could provide more than enough abatement to cover the city's residual heating loads, though at a significant cost. Installing distributed systems in all five boroughs – which would require laying up to 4 thousand miles of pipe – could cost up to $27 billion. When coupled with an additional $3 billion in cost for the equipment itself, this would result in 2050 abatement cost of $220/ton.

Advanced biodiesel

Biodiesel from cellulosic ethanol and soybeans has been available for some years now, but its costs were generally too high. Recently, the production of biodiesel using algae or bacteria has started to become viable – and if the emerging trends continue and biodiesel production scales as expected, the fuel could in the future become a large-scale abatement option – especially because it can easily be substituted for conventional liquid fuels in existing heating systems. By 2050, assuming a production cost of $75 per barrel of biodiesel equivalent, abatement costs would come in at $100/ton if replacing natural gas and at -$210/ton if replacing heating oil, potentially offering lower-cost abatement than either biogas or biomass district CHP. (See chart: *Abatement Costs by Biofuel Technology*)

Abatement Costs by Biofuel Technology
US$/ $MtCO_2e$



Source: NYC Mayor's Office

The Costs and Economics of Carbon Abatement for Buildings

The city's building sector is an important part of the economy – every year, New Yorkers spend more than $18.9 billion on electricity and building fuels to power electrical and mechanical equipment, and more than $30 billion worth of construction activity takes place. Reducing the sector's carbon emissions would bring about major changes to these spending patterns, but the economy would benefit overall.

Most of the abatement measures would require incremental upfront investment – for example, purchasing high-performance equipment to replace existing less efficient equipment that is at the end of its useful life rather than replacing in-kind. However, the resulting energy savings would generally well exceed the cost of the incremental investment over the equipment's lifetime. The share of buildings measures that achieve abatement at a negative cost would exceed between 2020 and 2050. (See chart: *Carbon Abatement Costs by Year*)

The total required incremental investments would be sizeable: $2.2 billion a year in 2020 and $3.0 billion a year in 2030, peaking at $3.8 billion a year in 2045. This level of spending would be comparable to the annual capital investment programs of Con Edison and the Department of Environmental Protection – but in the context of the city's total annual construction spending of $30 billion, the costs would represent only a 10 percent increase in spending.

The incremental capital expenses would be more than offset by operational savings – already in 2020, the energy savings would nearly approach the incremental expenses at $1.9 billion, and by 2030, the savings from past measures would be more $6.6 billion, or more than double that year's budget for incremental capital spending.

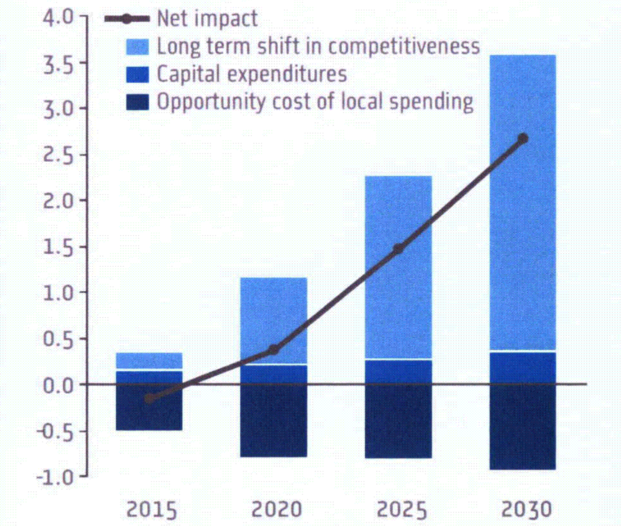
The effect of these abatement measures on employment would be overwhelmingly positive. The incremental capital spending could directly create more than 6,600 local jobs in building-related activities by 2020, while incurring 4,200 job losses in other sectors as spending is redirected, leading to a net gain of 2,200 jobs. The biggest benefits, however would come from lower energy use and lower costs of doing business across the economy. This would make the economy more competitive, potentially adding more than 4,400 new jobs by 2020 and 13,000 new ones by 2030 throughout all sectors. Together, direct and indirect employment gains would net an additional 6,600 new jobs by 2020 and 14,700 new ones by 2030. The resulting impact on GDP and personal income would stand at above $500 million in 2020 and above $1.6 billion in 2030. (See chart: *Employment Impacts of Buildings Sector Carbon Abatement*)

The changes would also create new industries around energy efficiency and retrofits, giving New York City an opportunity to lead in these areas just as it leads in architecture, design, and real estate development today.

Carbon Abatement Costs by Year
Percentage of total; Metric tons Co_2e

Source: NYC Mayor's Office

Employment Impacts of Buildings Sector Carbon Abatements
Thousands; by type of impact



Source: NYC Mayor's Office

Challenges

Awareness is limited about the financial and operational benefits of energy efficiency

While it is possible to identify the city-wide potential for reductions across building classes, individual building owners, operators, tenants and other decision-makers may not understand the full scope of opportunities in their specific buildings. The marketplace does not currently have sufficient levels of education and technical assistance to help decision-makers understand their options and identify available resources.

Financing options that recognizes the value of energy savings are not widely available

Although energy efficiency projects can yield substantial savings, most lenders are not willing to recognize these savings as part of the underwriting of a loan. A variety of factors have limited the development of financing options that recognize the value of energy savings, including lack of performance data, limited expertise in underwriting such transactions, challenges verifying energy savings, and apprehension that changes in building use will diminish potential returns.

Energy costs are relatively low and opportunity costs are high

Compared to other sources of energy, fossil fuels are relatively cheap. In the commercial sector, energy represents only a small fraction of overall rental costs, and building owners are much more likely to spend limited capital on more tangible projects to improve the value of their buildings. In multifamily buildings — many of which have low operating margins and limited available capital — building owners tend to defer capital investments until the end of the useful lives of equipment, or beyond.

Innovative technologies are slow in coming to market and building owners are risk averse

Although most of the potential carbon reductions could be achieved with today's tools, new and emerging technologies could accelerate the pace of change. However, building owners and managers are slow to adopt new technologies without a proven track record or tangible examples of successful implementation in similar New York City buildings.

Capturing the Potential

Strategy 1
Improving Information and Data Transparency

The City's approach to measuring energy efficiency potential through benchmarking has already yielded a wealth of information about the opportunities in the largest buildings. This approach could be expanded and improved.

Better benchmarking and energy performance metrics

Implementation of Local Law 84 — the benchmarking component of the Greener Greater Buildings Plan (GGBP) — has revealed that large buildings have tremendous potential to save energy and water. But in a city as complex as New York, measurement and assessment methods can always be improved. The City is partnering with the Environmental Protection Agency, the Department of Energy, NYSERDA, and research institutions to refine the benchmarking process to better account for the range of usage and economic factors that impact local energy consumption. The City is also partnering with the Federal government and utilities to simplify the process of energy disclosure while maintaining customer privacy and security.

Data transparency for midsize buildings

The city could build on the existing benchmarking program for large buildings by encouraging voluntary — or eventually mandatory — benchmarking for midsize buildings. The segment of buildings between 10,000 square feet and 50,000 square feet accounts for 5 percent of total built area, but it is responsible for nearly 19 percent of energy used by buildings. Expanding GGBP to cover these buildings would bring thousands of new buildings into the marketplace for energy efficiency.

Comparative billing for residential utility customers

Research suggests that people are more likely to conserve energy if they understand how their consumption compares to their neighbors. Utilities across the country are incorporating simple to read, visually dynamic, 'comparative billing' indicators on customers' bills. For households that use higher amounts of energy, the utility bill suggests performance targets and provide tips for saving energy. Some utilities have also created rewards programs for reducing energy use. A research pilot in partnership with utilities and academic institutions could be undertaken to assess the potential benefits of comparative billing in New York City.

Building informatics

As building systems monitoring becomes more and more sophisticated, enormous amounts of data can reveal real-time performance. This can lead to a much better picture of the aggregate efficiency of New York City's building stock, pointing the way to developing new strategies to reduce energy use. Because the volumes of data are staggering, the analysis should be carried out in partnership with specialized institutions, including New York City's existing and newly developed Applied Science Campuses, creating a foundation for ongoing innovative research into the city's building stock and nurturing a knowledge base in energy use metrics.

Strategy 2
Expanding Education and Training

Building operator training

Continuous commissioning of building systems has the potential to eliminate 1.6 million tons of emissions – but capturing this potential requires well-trained building operators. The City could work with key organizations to develop a training program for building operators to become skilled in continuous commissioning that can coincide with the recently enacted Local Law 87 of 2009 that requires periodic energy audits of base building systems and retro-commissioning of those systems.

Demonstrations centers for professionals and practitioners

Despite compelling advances in lighting technologies and controls in recent years, many designers and building professionals lack awareness of the full potential of the possibilities. A new lighting and energy efficiency center known as Green Light New York, due to open in Lower Manhattan in 2014, will begin to address this issue. The center will offer training to a broad range of disciplines as well as a physical venue to exhibit and mock-up emerging and accepted technologies. It will also provide a forum for discussion that will help to promote wider market transformation.

Educating building decision makers

In multifamily buildings that are cooperatively owned and managed, nothing gets done unless board members are educated and enthusiastic about the project. Even then decision-making and project-implementation timelines can span years because of competing demands for attention and limited capital. Reaching 80 by 50 would require cultivating champions for energy efficiency at buildings far and wide. The city could partner with multifamily housing organizations to create programs to train board members and cultivate excitement and follow-through for energy efficiency projects.

Consumer education campaigns

Building decision makers need better information, but so do average New Yorkers. The City's sustainability marketing program, GreeNYC — and its winged mascot, Birdie--encourages New Yorkers to alter their behaviors, from eliminating paper waste to installing energy efficient light bulbs in their homes. The program could be expanded to promote broader messaging about the importance of energy efficiency as well as product-specific plug load reduction campaigns that could be paired with rebates and incentives offered by utilities and NYSERDA.

Strategy 3
Removing Barriers to Energy Efficiency and Incentivizing Action

Aligning interests to undertake energy efficiency

Building owners often cite the existence of 'split incentives' as a major obstacle to undertaking energy efficiency. What they mean is that they cannot achieve a financial payback on their investments because most of the energy savings accrue to tenants – as an obstacle to pursuing energy efficiency projects. The City has already made some progress by working with leading real estate executives to develop terms that could be incorporated into standard commercial leases to specify how owners and tenants could share in both the costs and benefits of energy retrofits. Standardizing this practice could go a long way to overcoming split-incentives.

Improving access to financing

The Greener Greater Buildings Plan has created a marketplace for energy efficiency technologies and services of an unprecedented scale – but major lenders are only just beginning to respond with financing offerings that recognize the value proposition and the stable returns that investments in energy efficiency can yield. In response, the City created the New York City Energy Efficiency Corporation (NYCEEC), which has pioneered energy efficiency financing solutions and provided capital for dozens of clean energy projects that leveraged significant levels of private investment. NYCEEC is taking on the most challenging building segments by financing projects in affordable and market-rate multifamily buildings, Class B commercial buildings, and institutions. Continuing its work with NYCEEC, major lenders, and businesses to diversify and standardize financing offerings, improve performance monitoring, and foster the development of retail infrastructure could greatly benefit the marketplace for energy efficiency.

Providing technical support and assistance

Starting in January 2014, buildings covered by the Greener, Greater Buildings Plan will begin to report the results of their mandatory energy audits. These audits will enumerate specific opportunities to reduce energy use and quantify potential savings, however, buildings are not required to act on the findings. Buildings that choose to act could also encounter the practical difficulties in implementing energy efficiency measures: navigating multiple incentive programs, selecting quality contractors, securing financing, and managing the implementation process. The City could undertake a similar program to the successful NYC Clean Heat program, which utilized a sales-force approach to help thousands of buildings convert their boilers to cleaner fuels ahead of the required timeline through providing technical assistance, general information, and help accessing financing. A similar program can be developed to assist owners and managers of the city's large and mid-size buildings to follow through on the recommendations of their energy audits. It could also seamlessly link them to financing options available through NYCEEC and incentives through NYSERDA and local utilities—thereby acting as a one-stop shop for resources.

Tailoring incentive programs to NYC realities

Multiple NYSERDA and utility incentives are available to encourage buildings to undertake energy efficiency projects — but too many buildings in New York City may be ineligible, particularly those that use heating oil. NYSERDA has recommended allowing all buildings to gain access to state energy efficiency programs — including buildings that utilize fuel oil — and to ease restrictions that prevent efficiency measures that span energy types (for example solar thermal hot water heating). Following through on this recommendation would present a great opportunity to capture additional emissions reductions and the City could help accomplish this by partnering with NYSERDA and the Public Service Commission to develop a near-term pilot program to expand offerings to buildings that are seeking to convert to convert to cleaner heating fuels.

Expanding programs to recognize top achievers

The City launched the Mayor's Carbon Challenge in 2007, inviting 17 local universities to match City government's GHG reduction target of 30 percent in just ten years. Since then the Carbon Challenge has been expanded to include over 50 hospitals and a dozen major corporations. More and more organizations are being attracted to the Carbon Challenge because it inspires high-level commitment among decision makers, provides basic technical assistance and a platform for exchange for facilities managers, and fosters a spirit of competition. The results have been extremely encouraging: university and hospital participants have cumulatively reduced their emissions by 10 percent and six of the participants – NYU, Barnard College, the Fashion Institute of Technology, the Rockefeller University, New York Hospital Queens, and Weill Cornell Medical College – have already reached their 30 percent target already in less than half the time allotted. Expanding the Carbon Challenge or similar recognition programs to multifamily buildings, hotels, retail spaces, and commercial real estate could enroll tens of millions of additional square feet of space and broadly showcase the benefits of energy efficiency for relatively minimal commitment of City resources.

Promoting energy efficiency measures for small buildings

The city has over half a million one- to four-family houses. Achieving 80 by 50 will require action at many of these properties, but programs are not in place to accommodate the extraordinary scale and uniqueness of this marketplace. A program could be developed in partnership with the real estate industry, home inspectors and building trades to target energy efficiency improvements at the time of sale or tenant turnover in these buildings. The 'point-of-sale' is an ideal time to implement simple conservation measures such as pipe insulation, duct sealing, and weatherization and allow prospective buyers to factor energy performance into their decision making.

Promoting efficiency in historic and landmarked buildings

Historic preservation and energy efficiency are often misperceived as competing priorities. With over 30,000 historically landmarked buildings and a world-class community of design and preservation professionals, the city can revolutionize the discipline of energy efficient historic preservation. Demonstration projects jointly carried out by the City, building professionals, NYSERDA and building owners and covering a suite of historic building types could seek up to 50 percent energy savings without compromising architectural character and could create examples that the rest of the industry to follow. Targeted incentives, voluntary performance-based energy standards, and an education program could facilitate these projects and increase market uptake of best practices.

Strategy 4
Strengthening regulations and development incentives

Incorporating weatherization into existing façade improvement programs

Since 1998, the city has required buildings that are larger than six stories to conduct regularly scheduled façade inspections to ensure structural stability and safety (Local Law 11). This program could be expanded to include measures for improving thermal performance of facades through simple weatherization and air-sealing techniques that would be inexpensive to implement and would save building owners money.

Zoning for ultra-efficient buildings and developments

The city's zoning ordinance governs the allowable heights and sizes of new buildings. Over the past decade the City has proactively employed zoning incentives to promote policy objectives such as creating affordable housing, and developing open space and community infrastructure. Zoning can also be used to encourage energy efficiency. One way to do so could be to offer bonuses to new buildings that are built to ultra-high-performance standards or that include on-site clean energy technologies– a measure that would have no fiscal impact to the City and would help to prepare the construction industry for more stringent future codes.

Ensuring Energy Code compliance

New York City's Energy Code applies to both new buildings and major renovations and system replacements, and the codes, through a revision in 2014, will lead to a 30 percent improvement in energy performance compared to the original code adopted in 2009. The City is significantly strengthening code enforcement efforts to achieve 90 percent Energy Code compliance by 2017. Partnering with building trades and professional organizations to provide Energy Code training, and developing incentives with NYSERDA, Con Edison, and the PSC, could accelerate this goal and encourage projects to exceed code standards.

High performance energy conservation codes

The energy code evolves through regular review by building professionals and over time it demands higher performance from new construction and renovations. Further iterations, could be developed in partnership with the International Code Council, the building industry, and research institutions, and by 2015, could potentially yield a 50 percent improvement over today's standards.

Green Codes Task Force implementation

The Green Codes Task Force, convened at the request of the Mayor and City Council Speaker, put forward 111 proposals to increase efficiencies in building energy use and ensure sustainable construction methods. Since the recommendations were finalized in 2008, over 40 of the proposals have been enacted – but many more are still under development or consideration by the City Council and are worth implementing.

Expanding biodiesel use

Biodiesel holds the potential to reduce millions of tons of emissions in the future – and progress has already been made. The City is already showing leadership by using B5 biodiesel in all buildings that utilize heating oil and the municipal fleet is transitioning to B20 for non-winter months. City buildings and fleets can becoming a proving ground for biodiesel use at higher-concentrations and facilitate broader uptake in the private marketplace. In tandem, the City could work with ASTM International and boiler manufacturers to accelerate development of specifications for higher levels of biodiesel use and could also partner with NYSERDA, Brookhaven Labs and private buildings to undertake B20, B50, and B100 pilots. Ultimately, the City could consider increasing the current B2 requirement for heating oil to higher levels.

Enacting performance targets

Over the next decade, the city's largest buildings will be conducting deeper analyses of the potential benefits of improving operations and equipment through energy audits. With the exception of lighting upgrades, building owners are not required to execute specific retrofits; and such a requirement would likely be less cost-effective than allowing businesses to determine the best ways to save. Setting performance targets, however, could help to drive buildings towards improving operations and undertaking retrofits. The City could consider, for example, seeking to raise average energy utilization performance to the top 25th percentile by class as compared to buildings nationwide before 2025.

Strategy 5
Fostering Innovation

Conducting pilot projects for high-potential technologies

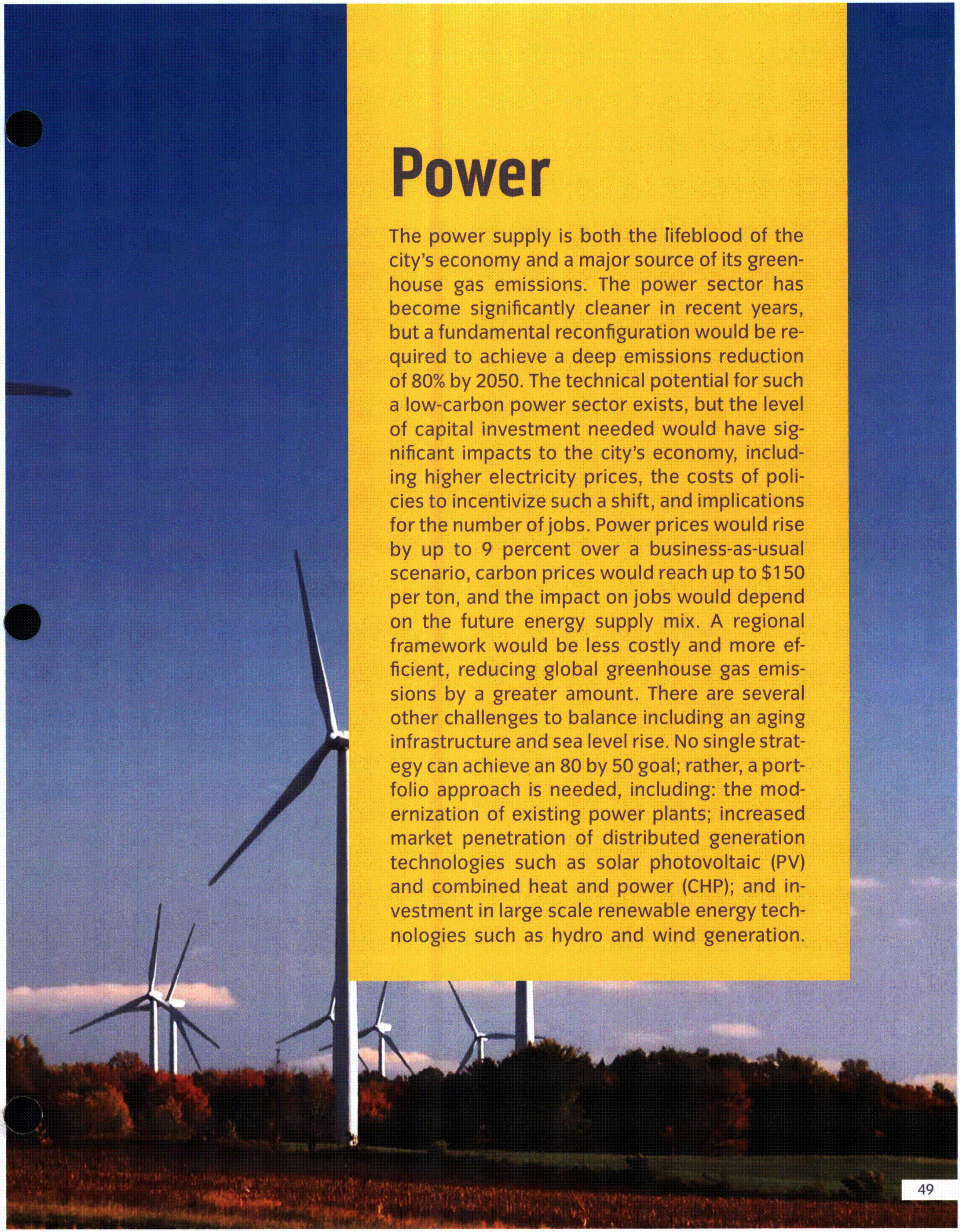
A number of promising building technologies could yield substantial carbon reductions but face technical barriers to implementation in New York City, and may therefore be good candidates for pilot projects that would establish their feasibility. One technology worth piloting is ground source heat pumps. Heat pumps are proven in other geographic settings and at several City buildings in New York, but generally they are difficult and expensive to site because of the diversity of the city's underground geology and infrastructure, space limitations, and inexperience in the marketplace. Another technology is liquid desiccant air conditioning, which is only in the early stages of commercialization but shows extraordinary promise. A demonstration program in partnership with a national laboratory partner and industry manufacturer could help foster understanding of these and other promising technologies.

Making New York City a living lab

New York City can demonstrate leadership and foster the commercialization of new low carbon technologies. The City operates 4,000 public buildings, over 300 public housing sites, 15 hospitals and health care centers, and 14 wastewater treatment plants. The City is currently executing a plan to increase its demand response capabilities from 20 MW of peak load reduction to 50MW, in part through the use of an innovative system that will perform automatic peak load shedding. The City could work with research institutions, Con Edison, NYSERDA, and the private sector to identify and test out other promising technologies, making New York's public facilities living laboratories for energy innovation.

Renewable power generation; Windmills

Credit: Daniel Novak/ danielnovakphoto.com



Power

The power supply is both the lifeblood of the city's economy and a major source of its greenhouse gas emissions. The power sector has become significantly cleaner in recent years, but a fundamental reconfiguration would be required to achieve a deep emissions reduction of 80% by 2050. The technical potential for such a low-carbon power sector exists, but the level of capital investment needed would have significant impacts to the city's economy, including higher electricity prices, the costs of policies to incentivize such a shift, and implications for the number of jobs. Power prices would rise by up to 9 percent over a business-as-usual scenario, carbon prices would reach up to $150 per ton, and the impact on jobs would depend on the future energy supply mix. A regional framework would be less costly and more efficient, reducing global greenhouse gas emissions by a greater amount. There are several other challenges to balance including an aging infrastructure and sea level rise. No single strategy can achieve an 80 by 50 goal; rather, a portfolio approach is needed, including: the modernization of existing power plants; increased market penetration of distributed generation technologies such as solar photovoltaic (PV) and combined heat and power (CHP); and investment in large scale renewable energy technologies such as hydro and wind generation.

Overview

Staten Island DSNY Solar Panels

On a late summer evening in 1882, workers at the Edison Electric Illuminating Company power station in Lower Manhattan threw the switches on a set of 27-ton generators, and 800 lamps lit up a 50-square block area of Manhattan's Financial District. In an instant, the electric age was born. For more than 120 years, electricity has illuminated New York City's most iconic landmarks and powered the city's climb to world preeminence.

The city's people and economy depend on power. New Yorkers spend $11 billion a year on electricity. Fortunately, the city is served by one of the world's most dependable and cleanest power generation and delivery systems. The frequency of interruptions to Con Edison's electric customers is the lowest of any investor owned utility in the nation. The per capita GHG footprint of the city's power sector is also among the lowest of any major city in the United States. Locally produced power is primarily generated with natural gas—as opposed to higher carbon intensive fuel oil or coal—and significant amounts of carbon-free energy is already transmitted from outside of the city, primarily from nuclear power.

However, our energy sector faces significant challenges in the coming years. Power plants are aging and in need of modernization. Renewables comprise less than 1 percent of installed generation capacity within city limits. Furthermore, Hurricanes Sandy and Irene have demonstrated that our energy systems are vulnerable to the impacts of climate change, which will include sea-level rise and more intense and frequent precipitation, wind, and heat waves in the future. More than two-thirds of critical generation and distribution assets are located within the 1-100 year flood zone today. These challenges raise fundamental questions about how to reconfigure and redefine the power sector in order to balance GHG mitigation and resilience investments.

Reducing global power sector emissions by 80 percent by 2050 cannot be done by any city alone. Yet, New York City is a test case for many of the key energy policy questions of the day. This includes innovations in energy efficiency financing, integration of renewables in dense urban environments, transition from carbon intensive fuels to natural gas and renewables, tradeoffs in the potential retirement of nuclear power plants, and the emergence of 21st century regulation of an increasingly complex power sector.

The technical potential exists in the regional endowment of renewable resources across the State, Canada, and offshore Great Lakes and Atlantic. However, because of the capital required, the interdependent nature of power systems, and an already-established regulatory and market framework, there are significant challenges to achieving a clean, diverse and resilient portfolio. This chapter explores the lowest cost pathways for the power sector to meet this carbon goal while meeting reliability standards and improving climate resilience.

Conceptual Framework for Power Analysis

To understand perspectives on what the city's energy portfolio should look like under a low-carbon pathway, the City assembled a group of experts including power producers, energy project developers, utilities, environmental stakeholders, and consumer advocates. A key challenge for the 80x50 goal is to meet the electricity demand of the city's businesses and residents in a reliable and affordable manner while significantly altering the generation technology resource base. Not surprisingly, for a system as complex and facing as many potential tradeoffs as the New York power sector, no single vision prevailed. However, several principles emerged.

Principle 1
Pursue a balanced portfolio, as there is no magic bullet

This report attempts to incorporate the best available climate science, technology learning curves, and power sector modeling appropriate for the long time frame of the analysis. However, long-term forecasting in the energy sector is inherently risky and therefore calls for a portfolio approach to resource planning and policymaking, rather than identification of specific technological "magic bullets."

Principle 2
Major changes are disruptive

The advisory group agreed that an 80 by 50 solution would require a major shift in technologies and markets over the long-term, but also cautioned that a realistic approach would take into consideration the utilization of existing assets to the extent possible. Some members of our advisory group also felt that a well-crafted 80 by 50 program should seek to balance the role of regulation and markets to drive private investments.

Principle 3
Meet reliability standards, including costs of integration

At a minimum, any vision must meet the minimum reliability criteria set forth by NERC and NYISO. A realistic analysis must include the "hidden" costs of integrating new resources, including deliverability within the utility distribution network, load balancing of intermittent resources, and the need for long distance transmission.

Principle 4
Balance climate mitigation and resilience

In the aftermath of Hurricane Sandy and recent summer heat waves, some members of the advisory group felt that scarce ratepayer and taxpayer dollars need to be spent on making the power sector not only less carbon intensive, but also more resilient to extreme weather events through storm hardening power assets and other measures. In June of 2013, Mayor Bloomberg released PlaNYC: A Stronger, More Resilient New York, an action plan to protect the city's coastline, critical infrastructure, businesses and communities from the risks of climate change. Although climate resilience is beyond the purview of this particular report, the power sector recommendations attempt to complement the City's planned resiliency measures.

Principle 5
Cities cannot do this alone

A deep reduction in New York City's greenhouse gas emissions is only the beginning, and action will eventually be required at a regional or national scale. While evaluating the viability of pursuing deep carbon reductions at a local level, the study should also emphasize the need for strong Federal and regional action.

Principle 6
Use City government as a test bed for new technologies

With over 4,000 facilities including 14 wastewater treatment plants, over 1,200 schools, hundreds of firehouses and garages, and other properties, the City is a major consumer of energy. In cases of market uncertainty, the City can use its resources to pilot emerging technologies and drive private investment.

Power System Fundamentals

New York City's electricity supply system is designed to keep up with the dynamic needs of its consumers. In-city plants are able to satisfy most of the local demand, but over half of the city's energy is generated in surrounding regions and then transmitted into the city. The system is owned, operated, and regulated by a wide array of private and public entities, all working together to keep the power flowing wherever and whenever it's needed.

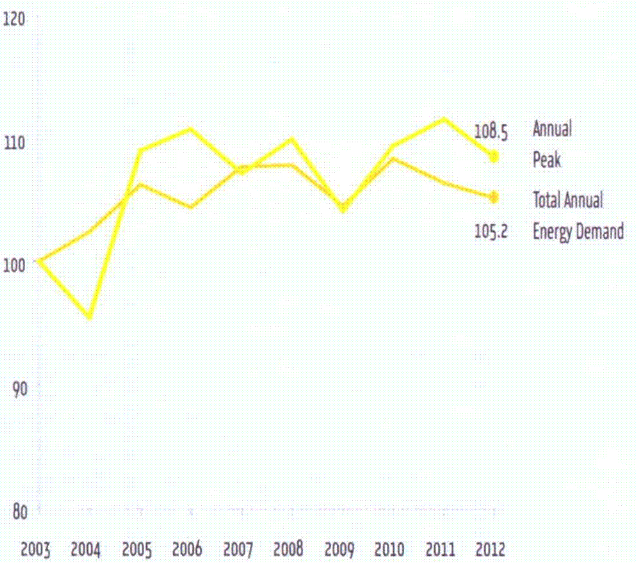
Energy Demand

Electricity is primarily consumed inside the city's buildings – residential, commercial, institutional and industrial– where it powers mechanical systems, lighting, and equipment, adding up to 94 percent of total usage; subways are responsible for 5 percent, and streetlights account for less than 1 percent. In 2012, New York City consumed over 53 TWh, amounting to approximately 0.25% of global electric consumption.

The city's demand for electricity has evolved with changes in the population and building stock, structural changes in the economy, emergence of new electronic devices and equipment, and innovations in energy efficiency. From 2003 to 2008, electricity demand grew at an annual rate of 1.5%. After the Great Recession of 2008 until 2012, however, energy demand reduced at an annual rate of 0.6%. The NYISO now forecasts energy demand in New York City to grow at an annual rate of 0.49% over the next decade. According to the EIA, this trend is consistent with national energy demand and has not recovered with the economy due to lower industrial energy consumption, investments in energy efficiency in buildings, and increasing amounts of distributed generation.

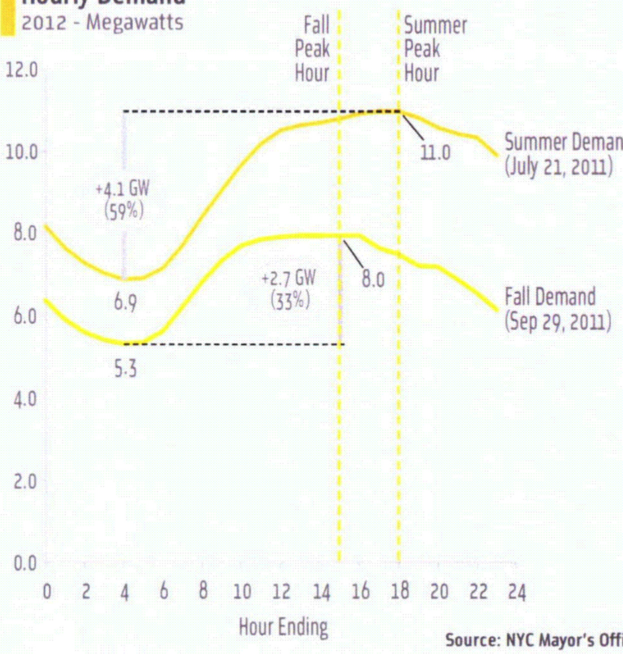
Despite the stagnant growth of aggregate energy consumption, peak demand has grown at an annual rate of 1.1%. As summers get hotter due to climate change, increasing the demand for air conditioning, the growth in peak demand can be expected to continue – projections from the New York City Panel on Climate Change indicate that the city may see 3-4 heat waves per year by the 2020's, and 5-7 heat waves per year by the 2050s, up from an average of 2 today. As highlighted in PlaNYC: A Stronger, More Resilient New York, heat waves have impacted the city's electrical grid more frequently and more significantly than any other type of weather event, including the Long Island City blackout in 2006, and historic peak load days in both 2011 and 2013. (See chart: *Growth in Peak and Annual Demand*)

Growth in Peak and Annual Demand
Index to 2003



Source: NYC Mayor's Office

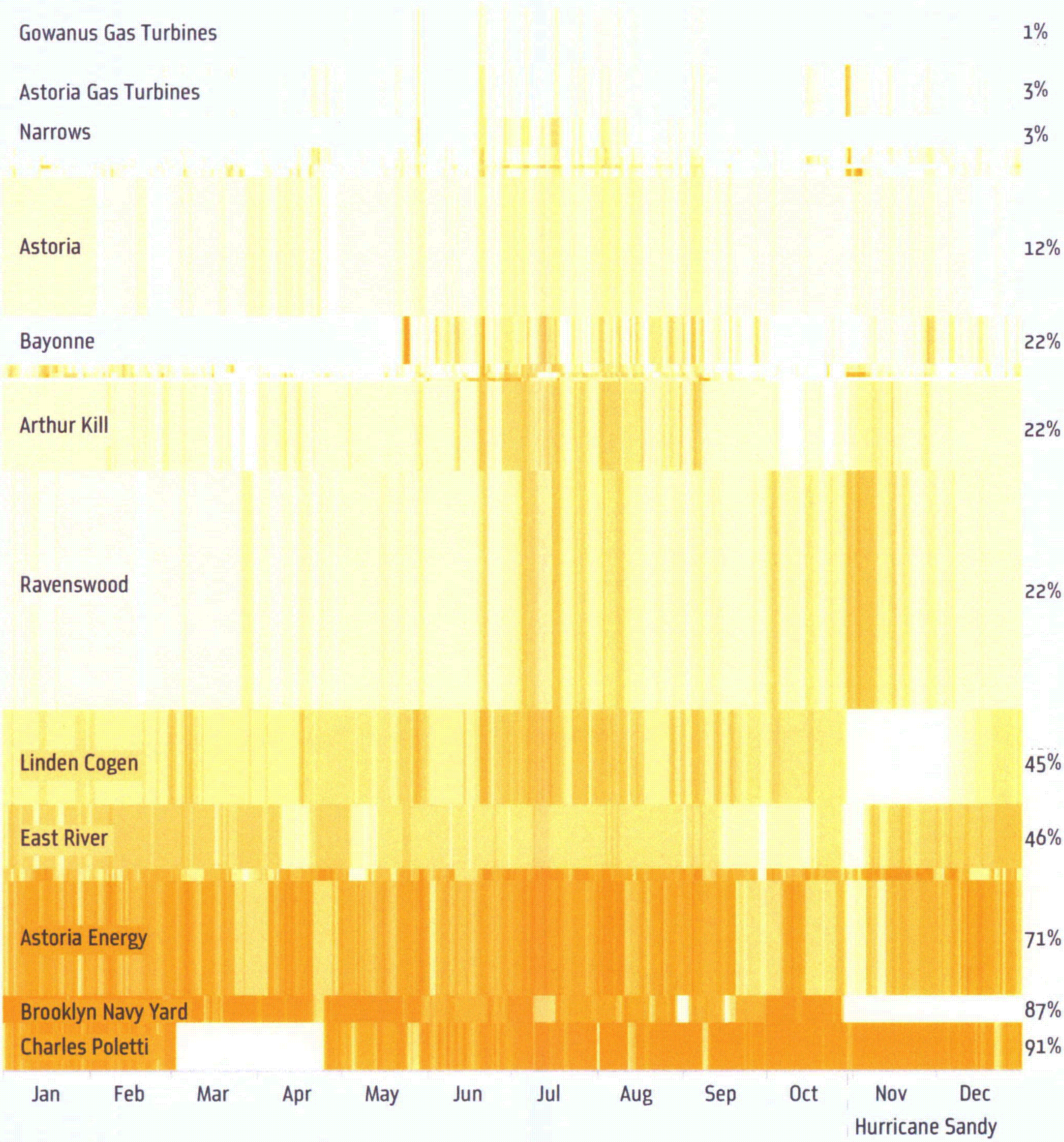
Hourly Demand
2012 - Megawatts



Source: NYC Mayor's Office

Daily Utilization Levels of In-City Power Plants

Color denotes days on which power plant is operational. Width of bar corresponds to size of power plant.



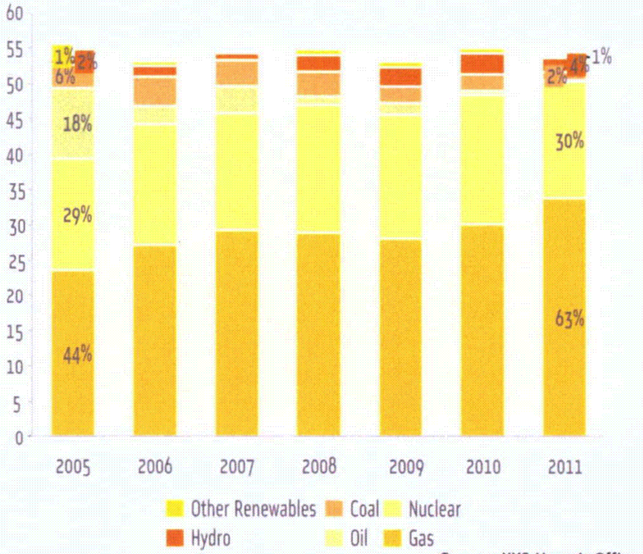
Source: NYC Mayor's Office

Electricity demand also varies hourly and seasonally. On a hot day in July, demand can rise almost 60 percent from 6.9 GW at four in the morning to 11 GW by six at night, while on a balmy day in September it will only go up by a third, from 5.3 to 8 GW within a day. In 2011, peak daily demand was at 6.9 GW in March, but at 11.4 GW in July — an increase of almost two thirds. To maintain system reliability, supply must meet demand at all times, requiring the existence of generation that often sits idle until needed.

Power Generation

The 24 power plants serving New York City directly have a capacity of approximately 10,398 MW, enough to meet at least 86 percent of the city's forecasted peak demand – a reliability requirement by the New York Independent System Operator. However, generation from these power plants provides only half of the electricity needs of New York City, with a majority of the balance originating from cheaper and cleaner sources in New York State and surrounding regions. In addition, most of the generation fleet is located along the waterfront, with more than half concentrated in Astoria and Long Island City in Queens. Today, nearly two thirds of the in-city plants are located within the existing 100-year flood plain, even before taking into account future sea level rise of up to 2.5 feet by the 2050s. (See map: *In-City Electric Generating Facilities in the Floodplain*)

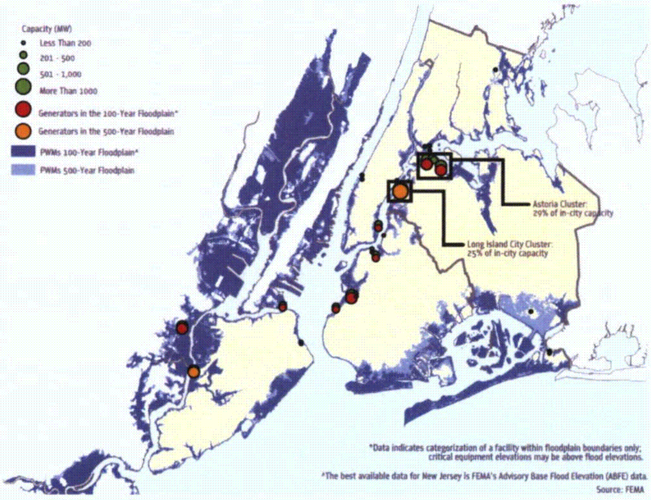
New York City Electricity Supply Mix
In-city and Imported, TWh



Source: NYC Mayor's Office

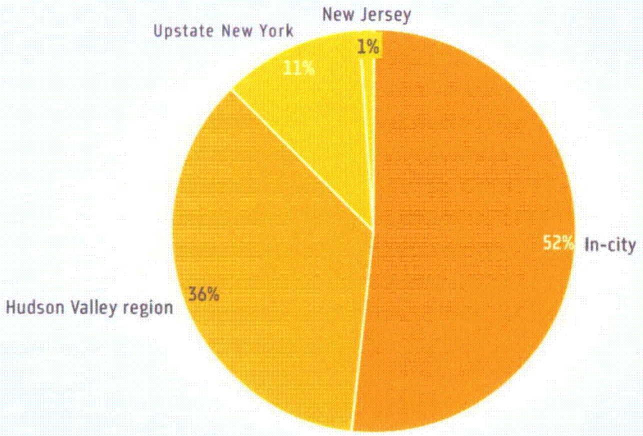
Energy is imported by high-voltage transmission lines that connect the city with up to 6,000 MW of power supply from areas as close as the Hudson Valley, Northern New Jersey, Long Island, and as far as Northern and Western New York State. Each region has a different fuel supply mix serving New York City's demand. In 2011, power transmitted into the city consisted of nuclear (56%), natural gas (31%), hydro (7%), coal (4%), wind (1%), and oil-fired (<1%) generation. (See figures: *New York City Electricity Supply Mix*)

In-City Electric Generating Facilities in the Floodplain



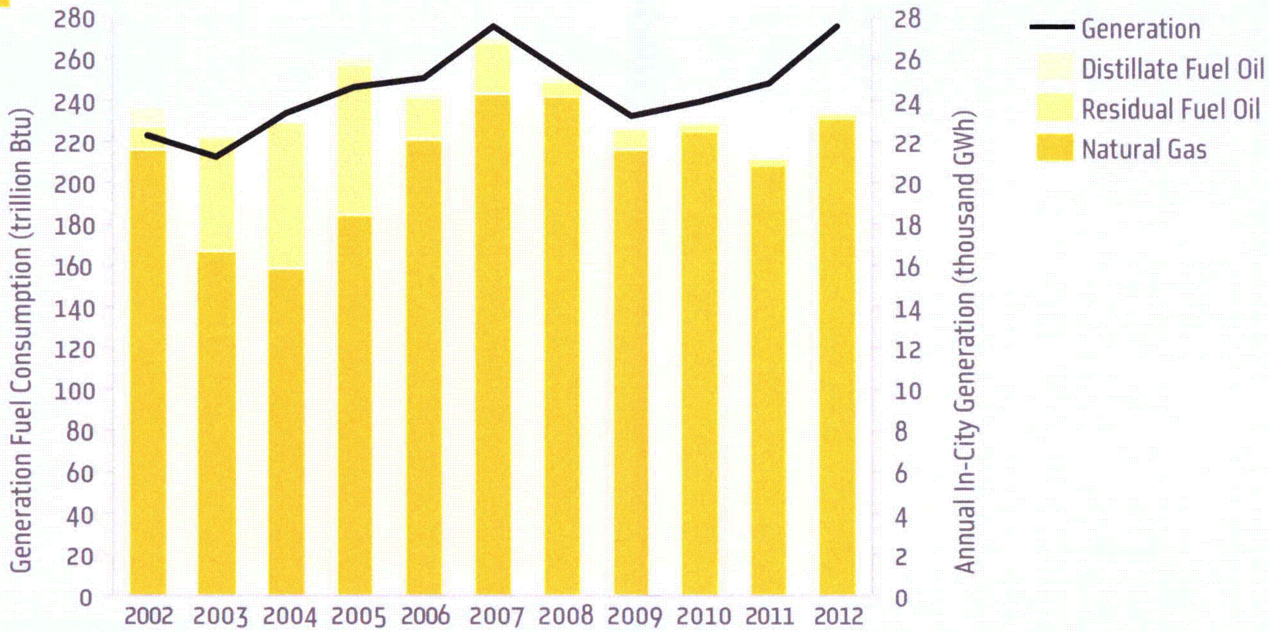
Source: NYC Mayor's Office

New York City Electricity Supply Mix
2012



Source: NYC Mayor's Office

Fuel Purchases for Electric Generation



Source: NYC Mayor's Office

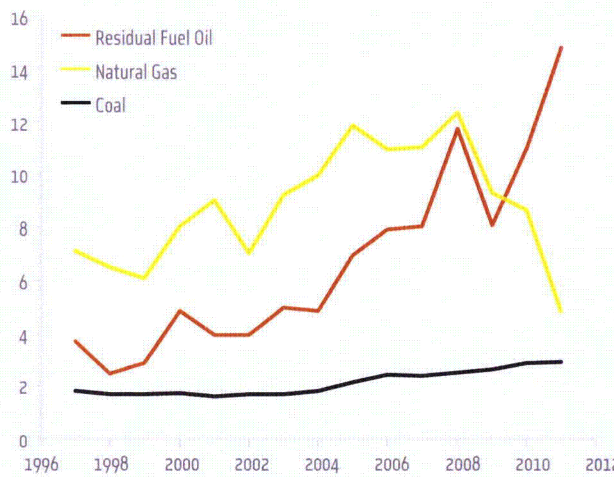
Sources of GHG Emissions

The power sector emitted 15.8 million tons of CO2e in 2012, or approximately one-third of the city's total emissions – a large number in absolute terms, but less than three times the U.S. per capita average. Because the majority of in-city generation is capable of burning natural gas — as opposed to more polluting coal or heavy fuel oil — and half of the city's power is imported from cleaner sources located outside of the five boroughs, New York City's power system GHG footprint is relatively low.

Between 2005 and 2011, the power sector's emissions decreased by 31 percent despite modest growth in demand over the same period. The greatest contributor to carbon reductions came from changes in market fundamentals due to the increase in the price of oil since 2005, and the development of new natural gas resources. As a result, "dual fuel" generators (capable of burning either natural gas or fuel oil) shifted increasingly towards cheaper natural gas. Second, natural gas-fired generators in the region became more competitive in the electricity market relative to coal and fuel oil-fired units, thus increasing their utilization rates. Over this period, heavy oil-fired generation from in-city plants decreased from 30 percent to just 2 percent (and was as high as 50% in the 1980's and 1990's). The city's electric supply mix (including imported generation) is now 63 percent natural gas-fired, with oil- and coal-fired generation accounting for less than 3 percent.

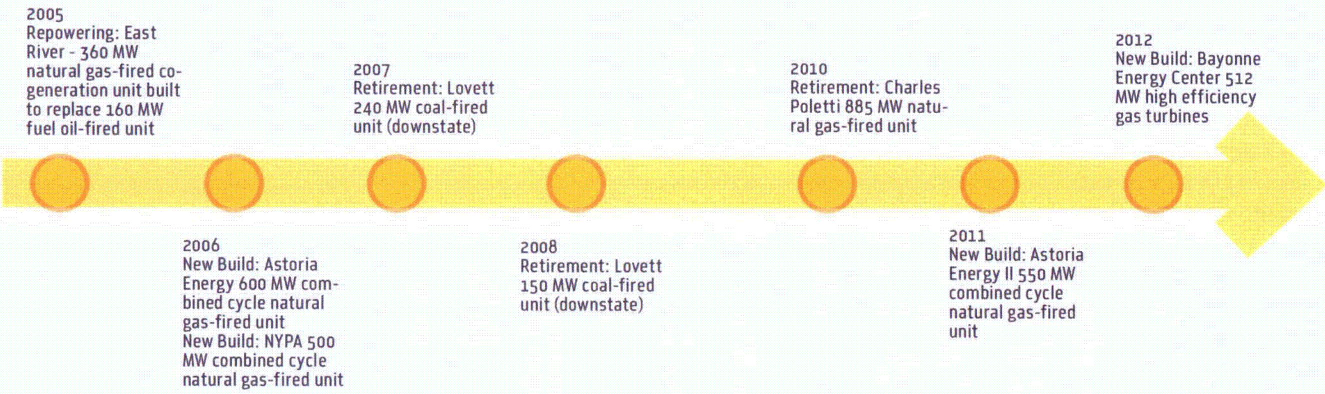
Fuel Prices for Electric Generation in New York State

2005 $/MMBtu



Source: Energy Information Administration

Electricity Generator Retirements and New Additions
2005-2012



Source: NYC Mayor's Office

The development of state-of-the-art power plants also reduced the city's greenhouse gas emissions from the power sector by 1 million metric tons. Over 2,500 MW of new in-city capacity were placed in service over the past seven years and 1,000 MW of old generation were retired. An additional 900 MW of coal-fired generation was retired in the Hudson Valley, resulting in the further decarbonization of power transmitted into the city. These changes helped to improve local air quality, reducing emissions of sulfur, nitrogen, and other criteria pollutants.

New York City's Clean Power Potential

The city's grid has become cleaner in recent years — but there is a long way to go to achieve the deep reductions in greenhouse gas emissions analyzed in this study. No one technology would be able to reduce emissions enough by itself; a cleaner system would have to rely on a portfolio of options including the repowering of existing plants, high penetration of "behind-the-meter" technologies such as solar PV and CHP, and large-scale hydropower and wind generation.

Modernizing Existing Generation

Repowering in-city generation

Today, nearly 60 percent of the power plants in the City are more than forty years old, and most of these plants utilize less efficient "single cycle" design. Repowering these plants with "combined cycle" units that are able to capture and reuse waste heat to generate additional electricity, can boost efficiency from ~30 percent to almost 60 percent, thus reducing carbon emissions by almost one-half for each MWh of electricity generated. Repowering in-city plants could also yield other public policy benefits, including increasing reliability, reducing criteria pollutant emissions, and incentivizing generators to invest in storm surge protection for new equipment. However, repowering fossil fuel-fired power plants alone will be insufficient to achieve an 80 percent GHG reduction.

Achieving deep carbon reductions at the city or regional level would ultimately have significant implications for existing in-city power plants. A carbon policy (such as a declining cap on emissions) would make existing plants gradually become less competitive relative to newer, more efficient plants. However, many of the in-city power plants would need to remain online in 2050 in order to meet critical system reliability standards, requiring additional compensation (for example, in the capacity market).

Repowering Projects in New York City

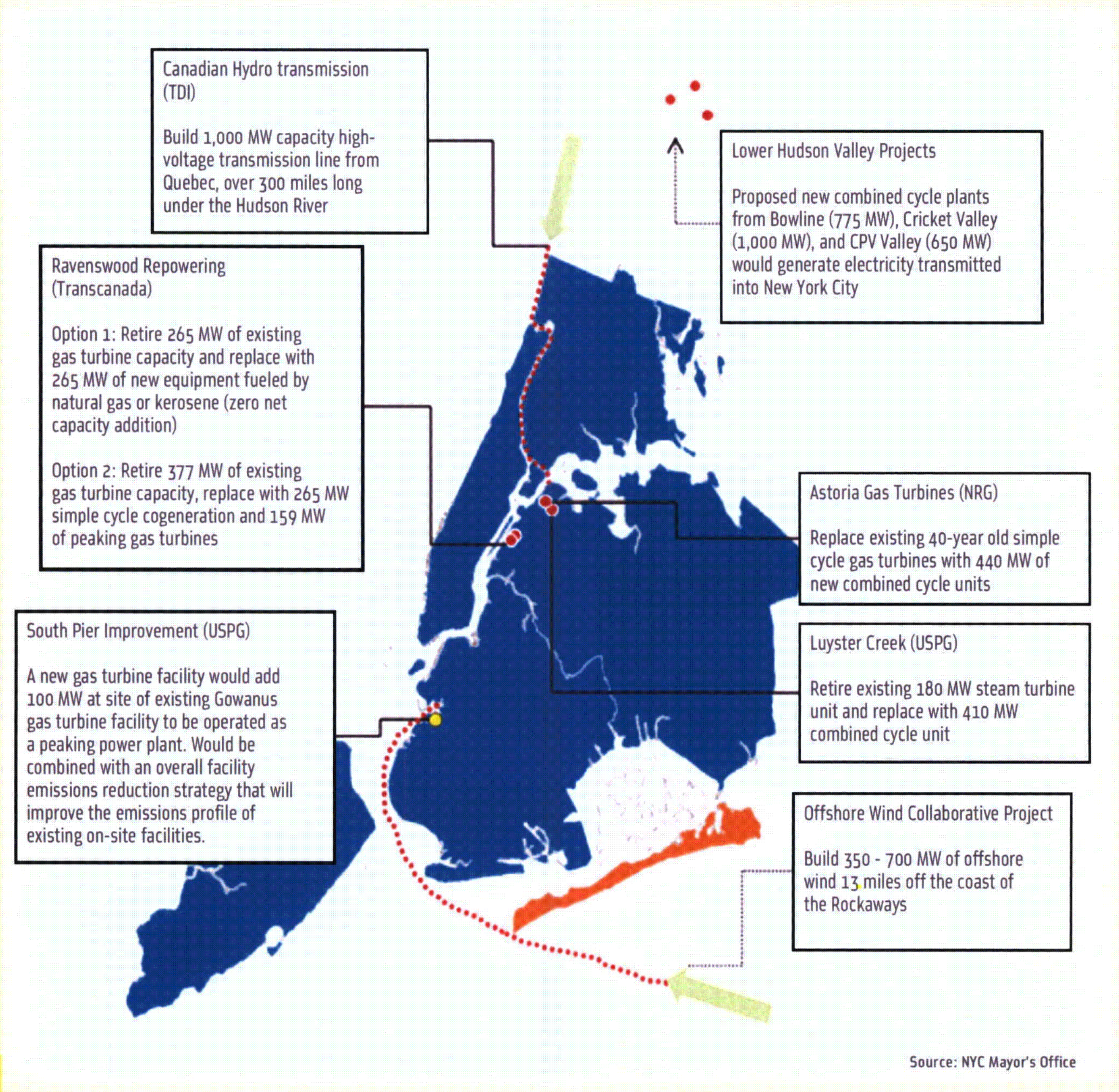
The City of New York has worked with its electricity supplier, the New York Power Authority, to enhance the efficiency and environmental profile of the power sources that serve the city. For example, the City entered into a contractual arrangement with NYPA that allowed the 500-megawatt Astoria Energy II power plant in northwest Queens to be built, and to enter service in 2011. The AE II plant has improved air quality and reduced greenhouse gas emissions in the region by displacing generation from less efficient plants. In a similar fashion, the City supported the 2010 retirement of the former Poletti Power Plant owned by NYPA in Astoria. The highly polluting facility was replaced by NYPA's state-of-the-art 500 MW combined-cycle plant, further reducing emissions. The 500 MW plant, along with AE II, contributed to a 5% reduction in the City's carbon footprint the year following startup.

Carbon Capture and Storage

Carbon capture and storage (CCS), in theory, could mitigate the greenhouse gas emissions of conventional fossil fuel generation by capturing carbon dioxide and then either storing it in geologic formations or reusing it in industrial applications. Since New York City lacks the space necessary for a feasible carbon "sink," CCS would require the siting and construction of dedicated pipelines and compressor stations to pressurize and pump the carbon dioxide to neighboring states. Although CCS may be technically possible, it has not yet been developed at a commercial scale in the power sector, and significant regulatory and engineering questions exist. Therefore, the study does not include CCS in the portfolio of large-scale mitigation measures for in-city gas generation – although it does allow it to emerge as a viable technology elsewhere in the region.

Currently Proposed Power Projects

NYC, New York



Source: NYC Mayor's Office

Grid-Scale Clean Energy

The city needs a diverse portfolio of power to satisfy demand, and although repowering can improve the efficiency of generation, it cannot provide a deep reduction in greenhouse gas emissions alone. For that, the city would have to rely on clean resources in other areas, whether new or existing, transmitting power via long distance lines. The three available options – hydro, nuclear, and wind – all have different tradeoffs, including transmission constraints, siting difficulty due to local opposition, and intermittency (in the case of wind).

Hydroelectric power

Hydroelectric power has several attractive features: operating costs are relatively low, it is available nearly all the time, and is most abundant when it is needed. Most of the regional potential lies in the Canadian Province of Québec, located just north of New York State, where, according to the public utility Hydro-Québec, close to 36 GW of capacity is already installed and an additional 35 GW of technical potential exists, of which the utility is planning to capture 5.5 GW by 2016. Because Québec has a winter-peaking demand for electricity, significant excess capacity – up to 10 GW – is already available during the summer months, exactly when New York City's demand is greatest.

Proposed Route for Canadian Hydropower Transmission Line

Source: NYC Mayor's Office

Indian Point Energy Center

Transmission, however, is a challenge: less than 900 MW of transmission capacity links Quebec to New York State, and within the state, weak transmission interconnections make it more difficult for energy to reach the downstate markets. Developers propose a 1,000 MW line directly linking Canadian hydro-power to New York City; this proposal was recently authorized for construction and operation by the State of New York. (See map: *Proposed Route for Canadian Hydropower Transmission Line*)

Nuclear

There are significant questions about the continuation of existing nuclear generation that serves New York City. The nuclear power sector also faces significant regulatory uncertainty, although this could change when next generation technologies, such as modular reactors that promise to be smaller, cheaper, and more reliable, become commercially available. In 2011, the City released its Indian Point Retirement Analysis, describing the impacts of the potential closure of the Indian Point Energy Center. Presently, nuclear power provides approximately 30 percent of the city's electricity; phase out of nuclear energy with natural gas-fired generation is estimated to increase New York City's greenhouse gas emissions by approximately 15%. The city also depends on Indian Point for reliability, as congested transmission lines limit power imports from more distant locations. This study assumes a 20 year extension for both units of the Indian Point Energy Center.

Wind

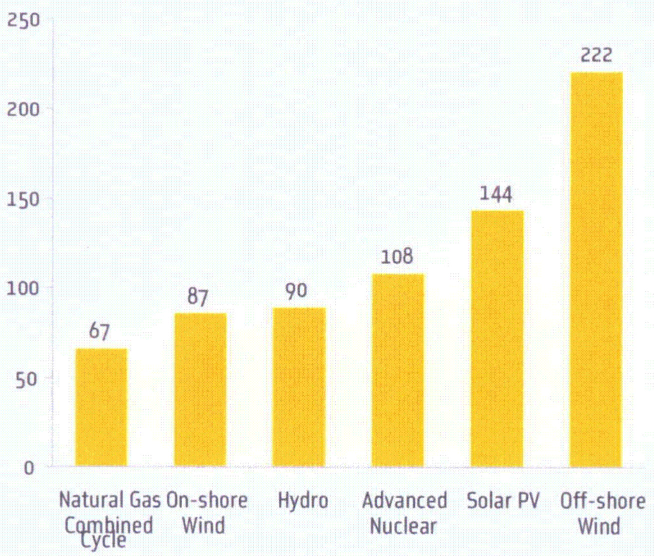
Wind sources represent a small but growing portion of our energy supply mix. Since 2005, NYSERDA has funded large-scale renewable energy projects through the Main Tier of the renewable portfolio standard. Over three-quarters of a billion dollars have supported the development of approximately 1,800 MW of renewable energy, 90 percent of which consists of on-shore wind resources located in Northern and Western New York State. However, only a small portion of the renewable power generated in these far regions has been able to serve demand in New York City and the downstate area.

The technical potential for wind is, however, abundant in New York State, estimated at 29.5 GW (though only 2.8 GW of it is in the most achievable wind classes based on wind power density and wind speed). Surrounding regions also have significant technical potential of wind resources: an additional 7.6 GW of potential is estimated within New England, and 0.8 GW in the New Jersey area. Off-shore wind potential is greater yet: up to 150 GW across different feasibility classes around the region, though for the purposes of this study, it was assumed that a total of 21 GW of off-shore wind is available in the Northeast from New York (2.8 GW), New England (8.5 GW), and the Mid-Atlantic area (9.6 GW).

However, whether on-shore or off-shore, wind is less reliable than hydro or nuclear power. Since wind blows irregularly, wind turbines only produce electricity around 30 percent of the time on-shore and around 40 percent of the time off-shore. The New York Independent System Operator (NYISO) "derates" wind generation to 10% during the summer due to lower average wind speeds. Effectively, a 1,000 MW of on-shore wind generation (nameplate) is estimated to generate 100 MW during summer periods.

Due to a significant decline in the capital and installation costs, on-shore wind generation is nearly cost-competitive with fossil fuel generation. Off-shore wind still has very high capital costs, especially in the US where not a single commercial project has been completed. Although it has also fallen on a per-MWh basis, it is still far costlier than hydro, nuclear, or onshore wind. (See chart: *Levelized Cost of New Generation*)

Levelized Cost of New Generation
$/MWh



Source: EIA -Annual Energy Outlook 2013

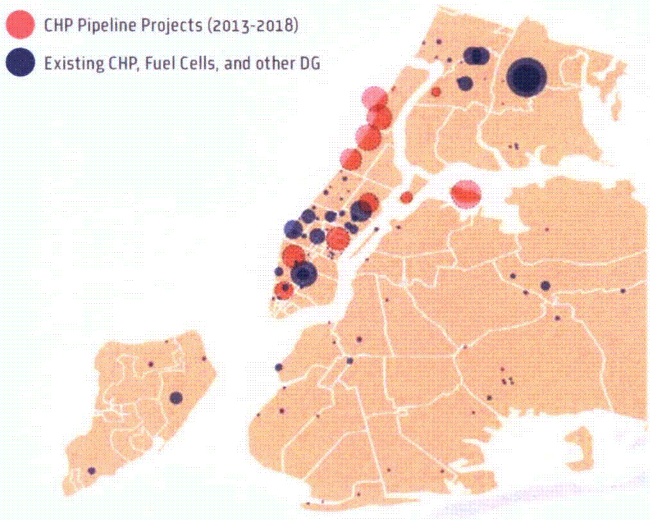
Distributed Generation

Another small but growing source of energy in the New York City market is customer-sited distributed generation (DG). These resources are comprised of several technologies including combined heat and power (CHP), fuel cells, and solar PV. DG resources have grown in recent years from under 50 MW in 2007 to over 160 MW today. With DG, customers have an alternative to the bulk power supply, adding power redundancy and reducing strain on local distribution systems depending on configuration and location.

Combined heat and power units generate electricity using fossil fuels or biofuels, recovering waste heat for onsite heating and cooling needs. They can be highly efficient and less carbon intensive than power generated at power plants — as high as 70 percent efficiency depending on the electric and heat loads they serve, compared with single-cycle units with efficiencies in the 30 percent range and more than the best combined-cycle units with efficiencies of up to 60 percent. CHP units can also be configured to operate during grid outages and reduce strain on certain local distribution networks with high demand, adding resilience to the facilities they serve as well as portions of the grid.

Policy support at the City and State levels have led to increased investment in CHP in recent years. Con Edison has adopted the CHP "offset tariff," allowing larger CHP systems serving campuses to more easily interconnect. NYSERDA has provided incentives through its CHP Market Acceleration Program. As a result of these policies, investment in CHP projects have begun to rise. Recent City-owned CHP projects under development include a 12 MW unit at the North River Wastewater Treatment plant and a 15 MW unit at Rikers Island. Many private investments have been under development as well, including CHP systems at NYU Langone Medical Center, Columbia University, as well as several hotels, and residential and commercial buildings. However, the high capital costs of CHP and the need for large and consistent thermal loads limit its potential application to only certain buildings. (See figure: *CHP Pipeline Map*)

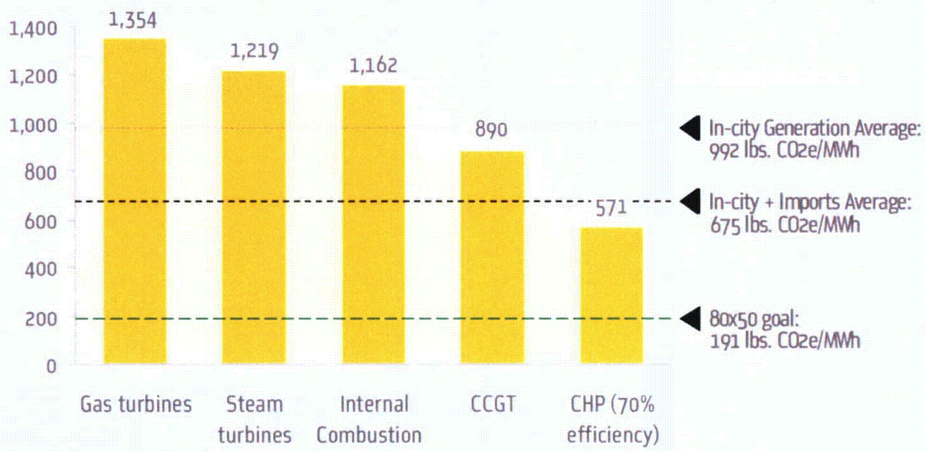
CHP Pipeline Map



Source: ConEd, NYC Mayor's Office

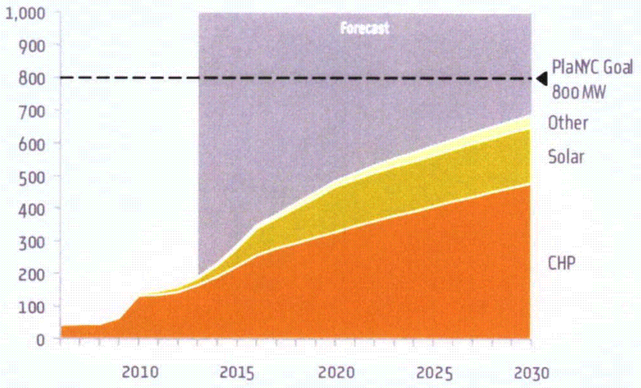
Efficiency of CHP vs. the Grid and Other Technologies

Emissions rate in lbs. CO2/MWh



Source: NYC Mayor's Office

Cumulative Installed Capacity
MW



Source: NYC Mayor's Office

Solar photovoltaic power

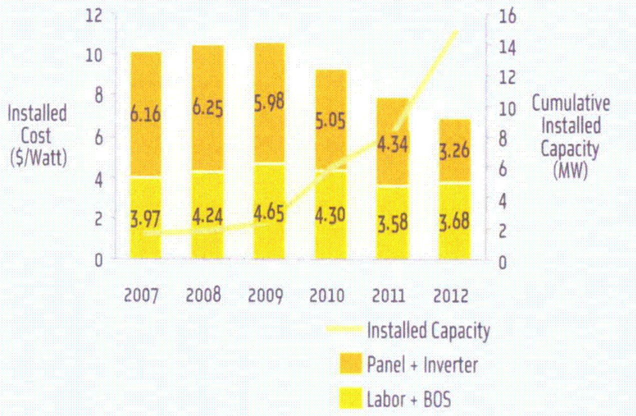
Installed solar PV capacity in New York City has grown from 1 MW in 2007 to just under 20 MW today. However, solar PV is still a small share of overall power production, amounting to less than 0.2 percent of the city's peak load. Investment in PV, however, is growing: the number of installers grew from 4-5 in 2006 to more than 60 in 2013. This growth is the result of several factors, including reduced equipment costs and robust incentive support both at the Federal, State and local levels. (See chart: *New York City Installed Solar PV Capacity and Costs*)

New York City has a sizeable technical potential for rooftop PV with roughly 1.6 billion square feet of rooftop space across approximately one million buildings. However, developing solar PV in dense urban environments with high transaction costs, a complex and varied building stock, and many building owners either without enough knowledge or financeable credit remains challenging. The growth rate of PV in New York City lags behind other regions with similar solar radiance such as neighboring Long Island, New Jersey, and Germany (the global leader).

Several policies at the local, State, and federal levels have attempted to overcome these challenges. At the federal level, the investment tax credit (ITC) for solar PV has been the main driver of investment, reducing business and personal tax liability by 30% of eligible PV system costs, and will continue to do so until the end of 2016. The City currently offers a property tax abatement for systems installed between 2008 and 2015. Working with CUNY, Con Ed, NYSERDA, and the Department of Energy, the City developed the NYC Solar Map: a web-based tool able to easily display the technical potential for PV on any rooftop in the city. Through NYSERDA, the State also offers incentives for PV in the forms of upfront rebates (per installed kW, systems less than 200 kW), and competitive production incentives (per kWh produced, systems greater than 200 kW).

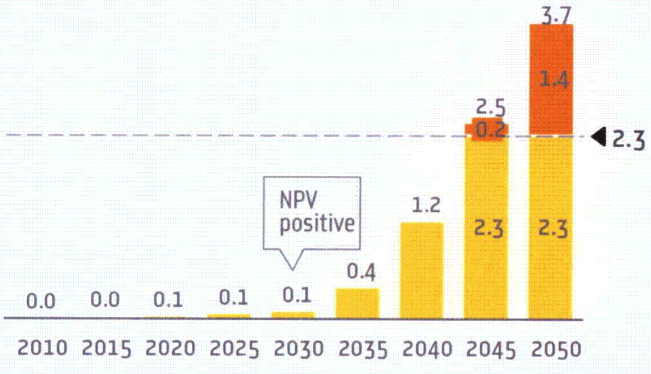
Given the amounts of solar radiance that New York City receives on average and current technological capability, solar panels produce approximately 14 percent of their full theoretical output on an annual basis. Using current commercially available technology, 2.3 GW of rooftop solar PV would provide 5 percent of the city's annual power needs.

New York City Installed Solar PV Capacity and Costs



Source: NYC Mayor's Office

Forecasted New York City Solar PV Capacity
GW AC Cumulative at Private 10% Pre-tax Discount Rate



Source: NYC Mayor's Office

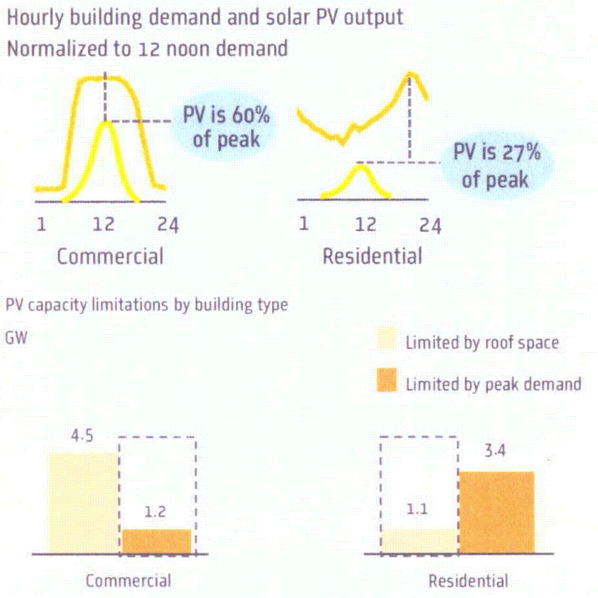
Measuring the Technical Potential for Photovoltaic Solar

The city's available rooftop space could theoretically translate into as much as 16.1 GW of solar PV potential, but only a small share of that potential can be realistically captured. Screening for high-rise buildings (due to technical challenges and costs) and adjusting for estimates of structurally unsound roofs, occupied, or shaded space decreases the potential from 16 GW to 5 GW – but even that amount cannot be fully captured under current "net metering" rules.

As written today, net metering rules allow building owners to offset their retail electricity bills by the amount of electricity generated by their rooftop solar installations, including generation in excess of load that is injected into the network. However, as a conservative assumption, this study assumes that these rules will not be expanded in the long-term.

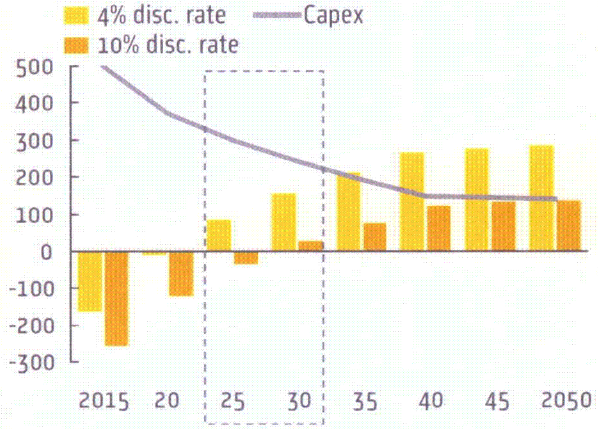
For the purposes of the model used in this study, a conservative assumption was made that the installation rate of solar technologies continues along a historic trend until prices reach grid parity around 2025-2030, by which point a combination of lower solar system costs and naturally higher electricity prices makes solar PV in New York City competitive on a retail basis. Technical potential is estimated at 2.3 GW based on both available roof space and load matching. (See charts: *Forecasted New York City Solar PV Capacity* and *NPV and Capital Expenditure of 100kW System*)

Hourly Building Demand and Solar PV Output
Normalized to 12 noon demand



Source: NYC Mayor's Office

NPV and Capital Expenditure of 100kW System
$ Thousands Pretaxed Unlevered



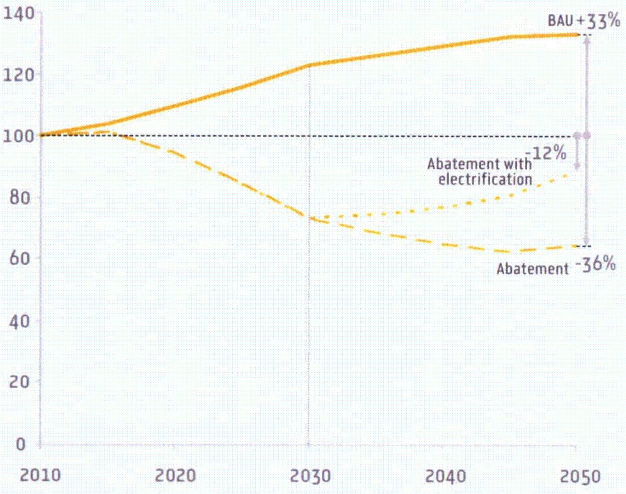
Source: NYC Mayor's Office

The 2050 Power Supply Mix

Several approaches to reach the 80 by 50 goal in the power sector were evaluated, including different scenarios for (1) demand, (2) generation technology constraints, as well as a (3) comparison of a NYC-only emissions reduction versus a regional reduction. Generation constraints were imposed in order to explore different bounds for the penetration of nuclear, hydropower, and renewables technologies, as the development of these resources will be determined in many cases by regulatory and legislative realities (see the previous section for technology constraints).

There are several potential electricity demand pathways. Under a "business as usual" scenario, demand is estimated to increase by 33 percent by 2050 (0.72% annually). Our 80 by 50 Abatement Scenario assumes a 30 percent reduction in aggregate energy demand by 2030. By 2050, demand could either fall further (36 percent) if buildings do not extensively rely on electric heating and power, or rise slightly if they do. (See chart: *Power Demand Scenarios on the 80 by 50 Pathway*)

Power Demand Scenarios on the 80 by 50 Pathway
Indexed to 2010



Source: NYC Mayor's Office

To analyze the feasibility and costs of reaching 80x50, an optimization model for the power sector was used to find the least-cost solutions to supplying power to the marketplace assuming a linearly declining carbon cap to 2050. Several different assumptions were explored to test the robustness of the modeling results, such as the definition of the geographic carbon "boundary," penetration of behind-the-meter technologies, and learning curves of new and emerging technologies. The model tested the results of a carbon cap for New York City, as well as one for RGGI states, that declines linearly from 2012 to 2050. (See charts: *Power Sector Emissions Under Different Cap Scenarios*)

Although the City is not advocating for a city-level carbon cap, it serves as a useful modeling tool and effective proxy for the power sector subsidies that would be required to achieve 80 by 50. As the carbon cap declines each year, the model determines the lowest cost mix of existing conventional generation and new, lower carbon resources needed to stay below the cap. The model utilizes exogenous demand projections that incorporate the deep energy efficiency gains as well as increased electrification (described in the Buildings chapter) that are needed to achieve 80 by 50.

Key Findings

Demand-side measures should be aggressively pursued

The least cost pathway would rely heavily on energy efficiency measures and behind-the-meter distributed generation technologies such as solar PV and CHP. If aggressive demand reduction measures are met, the carbon cap would not be "binding" on the power sector until the early 2030s, and could be met on the margin with cleaner imports as well as the "endowment" from the local power sector switching away from heavy fuel oil from 2005-2011. Conversely, without a significant reduction in demand, the carbon price would be prohibitively expensive.

The technical potential for achieving deep carbon reductions through large scale clean energy exists – in theory

New York City and the surrounding region has ample technical potential to reduce carbon emissions through higher efficiency conventional generation and renewable resources such as Canadian hydroelectric power, Atlantic offshore wind, and distributed solar generation. In theory, the technical potential that is available to New York City for zero-carbon resources is close to 30 GW, which would exceed existing installed capacity in the City even after de-rating capacity factors to account for the intermittency of solar and wind resources. There are, however, significant and untested challenges to achieving this potential.

In-city options for low-carbon generation are limited

The opportunities for decreasing carbon emissions with low-cost or incremental solutions such as fuel switching in the local power sector are limited as the city's generation mix has already shifted almost entirely to natural gas within the past 10 years. Repowering and solar PV would help reduce emissions, but the scale of their impact would not be sufficient for the 80 by 50 pathway. Large scale options such as hydro, nuclear and wind would need to be developed to bridge the gap for the 80 by 50 trajectory. This study limits achievable hydro to 1 GW, not adding any nuclear beyond existing capacity, and closing any remaining gaps through wind generation.

System integration of large-scale intermittent resources is untested in the U.S.

Although Europe has successfully developed more than 3 GW of offshore wind power, no utility-scale resources exist in the US. Navigating and aligning the objectives of numerous layers of government and regulatory oversight would be a process with little precedent that could take many years to work out. There are also significant technical questions regarding how the grid will remain reliable with large amounts of intermittent resources supplying a substantial portion of the energy. The experience of integrating large-scale renewable power resources into European electric grids poses both optimistic and cautionary tales. In Germany, where renewable resources now power up to 20% of peak load, the rising costs of energy have recently caused regulators, legislators, utilities, and private sector actors to rethink costly renewable energy goals. Due to the high penetration of solar PV, California is beginning to implement energy storage to balance the peak generation with non-coincident peak demand.

Meeting 80 by 50 in NYC would require "leapfrogging" to large scale renewables

If the city acts alone without regional or national carbon regulation frameworks, and assuming the constraints on hydro, nuclear, and on-shore wind, most of this capacity would have to come from off-shore wind – almost 7 GW of it by 2050. Carbon prices (or other incentives) would need to rise substantially to incentivize a massive investment in utility scale renewables. Gas-fired generation capacity would also remain, though it would be used primarily for load balancing, as discussed below. In-city or dedicated resources would produce 70 percent of the city's power, and imports would only account for the remaining 30 percent, far less than today.

Within a regional framework, the need for incremental capacity within NYC would be much lower: instead of adding 8.3 GW, the city would only add 3.2 GW of roughly equal shares of hydropower, off-shore wind, and on-shore wind. Those would generate about 27 percent of the city's total energy needs, and the rest would be covered through cleaned-up regional imports. (See charts: *Installed In-City Capacity and Generation Mix*)

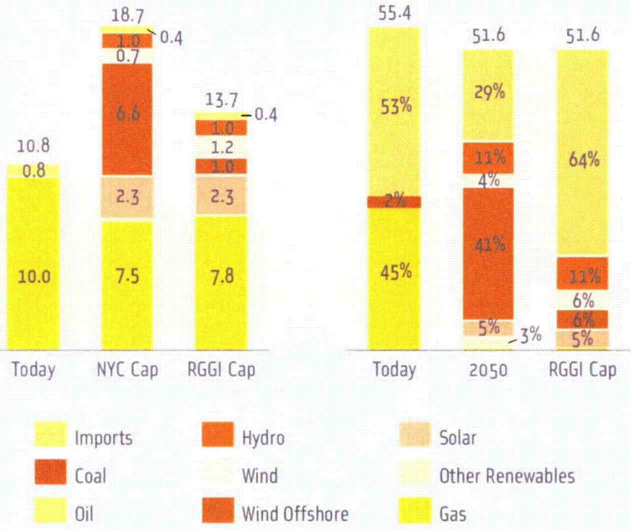
Under a regional GHG emissions reduction strategy, NYC would not meet 80 by 50, but regional reductions would more than offset the effect

With a NYC cap, the city's emissions would fall from 15 million tons today to 4 million tons, allowing it to meet 80 by 50. With a RGGI cap, they would only fall to 11 million tons within a RGGI cap, meaning that the 80 by 50 goal would not be achieved. This, however, is more than offset at the regional level — instead of only dropping 10 million tons if NYC acted alone, RGGI power emissions would drop an enormous 126 million tons within the RGGI framework, dwarfing the city's total emissions. The city may not reach its goal, but from a public policy perspective, this outcome would be preferable – both because of the scale of emissions reductions and because of the economic impacts, explained below. (See charts: *NYC power sector emissions under different cap scenarios* and *RGGI power sector emissions under different cap scenarios*)

The Cost and Economics of Clean Power

The technical potential for a low carbon power system exists if New York City acts without a regional or national solution in place, but it would be costly. Carbon prices would need to reach up to $150 per ton to drive a renewables portfolio for NYC. The development of renewables with transmission requires a significant financial incentive over and above wholesale power prices. A regional strategy would be more economic with the ability to retire coal plants and greater potential to site renewables. (See chart: *Implied Carbon Costs per Ton*)

Installed In-City Capacity and Generation Mix
GW and TWh, respectively

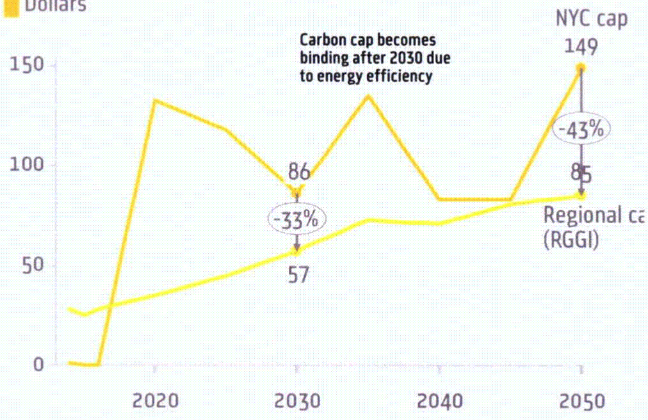


Source: NYC Mayor's Office

Electricity prices would increase, but magnitude would depend on the level of demand reduction

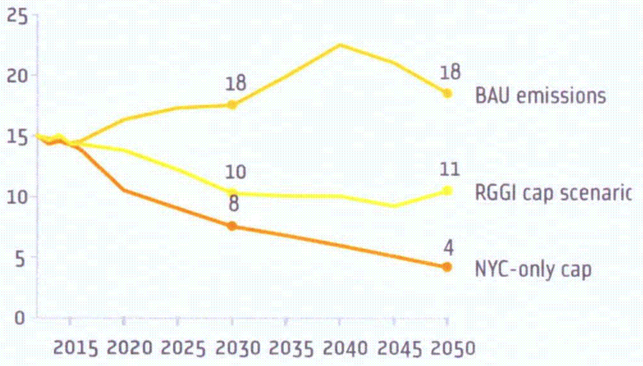
Power prices are expected to increase at a rate of 2.30% annually in real terms under the business as usual scenario: new generation alone would require at least $14 billion of capital investment in the next 37 years. In an 80 by 50 compliance scenario for New York City only, which assumes that demand would be reduced due to energy efficiency, wholesale prices would instead rise by 2.51% annually. Under a regional solution, power prices would rise less, at 2.47% annually.

Implied Carbon Costs Per Ton
Dollars



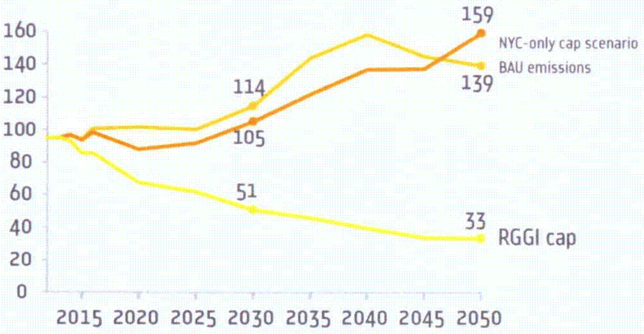
Source: NYC Mayor's Office

NYC Power Sector Emissions Under Different Cap Scenarios
MTCO2e



Source: NYC Mayor's Office

RGGI Power Sector Emissions Under Different Cap Scenarios
MTCO2e



Source: NYC Mayor's Office

Macroeconomic impacts vary by technology pathway

Employment and GDP impacts of clean power projects are mixed. As with any other investments, they impact the economy in three ways: they create direct jobs in construction, displace them in the rest of the economy through diverting spending from other sectors, and create or displace jobs through changing economy-wide power expenditures.

For solar PV, the positive effect of capital expenditures is slightly outweighed by the negative effect of the opportunity cost of local spending (up to 1,300 jobs created and 1,500 jobs destroyed), but this in turn is more than outweighed by the increasing economic competitiveness. Solar PV installations ultimately translate into savings, and the money that would have been spent on fossil fuels is spent throughout the economy instead (creating 1,200 jobs in the example case, for a net effect of 1,000 jobs created).

For offshore wind, the calculus is different: capital expenditures still create jobs, but the resulting power prices have uncertain economic impacts that depend on assumed technology learning curves, construction costs, and the amount of local economic activity (e.g. manufacturing and research) that could make New York a hub of off-shore wind.

Other Challenges

Finding and siting energy projects are difficult

Large scale energy projects face high capital risk in New York. Onshore wind projects are generally not located close to areas with energy demand. Offshore wind projects have not yet been built to scale in the US and still face a lengthy permitting process at the federal, state and local level. Transmission projects that would deliver wind or hydro power also go through lengthy permitting processes and face significant challenges to financing. For distributed energy, developers often site difficulties in finding customers with the combination of enough technical knowledge, the right building characteristics, and high enough credit. All of these challenges require a lot of developer resources, resulting in projects facing higher costs and taking several years to come to fruition.

Existing infrastructure and regulations do not support the utility of the future

The traditional utility model of centrally located power plants delivering power across a single entity-owned distribution system has been around since the 1800's. As such, infrastructure, markets, and regulations were all designed to support this model. New concepts emerging today in which customers have a choice to generate all or a portion of their own energy would require new ways of assigning costs and benefits of distributed systems. As DG market penetration increases, several questions arise: What will the role of the utility be in a distributed world? What costs are to be borne by individuals vs. all customers? What fundamental changes to energy markets are needed? Greater penetration of distributed generation will not happen until these questions are answered.

Power markets would need a new set of rules

The rules for today's power markets are written based on the assumption that most power generation carries a significant marginal cost. Gas-fired plants need to burn natural gas to produce electricity; they do it with different efficiencies, occupying different positions on the supply curve – and where the demand curve intersects the supply curve, power price is established. Since renewable generation has high capital costs and low operating costs, the traditional paradigm breaks down. especially with increased market penetration. On the 80 by 50 pathway, power market rules would have to change to follow the evolving realities.

Paying a premium for clean energy

The level of investment required to obtain deep carbon reductions poses basic questions about who will fund these investments. Until the capital cost of clean energy is reduced, such projects will require subsidies in the forms of incentives and financing. There are two basic sources of subsidies for energy projects: ratepayers and taxpayers - although practically the same, they have different implications. Using the former source results in higher energy rates, while using the latter either results in opportunity costs or in higher taxes. Ultimately, any subsidy must balance the needs of consumers with their willingness to pay.

Achieving Major Reductions in Power Sector Emissions

Modernizing Existing Generation

Advocate for improved market rules that encourage repowering and cleaner generation

The regulatory rules governing the wholesale electricity markets create barriers and disincentives to repowering. Those rules restrict the ability of repowered units from fully participating in the capacity market and competing against incumbent units for market share. Altering NYISO capacity market rules to remove the disincentive to repowering would be an important step to reducing carbon emissions in New York State and regionally. The City has been involved through public commenting, and should continue advocating for improved capacity market rules to the NYISO and FERC.

Developing Grid Scale Clean Energy

Hydroelectric Power

Study the supply impacts of increased hydropower

The Champlain Hudson line connects the city to only a small part of resources available in Canada. Increased hydro imports could reduce electricity prices for residents of New York City – but the economic, technical, and political constraints of integrating so much hydro power into the city's energy mix would need to be investigated separately. Technical concerns about generation portfolio diversity and system integration, regulatory and political issues surrounding market competition, the impacts within New York State, and environmental questions about new hydropower development in Eastern Canada still remain unaddressed.

Off-shore Wind

Convene Northeastern Atlantic offshore wind collaborative

Scaling up off-shore wind projects would require a regional approach – and one way to jumpstart the discussion would be to assemble a Northeastern Atlantic offshore wind collaborative that would bring together the states of Delaware, New Jersey, Connecticut and Massachusetts along with the Department of the Interior, FERC, and regional transmission operators to create a regional strategy to develop offshore wind resources and transmission interconnections. To support the collaborative's work, the NYISO, PJM East, and the PSC could integrate offshore wind into long-term transmission planning processes.

Pilot a demonstration scale off-shore wind power project

Planning for a large-scale off-shore wind project can take years, but the City can begin acting even as it participates in the long-term planning processes. Specifically, the City could work with the State to explore options to develop a smaller, demonstration scale 20-30 MW project in state waters – similar to what Maine, Rhode Island, New Jersey, and Virginia are pursuing now. A smaller demonstration project would allow New York to advance on the learning curve and test the concept of off-shore wind with relatively minimal capital risk.

Local, State and federal coordination to accelerate siting

Siting and leasing processes can add significant amounts of time to any off-shore wind project timeline. The City can work with New York State and the Department of Interior to expeditiously designate the federal waters off of New York as a Wind Energy Area (WEA) in order to accelerate the siting and leasing processes. WEAs have already been established in waters off of most other Mid-Atlantic and New England states.

Explore measures to lower financing costs

Off-shore wind projects require hundreds of millions of dollars. Working with the State, NYPA, LIPA, Con Edison, the Green Bank, and the Federal government, the City can explore creative financing support mechanisms such as loan guarantees, public-private ownership, and power purchase agreements for offshore wind that will help overcome the challenges of financing offshore wind, a major untapped resource.

Analyze regional economic benefits of off-shore wind

Off-shore wind costs are high, and the share of local spending relatively low – but shifting as much of the production and installation process to New York State could help make the projects more economically attractive. A rigorous analysis of the economic benefits of offshore wind could examine the establishment of a regional hub in New York State. The City could work with the State, the Port Authority of NYNJ and NYSERDA, among others, to develop an economic development plan for off-shore wind. This plan could both identify appropriate sites for offshore wind port facilities and recommend actions that should be taken by the City and State to realize the greatest economic development benefit from this emerging sector.

Distributed Generation (DG)

Develop a "one-stop-shop" for information and permitting

DG development has been subject to a complex permitting and interconnection process that spans several city, state and private agencies including Department of Buildings, Fire Department, Department of Finance, Landmarks Commission, Con Edison, NYSERDA, and more. Multiple handoffs between agencies and separate processes that do not run in parallel result in project delays, increased labor and permitting fees, and high opportunity costs. The City University of New York (CUNY) has begun to examine these issues with the creation of ombudsmen who work with all of the agencies involved, and each agency has simplified their own internal processes, but recent progress has not brought down balance-of-systems costs enough. Developing a standardized installation process spanning every party would reduce the installed cost of distributed generation.

Further, lack of customer knowledge of DG options, available incentives and guides, and complexities of the permitting and interconnection processes has presented a high information barrier to those property owners who are interested and financially able to install DG in the city – and there currently is no repository of the information that property owners need. The City is in the process of developing a web-based tool to better inform property owners, providing them with the information needed to convert interest in DG into actual investments. CUNY and the City will also expand the NYC Solar Map, a tool used to evaluate the feasibility of PV on every rooftop in New York City, to connect property owners with PV developers and installers, as well as evaluate a customer outreach, education and acquisition program.

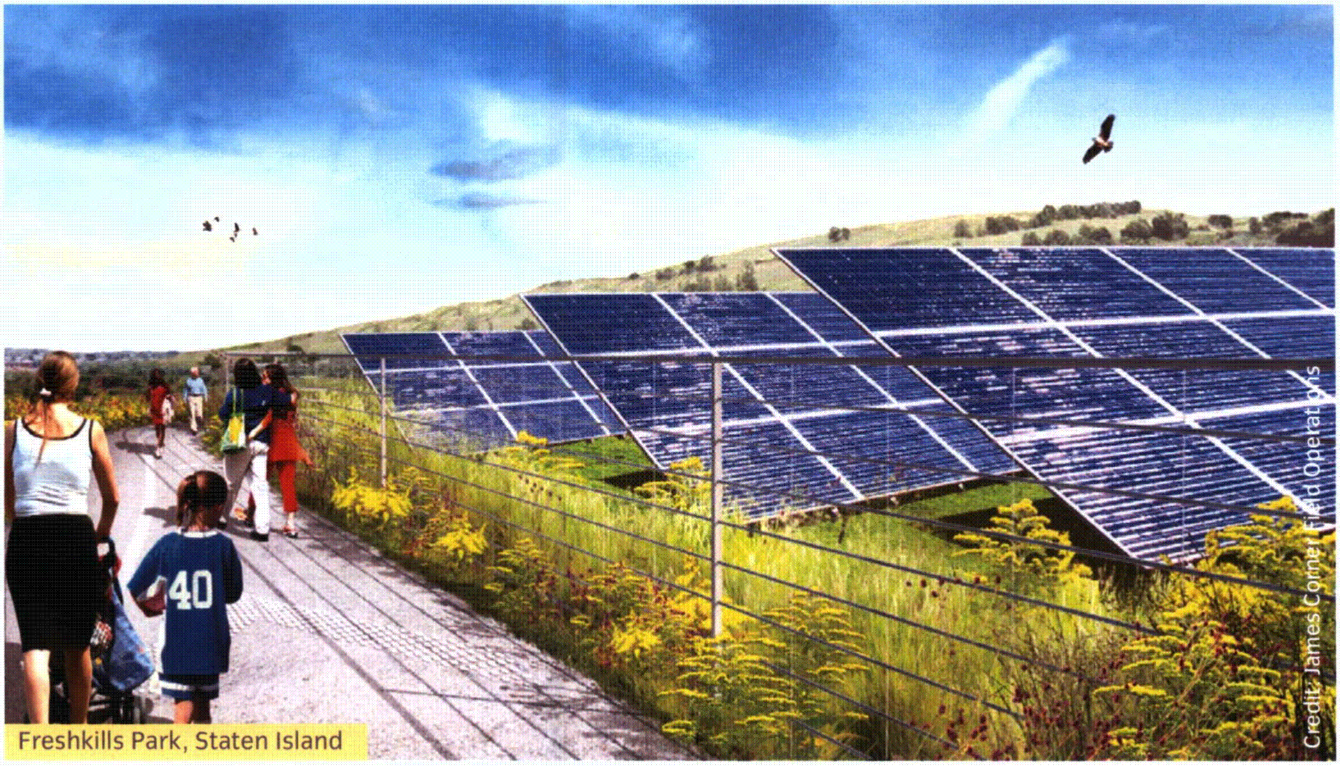
Pilot emerging models for increasing solar PV

One emerging model that is growing the market in other areas is shared ownership of PV systems, or "community solar." Much of the city's population and businesses do not have access to the roof space required to install PV. Community solar systems conceptually allow those who don't own roof space to invest in solar PV systems. Existing incentives and regulations are untested for group-owned systems. Through the US Department of Energy's Rooftop Solar Challenge, the City and CUNY committed to pilot a community solar project in New York City. This pilot would clarify the eligibility of both the personal income tax credit as well as the NYSERDA standard offer rebate, and test the applicability of this new business model in New York City.

Another emerging model is group purchasing of PV at the local level. By engaging with communities, pooling customer interest, and locking in low installation costs, these programs have proven to cost effectively increase solar PV capacity in other cities. This model is now being adopted through the "Solarize Brooklyn" program, a partnership between the Sustainable Kensington-Windsor Terrace and Sustainable Flatbush neighborhood organizations and Solar One. This group purchasing model will determine the ability of community outreach to reduce customer acquisition costs, and test the permitting and interconnection processes with large volumes of applications for PV installations. Analysis of the successes of, and challenges faced by the Solarize Brooklyn program for expansion across other neighborhoods in the five boroughs will also be conducted.

Evaluate the role of net metering in the short and long term

Net metering allows for a customer to receive energy credits at the retail rate for solar PV generation exported to the grid (i.e. not consumed on-site). Remote net metering allows this to occur across multiple properties, disaggregating the location of demand from the location of a PV system. Both mechanisms allow for investments, but existing requirements for these mechanisms have resulted in the inability of emerging PV ownership models to exist in New York City. In addition, there is no long-term vision for net metering beyond the current aggregate capacity that Con Edison is required to allow to net meter. Short term revisions to net metering are needed to allow for new business models that would drive investments, while a long-term plan that addresses the true value of exported renewable energy is needed for high penetration of PV in the Con Edison system. The City should evaluate short-term and long-term revisions to net metering that satisfy the needs of ratepayers and long-term environmental goals.



Freshkills Park, Staten Island

Expand solar PV on government facilities

Government customers, including City, NYCHA, MTA, and Port Authority, own thousands of buildings and facilities throughout the city: Municipal operations alone consist of over 4,000 buildings including schools, wastewater treatment plants, hospitals, office buildings, garages, firehouses, and other facilities. Together these buildings have a total of 25 million square feet of viable roof space and a vast technical potential for PV estimated to be over 200 MW. Working with NYPA, NYSERDA, NYCHA, MTA, the Port Authority, and other government parties would develop a plan to achieve at least some of the potential.

To overcome high upfront capital costs, the City, in 2013, announced the completion of a power purchase agreement with Tangent Energy Solutions, allowing the City to purchase energy from solar PV systems on its property without owning it. A total of 1.85 MW will be installed between the Port Richmond Wastewater Treatment Plant in Staten Island, Staten Island Ferry Maintenance building, and two high schools in the Bronx. These projects serve as an innovative model for siting privately-owned solar PV on City-owned property without incurring upfront capital costs.

Another innovative approach to solar PV on government property is through private ownership. The City, in 2013, announced the selection of Sun Edison to develop, own, and operate up to 10 MW of solar PV at the former Fresh Kills landfill. However, several regulatory challenges ahead will require careful coordination between the City, State, and Con Edison. Completion of the project will test the technical feasibility and impacts of integrating large scale solar PV into the grid. It will also test new concepts of remote net metering and electrical interconnection, the limits of the existing incentive structure at the State and local levels, and regulations surrounding landfill post-closure care in New York.

Evaluate a feed-in-tariff

Existing incentives have led to growth in solar PV capacity, but are insufficient to achieve scale, with many projects having proven to be too difficult to complete. Building owners still require high credit in order to secure financing, net metering is still required to build many systems, and customers still require the knowledge and interest to contact a PV developer. These requirements alienate a large portion of the New York City market from accessing incentives and investing in solar PV. Feed-in-tariff programs in other regions offer certain direct payment for PV power from the State or utility, circumventing all of the above requirements. The piloting of a PV system will yield an analysis of the applicability of such a program in New York City.

Analyze integration of energy storage

Solar power's potential contribution to carbon emissions reductions is limited by its intermittency — but energy storage can potentially address some of the issues. In one example, a project at the Brooklyn Army Terminal integrates a 100 kW PV system, 400 kWh battery, and a building management system. This project will demonstrate how these technologies interact with each other and the existing Buildings and Fire Codes.

New York City as a Center for Energy Innovation

New York City's dense urban environment is both a challenge and opportunity for reducing power sector emissions. As systems integration will need to take place on an urban level, the city has an opportunity to transform into a 'living laboratory' for clean energy systems. City government could play an important role: it operates roughly 4,000 public buildings, 14 wastewater treatment plants, 11 hospitals, and over 27,000 vehicles across various fleets. With this in mind, the goal of the Living Laboratory concept is to demonstrate leadership and foster market development of new technology — both by promoting innovation in the private sector and by leveraging City assets as a platform for testing and demonstrating commercial viability of new technologies.

Research and private sector innovation

Support world class research on clean energy

Innovation and commercialization in the energy sector not only requires the right policy environment but also world-class engineering expertise and workforce – and that is something that the City can help advance. Cornell NYCTech, a new applied science campus administered through the partnership of Cornell University and Israel's Technion University, is one example: it will focus on both software and hardware in environmental science and green energy. Another applied science research institute, known as the Center for Urban Science and Progress (CUSP), is led by NYU-Poly with a consortium of world-class universities and technology companies, including IBM, Cisco, and Siemens. It will focus on 'urban informatics', or the science of using large data sets to analyze and find solutions to urban operations and sustainability challenges. Both campuses, as well as the Columbia Center on Global Energy Policy, CUNY Sustainability, USDOE Northeast Clean Energy Application Center at Pace University, and other local institutions could play instrumental roles in solving some of the technological challenges behind clean energy deployment.

Evaluate energy from tides and thermal flows

Tidal and thermal flows are one example of an area that could benefit from greater research. The potential is available: New York is one of only a few states that possess sufficient free-flowing waters in tides, rivers, and waves to make kinetic hydropower a viable energy source. Already, the City has partnered with a private sector innovator to pilot underwater kinetic turbines that convert energy from tidal flows into electricity. Turbines are completely underwater, silent, and invisible from shore. They do not require dams or other structures and they have minimal impact on aquatic life. The City could investigate opportunities to expand kinetic hydropower resources and where possible, interconnecting tidal resources with wastewater treatment plants and other industrial facilities.

Another promising area for research is the option of tapping the kinetic and potential energy in water supply and wastewater treatment, including, for example, by using the sewer system to assist in conditioning space (e.g., to serve MTA's Second Avenue Subway Line Stations, thereby reducing the size of cooling towers).

Support clean energy entrepreneurs

Promoting clean energy technology through creating a stable policy framework, cutting red tape, working with utilities and permitting authorities to clarify and streamline installation and interconnection procedures, and provide information resources to decision-makers is a necessity – but the city also needs locally based entrepreneurs who intimately know New York City and the opportunities of starting businesses here. To encourage entrepreneurship, the NYC Economic Development Corporation (EDC) has built a network of "incubators" across the city that provide low-cost office space — currently over 120,000 square feet — as well as training and networking opportunities to hundreds of start-ups and small

Tidal turbine, East River

businesses. Approximately 600 startup businesses with over 1,000 employees currently reside at City-sponsored incubators, and these companies have raised more than $125 million in investor funding. Future efforts could build on what has already been achieved.

Support clean energy technology and energy efficiency demonstration centers

It can take time for new and emerging technologies to be adopted en masse — but New York City can become a hub for demonstration facilities for the public and private sector to have hands-on experience with them. Having physical centers of energy excellence that can showcase implementations of new energy technologies will enable people to tangibly appreciate the benefits of technologies in lighting improvements, clean resources, building management systems, and more. There are already burgeoning centers within the City such as the new lighting center which will be a demonstration of lighting technologies as well as energy efficiency education. More centers for specific resources could help bring more real examples of clean energy technologies directly to future users.

Using City facilities as test beds for new technologies

Pilot advanced systems for monitoring electric consumption and on-demand curtailment

City government is one of New York City's largest energy users, meaning that any improvements to its operations could have a sizable citywide impact. Peak demand management and energy use monitoring are two examples. With peak demand, the City is currently on track to increase its ability to curtail peak loads to 50MW in five years — 5 percent of the City's peak — in part through the use of a system that will perform automatic peak load shedding. To support energy monitoring, the City can pilot facility and campus level equipment and aggregate nodes of energy usage across agencies and facilities. This will improve the City's capability to view energy consumption, therefore improving energy management optimization.

Launch competitive program to pilot technologies at City facilities

Almost 75% of New York City's annual greenhouse gas emissions come from buildings, so the success of any reduction strategy hinges on building efficiency technologies. To that end the City will open up the over 4,000 buildings it operates as a proving ground for new technology. Specifically, the City will work with clean energy partners to develop a process for energy technologies that could be piloted and tested in City buildings and operations, involving both the private sector and governmental partners like the MTA, the Port Authority of New York and New Jersey, the General Services Administration, and State governments. The marriage of readily available City assets and technology entrepreneurship will support growth of New York City as a center for energy innovation.

Pursue "net-zero" energy consumption at a wastewater treatment plant

In December 2013, the City announced one of the nation's first biogas to local natural gas distribution projects at the Newtown Creek Wastewater Treatment Plant.

This innovative partnership will reduce greenhouse gas emissions by diverting waste from landfills, reducing emissions from the plant itself, and producing renewable energy. Several other projects are already underway, including a 1 MW solar PV system to be installed at the Port Richmond facility and a 12 MW cogeneration facility under development at the North River facility. In the next decade, the City could seek to achieve further reductions in energy consumption at other wastewater treatment plants through decreasing demand, increasing onsite power generation, recovering and reusing biogas, and undertaking co-digestion of organic wastes.