AIR POLLUTION CONTROL STRATEGIES IN NEW YORK CITY: A CASE STUDY OF THE ROLE OF ENVIRONMENTAL MONITORING, DATA ANALYSIS, AND STAKEHOLDER NETWORKS IN COMPREHENSIVE GOVERNMENT POLICY DEVELOPMENT

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Abstract

New York City's air quality has improved over time as regulations have made Federal, State, and local air quality standards more stringent over the last two decades. Still, the City's air quality fails to meet Federal standards for ozone and fine particles ($PM_{2.5}$). There are known public health impacts associated with air pollution, especially among vulnerable populations such as children. The New York City Department of Health and Mental Hygiene projects that, every year, $PM_{2.5}$ pollution in New York City causes more than 3,000 deaths, 2,000 hospital admissions for lung and heart conditions, and approximately 6,000 emergency department visits for asthma in children and adults. Locally, through PlaNYC 2030, the City of New York's sustainability plan, policymakers have pursued several initiatives to reduce emissions from key local sources of air pollution such as transportation and heating fuels.

This practicum describes the comprehensive effort to reduce emissions specifically from the combustion of heating fuels in New York City, which is responsible for approximately 14% of local $PM_{2.5}$ emissions. Through the accounting and evaluation of this multi-year policy process—from the identification of the policy issue to the legitimation and implementation of the policy solutions—this analysis finds that environmental monitoring and data analysis and collective action and coalition building in the refinement and enactment of sweeping air pollution control strategies were critical to enable implementation and ultimately pollution abatement. Greater integration of monitoring and scientific data analysis to identify and prioritize policy solutions and early and consistent stakeholder group and agency engagement and coalition building were also found to be important to the development and implementation of effective environmental sustainability strategies.

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Introduction

Air pollution is a leading environmental issue and a key public health threat in urban centers. Federal and State regulatory efforts to reduce emissions from the transportation, off-road, and stationary source sectors have driven continued national improvements in air quality. As required by the federal Clean Air Act, the U.S. Environmental Protection Agency (U.S. EPA) sets standards for particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) emissions from large fossil-fuel combustion sources and also designates areas that fail to meet health-based standards for air quality established by the agency.[1,2] Most recently, between 2006 and 2010, the U.S. EPA phased-in stringent emissions standards for heavy duty diesel vehicles such as trucks and for gasoline passenger vehicles while also reducing the sulfur content of diesel fuel and gasoline.[3,4] These new emissions standards, once fully implemented, are expected to significantly reduce air pollution from key transportation sectors and reduce their associated public health impacts, thus contributing to improved air quality in New York City.

Still, despite decades of progress, the American Lung Associations' 2012 *State of the Air* report cites the New York City (NYC) metropolitan area as having significant $PM_{2.5}$ and ozone pollution,[5] while the U.S. EPA designated the NY/NJ/CT region as being a non-attainment area for the 2006 $PM_{2.5}$ air quality standards and as a "severe" non-attainment area for the ozone air quality standards.[6] The New York State Department of Environmental Conservation's (NYS DEC) monitoring data also indicates that while air pollution levels have been declining since the early 2000's, $PM_{2.5}$ and other key air pollutant levels are still higher in urban areas compared with suburban counties.[7]

As will be described in detail in subsequent sections, air pollutants have been widely documented as negatively impacting public health. Exposure to $PM_{2.5}$ and ozone has been linked to a host of respiratory and cardiovascular illnesses; irritating lungs, triggering asthma attacks and worsening emphysema, and also increasing the risk of heart attacks and premature death.[8,9,10] Key subpopulations, including seniors and young children, are especially vulnerable to air pollution.[11,12] Further, in a national study published in 2009, researchers found that residents in cities with poorer air quality generally had shorter life expectancies and that cities that achieved larger reductions in $PM_{2.5}$ air emissions during the 1980s and 90s enjoyed greater health gains during those decades.[13] A recent study by the NYC Department of Health and Mental Hygiene also showed that each year, $PM_{2.5}$ pollution in NYC causes more than 3,000 deaths, 2,000 hospital admissions for lung and heart conditions, and approximately 6,000 emergency department visits for asthma in children and adults.[14]

This study utilizes a policy analysis framework to describe the development and success of recent air pollution reduction strategies enacted to address emissions from home heating fuels.[a] For over three years, I conducted relevant literature and technical reviews, and I

[a] In my role as policy advisor for air quality in New York City Mayor Michael R. Bloomberg's Office of Long Term Planning and Sustainability, I oversaw, implemented and facilitated planning and research for the

performed and reviewed qualitative and quantitative analysis of proposals and initiatives, including assessment of impacts, feasibility, and costs/benefits; and made recommendations accordingly. Also during this time, I analyzed, monitored and commented on relevant national, state and local environmental legislation; briefed New York City Council members and staff on relevant initiatives and proposed legislation, and conducted meetings with stakeholders affected by proposed legislation and rulemakings; acting as a liaison with community boards, advocacy and civic organizations and elected officials to communicate on behalf of the City and represent the Mayor's Office. Thus, the policy analysis and development processes that will be detailed in subsequent sections of this narrative have been informed by and developed from my access to City agency materials and databases, including permit and equipment registration data; from numerous in person and written communications with a variety of stakeholders including written testimonies, interviews and public meetings; from support and opposition memoranda submitted by advocacy organizations in response to proposed legislation; and finally, from unpublished industry technical reviews and analysis developed in response to any of the aforementioned information avenues.

Through the accounting and evaluation of this multi-year policy process—from the identification of the policy issue to the legitimation and implementation of the policy solutions—this analysis identifies the critical role of incorporating environmental monitoring and data analysis, of quantifying to the extent possible the public health impacts of environmental regulations and policies, and of developing and engaging multi-stakeholder networks in the development, refinement and enactment of sweeping and comprehensive air pollution control strategies.

As will be described in the discussion section of this narrative, the Mayor's Office success in enacting regulations to curb emissions from heating fuels is partly due to a comprehensive policy approach involving City and State legislation framed through a public health lens. Secondly, the policy analysis and development process benefited greatly from the integration of local environmental monitoring data collected, analyzed, and published by the New York City Department of Health and Mental Hygiene; providing a timely, credible and mobilizing step in galvanizing the public's understanding of heating oil as a systemic and unnecessary public health threat. Thirdly, the analysis and utilization of agency permitting data—in this case, boiler registration and permit information from the New York City Department of Environmental Protection—allowed for the identification of cost-effective policy levers which could be presented to and refined with key stakeholders. The availability of this dataset and the willingness of this city agency to share, explain, edit and follow up on key dataset components allowed for the development of a model to assess potential capital and operating costs separately with respect to various fuel conversion options in order to discern and prioritize the most cost-effective technical solutions. Finally, the consistent engagement of an array of critical stakeholders ranging from environmental advocacy and health-based organizations, private industry, local utilities, labor unions, and government agencies, contributed to the identification and dissemination of information and the generation of

development of the air quality initiatives and other planning efforts outlined in PlaNYC 2030 in coordination with City, State and Federal agencies, the private sector, and other stakeholders. The work reported in this practicum reflects in part the work I performed for the City of New York.

needed support for proposed policies and strategies. This model of stakeholder engagement, which was characteristic of PlaNYC campaigns, allowed for the identification of policy provisions that combine "stick and carrot" approaches and facilitate the enactment and implementation of needed legislation. While some of these factors yielded more success than others, they will be described systematically throughout the remainder of this narrative.

This report highlights key interrelationships between factors and strategies that may be of strategic relevance to other cities and to other environmental policy campaigns in New York City. Overall, ensuring that the policy development process is comprehensive by combining science and technical research, environmental monitoring, cost and benefit analysis, and stakeholder and agency and engagement strategies that supplement, complement or reinforce each other may be a successful approach in achieving key environmental policy goals.

Part I. Background: Air Quality Policy in New York City

PLANYC 2030

In recent years, New York City has undertaken numerous actions to reduce emissions from local sources of pollution such as the enactment of legislation to regulate emissions from a number of sources including idling vehicles,[15] privately operated diesel-powered sightseeing buses,[16] school buses,[17] and from the municipally-owned and operated heavy duty fleet including sanitation trucks and other diesel-fueled vehicles.[18,19,20] Similarly, New York City is legally required to purchase clean light-duty and medium-duty vehicles for its municipal fleet,[21] and requires the use of ultra-low sulfur diesel fuel and best available retrofit technology in the fulfillment of solid waste contracts and recyclable materials contracts.[22]

In 2007, NYC Mayor Michael R. Bloomberg launched PlaNYC 2030—the City's first sustainability plan.[23] PlaNYC was a comprehensive set of initiatives developed to improve environmental quality and enhance the quality of life of New Yorkers. The plan was developed in response to the 2006 Department of City Planning's projection that NYC's population would grow by one million more people by the year 2030.[24] The plan included 10 sustainability goals grouped within six areas: Land, Water, Air, Transportation, Energy, and Climate Change. Each PlaNYC goal included a variety of initiatives and sub-initiatives that aimed to measurably achieve progress towards that goal. The plan's implementation approach included milestones for each initiative, specific timelines and sustainability indicators, and an annual report on the City's implementation progress of each initiative.[25]

One of PlaNYC's goals was to achieve the cleanest air quality of any big city in the U.S. This goal included fourteen initiatives that together would reduce citywide $PM_{2.5}$ emissions by 40%.[26] The initiatives were grouped into five strategies that included: reducing road vehicle emissions, reducing other transportation emissions, reducing emissions from buildings, pursuing natural solutions to improve air quality and further understanding the scope of the air pollution challenge. The plan's air quality initiatives ranged from promoting fuel efficiency, cleaner fuels, and cleaner or upgraded engines for private and public diesel vehicles and ferries, to monitoring street-level air quality, to planting one million trees throughout the city.[27]

While not without challenges, progress to date has been significant since the release of PlaNYC. For example, in 2005 travel by motor vehicles in New York City generated 11% of the local $PM_{2.5}$ emissions, 28% of NO_X and 17% of VOC emissions (both are precursors to $PM_{2.5}$). Hence, several of the 2007 PlaNYC air quality initiatives focused on addressing emissions from the transportation sector. To date, the City owns and operates a fleet of more than 26,000 vehicles and motorized equipment, and of these vehicles, already 25% are hybrid or another alternative fuel, including hybrid garbage trucks, police cars, and heavy loaders; the City already operates 430 electric vehicles, making it the largest clean fuel municipal fleet in the United States.[28] Also, while the City cannot regulate emissions from the private transportation sector, since the launch of PlaNYC in 2007, over 30% of the city's 13,237 yellow cabs have converted to hybrids or clean diesel vehicles, giving New York the largest fleet of clean vehicle taxis in the country. Further, the City has worked with the New York State Energy Research Development Authority to manage a Federal Congestion Mitigation and Air Quality (CMAQ) initiative that funds private sector companies to retrofit or convert their vehicles to alternative fuels. Under this program, participants can convert to either compressed natural gas or hybrid vehicles, or retrofit their diesel vehicles. To date, the City has spent roughly $15 million to retrofit, replace, or repower approximately 280 trucks, reducing 63 tons of $PM_{2.5}$. The City completed cleaner engine upgrades on four Staten Island Ferries and through CMAQ funding, installed air pollution filters on 32 privately-owned ferries.[29] It also plans to complete upgrades of 400 additional private vehicles through existing CMAQ and other funding sources, all under the premise that reducing fuel use and utilizing cleaner fuels will in turn reduce associated $PM_{2.5}$ and greenhouse gas emissions. Relevant indicators to measure progress on achieving PlaNYC's air quality goal include NYC's 3-year annual average of $PM_{2.5}$ and the ranking of NYC in air quality among the eight largest U.S. cities.[30]

Other PlaNYC air quality initiatives fell short of being enacted or faced significant legal or funding challenges; impeding key progress towards the achieving the air quality goals set forth by the City of New York. For example, in 2008 a Federal District Court ruled that only the Federal government could enact regulations on fuel efficiency standards for vehicles; invalidating the New York City Taxi and Limousine Commission's adoption of minimum fuel economy regulations in 2007—a key effort to green the city's yellow taxi fleet. In response, in 2009, the Commission enacted new rules—a package of lease cap modifications that offered financial incentives to taxi owners who purchased fuel efficient taxis—but these rules were again struck down by the Court system. While the City's Law Department unsuccessfully appealed the rulings, the Mayor's Office worked with New York State congress representatives to introduce the Federal Green Taxis Act of 2009—legislation that would amend the federal Energy Policy and Conservation Act and the Clean Air Act to allow local governments to regulate fuel efficiency and emissions standards for their for-hire vehicles. This legislation has not been enacted by the Federal government.

Similarly, Federal and State fiscal constraints during the economic crisis of 2008 and 2009 impeded or delayed initiatives to incentivize fuel efficient or hybrid vehicles and to fund the installation of diesel retrofit technologies in key fleets. For example, with the Federal Highway Administration eliminating several million dollars in funds, at least one of the grant programs that funded diesel emissions reduction projects for private fleet owners was on hold for more than a year (the CMAQ grants). Another key PlaNYC proposal, to pilot a congestion pricing system for the central business district in Manhattan in order to reduce traffic congestion during certain hours, raise needed funds to for the public transit system, and reap the related air quality benefits, also failed to be enacted. While the U.S. Department of Transportation offered a $354 million grant from the Urban Partnership Program to support the implementation of the pricing scheme and the expansion of mass transit services, the grant was conditional on the approval of this PlaNYC strategy (or of a similar plan) by the New York State Legislature by April of 2008. Unfortunately, though the local government body—the New York City Council—approved the Mayor's congestion pricing plan; the New York State legislature refused to vote on legislation authorizing the plan. Opponents expressed much skepticism that the plan would yield the touted benefits, perceived the fee as a regressive tax on some commuters, resented the lack of state control on the scheme, and expressed concern about the environmental and traffic impacts of the proposals on neighborhoods adjacent to the congestion zone. Despite more than two years of analysis, evaluation and incorporation of alternatives and significant public engagement via at least 14 public hearings, the State Legislature's failure to act prevented the City from piloting an approach proven to reduce traffic congestion and improve local air quality in several countries around the world. In addition, the lack of action by the stipulated deadline caused New York City to also forgo the U.S. Department of Transportation grant; which included, aside from $10.4 million to support launching of the congestion pricing plan and $2 million for research, $213.6 million to improve and develop new public bus depots, $112.7 million to implement bus rapid transit routes, and $15.8 million to expand ferry services.[31,32]

Despite the challenges, PlaNYC pushed forward with implementing the array of its air quality initiatives, as described earlier, to make progress towards the PlaNYC goal of achieving the cleanest air of any large city in the United States. To date, New York City continues to lag behind other large cities in $PM_{2.5}$ levels.[33] To meet the City's goal of achieving the cleanest air quality of any big city in the U.S., the City estimated that a reduction of average $PM_{2.5}$ concentrations by 22% below 2005 levels is necessary.[34] The New York City Department of Health and Mental Hygiene projected that attaining the PlaNYC goal could prevent over 750 premature deaths and almost 2,000 hospital admissions and emergency room visits.[35]

The plan acknowledged that over half of New York City's $PM_{2.5}$ emissions originates outside the city, drifting from sources in neighboring states and more distant jurisdictions, including traffic, industry, and power plants. Depending on the time of year, up to 70% of particulate matter measured in the city comes from somewhere else, limiting local government's ability to meet its air quality goals without the support and partnership of surrounding counties.[36] Still, a significant portion of the city's air pollution is emitted by local sources including heavily-trafficked roadways and buildings burning residual heating oils, as will be described in the next section of this narrative.[37]

Part II. Addressing Air Pollution from Heating Oil in New York City

Reducing harmful emissions from the burning of heating oil was a key initiative under PlaNYC to improve air quality. This section will outline the development of those strategic initiatives and their progress to date; and will explain how a local environmental monitoring effort, the development of an air emissions modeling tool, and policy advocacy work with a coalition of industry and environmental advocates led to the development of a multi-pronged strategy to significantly reduce $PM_{2.5}$ emissions from heating fuels in New York State and New York City. A discussion of the technical, regulatory and public health background on this issue will provide context for the development of policy strategies that are NYC-specific. The strategies described in subsequent sections include, among others:

1. Implementing neighborhood-level air quality monitoring.
2. Reducing sulfur levels in heating fuels:
   a. Statewide bill requiring all Number 2 heating oil used in New York State to be ultra-low sulfur.
   b. Intro 194-A, a NYC -wide bill requiring a sulfur cap on Number 4 heating oil and requiring the mixing/use of biodiesel into home heating oil.
3. Promoting the use of biodiesel.
4. Promoting retirement of old, inefficient boilers.
5. Promoting cleaner burning fuels.
6. Converting school boilers to allow combustion of cleaner heating fuels.

Not since the 1970's with the ban on coal combustion for heating purposes, had NYC undertaken such a comprehensive effort to improve air quality by regulating heating fuels.

A. Technical Background

Heating oil is a type of fuel refined from crude petroleum and which is used for space heating purposes. Depending on the degree of refinement and processing, heating oil is classified as either "distillate" or "residual." Distillate fuels include Number 2 heating oil and highway diesel fuel, the latter of which is used in transportation. Transportation diesel fuel is required by federal law to contain a very limited amount of sulfur, requiring additional processing called "desulfurization." While chemically identical to this highway diesel, Number 2 heating oil is allowed to contain much higher levels of sulfur, levels of which vary across states. This type of heating oil is also dyed red to signify that it is tax-exempt and cannot be legally used as highway fuel.[38]

Residual fuels include Number 6 heating oil, which unlike Number 2 oil, is the heavy fuel sludge that remains from the petroleum refining process after all distilled products are extracted. This solid, high-sulfur, high-ash, high pollutant fuel is used primarily to run boilers for power generation, for industrial purposes and to propel tankers and other large vessels.[39] According to the U.S. Energy Information Administration, this fuel "once accounted for as much as 30% of the oil burned in stationary uses, and 20% of all United States oil use. By 1997, those shares had fallen to 7% and 4%, respectively. Residual fuel oil's use for apartment building space heating is now confined largely to older buildings in New York

City, and its use in electric generation is limited largely to a few utilities in Florida and the Northeast."[40]

The grade of heating oil dictates not only its sulfur and ash content, with Number 6 heating oil being much higher in sulfur and ash, making it significantly more polluting than Number 2 heating oil, but it also dictates the volatility, boiling range and viscosity of the fuel. Average concentrations for heavy metals, nickel and zinc trace elements, are also higher in residual fuel oils than in distillate oils.[41] Number 6 heating oil is almost solid in consistency and less volatile than distillate fuels, and must therefore be heated to maintain it in a liquid form to enable handling and ensure its combustion or atomization.[42,43] This is significant in that buildings that utilize Number 6 heating oil require boilers or installations that are equipped with pre-heating equipment and, in New York City, also require staff to operate such a boiler or preheating installation.

Finally, Number 4 heating oil is the mixture that results from blending Number 6 heating oil, a residual fuel, with Number 2 heating oil, a distillate fuel. It is often used in boilers that are not equipped with preheating equipment for residential and industrial uses.[44]

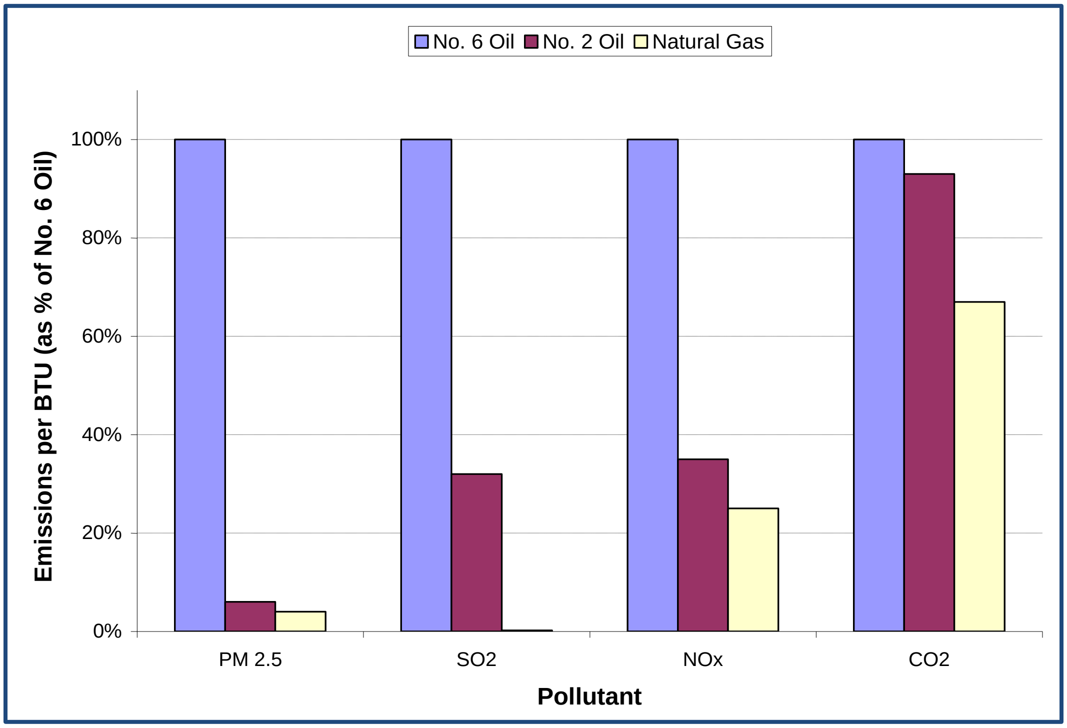
Number 6 and Number 4 heating oils are more polluting than distillate heating oil, which is a lower-sulfur, more refined product. Buildings can also use natural gas as a heating fuel, which is less polluting than any heating oil. Table 1 and figure 1 show the level of Particulate Matter (PM) and Nitrogen Oxide (NOx) produced from natural gas and Number 2, Number 4, and Number 6 fuel oil. Emissions levels from the use of cleaner burning fuels, such as Number 2 fuel oil and/or natural gas, are significantly lower than the emissions levels from the use of Number 4 and Number 6 fuel oils, unless there are emission control devices or changes made to the fuel.

Table 1. NOx and PM Pollutant Levels Emitted by Different Fuel Types.

	NOx (lb./MMBTU)	PM (lb./MMBTU)
Natural Gas	0.10	0.008
Number 2 Oil	0.14	0.024
Number 4 Oil	0.29	0.041
Number 6 Oil	0.37	0.050

Source: Office of Air Quality Planning and Standards, United States Environmental Protection Agency, AP-42, Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources (5th ed. 1995).

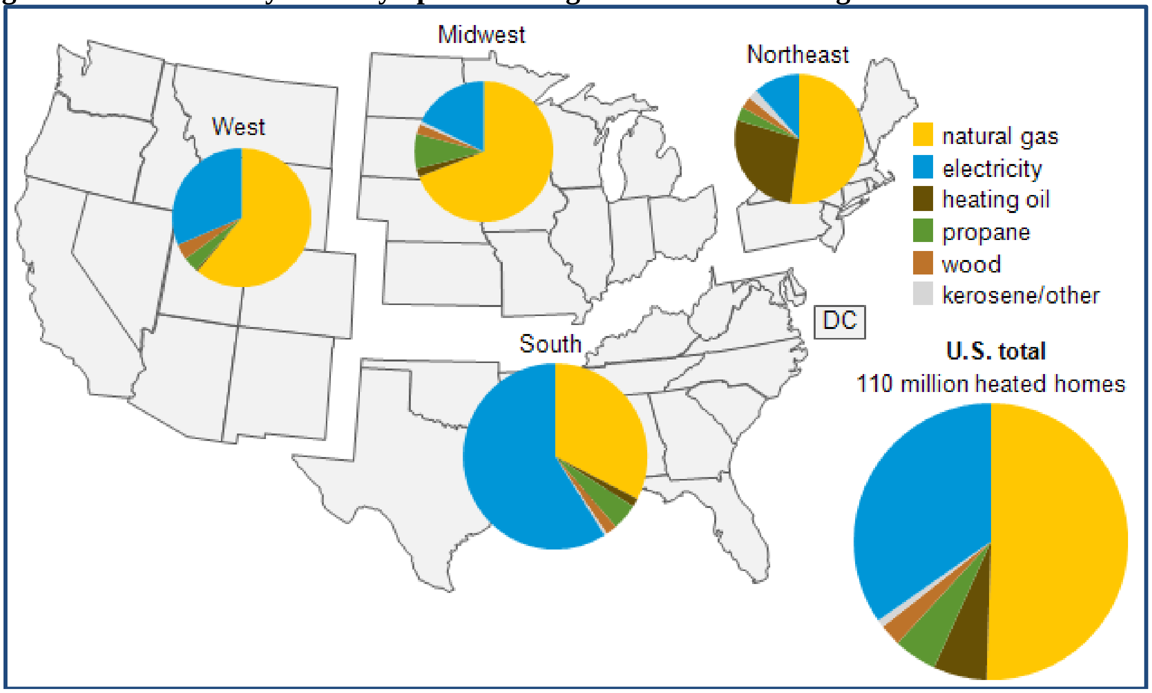
Figure 1. Comparison of Harmful Emissions from Combustion of Heating Fuels.



Source: Environmental Defense Fund & Urban Green Council. (2009, December 16). How the Dirtiest Heating Oil Pollutes Our Air and Harms Our Health. http://www.edf.org/sites/default/files/10085_EDF_Heating_Oil_Report.pdf

Heating fuel types vary widely across the United States. The previously described heating oils are used mostly in the Northeast region of the country for space heating purposes, with 38% of households in the U.S. Northeast Census Region using heating oil for that reason, while other regions rely mainly on natural gas and electricity, with no more than 5% of households in any of the other regions using the fuel for any use (see figure 2). New York State is the top heating oil consuming state.[45] (See figure 3). About 54% of the total demand for heating oil in the Northeast comprises Number 2 oil.[46] NYC consumes 1 billion gallons of heating oil annually, more than any other city in the U.S., accounting for nearly 14% of NYC's total $PM_{2.5}$ emissions—more than air emissions than from vehicles or from power plants.[47]

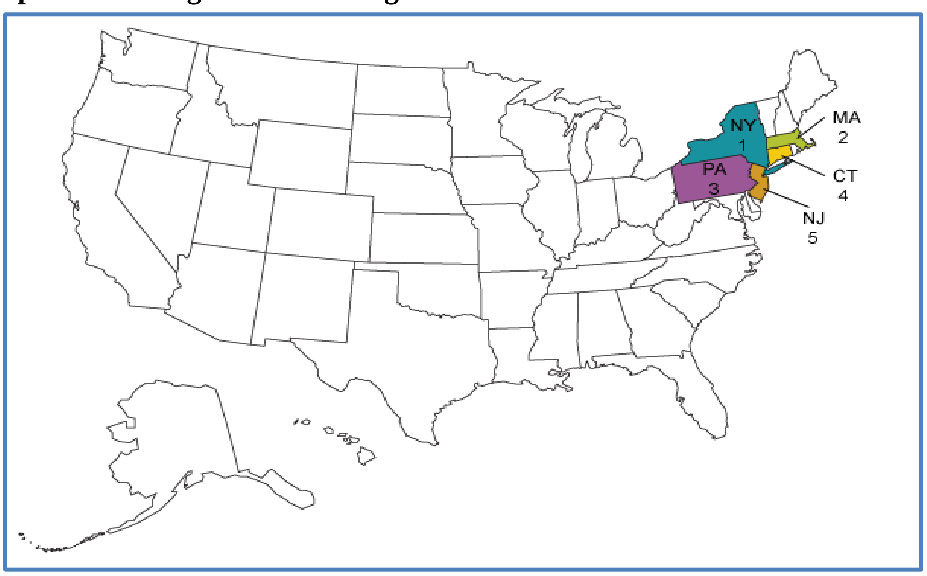
Figure 2. U.S. Homes by Primary Space Heating Fuel and Census Region in 2009.



Source: U.S. Energy Information Administration, Residential Energy Consumption Survey. Share of homes by primary space heating fuel and Census Region, 2009. http://www.eia.gov/todayinenergy/detail.cfm?id=3690

Note: Pie sizes are approximate but represent the total number of homes in that Census Region.

Figure 3. Top Five Heating Oil Consuming U.S. States in 2009.



Source: U.S. Energy Information Administration, Fuel and Kerosene Sales 2009 (February 2011).

Bioheating fuel is another increasingly utilized fuel type. Bioheating fuel is made partially from biodiesel, a liquid fuel produced from renewable, biological resources. It is produced through a chemical process called transesterification in which alcohol is used to separate the glycerin from oil, leaving methyl esters (biodiesel) and glycerin.[48] In the United States, biodiesel is usually made from soybean oil or recycled restaurant grease. It can, however, be derived from various sources, including native switchgrass, woody vegetation, and animal and vegetable fats.[49]

The American Society for Testing and Materials (ASTM International) is an international standards organization that develops and publishes voluntary technical specifications and standards for various materials, systems and products.[50] ASTM standard D 6751-07b is the specification for 100% biodiesel, and the implementation of this enforceable benchmark ensures that biodiesel refiners will meet acceptable quality standards. In addition, the National Biodiesel Accreditation Program developed BQ9000, a third-party, voluntary quality certification program for producers, distributors and marketers of biodiesel. The program employs a combination of ASTM D 6751-07b standards and a quality systems program that includes storage, sampling, testing, blending, shipping, distribution, and fuel management practices.[51]

The term Bioheat® is a registered trademark of the National Biodiesel Board and the National Oilheat Research Alliance. It is the widely used, industry accepted term to describe the blend of pure biodiesel with petroleum-based home heating oil. Bioheating fuel can be directly substituted for heating fuel in domestic and commercial boilers with few or no modifications, as described in a later section. Common blends include B20 (a mixture of 20% biodiesel with 80% heating oil), B10 (a mixture of 10% biodiesel with 90% heating oil) and B5 (a mixture of 5% biodiesel with 95% heating oil).

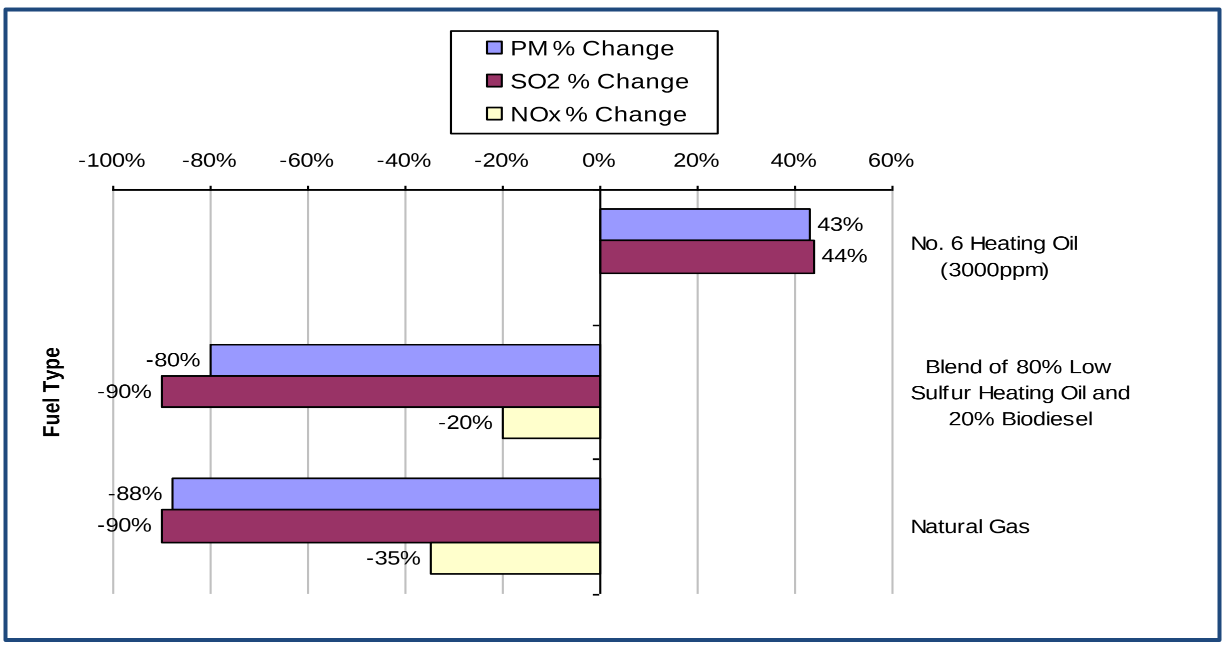
Pure biodiesel is sulfur-free and will therefore dilute the overall sulfur content of any heating fuel by displacing a percentage of the petroleum-based diesel in the blend and by incorporating an emissions-free product into a fuel that generates significant emissions of air pollutants. For example, blending Ultra-Low Sulfur Number 2 heating fuel (which only contains 15 ppm sulfur) with 20% biodiesel (B20) could reduce sulfur dioxide emissions by an additional 10%.[52] Studies show that, when compared with regular Number 2 or Number 6 petroleum fuel oil, bioheating fuel with even a low percentage of biodiesel achieves a significant decrease in emissions of particulate matter, sulfur oxide and greenhouse gases (table 2 and figure 4).[53,54,55,56,57] The use of bioheating fuel can decrease harmful emissions while also improving fuel efficiency since lower sulfur heating oil improves burner efficiency.[58] With lower sulfur content, bioheating fuel blends therefore decrease the amount of fuel used as well as decrease maintenance and servicing costs for the customers.

Table 2. Comparison of Pollutant Emissions from Various Heating Fuels.

Emitted Pollutants	Pounds per Million BTUs			Emissions Reduction of Using B20/No. 2 Blend Compared to No. 2 Oil	Emissions Reduction of Using B20/No. 2 Blend Compared to No. 6 Oil
	No. 2 Heating Oil (0.225%S)	No. 6 Heating Oil (2.2%S)	B20 blended with No. 2 Oil (0.05%S)		
Particulate Matter	0.0123	0.0700	0.0035	12%	95%
Nitrogen Oxides	0.1500	0.3670	0.1200	0-2%	67%
Hydrocarbons	0.0017	0.0080	0.0017	20%	78%
Carbon Dioxide	159.0000	163.0000	134.0000	15%	18%
Sulfur Oxides	0.2300	2.3300	0.0400	20%	98%

Source: Batey, John. Energy Research Center and U.S. Environmental Protection Agency.
Draft Technical Report EPA420-P-02-001.
Note: Sulfur content of fuels compared may vary from current legal limits in NYC.

Figure 4. Estimated Emissions Changes in Key Pollutants of Heating Fuels Compared to Regular Number 2 Heating Oil.



Sources: NESCAUM, American Lung Association, Environmental Defense, U.S. Energy Information Administration, and Environment Canada.
Note: Sulfur content of fuels compared varies statewide from current legal limits in NYC.

B. Background: Air Pollution and Public Health Impacts from Heating Fuels

Particularly among urban centers, combustion of heating fuels represents a significant source of air pollution emissions.[59] According to Northeast States for Coordinated Air Use Management's 2005 report, the Northeast region of the United States is one of the world's largest consumers of heating oil, with about four billion gallons burned per year, contributing to high levels of ambient $PM_{2.5}$.[60] In addition to particulate matter, heating oil combustion emissions consist of a diverse array of pollutants such as nitrogen dioxide, sulfur dioxide, mercury, carbon dioxide, and other heavy metals, all of which can cause numerous negative health impacts.[61] About 10% of total carbon dioxide emissions and 25% of mercury emissions in the Northeast result from burning heating oil.[62] Exposure to such chemicals can induce carcinogenicity or inhalation toxicity, and emissions of heavy metals such as nickel and vanadium are particularly concerning as associations have been found between trace concentrations of these elements in fine particulate matter and average daily mortality risk.[63,64,65]

Air Pollution Health Effects Research

While researchers still need to fully explore the health effects associated with nickel concentrations and concentrations of other components of residual oil combustion, numerous laboratory animal experiments have shown adverse effects of metals on both respiratory and cardiovascular systems,[66,67,68] as well as allergic sensitization to exposures.[69] Other micro-ecological studies using human cells suggest that exposure to these metal concentration byproducts of residential heating oil combustion can contribute to inflammation responses as well as immune system changes.[70,71,72] Furthermore, additive exposure to both $PM_{2.5}$ and nickel concentrations may lead to greater detrimental health effects than isolated exposure.[73,74,75]

Apart from studies examining specific health effects attributable to heating oil combustion, the literature on air pollution in general is quite extensive. Numerous research studies have observed associations between reduced exposure to ambient fine particulate pollutants and measurable improvements in life expectancy, including population based cross-sectional studies,[76,77,78] cohort based studies,[79,80,81,82,83,84,85] natural intervention studies,[86,87,88,89] and daily time series studies.[90,91,92,93] Overall, reducing exposure to ambient fine particulate pollutants has been correlated with an observable, significant improvement in life expectancy.[94] In 2009 Pope et al. explored this relationship by matching data on fine particulate air pollution from the late 1970s/early 1980s to data from the late 1990s/early 2000s. Regression models were used to show that a decrease of 10 $\mu g/m^3$ in concentration of fine particulate matter was associated with an increase in mean life expectancy of 0.61 years, estimating that reduced exposure to air pollution accounted for about 15% of the overall increase in life expectancy observed.[95] Similarly, Laden et al. studied various sources of particulate matter, such as from motor vehicle exhaust and coal combustion, to show that a 10 $\mu g/m^3$ increase in $PM_{2.5}$ from mobile sources accounted for a 3.4% increase in daily morality.[96]

In addition to negative health effects associated with short-term exposure, studies have also assessed how long-term exposure to certain air pollutants affects overall public health. In order to assess the relationship between long term exposure to fine particulate air pollution and all-cause mortality, lung cancer, and cardiopulmonary mortality, in 2002 Pope et al. analyzed mortality data from the American Cancer Society's Cancer Prevention II Study.[97] Results showed that for each 10 $\mu g/m^3$ increase in fine particulate air pollution there was 4% increased risk of all-cause mortality, 6% increase risk of cardiopulmonary mortality, and 8% increased risk of lung cancer mortality.[98] This type of study holds implications for the long-term public health benefits that can result from decreases in air pollution emissions. Nevertheless, most recent research studies have focused on short-term benefits and associations between increased concentrations of particulate matter and increased hospital admissions and emergency room visits for heart and lung diseases.[99,100,101,102,103]

One study on a specific 1990 regulation in Hong Kong that required power plants and road vehicles to use fuel oil with a sulfur content of no more than 0.5% by weight found a 45% reduction in ambient SO_2 in a five-year period, and reported significant gains in life expectancy of 20 days for females and 41 days for males per year of exposure to the lower concentration.[104] Another regulation in Dublin, Ireland, that banned the sale of bituminous coal led to a two-thirds decrease in black smoke concentration and one-third decrease in sulfur dioxide concentration. A study conducted in the 72 month period following the regulation found a 5.7% decrease in non-trauma age-standardized death rates, 15.5% decrease in respiratory deaths, and 10.3% decrease in cardiovascular deaths.[105] A natural experiment conducted by Parker et al. in 2008 found that risk of preterm birth decreased substantially among expectant mothers when air pollution was reduced due to a nearby steel mill closure in Utah.[106]

In order to assess the impact of air pollution at the molecular level, Vinitketkumnuen et al. examined the association between fine particulate emission exposures and mutagenicity. Researchers from Chiang Mai, Thailand (an area with new air pollution challenges due to rapid population growth and urbanization) collected data in 1998 on $PM_{2.5}$ and PM_{10} in high traffic density sites.[107] These fine particulate matter samples were then introduced to colonized *Salmonella typhimurium* bacteria cultures, and were found to account for most of the mutagenic activity.[108] Overall, these studies provide quantified evidence of the negative health effects of various air pollutants, especially particulate matter, that offer insight into the need for policies that address pollution problems to protect human health.

Air Pollution & Public Health in NYC

Researchers from the New York City Department of Health and Mental Hygiene have conducted analyses to quantify the impact on fine particulate and other heavy metal emissions from residual heating oil combustion on the health and well-being of New Yorkers, and have arrived at very similar conclusions as have researchers in other cities concerning the public health benefits of reduced pollution.

An analysis released by the New York City Department of Health and Mental Hygiene entitled "Air Pollution and the Health of New Yorkers" analyzes the health benefits that would result from a 10% reduction from current $PM_{2.5}$ emissions. According to current estimates, annual average concentrations of $PM_{2.5}$ are major contributing factors in more than 3,000 premature deaths, 2,000 hospitalizations due to respiratory and cardiovascular causes, and 6,000 emergency department visits for asthma in New York City each year.[109] Therefore, even the modest proposed 10% reduction in $PM_{2.5}$ concentration could prevent more than 300 premature deaths, 200 hospital admissions, and 600 emergency department visits. Researchers estimate that 3,200 deaths occur annually among adults aged 30 years and older due to exposure to current $PM_{2.5}$ levels; three out of four deaths resulting from $PM_{2.5}$ exposure are among adults aged 65 years and older, also illustrating the higher overall mortality rate for this age group.[110]

Vulnerable populations such as elderly people, children and infants, and those with preexisting heart and lung conditions are most affected by exposure to these pollutants.[111] People who live in areas with higher residential population density may therefore be disproportionally affected by health problems stemming from air pollution, especially if these populations lack access to quality health care and have higher rates of chronic disease.[112]

While more than one in four deaths in more affluent NYC neighborhoods is attributable to $PM_{2.5}$ exposures, the death rate among poorer neighborhoods attributable to $PM_{2.5}$ exposure is anticipated to be even greater.[113] About 1,200 hospital admissions for respiratory disease among adults aged 20 years and older every year are attributable to current levels of $PM_{2.5}$, and these hospital admission rates vary greatly among neighborhoods.[114] The highest burdens are found in South Bronx, Northern Manhattan, and Northern Brooklyn, and these patterns reflect the overall respiratory hospitalization rates in adults in these areas. The estimated rate of hospitalization due to $PM_{2.5}$-related respiratory issues is nearly twice as high among areas of high poverty neighborhoods compared to low poverty neighborhoods.[115]

Research in New York City has shown that areas with high concentrations of particulate matter and heavy metals also have high concentration of buildings or land uses that rely heavily on residual heating oil for heating and energy needs. In December 2008, the New York City Department of Health and Mental Hygiene began an air monitoring initiative at 150 locations throughout NYC's five boroughs as a part of PlaNYC. The findings from the most recent 2008-2009 New York City Community Air Survey (NYCCAS) illustrate how combustion of heating fuels leads to emission of fine particulate matter and elemental metals, all of which have negative effects on human health. NYCCAS showed that particulate matter ($PM_{2.5}$) concentrations varied enormously throughout New York City, with measurements ranging from 9 $\mu g/m^3$ to almost 20 $\mu g/m^3$. NYCCAS examined patterns of other pollutants as well, such as elemental carbon, another by-product of heating oil combustion. Because elemental carbon is a component of $PM_{2.5}$ resulting from fossil fuel combustion, emission of elemental carbon can lead to negative health effects as well as greenhouse gases effects. Exposure to elemental carbon can lead to irritation of the airways and can increase symptoms of asthma and risk of lung cancer.[116] In-depth results of the NYCCAS monitoring effort will be described in a subsequent section.

Considering the evidence of negative health impacts of air pollutants in cities around the world, and the established relationship between these pollutant concentrations and heating oil use, addressing pollution from burning heating fuels remains an important public health goal, particularly in New York City. Current emission rates of $PM_{2.5}$ in NYC exceed National Ambient Air Quality Standards,[117,118] a significant fact considering that previous research has shown that health effects associated with exposure to $PM_{2.5}$ and elemental carbon occur well below the national standards.[119] Research suggests that emissions from residual oil boilers are especially harmful to public health given the high concentration of heavy metals such as nickel and vanadium present in the particulate matter emitted by the combustion of these fuels.[120] Particulate matter, sulfur dioxide, nitrogen oxides and heavy metals from the combustion of residual heating oil all contribute to asthma, heart disease, decreased life expectancy and other negative health effects. Therefore, addressing particulate matter pollution from residual heating fuels is critical to improve public health outcomes in New York City.

C. Regulatory Background

It is important to have an understanding of the regulatory context within which any policy changes may occur. The maximum amount of sulfur allowed in heating oil is regulated at both the state and local levels. The New York State Department of Environmental Conservation has jurisdiction over the state limit for sulfur content in fuel. Regulation maintains that fuel in New York State cannot be used, stored, purchased, or sold if it contains more than 0.75% of sulfur by weight (7,500 ppm)[b] for any stationary combustion installation with a total heat input greater than 250mmBTU/hour, although certain cities and counties have specified lower allowances.[121] New York City has slightly more stringent rules regarding the fuel sulfur limit. Prior to recent legislation that will be discussed in later sections, Number 2 heating oil had a maximum limit set at 0.2% of sulfur by weight (2,000 ppm) and Number 4 and 6 oils had a limit of 0.3% of sulfur by weight (3,000 ppm).[122]

Air emissions are also regulated on a local level. The New York City Department of Environmental Protection (DEP) is a city agency whose primary purpose is to manage and protect the city's water supply, but who also has a key role in regulating air quality.[123] The DEP is responsible for updating and enforcing the Air Pollution Control Code (Air Code) that ultimately improves the air resources of the city.[124] Thus, DEP is in control of processing and enacting a series of Air Code regulations dealing with compliance, applications for new boilers and heating equipment, renewal requests, and equipment applications, to name a few.[125] Specifically, DEP issues permits and certificates for boilers that are rated over 2.8 million BTU/hr, and issues registrations for boilers that are rated between 350,000 BTU/hr and 2.8 million BTU/hour. That is, the DEP does not have regulatory jurisdiction over very large sources such as power plants, or over fuel burning equipment in one or two family homes, or equipment with a gross input of 350,000 BTU/hr. or less. The latter buildings tend to use Number 2 heating oil or natural gas for space heating purposes.

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[b] Multiplying percentage by weight by 10,000 gives the maximum limit in parts per million. See New Jersey Register Rule Proposals, page 15 http://www.nj.gov/dep/rules/proposals/111609a.pdf

D. Heating fuel use characterization in New York City

Emissions from boilers are of particular concern to NYC because, unlike other sources, boilers in residential and commercial buildings have emissions that are largely unregulated by the state or federal governments. Many boilers, especially older ones, are inefficient and oversized, leading to wasteful fuel and energy usage. They are also often poorly maintained, leading to additional emissions from system fouling and inefficiencies. As stated, until PlaNYC's heating oil initiatives led to the enactment of new requirements which will be described in a subsequent section, the sulfur level in Number 2 heating oil was capped at 2,000 ppm and the sulfur level in Number 6 oil in New York City was capped at 3,000 ppm.[126]

Initially, it was critical to characterize the universe of boiler installations, including their age and fuel types, which are housed in the approximately 975,000 buildings in New York City.[127] A 2009 analysis of the NYC DEP's boiler registration database indicated that almost 10,000 buildings in the city burned Number 4 and 6 heating oils (see table 3) which, as noted, are the dirtiest heating oil types available and have significantly higher levels of sulfur, nickel, and other pollutants compared to other available heating fuels.[128] This analysis also indicated that boilers using only Number 6 oil represent the majority (55%) of boilers registered in NYC, and that 8% of the registered boilers are "dual fuel" with natural gas as a secondary, or back-up, fuel type. This 8% indicated that a small sub-section of the total number of boilers already had the technical capability of burning a much cleaner fuel.

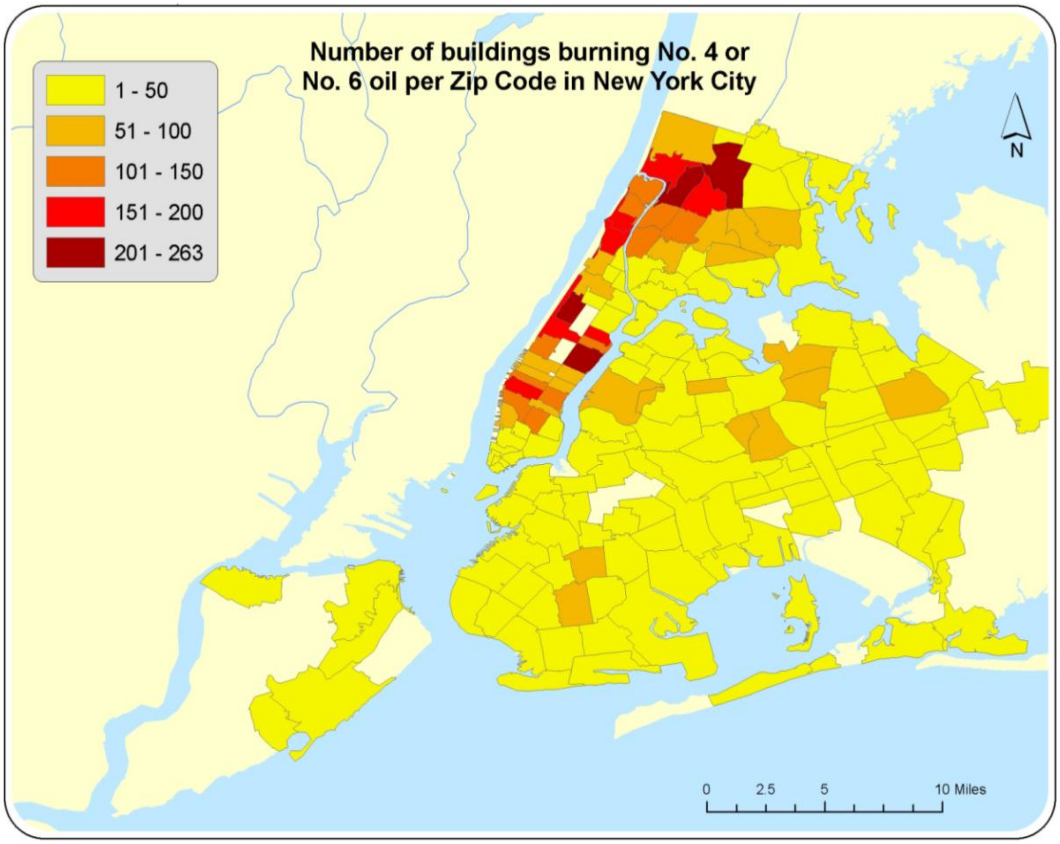
Finally, a key insight from this analysis was that residual fuel boilers are concentrated in certain neighborhoods in New York City (see figure 5) and that in fact, about a third of all the city's active permits that burn this type of fuel were residential buildings located in Manhattan (see figure 6).

Table 3. Fuel Type of Number 4 and Number 6 Oil Boilers in the NYC DEP Database.

Dual Fuel?	Primary Fuel	Second-ary Fuel	No. of boilers	% of boilers	Total MMBTU (est.)	% of MMBTU (est.)
Oil only	**#6 Total**		**5424**	**55%**	**63,416,133**	**62%**
	#4 Total		**3491**	**35%**	**20,887,997**	**21%**
Oil and natural gas	#6	NG	426	4%	10,737,097	11%
	#6 Total		**426**	**4%**	**10,737,097**	**11%**
	#4	NG	374	4%	4,116,787	4%
	#4 Total		**374**	**4%**	**4,116,787**	**4%**
	NG	#6	58	1%	1,251,361	1%
		#4	78	1%	773,495	1%
	NG Total		**136**	**1%**	**2,024,857**	**2%**
Grand Total*			**9896**	**100%**	**101,807,001**	**100%**

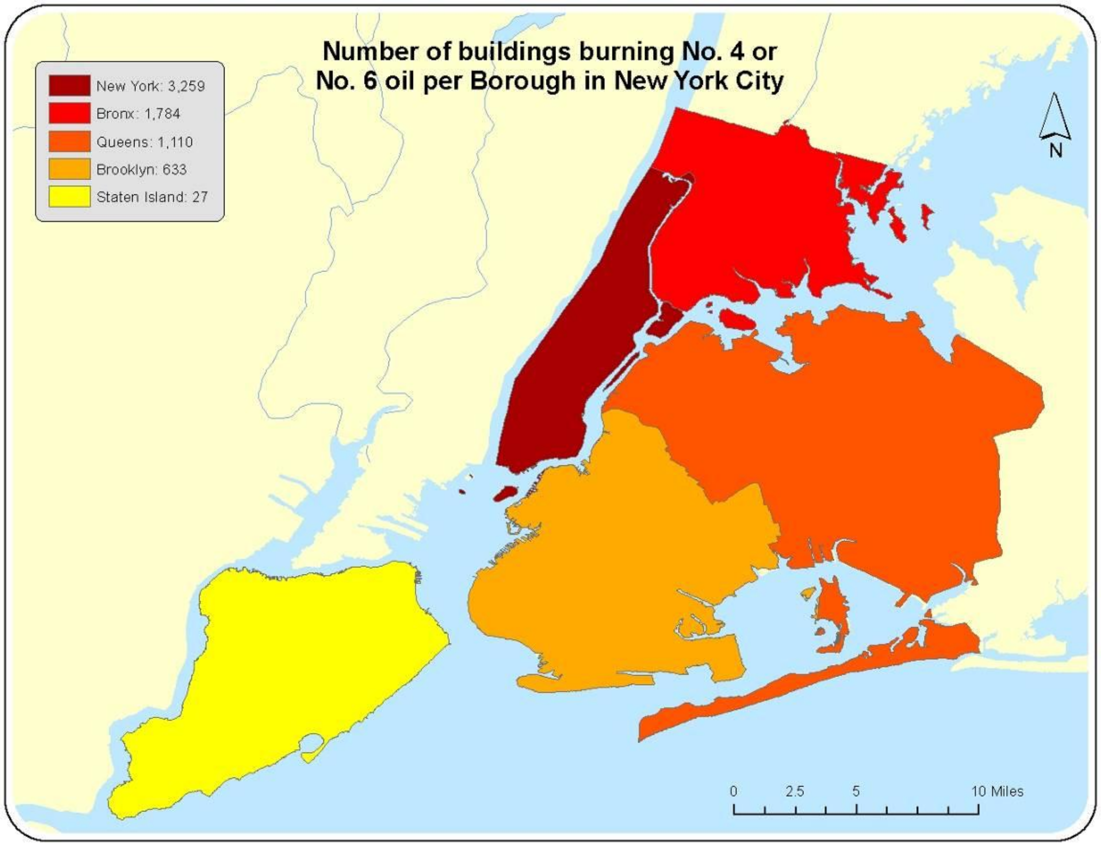
Source: Office of Long Term Planning and Sustainability. (2010). Data obtained from Department of Environmental Protection boiler registration database. *Total includes 45 boilers excluded from the table for clarity.

Figure 5. Concentration of NYC Buildings Burning Number 4 And 6 Oil by Zip Code.



Source: Environmental Defense Fund & Urban Green Council. (2009, December 16). How the Dirtiest Heating Oil Pollutes our Air and Harms our Health. http://www.edf.org/sites/default/files/10085_EDF_Heating_Oil_Report.pdf

Figure 6. Distribution of the 7,000 Buildings with Active Permits That Burn Number 4 or Number 6 Heating Oil in NYC.



Source: Environmental Defense Fund & Urban Green Council. (2009, December 16). How the Dirtiest Heating Oil Pollutes our Air and Harms our Health. http://www.edf.org/sites/default/files/10085_EDF_Heating_Oil_Report.pdf

Table 4. Estimated NYC Emissions Data for Different Fuel Types from NYC DEP Database.

Fuel	Cert.*	Reg.*	Gallons per year	PM emitted (tons)**	NOx emitted (tons)	CO_2 emitted (MMT)	Ni emitted (lbs)***
No. 6	~6,000	n/a	228,000,000	1,145	6,270	2.59	19,266
No. 4	~4,100	~30	84,000,000	353	840	0.90	n/a
No. 2	~5,700	~23,700	322,000,000	531	3,220	3.26	143

Source: Office of Long Term Planning and Sustainability. (2010). Data obtained from Department of Environmental Protection boiler registration database.

These almost 10,000 buildings, which represent only 1% of the total buildings in the city, are responsible for more $PM_{2.5}$ emissions than all cars and trucks in the city combined.[129]

According to the Environmental Defense Fund, a national environmental advocacy organization, this 1% of buildings is responsible for 86% of the heating oil-related particulate matter and nickel levels in New York City.[130] From a policy perspective, it became clear that to improve air quality in New York City, buildings would have to be required to use cleaner burning fuels with much lower sulfur levels, and this is the premise on which the following policy development process is based.

E. Policy Development

STRATEGY 1: MONITORING NEIGHBORHOOD-LEVEL AIR QUALITY

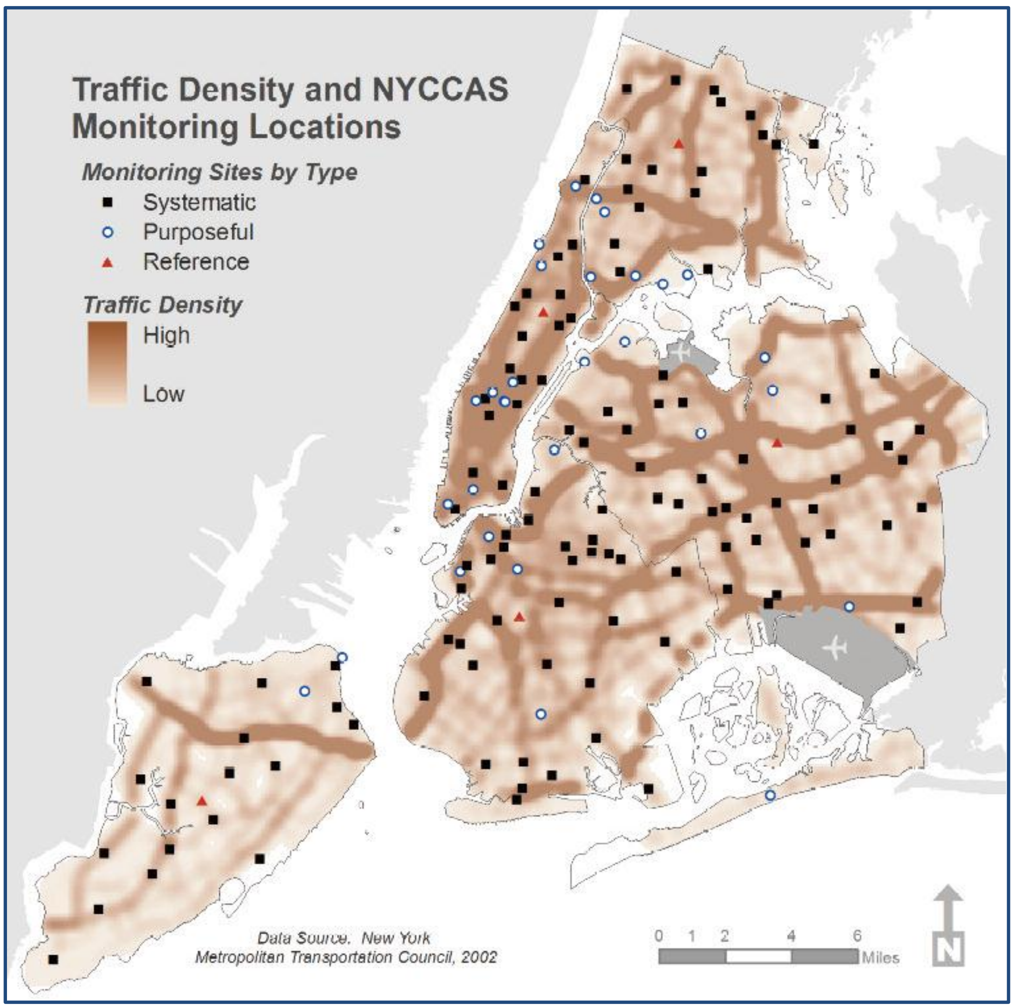
While seeking to understand the City's existing boiler installations, the Mayor's Office of Long Term Planning and Sustainability (OLTPS) and the New York City Department of Health and Mental Hygiene launched the New York City Community Air Survey (NYCCAS), the largest comprehensive street-level air monitoring survey in the U.S. Prior to this effort, air pollution monitoring, as undertaken by the EPA and DEC, examined overall average concentrations on a large geographic scale, more suited to depict broad trends than to measure human exposure.[131] In NYC's five boroughs there were only 24 monitors, located on top of rooftops, away from traffic and sidewalks.[132] Such ambient monitoring was thought to be inadequate for measuring exposure in a city like New York where roads, highways, and power plants are interwoven throughout NYC's 188 communities.

Thus, in PlaNYC, the Mayor's Office of Long Term Planning and Sustainability and the New York City Department of Health and Mental Hygiene committed to obtain an improved measurement of human exposure to air pollutants in order to better understand neighborhood-level variation—it was recognized that despite significant progress in air pollution, improvements were not experienced equally by all New Yorkers. A better measure of human exposure would help to understand the scope of the challenge to improve the air quality and therefore the health of New Yorkers in every community. Monitoring under NYCCAS was designed to occur periodically at 150 sites throughout NYC, using portable air samplers mounted 10 to 12 feet from the ground on light poles, close to street level (example of such a monitor in figure 7). Figure 8 is a map of NYCCAS monitoring locations throughout NYC, also depicting traffic density patterns. Data specifically incorporated traffic and land use patterns to see how various emissions sources correlated with air quality; such data established priority neighborhoods to help decrease environmental disparities. In addition, results showed that $PM_{2.5}$ concentrations at road level had an average measurement of 11.3 $\mu g/m^3$ compared with an average rooftop regulatory measurement site average of 10.5 $\mu g/m^3$,[133] which demonstrated how rooftop measurements could indeed be an inaccurate depiction of human exposure.

Figure 7. Portable Air Sampler Used by the NYC Community Air Survey to Measure Street Level Air Quality at 10-12 Feet From the Ground.

Source: NYC Department of Health and Mental Hygiene. The New York City Community Air Survey, Results from Year One Monitoring 2008-2009.

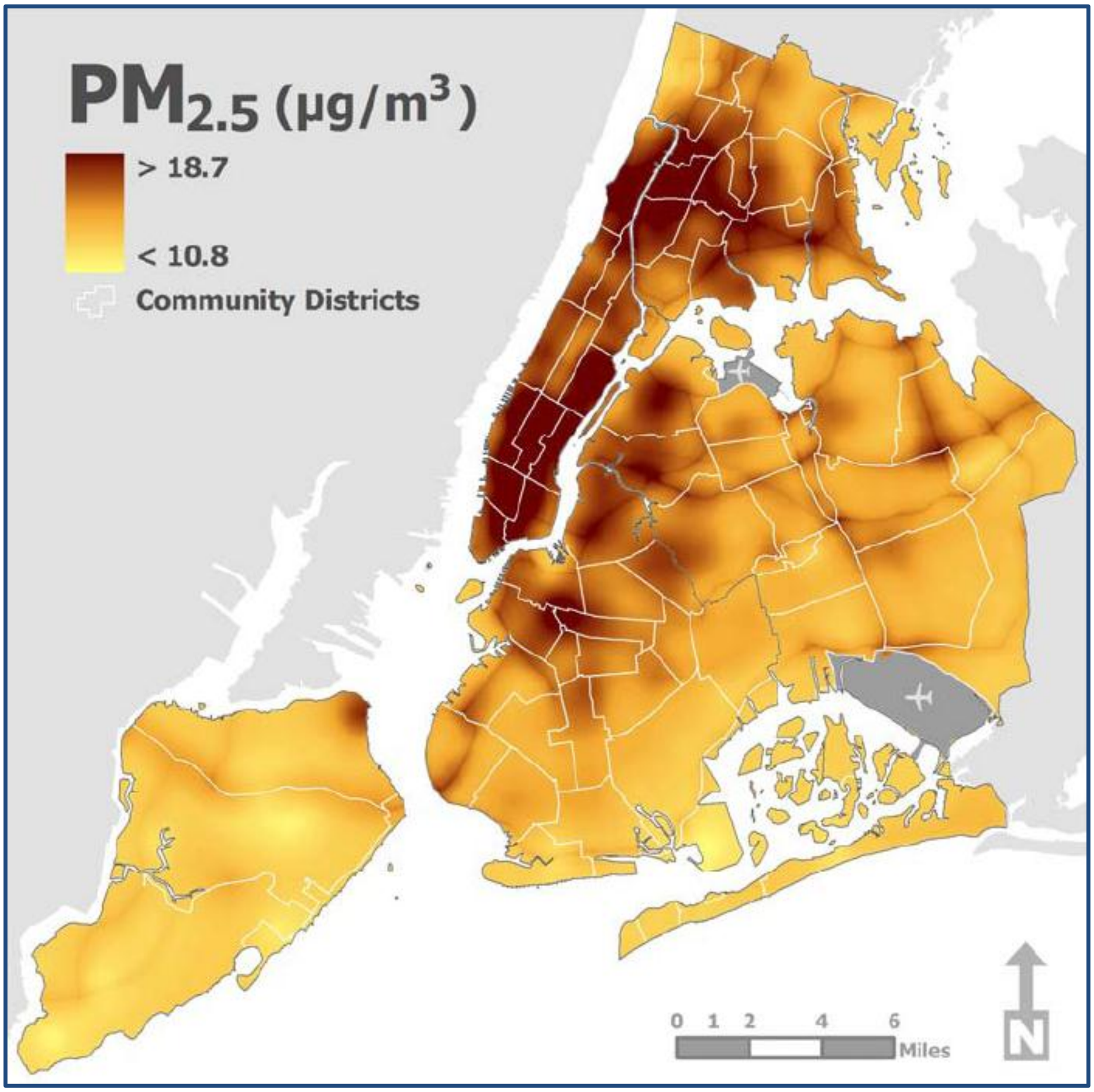
Figure 8. New York City Community Air Survey Monitoring Locations.



Source: NYC Department of Health and Mental Hygiene. The New York City Community Air Survey, Results from Year One Monitoring 2008-2009.

Researchers used land use regression models to analyze the association between average $PM_{2.5}$ concentrations with certain predictor variables such as traffic counts, land use types, and building densities, and found that the most important predictors of annual average $PM_{2.5}$ concentrations at monitoring sites included: average truck traffic density within one mile and average traffic density within 100 meters, number of boilers burning residual oil within one kilometer, area of industrial land use within 500 meters, and (inversely) area of land with vegetative cover within 100 meters.[134] So, the variation in $PM_{2.5}$ concentration is attributable to both nearby traffic patterns as well as the density of boilers using residual heating oil numbers 4 or 6 (see figures 9 and 10).[135]

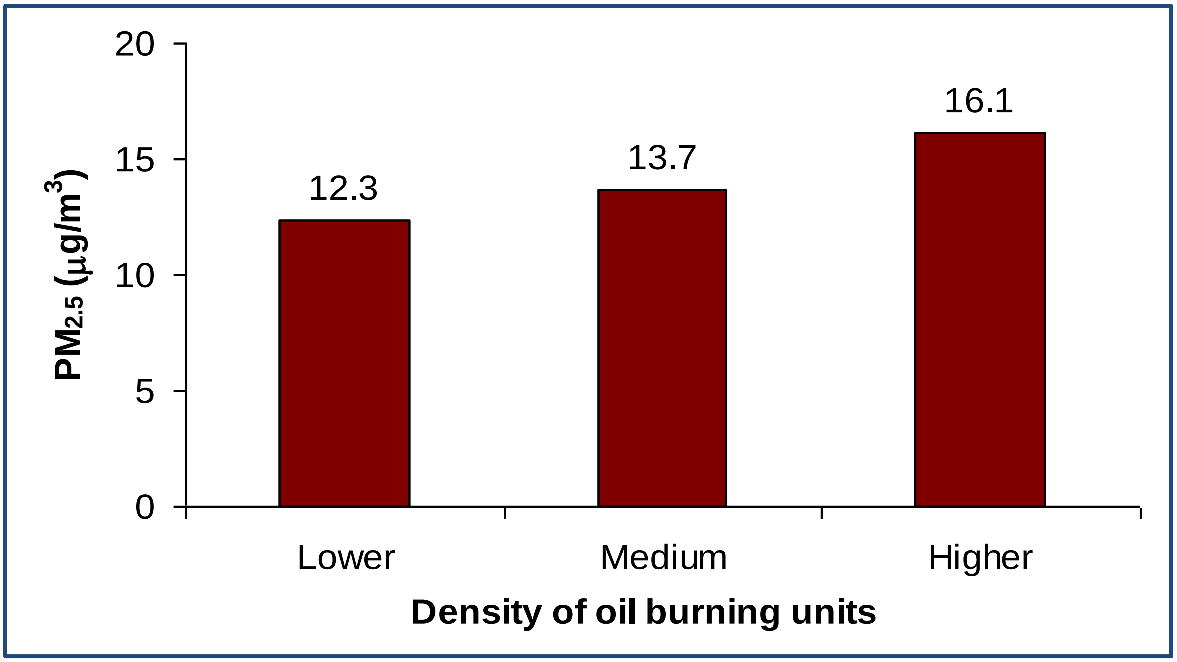
Figure 9. Map of Estimated Fine Particle Concentrations in NYC, Winter 2008-2009.



Source: NYC Department of Health and Mental Hygiene. The New York City Community Air Survey, Results from Year One Monitoring 2008-2009.

Figure 10. Annual Average Fine Particulate Matter Concentrations and Density of Residual Number 4 and 6 Oil Burning Units in NYC, Winter 2008-2009.

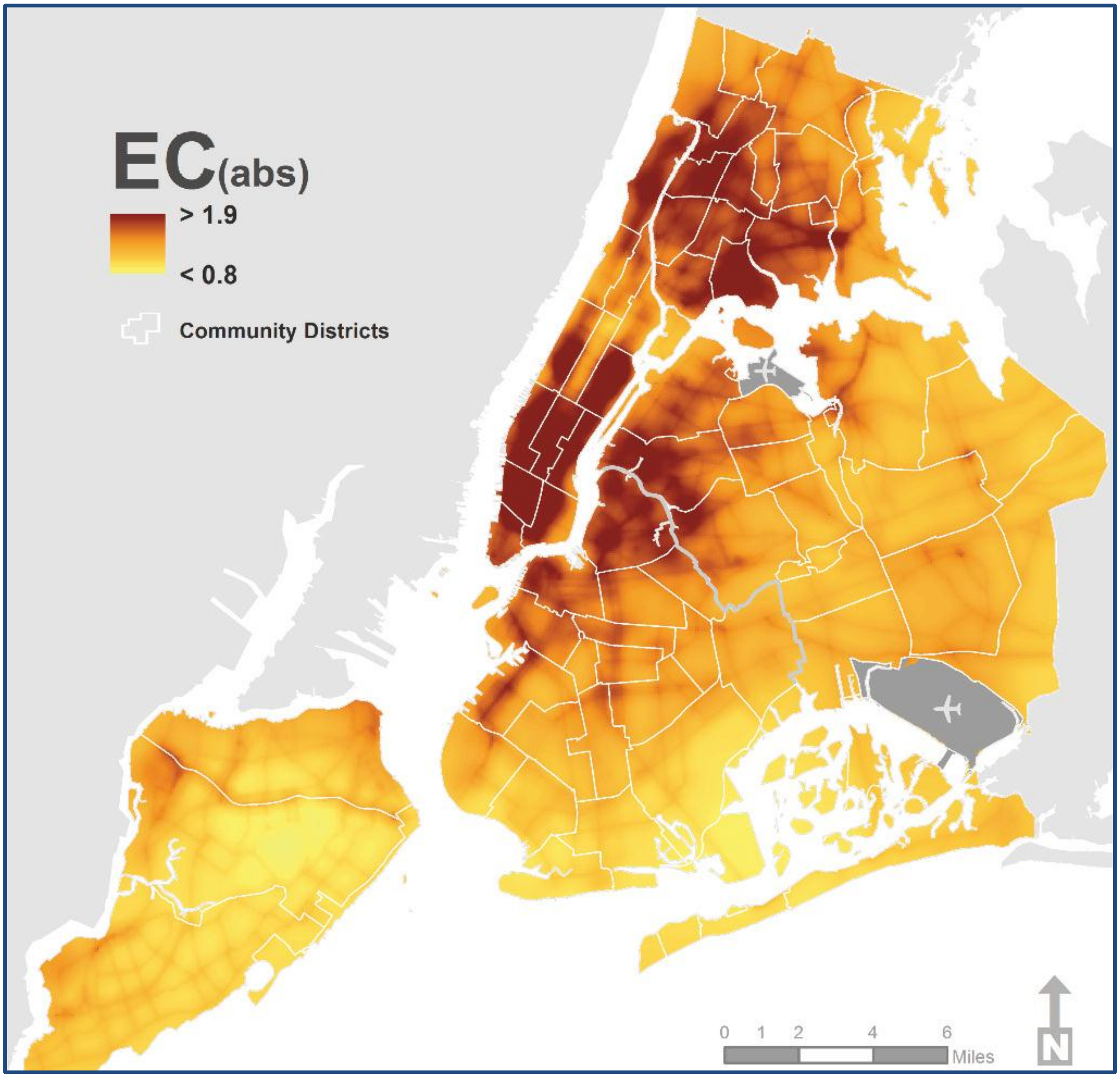
NYCCAS found that winter fine particulate matter concentrations were 30% greater at sites in regions of higher, compared to lower, density of oil burning units.



Source: NYC Department of Health and Mental Hygiene. The New York City Community Air Survey, Results from Year One Monitoring 2008-2009.

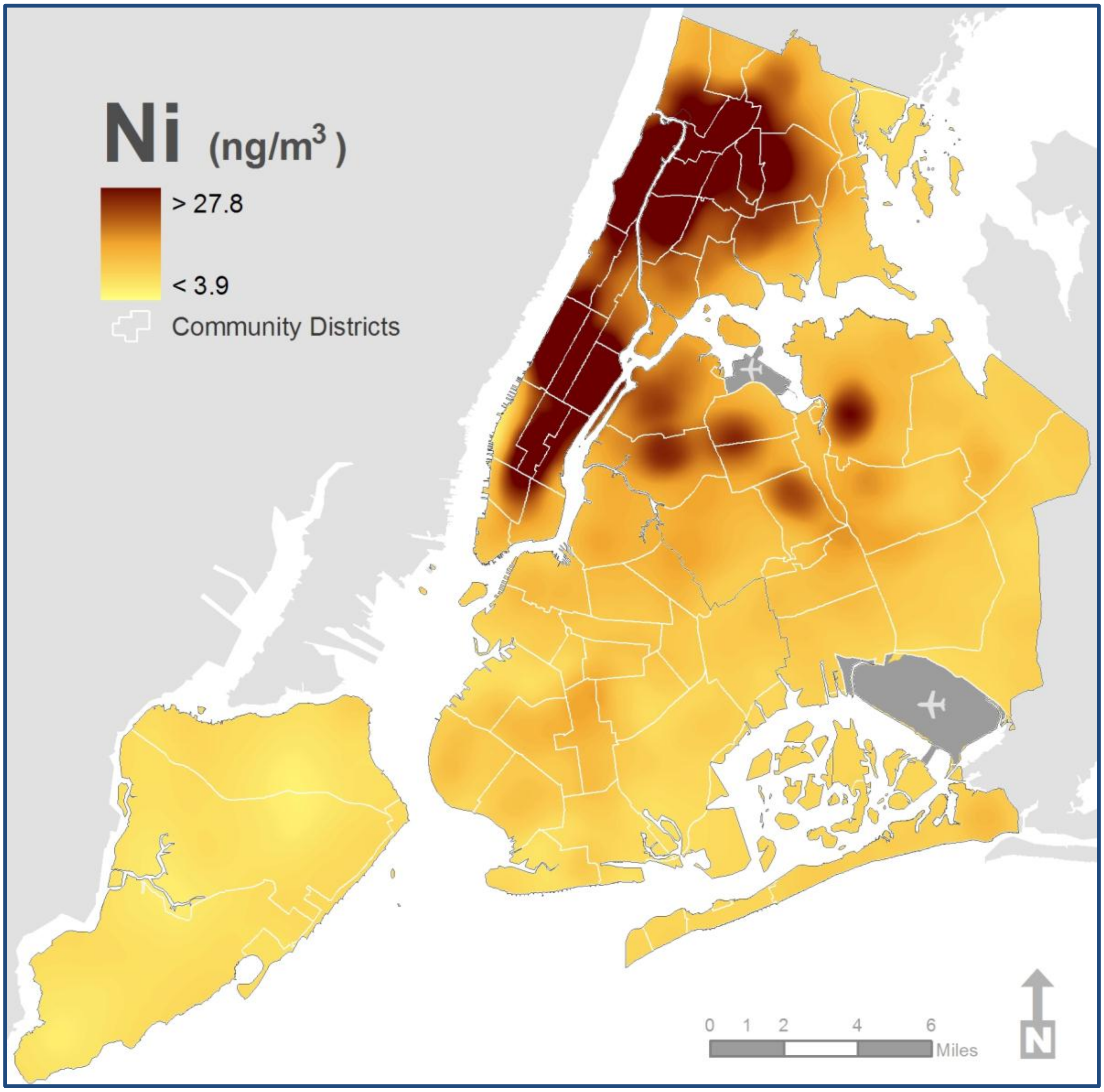
As with $PM_{2.5}$ variations, observed measurements of elemental carbon were also strongly correlated with boiler density and nearby truck routes (see figure 11).[136] During the winter season, NYCCAS sampling sites also measured nickel concentrations, which are commonly introduced into the environment through the combustion of residual heating oils. While the average concentration of nickel was 13 $\mu g/m^3$, these measurements varied considerably based upon location.[137] Similar to results observed in the analysis with $PM_{2.5}$, higher concentrations of nickel were observed among locations that housed more nearby units permitting the combustion of number 4 and 6 heating oils and among areas with higher residential population density (see figure 12).[138] Areas with high density of residual heating oil burning units had nickel concentration levels almost four times greater than areas with low density levels, and areas with high residential population density had nickel concentration levels three times higher than areas with low residential population density (see figure 13).[139] Further, previous research by Doctor Morton Lippmann, at the New York University School of Medicine, Department of Environmental Medicine, and others showed that the seasonal and spatial concentration of nickel levels in New York City's air correlated strongly with the heating season (see figure 14).[140]

Figure 11. Map of Estimated Elemental Carbon Concentrations in NYC, Winter 2008-2009.



Source: NYC Department of Health and Mental Hygiene. The New York City Community Air Survey, Results from Year One Monitoring 2008-2009.

Figure 12. Map of Estimated Nickel Concentrations in NYC, Winter 2008-2009.



Source: New York City Community Air Survey Supplemental Report: Nickel Concentrations Winter 2008-2009.

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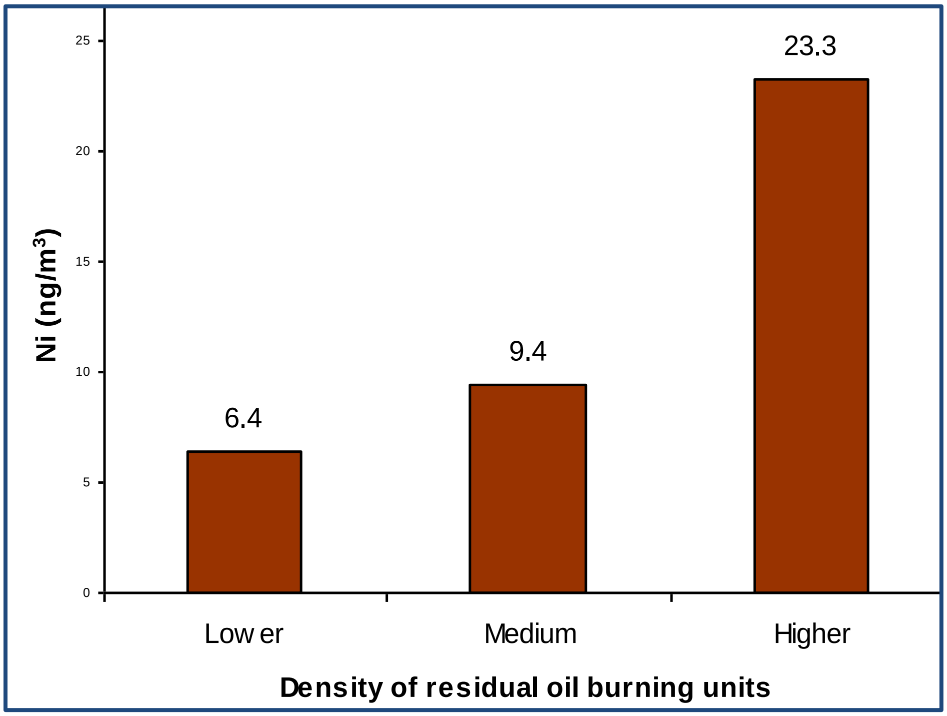
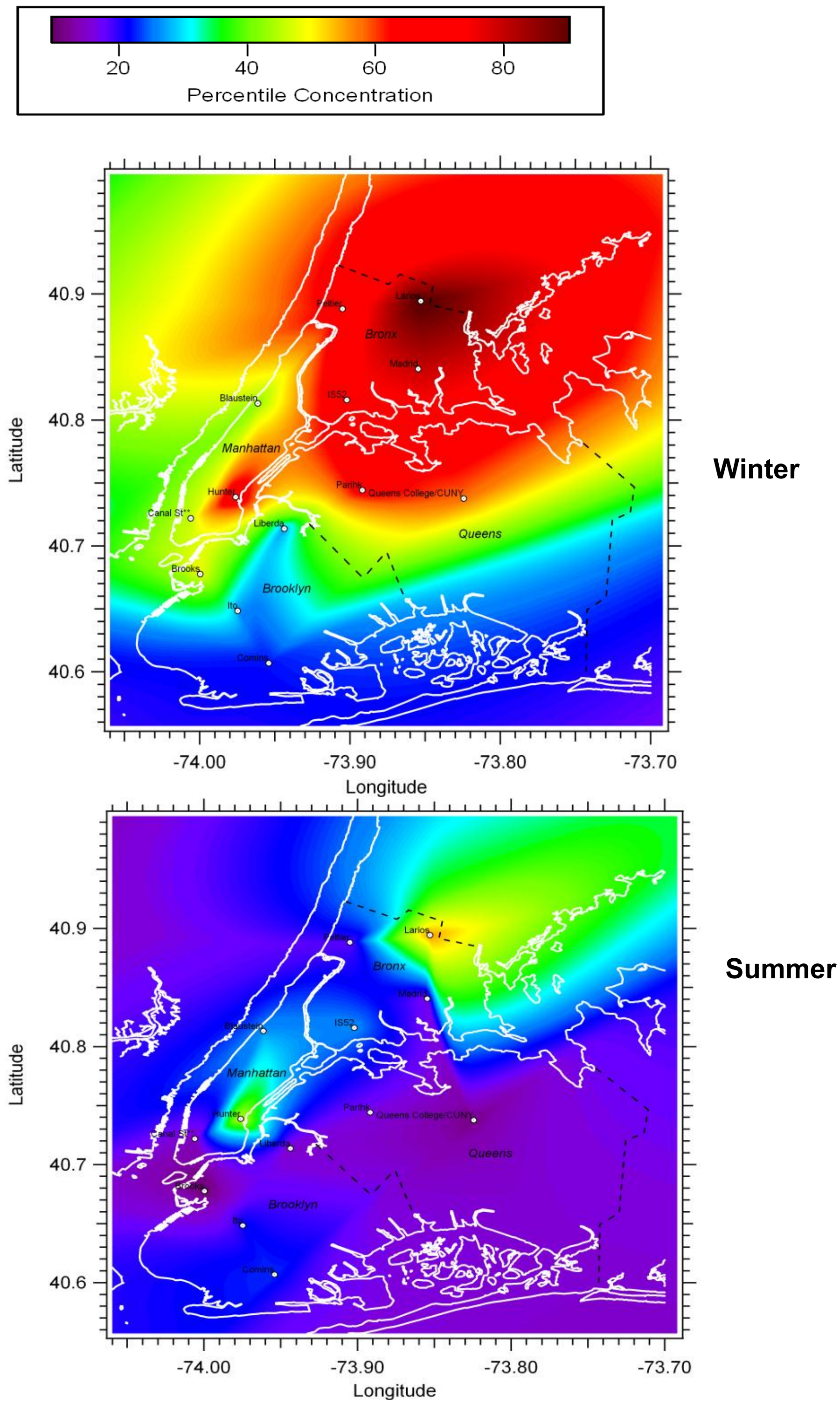
Figure 13. Annual Average Nickel Concentrations and Density of Residual Number 4 and 6 Oil Burning Units in NYC, Winter 2008-2009.

The NYC Community Air Survey showed that nickel levels are 263% greater in areas of high, compared with low, density of residual oil burning units.



Source: New York City Community Air Survey Supplemental Report: Nickel Concentrations Winter 2008-2009.

Figure 14. Map of Seasonal Distribution of Nickel Concentrations in NYC.



Source: Lippmann, M. & Peltier, R.E. (2008). Seasonal and Spatial Distributions of Nickel in New York City Ambient Air. (adopted from paper in press in *J. Expos. Sci & Environ. Epidemiol*.) ISES–ISEE Joint Annual Conference, Pasadena, CA.

Because the areas with highest estimated concentrations of $PM_{2.5}$, elemental carbon, and nickel contained both highest traffic and building density, such as Midtown Manhattan, researchers were particularly interested in areas characterized as having major roads and highways nearby. Outer boroughs, such as Brooklyn and Staten Island, which are farther from major roadways, had the lowest estimated average $PM_{2.5}$ levels.[141]

Thus, results from NYCCAS recognized the main drivers of street level air pollution as high traffic volume and the use of residual heating oil. Such results informed and reaffirmed the need for strategic policy efforts to improve air quality in the city by targeting the most polluting sources and locations, as well as showing the need for accurate measurement of exposure concentrations of important air pollutants.[142] Such data will continue to allow policymakers to track changes over time, measure the effects of local emission reduction initiatives, and focus on reducing $PM_{2.5}$ emissions and exposure disparities across NYC neighborhoods that are disproportionately afflicted by related health impacts.[143] Plans to enhance NYCCAS include the expansion of monitoring efforts to examine exposure in different traffic configurations and at different times of day.[144]

STRATEGY 2: REDUCING SULFUR LEVELS IN HEATING FUELS

Because the combustion of sulfur-laden heating fuel was found to contribute significantly to air pollution in New York State—particularly in New York City—a critical method to reduce pollutants from this source was to limit the sulfur content of heating fuels. Sulfur is a natural component in fossil fuels and during the petroleum refining process it is removed from the fuel via desulfurization mechanisms. Heating fuel can contain levels of sulfur ranging from 2,000 ppm in distillate oils used for domestic/residential applications, to as much as 10,000 ppm sulfur and even 25,000 ppm sulfur in residual oils used by industrial and large commercial applications.[145] By comparison, diesel fuel used in on-road applications, such as long-haul trucks, is capped by the U.S. EPA at 15 ppm.[146] As previously mentioned, this highway low-sulfur diesel fuel can be used in many heating applications, thereby reducing the level of air pollutants such as SO_2 and $PM_{2.5}$ that are emitted when fuels are combusted. Due to additional processing to desulfurize petroleum products, heating fuels with lower sulfur contents are more costly than their high-sulfur counterparts. However, low-sulfur heating fuels produce fewer by-products, reduce the rate of heating equipment fouling, and improve burner efficiency so that the amount of fuel consumed is reduced. Additionally, boilers or furnaces burning cleaner fuels do not have to be serviced or vacuumed as frequently. Therefore, low sulfur fuels actually reduce boiler operating and maintenance costs for homeowners and building operators.[147]

As discussed, in New York City the level of sulfur in Number 2 heating oil was limited by regulation at 2,000 ppm while the sulfur level allowed in Number 6 heating oil was limited to 3,000 ppm.[148] However, in the Northeast region, the sulfur limits for heating fuels varied from state to state.[149] Meanwhile, the Clean Air Act requires the U.S. EPA to address regional haze—impaired visibility—in key federally designated areas.[150] The EPA issued regulations requiring states to develop State Implementation Plans (SIPs) to reduce haze-causing pollution, specifically SO_2, to improve visibility in the designated areas and also established five regional planning organizations across the U.S. to coordinate regional efforts. In a 2005 report, the eight state region comprising NESCAUM (Northeast States for Coordinated Air Use Management) outlined a plan to transition each member state to adopt a low sulfur heating oil standard.[151] The idea was that enacting coordinated policies across states would create economies of scale and provide a market that could encourage fuel refiners and distributors to invest in desulfurization equipment and provide cleaner, less polluting fuels.

One of the EPA-established regional organizations, the Mid-Atlantic Northeast Visibility Union (MANE-VU), comprised of Mid-Atlantic and Northeast states, tribes, and federal agencies, agreed in 2007 to pursue several regional strategies to reduce SO_2 emissions, the main contributor to regional haze in the region. One key strategy was to decrease the sulfur content limit in distillate and residual fuel oils. Individual member states were tasked with pursuing appropriate policy options to adopt a regionally consistent standard and reduce fuel sulfur to specified levels by an agreed-upon timeframe (displayed in table 5).

Table 5. MANE-VU Sulfur-In-Fuel Strategy and Timeline.

Low Sulfur Oil – inner zone (NJ, NY, PA, DE)

STRATEGY	SULFUR LEVEL 1	SULFUR LEVEL 2
Distillate (#2 oil)	500 ppm	15ppm
#4 oil	2,500 ppm	2,500 ppm
#6 oil	3,000-5,000 ppm	3,000-5,000 ppm
Required no later than	2012	2016

Low Sulfur Oil – outer zone (NH, RI, CT, DC, VT, etc.)

STRATEGY	SULFUR LEVEL 1	SULFUR LEVEL 2
Distillate (#2 oil)	500 ppm	15 ppm
#4 oil		2,500 ppm
#6 oil		3,000-5,000 ppm
Required no later than	2014	2018

In 2007, the New York City Mayor’s Office of Long Term Planning and Sustainability began conversations with MANE-VU, NESCAUM, and the New York State Department of Environmental Conservation (NYS DEC) to understand the legislative strategy and timing of reducing New York State’s heating oil sulfur levels. However, many factors contributed to the NYS legislature’s failure to act in developing or enacting legislation to adopt the proposed sulfur caps. Importantly, certain political events, including then-Governor Elliot Spitzer’s resignation from his post in March of 2008 given his involvement in a prostitution scandal,[152] caused a slew of state-sponsored legislation and policy initiatives to take a back seat. A period of leadership and policy staff transition followed, with lieutenant governor David Paterson serving the remainder of Governor Spitzer’s term, as required by the New York State constitution. Further, the enactment of regional sulfur limits for heating fuels did not have the backing of the petroleum industry, which argued that costly capital upgrades such as the installation of desulfurizing equipment would be needed at refineries in order to procure these boutique fuels to consumers in the northeast region. While advocacy organizations pushed for shorter implementation timelines, the petroleum industry continued to work with MANE-VU, NESCAUM and the NYS DEC to push the effective date of the schedule further into the future, allegedly to accommodate the needed industry upgrades.

In light of New York State's inaction to address air pollution and regional haze through the enactment of stricter fuel sulfur limits, and given that the implementation timeframe in consideration seemed unnecessarily far into the future, and that the sulfur limits for residual oil were higher than what was already required in New York City, the NYC Mayor's Office of Long Term Planning and Sustainability began a comprehensive analysis to develop its own citywide air quality policy strategy in order to meet its ambitious goal of achieving the cleanest air of any large American city. It should be noted that New York City government has the authority to regulate a variety of areas such that its laws can be stricter than New York State laws; unless the policy is preempted by the Federal or State government.[c] Over the years, New York City has enacted many air quality regulations under its authority to protect the health and safety of its residents; including the stricter sulfur limit in heating oil sold in New York City versus in the rest of the state and the purchasing requirements of cleaner vehicles for city government fleets.

As part of its charge to implement the air quality initiatives outlined in PlaNYC 2030 by developing legislation to reduce pollution from heating fuels, the Mayor's Office of Long Term Planning and Sustainability identified the following strategic priorities:

- Reducing key pollutants from heating oil, weighing short-term and long-term improvements appropriately.
- Focusing on reducing pollution rather than eliminating a specific type of fuel.
- Seeking the most cost-effective approaches to meaningful pollution reduction.
- Seeking a healthy fuel mix for supply reliability and system flexibility, as long as clean standards can be achieved.
- Minimizing Major Capital Improvements (MCIs)/capital assessments that would not have otherwise happened.[d]

To achieve these goals, after consultation with technical, industry and advocacy stakeholders, the Mayor's Office of Long Term Planning and Sustainability identified and considered the following implications:

- The timing as well as magnitude of reductions, and apply a discount rate.
- Ensuring the goal is the maximum reduction at a reasonable cost, rather than symbolic deadlines or targets.
- Both capital and operating costs, as well as the value of lives saved, on a unit basis.

[c] Under the Supremacy Clause of the U.S. Constitution, federal law preempts State law when preemption is the clear and manifest purpose of Congress.

[d] Under New York State's Rent Stabilization/Control Laws, "when owners make improvements or installations to a building subject to the rent stabilization or rent control laws, they can apply to the Division of Housing and Community Renewal for approval to raise the rents of the tenants based on the actual, verified cost of improvement or installation. Some examples of MCI items include boilers, windows, electrical rewiring, plumbing and roofs… To be eligible for a rent increase, the MCI must be a new installation and not a repair to old equipment." State of New York Division of Housing and Community Renewal. http://www.nyshcr.org/Rent/factsheets/orafac24.htm

– The cost impacts of the policy above business-as-usual; and assess capital and operating costs separately.
– Adopting neutrality between Ultra Low Sulfur Diesel Number 2 heating oil (ULSD#2) and natural gas, and encouraging dual fuel/interruptible gas where possible; which are systems in which gas is used as a primary fuel but Number 2 heating oil is used as a backup in case of emergencies, gas curtailments, etc.

Once the priorities were established, an emissions model was developed by the Mayor's Office of Long Term Planning and Sustainability. The model enabled the office to understand the age, fuel type and state of boilers currently permitted by the New York City Department of Environmental Protection, to assess the remaining useful life and regulatory needs of the city's boilers, and to evaluate various policy solutions that would reduce the emissions from this sector.

The model was Microsoft-Excel-based and it performed manipulations to a database of existing heating oil boilers permitted for use by the City's Department of Environmental Protection. This database included the approximately 10,000 existing boilers that have Number 4 or Number 6 as either their primary or secondary fuel. Given the type and the amount of fuel that each boiler utilized, and because it included air emissions coefficients for each heating fuel type, the model was able to compute the associated particulate matter and nickel emissions.

The model was dynamic in that the user—that is, the policy advisors at the Mayor's Office of Long Term Planning and Sustainability—could change any number of key assumptions including the discount rate, the retirement age of the boiler, the fuel cost scenarios and the capital cost variability. The model had a 2040 time horizon, that is, all policy scenarios must come to a stable end state by 2040. Finally, the model could test four public policy levers, all of which could be used in combination with one another. Options included an early cutoff for residual fuel use, disallowing in-kind residual fuel boiler replacement, a final force out of old, inefficient residual oil equipment, and introducing low-sulfur fuels into any of the previous scenarios (described in detail in table 6). The outputs of this analysis have been summarized in tables 7 and 8 and the lessons learned from this model that shaped the policy outcomes have been discussed below.

Table 6. Policy Levers Examined Through OLTPS Model, With Examples.

	Explanation	Example(s)
1. Early cutoff	• Tests the impact of an initial switch to a cleaner fuel before a final switch to a cleaner fuel than the intermediary choice • Can pick any destination fuel in any year for any primary or secondary fuel in the model	• #6 to #4 in 2012 before #6 and #4 go to #2 in 2030 • #6 and #4 go to #2 in 2015 before #6, #4, and #2 all go to NG in 2035
2. Disallow in-kind replacement	• Tests the impact of disallowing in-kind replacement • After a chosen year, #4 and #6 oil can only be replaced by #2 or NG • Conservative assumption that on retirement all oil boilers that current elect to stay oil (94% of #4, 95% of #6) , remainder switch to natural gas	• No in-kind replacement after 2012 • No in-kind replacement after 2013
3. Final force-out	• Tests the impact of a final switch to a cleaner fuel • Can pick any destination fuel in any year for any primary or secondary fuel in the model	• #6 to #4 in 2012 before #6 and #4 go to #2 in 2030 • #6, #4, and #2 must become NG in 2025
4. Low-sulfur	• Tests the impact of introducing low-sulfur versions of #4 and #2 into any of the above three scenarios • For early cut-off / final force-out, allows a switch to #4LS or #2USLD • For in-kind replacement, retired boilers can become either #2USLD or NG at the same rates as #2 or NG respectively	• #6 to #4LS in 2011 before #6 and #4 go to #2ULSD in 2025 • #6, #4, and #2 must become #2ULSD in 2035 • No in-kind replacement after 2013, replacements must be with a low sulfur fuel

The model was also able to measure the capital and operating costs associated with various fuel conversion options for each boiler; including a "business as usual" scenario. Specifically, the model included a cost range for each type of operational and capital conversion option (such as fuel cost difference, or boiler replacement costs from oil to natural gas, or from Number 6 heating oil to cleaner Number 2 heating oil, for example). The model also calculated the emissions impact of introducing a low-sulfur version of Number 2 and Number 4 oils by calculating the particulate matter and nickel emissions of those fuels using U.S. EPA-established factors or coefficients and comparing the emissions of cleaner versions of those fuels using newly calculated coefficients that took into consideration the lower sulfur content of those fuels (see tables 7 and 8 for a summary of results).

Table 7. Policy Options Analysis Showing Calculated Emissions Reductions and Costs.

Option	Emissions reductions (NPV)		Costs incurred (NPV, $M)			Total cost/ton
	PM (tons)	Ni (lbs)	Capex	Opex		
				NYSERDA	EIA	PM ($M)
BAU	1,545	54,927	945	499	211	0.75-0.94
All natural gas (2012)	23,639	592,649	2,488	71	(6,284)	0.00-0.11
All #2 (2012)	13,873	591,508	1,854	7,544	5,688	0.54-0.68
All #4 (2012)	6,245	263,300	1,173	3,304	2,445	0.58-0.72
Retirement-based phase-out to #2; no cutoff	7,661	313,372	1,144	3,766	2,675	0.50-0.64
Retirement-based phase-out to #2; 2040 cutoff	7,757	317,493	1,269	3,874	2,801	0.52-0.66
Retirement-based phase-out to #2; 2020 cutoff	9,695	400,138	1,517	5,006	3,744	0.54-0.67
Mix -- #4 in 2012; retirement-based phase-out; 2040 cutoff	10,454	432,485	1,481	5,355	3,919	0.52-0.65

Source: Mayor's Office of Long Term Planning and Sustainability.

Table 8. Policy Options with Ultra-Low Sulfur Fuel Analysis Showing Emissions Reductions and Costs.

Option	Emissions reductions (NPV)		Costs incurred (NPV, $M)			Total cost/ton
	PM (tons)	Ni (lbs)	Capex	Opex		
				NYSERDA	EIA	PM ($M)
BAU	1,545	54,927	945	499	211	0.75-0.94
All natural gas (2012)	23,639	592,649	2,488	71	(6,284)	0.00-0.11
All #2 (2012)	20,883	591,508	1,854	7,572	5,715	0.36-0.45
All #4 (2012)	9,477	263,300	1,173	3,328	2,470	0.38-0.47
Retirement-based phase-out to #2; no cutoff	11,090	313,372	1,144	3,780	2,689	0.35-0.44
Retirement-based phase-out to #2; 2040 cutoff	11,235	317,493	1,269	3,888	2,815	0.36-0.46
Retirement-based phase-out to #2; 2020 cutoff	14,173	400,138	1,517	5,025	3,762	0.37-0.46
Mix -- #4 in 2012; retirement-based phase-out; 2040 cutoff	15,583	432,485	1,481	5,383	3,946	0.35-0.44

Source: Mayor's Office of Long Term Planning and Sustainability.

Whether by providing a clear picture of the age distribution of existing permitted boilers (which shed light on their expected retirement age and the related timing of policy interventions) or by quantifying the emissions benefits of a given policy option, this model helped to inform each of the strategies considered for policy development.

First, it was clear that, technically, buildings and homes currently using Number 2 heating fuel with 2,000 ppm sulfur could easily switch to Number 2 heating fuel with 15 ppm sulfur (ULSD#2), offering significant environmental benefits and requiring no capital expense (though the operational costs could be expected to be higher given the marginally higher price of each gallon of low sulfur heating fuel). Thus, the policy goal was to require buildings to use ULSD#2 if keeping their existing boiler or to switch to natural gas if upgrading their existing boiler. Because most users of Number 6 heating fuel must make costly equipment upgrades, and potentially replace their entire boiler, in order to burn Number 2 heating fuel regardless of the sulfur content of the Number 2 oil, the policy strategy consisted of lowering the maximum allowable sulfur content of Number 2 heating oil at the New York State level (not just citywide) to maximize environmental and related public health benefits; and also of lowering the sulfur content of Number 4 heating oil at the New York City level, where it is primarily consumed. Reducing emissions from Number 6 heating oil would become a separate initiative which will be described subsequently.

a) State-wide bill S. 1145-A/A. 8642

As discussed, the allowable maximum sulfur content for Number 2 heating oil in New York State ranged from 2,000 ppm to over 15,000 ppm in certain parts of the state. Together with a coalition of environmental, industry and public health advocates, the Mayor's Office of Long Term Planning and Sustainability worked to enact state legislation to impose a cap on sulfur in Number 2 heating fuel sold in New York State for use in residential, commercial or industrial heating systems. The state bill (S. 1145-A/A. 8642) went into effect on July 1, 2012, and reduced sulfur levels in all Number 2 heating oil sold in the state by up to a thousand-fold; from the prior existing range of between 2,000-15,000 ppm sulfur, depending on the municipality, to the EPA limit for transportation fuel of up to 15 ppm. This law thus created a new fuel class: ULSD #2 heating oil.[153] The bill also provided an exemption mechanism for the Governor to temporarily suspend the requirements of the legislation, if a determination was made that the fuel supply was inadequate to meet demand.[154]

During the policy development process, issue-based coalitions played an important role in demonstrating and developing support for key components of the proposed state and city legislation. Opponents of the State bill, S.1145-A/A.8642, claimed that it would drive up home heating oil prices by forcing producers to desulfurize existing fuel (i.e. make expensive infrastructure changes in the refining processes). In addition, they argued that because 15 ppm is also the sulfur limit for transportation diesel, competition between diesel vehicles and residential heating systems for the same fuel would lead to tighter supplies that would push prices even higher.[155] However, certain heating oil industry officials dismissed these claims, pointing to the large quantities of low-sulfur diesel that U.S. refiners export to Europe.[156] Opponents such as the Rent Stabilization Association also argued that higher prices for low sulfur heating oil would negatively impact owners of buildings that provide affordable housing and rent-controlled housing in New York City, as those buildings were already operating at low profit margins.[157] Housing advocates feared that landlords would cut back on fuel deliveries during the winter months as a means to control their heating expenses.[158] In response, industry advocates calculated that low-sulfur heating oil consumers would save up to 6% in their heating costs due to higher boiler efficiency, reduced maintenance needs and reduced fuel use that results from cleaner fuel, and emphasized that these savings more than offset any price increase from switching given that since January 2008, the premium for 15 ppm transportation diesel had been just 1.74% over the cost of Number 2 heating oil in New York State.[159]

Supporters of the State bill included a coalition of environmental advocates including Environmental Advocates, the Natural Resources Defense Council, the Environmental Defense Fund, the NY League of Conservation Voters, UPROSE, and WE ACT for Environmental Justice; the heating oil industry including the NY Oil Heating Association, the Empire State Petroleum Association, the Oil Heat Institute of Long Island and their counterparts in Central New York, the Hudson Valley and Eastern New York; public health advocates at the American Lung Association of NY; and labor unions including the Teamsters Joint Council 16 and Local 553. The New York Oil Heating Association hailed the legislation as an important stepping stone to increasing energy efficiency and fuel diversity; the American Lung Association called it a great public health improvement, and labor unions praised the bill for its ability to allow the heating oil industry to remain competitive and active.[160] The NYC Mayor's Office often coordinated information meetings and tactics, including supporting coalition members, securing the support of labor unions, and providing information to housing and tenant advocate organizations that were concerned about the potential rise in housing costs associated with the clean fuel requirements.

After months of debate and advocacy, the New York State Assembly passed the measure and, after a contentious vote, the bill passed the New York State Senate in June 2010. Then-Governor David Paterson signed the measure into law in July 2010.[161] The NYS requirement was similar to those enacted in the heating oil-reliant state of Maine in April of 2010, [162] which required heating oil to contain no more than 500 ppm sulfur starting January 1, 2014 and no more than 15 ppm starting January 1, 2018; and in the state of Connecticut in June of 2010, which required heating oil sold in Connecticut to contain no more than 15 ppm sulfur by 2014 and no less than 2% biodiesel by 2011.[163]

The NYC Mayor's Office of Long Term Planning and Sustainability estimated that the pollution benefits of implementing the New York State mandate would be comparable to shutting down two and a half coal plants in New York State.

b) <u>NYC Council Introduction 194-A/ Local Law 43</u>

The aforementioned modeling effort also indicated that reducing the sulfur content in #4 heating oil and phasing out the use of #6 heating oil was a cost-effective way to improve the city's air quality.[e] As mentioned, different policy options were considered, including a boiler retirement-based phase out of Number 6 boilers to Number 2 oil, a mandate-based fuel conversion to Number 2 oil or Natural Gas for all Number 4 or Number 6 boilers within certain timelines, and combinations of retirement-based boiler or fuel replacement scenarios.

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[e] Switching from #6 to #4 heating oil does not require a new boiler; however, facilities' managers do need to adjust the boiler's burner and clean the fuel tank and oil lines.

A key insight that was gained from the model was that the combination of introducing ultra-low sulfur Number 2 heating oil at the New York State level, requiring a fuel switch to Number 4 oil by 2012 in New York City, and a retirement-based phase-out of Number 6 heating oil boilers in New York City would create a 66% reduction of particulate matter emissions and result in the lowest cost per ton of particulate matter reduced once operating and capital costs of such a policy was considered. Thus, as part of PlaNYC, the NYC Department of Environmental Protection (DEP) and the Mayor's Office of Long Term Planning and Sustainability worked on developing legislation to be introduced at the NYC Council that would lower the existing sulfur cap in Number 4 heating oil and on agency regulations that, over time, would significantly reduce the use of #4 heating oil and effectively phase out the use of #6 oil in New York City.[f] The DEP's regulations will be discussed in a later section of this narrative.

Because, as discussed, Number 4 heating oil is the mixture that results from blending specific ratios of Number 2 and Number 6 heating oils, the developed legislation, Intro 194-A, complemented the previously discussed new State law that reduced the sulfur content in Number 2 heating oil, which accounted for 70% of the heating oil used throughout NYC, by 99%. This change in the primary ingredient of Number 2 oil was understood to have the spillover effect of reducing the sulfur content of Number 4 oil used in New York City.

However, it was necessary to guarantee this effect via legislation to prevent a situation in which, through different mixing ratios or other means, the expected decrease through the mixing process would not take place at the refinery. In this way, after much negotiation, in August 2010, NYC Mayor Michael R. Bloomberg enacted Intro 194-A, which established a sulfur cap of 1,500 parts per million for Number 4 heating oil used in New York City as of October 1, 2012—one half of the existing sulfur cap of 3000 ppm for that fuel.[164] Number 6 oil cannot be made significantly cleaner than the current standards require; Intro 194-A essentially required suppliers to create Number 4 heating oil using a portion of low-sulfur or ultra-low-sulfur Number 2 oil. Despite keen opposition by certain industry advocates, this feedstock was thought to be readily available because ultra-low sulfur Number 2 oil is the current standard for transportation diesel oil in the United States.[165]

Once again, issue coalitions played a significant role in supporting and increasing the visibility of the key components of the proposed city legislation by offering public testimony, utilizing social media and blogs, circulating policy action alerts via email to their members, speaking to the press and other media outlets, and educating local City Council members on the strengths and needs of the proposed legislation. For example, the Environmental Defense Fund named Intro 194-A a "landmark legislation" that would especially benefit children, senior citizens, and those with respiratory illnesses in New York City by quickly reducing soot pollution.[166] The American Lung Association and New York City Department of Health both also cited the enormous public health benefits, while other stakeholders such as the New York Oil Heating Association, Metro Terminals and Metro Biofuels, and Teamsters Local 553 gave strong support to the legislation, not only for the reduction in sulfur levels, but also

[f] Of the city's million buildings, less than 10,000 use No. 4 or No. 6 heating oil, while the rest use No. 2 oil or natural gas. These buildings host 9,896 boilers that use No. 6 and/or No. 4 fuel oil (6,211 operate using No. 6 fuel oil and 3,865 operate using No. 4.)

for the additional biodiesel requirement.[167] Intro 194-A additionally required that all heating oil used in New York City would have to contain at least 2% biodiesel fuel.[g] By prescribing a cap on the amount of allowable sulfur in Number 4 heating oil and further displacing heating fuel by replacing it with 2% biodiesel, this measure was expected to lead to quantifiable reductions in the particulate matter emissions attributed to this fuel source. This broad-based coalition of civic, professional, environmental, labor and industry organizations was critical in developing widespread public and political support for the policy. This coalition of groups does not permanently disband after a policy win, as will be described in a later section of this report. While individual organizations may be more or less active depending on the issue, in fact, this type of coalition has been an ongoing policy force in New York City in support of a wide array of other PlaNYC initiatives such as the push in support of Mayor Bloomberg's 2007 congestion charge on vehicles entering Manhattan's central business district proposal and the push in support of the recently enacted Greener, Greater, Buildings Plan for the City of New York.

STRATEGY 3: PROMOTING THE USE OF BIODIESEL IN HEATING FUELS

The biodiesel industry has seen tremendous growth in the past few years in the U.S. The National Biodiesel Board reported that the biodiesel industry had 1.85 billion gallons per year production capacity at 165 plants in 2007 and that, due to underutilization by the petroleum industry, only approximately 22% of that capacity was actually being realized that year.[168] However, federal tax incentives and other state policies have encouraged the biodiesel industry's growth and the ramping up of biodiesel production. The federal biodiesel blender's tax incentive, for example, mandated a $1.00/gallon tax credit for agri-biodiesel and $0.50/gallon tax credit for waste-grease biodiesel (although the tax credit expired in December 2011).[169] Also, the Renewable Fuels Standard (RFS), created under the Energy Policy Act of 2005, set a blend level for the production of renewable fuels, including biodiesel, as well as secured a fuel volume mandate.[170] The RFS was amended by the Energy Independence and Security Act of 2007, which grew the RFS from 9 billion gallons by 2008 to 36 billion gallons by 2022,[171] and also raised yearly production of renewable fuels, specifically requiring that 500 million gallons of biodiesel and biomass-derived diesel fuel be blended into motor diesel in 2009, ramping up to one billion gallons by 2012.[172] The one billion gallon goal was met in January 2012, and a study by the National Biodiesel Board estimated that such production supported 39,027 U.S. jobs accounting for $2.1 billion in household income.[173]

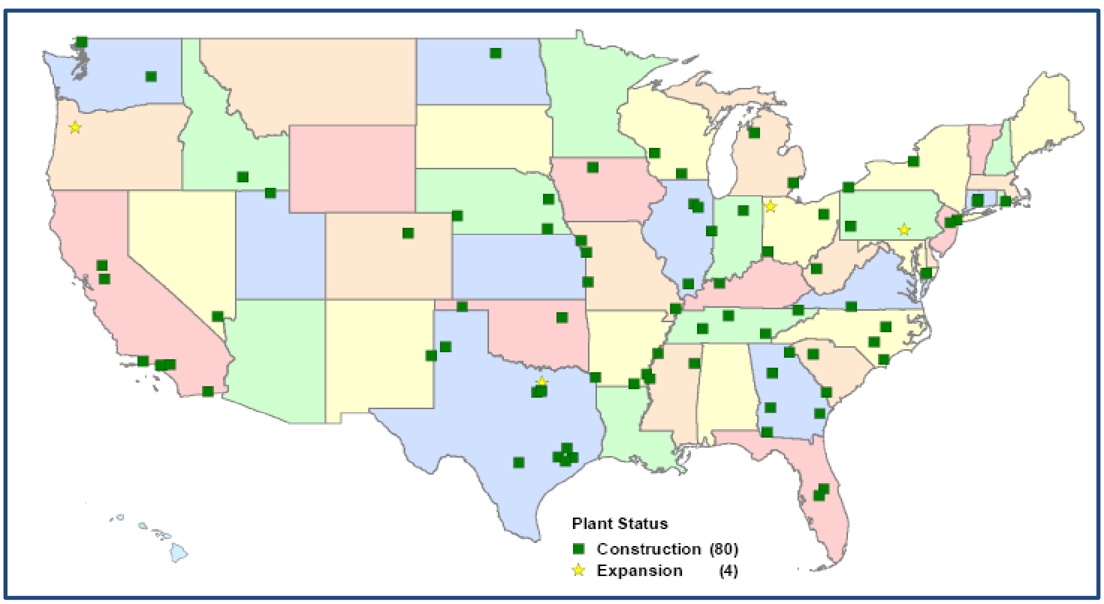
In addition, a number of local and state governments had also concluded that supporting the use of bioheating fuel would provide significant and achievable benefits. In 2004, for example, 130 biodiesel-related bills were introduced across the country, and 27 of these bills passed in 25 states.[174] In 2005, 30 biodiesel bills passed in 36 states and in 2006, by the time PlaNYC-related initiatives were being conceptualized, 100 biodiesel specific bills were

[g] One of the primary ways this can be accomplished is through recycled restaurant grease. Estimates of waste vegetable oil available from the City's 22,822 restaurants vary but stay within a range between 13 and 53 million gallons. This represents more than ample supply of feedstock for the majority of the biodiesel volume required by Intro 194-A.

considered in 28 states. These bills included incentive programs, tax credits, usage mandates and/or goals in transportation and heating oil fuel by state and local governments, and research and development grants. These laws and proposals were complemented by the significant support provided by the federal government and 35 states, including New York, for the production of biodiesel. Although envisioned for the transportation market in many cases, the biodiesel produced as a result of these incentives was also being used in blends for the heating market and for export to Europe, where biodiesel is widely used. Legislation to encourage the production of biodiesel has been enacted in many states including Arizona, Colorado, Connecticut, Florida, Georgia, Illinois, Indiana, Iowa, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Oregon, Pennsylvania, Rhode Island, South Carolina, Texas, Virginia and Washington.

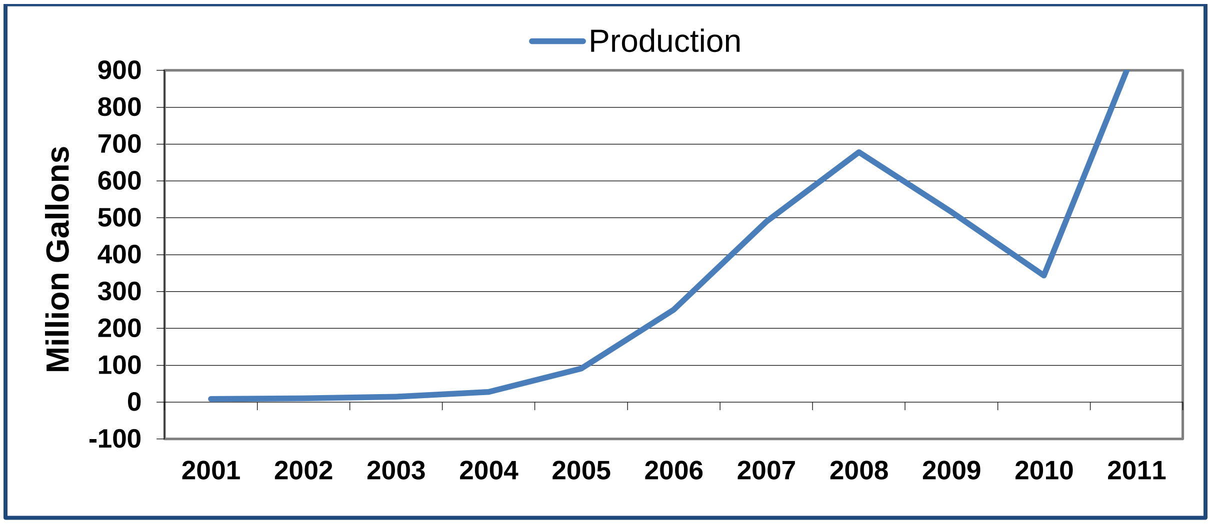
According to the National Biodiesel Board, there were 165 operating biodiesel production facilities with 84 plants under construction as of 2007 (most recent available data), which greatly expanded production capacity (see figure 15 below).[175] The national production capacity has continued to rise as more companies expand or open new terminals across the United States—some of them in the New York Metro area and neighboring states. New York State has a few incentives to support this industry. For example, sales of B20 are partially exempt from motor fuel, petroleum business, fuel use and sales and compensating use. Moreover, producers get a $0.15 per gallon credit after the first 40,000 gallons produced per year, capped at $2.5 million per year for no more than four consecutive taxable years per bioheating fuel plant.[176,177] These incentives and other market forces have caused the biodiesel supply to increase exponentially year after year; volumes rose from 25 million gallons in 2004 to 400 million gallons in 2007, jumping to 1.1 billion in 2011 (see figure 16) and 557 million for the first half of 2012.[178] (Again, note that production capacity is greater than the actual number of gallons of biodiesel sold.)

Figure 15. U.S. Biodiesel Production Plants under Construction or Expansion as of 09/07/2007.



Source: National Biodiesel Board

Figure 16. U.S. Biodiesel Production, 2001-2011.



Source: EIA Monthly Energy Review, Table 10.4. http://www.eia.gov/totalenergy/data/monthly/#renewable

Though biodiesel is considered by many to be cleaner than petroleum-based diesel fuels, in 2008, a national debate erupted on the sustainability of producing fuel from food crops. Publications by Timothy Searchinger and others argued that the production of some forms of vegetable-based biodiesel—specifically soybean-based biodiesel, the most prevalent feedstock used in biodiesel production—can displace food crops, increase global food prices, and promote the clearing of tropical forests, wetlands or grasslands.[179,180] It was hypothesized that the demand for biofuels in the United States and other countries, and the demand for food displaced by biofuels production, would cause widespread deforestation and other "indirect land use impacts." Carbon emissions from deforestation are critical to the global carbon budget, as tropical forest clearing accounts for almost 20% of anthropogenic carbon emissions and destroys globally significant carbon sinks,[181] not to mention has impacts ranging from loss of biodiversity and habitat to increased local vulnerability to fires, to increased stress on water sources and to the loss of subsistence forest products. In addition, the production of any agricultural crop may generate greenhouse gases through the use of fossil-fuel based crop fertilizers and pesticides, and the use of fossil fuels to transport fuel stocks over long distances for processing and distribution.

While new, and not uniformly accepted, these arguments were quickly taken up by the Union of Concerned Scientists, the Natural Resources Defense Council and other groups. Other researchers, scientists, and trade groups (1) noted the uncertainty in attributing indirect land use change to biofuels as opposed to the growth in population, demand for meat, timber extraction, internal migration, suburbanization, and other land use changes, (2) questioned the assumptions made about the elasticity in food demand, land productivity, and land conversion, and (3) pointed out that the indirect effects of the exploration, production, and development of petroleum fuels has not been calculated. Clearly, at the time, there were significant differences of opinion among qualified parties on critical issues.

Up to that point, much of the biodiesel legislation passed in the United States did not address the sustainability issues associated with biofuel production and included no limitations on the sources of the fuel to restrict the sale and purchase of fuel produced in environmentally damaging ways. The debate managed to suspend or slow down many biodiesel initiatives by cities, states, and even several European countries, because many existing biofuel mandates did not have provisions or mechanisms to address sources or sustainability. For example, neither the 2006 New York State executive order that required state agencies to use biodiesel,[182] nor the 2007 Maine law that instituted alternative-fuel vehicle rebates and grants,[183] addressed issues of source or sustainability. Other states such as Pennsylvania, Virginia, Illinois, and Minnesota have enacted biofuels legislation that promotes the use of "domestic" or in-state biofuels through incentives or triggers based on attaining certain thresholds of in-state production; these laws addressed sourcing to some degree but not in a way that would allow for consideration of indirect land use effects or other sustainability factors.

Several European and Asian nations, as well as the European Union as a whole, had recently enacted or were contemplating policies limiting the types of bioheating fuels eligible for financial incentives and other regulatory programs on the basis of lifecycle greenhouse gas emissions and other sustainability criteria.[184,185,186] Meanwhile, at the policy analysis phase by the Mayor's Office of Long Term Planning and Sustainability, the U.S. EPA had not yet developed a regulatory standard, and the resolution of the rulemaking process for the U.S. Energy Independence and Security Act of 2007 concerning "biomass-based diesel" that would require such fuel to have at least 50% less lifecycle greenhouse gas emissions than baseline petroleum based fuels,[187] was thought to be years away.

The Mayor's Office of Long Term Planning and Sustainability understood that to guard against environmentally harmful effects, it would be necessary to apply a sustainability standard to bioheating fuel purchases to ensure that the fuel New York City uses decreases, rather than increases, the city's carbon footprint and does not contribute to the global clearing of tropical forests and the related threats to biodiversity. With a number of local stakeholders urging for the inclusion of a sustainability standard in any bioheating fuel legislation introduced in NYC,[188,189,190,191] the City considered various pragmatic and enforceable ways to prevent the purchase of fuels from sources that were potentially unsustainable.

One idea was to wait until the U.S. EPA promulgated a sustainability standard and issued fuel determinations, so that the City would be able to analyze those standards and determine whether it could be used as a criterion for the selection of all heating fuels. Another idea was to apply a fuel-neutral performance standard rather than to specify the purchase of one designated fuel, so that the market could sort out the lowest cost and most sustainable alternative. However, given the uncertain and potentially lengthy timeline of any federal regulatory action and the challenges with enforcing performance standards, the City of New York decided to enact a low-level biodiesel requirement (B2 or 2% biodiesel) and to encourage and support a private-sector partnership that facilitated the collection, processing and delivery of biodiesel made from the City's waste restaurant grease in order to meet that mandate. Long Island's METRO Biofuels LLC, one of the first biodiesel manufacturers to blend biodiesel with heating oil, partnered with the Doe Fund's Ready Willing and Able (RWA) Community Improvement Project's Resource Recovery Initiative, which provides transitional work to formerly homeless and incarcerated men.[192] The Doe Fund hired such workers to collect thousands of gallons of used cooking oil from the City's restaurants and transport it to Metro's biodiesel processing facility in Brooklyn. This partnership was hailed by the NYC's Mayor's Office as a step towards a cleaner, greener, and energy-independent City that also illustrated the significant value that creating green jobs can bring to the local economy.[193] The shaping of this legislative proposal in this way, proved significant in securing broad stakeholder support for the legislation and led to the development of a more expeditious and sustainable set of solutions that addressed not only environmental goals, but also economic and social goals.

NYC then continued to move forward with the implementation of initiatives related to increasing biodiesel use in the City's transportation fleet and continued to consider bioheating fuel blends as a feasible, short-term strategy to reduce building emissions and achieve a wide array of benefits, including lowering air pollutants and greenhouse gas emissions, reducing maintenance costs, providing operational benefits, strengthening the alternative fuels market, supporting local businesses, and increasing energy independence and the diversity of supply.

Further, the use of these fuel blends did not require boiler retrofits or significant changes in existing distribution systems, and information from area fuel suppliers showed a minor price difference, if any, from comparable grades of petroleum heating oil. Indeed, cost analysis gave evidence that biodiesel blends can help lower and stabilize space heating and/or transportation costs because soybean oil and biodiesel prices are never as high or fluctuate as much as the price of crude oil.

Because there were some operational concerns among the fuel purchasers and facilities' managers and operators in key New York City agencies, before pursuing legislation the Mayor's Office of Long Term Planning and Sustainability undertook a benchmarking analysis to identify large-scale users, determine best practices for implementation, and assess operational and cost concerns. This analysis concluded that bioheating fuel had been successfully tested in a number of field, laboratory, and pilot tests in New York and other states including one high profile demonstration project to heat Teddy Roosevelt's Sagamore Hill home in Long Island and in many residences and buildings in New York City. One supplier in the Bronx, Schildwachter and Sons, has been blending, storing, and selling millions of gallons of a B20/Low Sulfur heating oil blend to 8,000 customers in New York City and Westchester for over five years, without any significant complaints.[194] In addition, field tests of biodiesel blends with No. 2 and No. 6 oils in residential or commercial boilers have revealed no operational problems. For example, a study in Newburgh, New York, tracked the use of B20 in approximately 100 homes over four heating seasons, and found no problems related to the storing, blending, delivery or use of the bioheating fuel.[195]

Similarly, officials at the U.S. Department of Agriculture's Beltsville Agricultural Research Center have successfully used bioheating fuel since 2000; and the Vermont Department of Buildings and General Services and the New York Power Authority's Charles Poletti Power Plant in New York City also conducted successful field projects testing biodiesel blends with No. 6 fuel oil. Biodiesel does act as a solvent, and when first used may dissolve sediments and deposits in fuel lines that are left by higher sulfur petroleum-based fuels. Initially, the use of high percentage bioheating blends may hasten the clogging of fuel filters and warrant an additional filter replacement during the initial transition from the exclusive use of petroleum-based diesel. However, after the initial transition, maintenance needs would actually decrease because biodiesel produces less soot and residue, helping to prevent clogging and deposits of residual materials on the heat transfer surfaces of the boiler equipment. Residue adds resistance to heat transfer, reducing the operational capability of the heat exchanger. Testers found that with the use of bioheating fuel, the boilers remained cleaner longer, required less maintenance and delivered more heat. The analysis revealed that given its properties as a solvent, the use of pure B100 would require special additives or special fuel heating systems to operate in colder weather and may cause rubber seals and gaskets to wear faster. However, the B20 and lower blends commonly used in bioheating fuel applications do not cause such problems. Extensive research showed that operational concerns related to bioheating fuel are largely eliminated with the use of blends of B20 or lower, and laboratory and field tests had demonstrated that B2, B5, B10 and B20 bioheating fuel can be used in almost every home or building without any additions or modifications to existing heating systems.

Finally, B20 was also used as a transportation fuel by about 500 government and commercial fleets across the U.S and, in New York City, government agencies had introduced B5 or B20 biodiesel blends into its existing fleet of thousands of heavy trucks and eight large ferries without experiencing any operational or maintenance problems. Indeed, the greater viscosity of biodiesel improved engine performance. Moreover, biodiesel blends increased the lubricity of diesel, reducing wear and extending fuel system and engine life.

These well-documented operational benefits and fuel availability data further confirmed that the opportunity existed in New York City to blend biodiesel with home heating oil to improve its environmental performance. Before this analysis was completed, two bills were already pending before the New York City Council that would phase-in the use of bioheating fuel: Introduction 594 and Introduction 599 of 2007.

Introduction 594 would mandate the use of bioheating fuel blends in New York City, starting with a blend of 5% biodiesel and 95% regular heating oil (B5) and increasing the biodiesel percentage every two years until reaching the widespread use of B20 bioheating fuel. This bill also included a sulfur reduction requirement for all heating oil sold in New York City. Finally, Introduction 594 addressed sustainability concerns by defining “biofuels” as those produced “in a sustainable manner,” and leaving that determination to administrative rulemaking to classification of fuels on the basis of their lifecycle greenhouse gas emissions, local greenhouse gas emissions, or other relevant criteria. Introduction 599 proposed an identical mandate to blend a certain percentage of biodiesel into heating fuel but starting at a later timeframe.

Each of these bills had key legislative language issues that required additional analysis, discussion and negotiation including, for example, the percentage of biodiesel that was required under each proposal, the timeframe for implementation, the definition of “sustainable” biodiesel, and the required reporting by fuel terminals and regulating city agencies. Still, after much research and consultation with stakeholders, the Mayor's Office was certain that requiring sellers of heating oil to blend biodiesel into traditional petroleum-based fuels was a critical way to reduce air pollution from buildings in New York City, reduce the City's dependence on petroleum, and reduce the City's overall greenhouse gas (GHG) emissions.[196]

Key goals of the new legislation included ensuring that an adequate supply of locally-produced, more sustainable biodiesel could be procured—that is, that enough waste vegetable grease could be collected from local restaurants and processed at local fuel terminals to supply the new blending requirements—and supporting the creation of local jobs as an effect of the legislation. In this manner, as mentioned in the previous section of this narrative, the revised Introduction 194-A was drafted to include a B2 mandate, which followed with two controversial hearings in 2009 and 2010.

Heating systems in NYC buildings use about a billion gallons of fuel oil annually and if biodiesel blends were used at a B2 level citywide, about 20 million gallons of biodiesel would be needed each year to satisfy the B2 mandate.[197] Representatives from METRO Terminals and METRO Biofuels claimed that the proposed 2% biodiesel requirement could be easily met because of wide availability and no need for new equipment; resulting in the elimination of over 320 million pounds of carbon each year due to reduced use of petroleum-based diesel.[198] A study conducted by Cornell University and NYSERDA showed that potential waste vegetable oil production in NYC could yield between 32% and 85% of the biodiesel needed for a mandate, while local biodiesel industry members claimed that 50-75% of a mandate could be fulfilled with locally derived waste vegetable oil.[199] Studies of the capacity of New York City's restaurants to produce waste grease for use in biodiesel showed that approximately 1-1.5% of New York City's entire heating oil needs could be filled using New York City restaurant grease[h]—more volume than necessary to meet a 2% biodiesel mandate. The DEP also cited the benefits to sewer infrastructure and improved water quality, as less waste grease would be circulating and contributing to problematic clogged sewers.[200]

After much research, analysis and negotiation, the revised Intro 194-A was adopted in New York City in 2010 when Mayor Bloomberg signed the legislation as Local Law 43. The final legislation contained two main components regarding strategies that dealt with sulfur and biodiesel level requirements:

- As of October 1, 2012, sulfur levels in heating oil No. 4 are capped at 1,500 ppm.
- As of October 1, 2012, all heating oils are required to contain at least 2% biofuel.

The sulfur level requirement was estimated to reduce soot emissions in the city by 40%, while the biodiesel replacement would mean the elimination of petroleum emissions, resulting in even greater public health benefits.[201] This legislation complemented the newly enacted New York State law, and together with certain DEP regulations that will be

[h] Calculations based on: Cornell Cooperative Extension, 2005: An Assessment of Waste Vegetable Oil Supply in Brooklyn, NY and its Potential as a Biodiesel Feedstock; and NYSERDA, 2003: Statewide Feasibility Study for a Potential New York State Biodiesel Industry.

described subsequently, resulted in a network of policies that were sensible, cost-effective, and beneficial to the health of New Yorkers.[202]

STRATEGY 4: PROMOTING THE RETIREMENT OF OLD, INEFFICIENT CITY BOILERS

Of the city's million buildings, less than 10,000 buildings use #4 or #6 heating oil; while the rest use cleaner, but more expensive, Number 2 oil or natural gas. However, as discussed, these 10,000 are often the largest buildings that consume a significant amount of fuel. A recent study found that just this 1% of New York City's buildings produce more air pollution—86%— than all the city's cars and trucks combined.[203] Thus, phasing out the use of residual oil was priority for the Bloomberg Administration. The mayor's only PlaNYC-related announcement in the 2010 State of the City address was a commitment to "green" the fuel used to heat buildings in the city given that New York City is the only place in the U.S. where bunker fuel is widely used as a heating fuel. To this end, the Mayor's Office of Long Term Planning and Sustainability and the NYC Department of Environmental Protection developed an approach to phase out residual heating oil in an aggressive but realistic way over the next 20 years. This regulatory effort complemented the aforementioned legislation introduced in the New York City Council.

Section 24-102 of the Administrative Code of the City of New York declares that it is the public policy of the City to "preserve, protect, and improve the air resources of the City because every person is entitled to air that is not detrimental to life, health, and enjoyment of property."[204] Specifically, the section declares air emission of toxic substances and pollutants, including those resulting from the use of fuel burning equipment, as detrimental to the health and welfare of New Yorkers, and that it is the public policy authority of the NYC Department of Environmental Protection (DEP) to actively regulate and reduce air emissions. Similarly, Section 1403(c) of the Charter of the City of New York and Section 24-105 of the Administrative Code authorize the DEP Commissioner to regulate and control the emission of harmful air pollutants through the issuance of Work Permits and Certificates of Operation that are contingent on the use of equipment, and by extension fuel, that will satisfy the Commissioner as to their emission of contaminants. Finally, Section 24-125(b) of the NYC Administrative Code states that in order to reduce the emission of air contaminants and to insure optimum combustion in fuel burning equipment, the NYC DEP may not issue a permit or a certificate of operation unless the equipment is shown to the satisfaction of the department to burn appropriate fuel and, if the equipment uses residual fuels, that it uses emissions controlling devices as determined by the NYC DEP.[205]

Given this regulatory authority, the Department of Environmental Protection proposed to amend Chapter 2 of Title 15 of the Rules of the City of New York to prohibit the use of Number 4 and Number 6 fuel oils in heat and hot water boilers and burners, unless it can be demonstrated that the emissions of Particulate Matter (PM) and Oxides of Nitrogen (NOx) are equivalent to or cleaner than prescribed fuel types such as Natural Gas.

The rule further sought to improve air quality by requiring an annual efficiency test of all DEP-regulated gas and oil combustion equipment for heating or hot water of a certain size (i.e. those with a heat input rating of 1 million btu/hr or greater); certified by a licensed professional engineer. While the DEP already tested boiler combustion efficiency in very large boilers every three years upon permit renewal, new testing equipment makes possible annual testing of a greater number of regulated boilers on a more frequent basis. Annual testing of more boilers, hot water heaters, and other regulated combustion devices would detect malfunctions, permit tuning and repair, and result in more efficient fuel combustion, which will result in decreased fuel use and air pollution. Finally, additional testing would provide building managers with key information on the efficiency of their central heating systems. The DEP anticipated that this information would help building boiler operators make better decisions about investments in their boilers and heating systems that would in turn allow for fuel savings. Overall, the DEP's new inspection rules would ensure that boiler performance and fuel efficiency does not decline over time because of poor maintenance or because building owners were holding on to old, inefficient, outdated equipment.

Specifically, the developed rulemaking decreed the following:[206]

- Effective immediately, no new boiler or burner installations will be permitted to use No. 6 or No. 4 oil, and instead must use one of the cleanest fuels, such as ultra-low sulfur No. 2 oil, biodiesel, natural gas, or steam.
- Beginning July 1, 2012, existing buildings that use No. 6 oil must convert to a cleaner fuel (low-sulfur No. 4 oil or cleaner) before their three-year certificate of operation expires. This will result in a full phase-out of No. 6 oil by mid-2015.
- By 2030 or upon boiler or burner replacement, whichever is sooner, all buildings must convert to one of the cleanest fuels.

The provisions of the enacted regulations were the product of much research, analysis, and many meetings with stakeholder groups including environmental, real estate, utility and oil industry representatives. As a result of these discussions, it was decided, for example, that though all landlords had to comply with the new regulations, property owners that could demonstrate a severe financial hardship would be able to apply to the DEP to develop an appropriate compliance schedule—that is, to follow the new regulations in an extended, but defined timeline. Given this compliance waiver language, it is up to the discretion of the DEP to enter into binding agreements with landlords on an extended schedule to comply with the new rule.[207] The implementation timeline, for example, was originally devised given the insights of the aforementioned Excel-based model developed by the Mayor's Office of Long Term Planning and Sustainability; which included an assessment of the ages, fuel characteristics, pollutant emissions, and boiler system retirement patterns of the existing fleet of permitted boilers in New York City under "business as usual" conditions compared to accelerated retirement policy options.

The proposed regulations were published for comment in the City Record on January 27th, 2011 and the required public hearing was held on February 28th, 2011.[208] They were officially enacted as part of the Rules of the City of New York and became effective on the 1st of July of 2012. These adopted regulations to phase out Numbers 4 and 6 heating oil, upon full implementation, will reduce the amount of fine particles emitted from heating buildings by at least 63%, and could lower the overall concentration of fine particles in the city's air from all sources by 5%.[209] The $PM_{2.5}$ eliminated by these regulations would be the equivalent of removing approximately 1.5 billion to 3.3 billion miles of heavy-duty truck traffic from New York City roads every year. The NYC Department of Health and Mental Hygiene estimated that these air quality improvements could prevent approximately 200 deaths, 100 hospitalizations, and 300 emergency room visits for diseases caused by air pollution each year. Finally, the regulations will also reduce carbon dioxide emissions by approximately one million metric tons, or over 3% below 2005 levels, constituting a significant strategy in addressing the City's greenhouse gas emissions.[210]

STRATEGY 5: PROMOTING THE USE OF CLEANER-BURNING HEATING FUELS

By working with partners in the City Council and the environmental and business communities to enact a local law that lowers the sulfur limits in Number 4 oil to 1,500 ppm starting in 2012; and by enacting the City's DEP rules that, when fully in effect, will require that all boilers in New York City burn low-sulfur Number 2 oil, natural gas or other clean fuel; and by working with a coalition to enact a New York State law to reduce the sulfur content of Number 2 oil to only 15 parts per million of sulfur; the City of New York led a contagious effort to promote the use of cleaner heating fuels and reap significant air quality and public health benefits.

Still, Mayor Bloomberg recognized that more could be done to ensure that New York City achieved its goal to attain "the cleanest air quality of any large U.S. city," as proposed in PlaNYC. Therefore, in an effort to supplement DEP oil regulations that would phase out Number 4 and 6 heating oil by 2030, NYC launched its Clean Heat Program, which utilized $100 million in financing to encourage buildings to convert to cleaner heating fuel at a quicker pace than the regulations mandated.[211] There was potential to accelerate air quality benefits if buildings voluntarily phased out these fuels prior to the regulatory deadlines. The idea was to go beyond simply telling building owners what to do, to educate them about public health impacts, and in turn help them to help New Yorkers breathe cleaner air. This effort brought together a number of major stakeholders, including banks, energy providers, and environmental groups; built private-public partnerships; and utilized a combination of incentives and educational tactics in collective action.

Together with environmental advocacy organizations such as Environmental Defense Fund and the gas utilities companies such as Consolidated Edison and National Grid, the Mayor's Office of Long-Term Planning and Sustainability and the Department of Environmental Protection began a program to educate building owners and residents about the risks associated with heavy oils, as well as the financial and operational benefits of switching to cleaner fuels. The campaign encouraged the real estate community and city residents to "Quit Six" by 2013, highlighting the public health impacts of Number 6 heating oil. Building owners and associations, environmental advocacy groups, the City's Mayor's Office, Department of Environmental Protection and the Mayor's NYC Service initiative were involved in launching a program to encourage and support the early phase out of Number 4 and 6 heating oils.

Figure 17. Soot Pollution Emitted From Number 4 and Number 6 Heating Oil Combustion in NYC.

Source: PlaNYC 2011.
Credit: Environmental Defense Fund/Isabelle Silverman

The campaign promoted three strategies to "Quit Six." First, it encouraged buildings that were able to switch to natural gas to do so as soon as possible given that natural gas is less expensive than cleaner Number 2 oil and hence buildings could recover capital expenses through operating savings in just a few years. Second, buildings that lacked sufficient gas service availability or equipment could pair efficiency measures with switching to slightly more expensive Number 2 oil (now required by the State to be low-sulfur), enabling the switch to occur on nearly a cost-neutral basis. Finally, the campaign aggregated buildings that were ready to convert to gas but that were located in neighborhoods of the city that required gas delivery system upgrades and expanded natural gas infrastructure; this aggregation created economies of scale that helped to lower the cost of fuel conversion, infrastructure upgrades, and investments needed by the local utilities.[212]

The City also worked with interested parties to create a large fund to finance fuel conversions; banks such as Chase, Deutsche Bank, Hudson Valley Bank, City, and Community Preservation Corporation collectively committed $90 million in private lending for conversion projects. The NYC Energy Efficiency Corporation (NYCEEC) committed $5 million to create a loan loss reserve fund; $40 million was secured from Deutsche Bank's Community Clean Heat Fund, while more was raised through the housing lender Community Preservation Corporation; each program of which focused on financing efforts specifically for low and moderate-income buildings.[213]

Other private stakeholders including energy companies such as Con Edison and National Grid, and major real estate portfolios helped mobilize customers and coordinate infrastructure planning. An expanded partnership with the Environmental Defense Fund offered technical assistance and outreach to buildings going through conversion processes, while Con Ed and National Grid tried to alleviate the financial burden of converting to natural gas by upgrading their own infrastructure.[214] The Hess Corporation, the City's largest provider of heating oil, also began to offer building owners incentives to switch to a cleaner fuel.

The City's Clean Heat Program was praised by National Grid, while Hess Energy Solutions deemed it a 'win-win-win;' the American Lung Association hailed Mayor Bloomberg for bringing together all the major stakeholders and formulating creative solutions to help accelerate the goals of the City's legislation.[215] These multiple private-public partnerships were cemented to reduce barriers to cleaner fuel availability, offer needed technical and financial assistance to building owners and managers, connect interested boiler managers to needed resources, accelerate the retirement of outdated, inefficient equipment, help reach the new PlaNYC goal of reducing $PM_{2.5}$ emissions by 50% within a two-year period, and capture the public health benefits of citywide air pollution reductions.[216]

STRATEGY 6: CONVERTING SCHOOLS BOILERS TO ALLOW THE COMBUSTION OF CLEANER HEATING FUELS

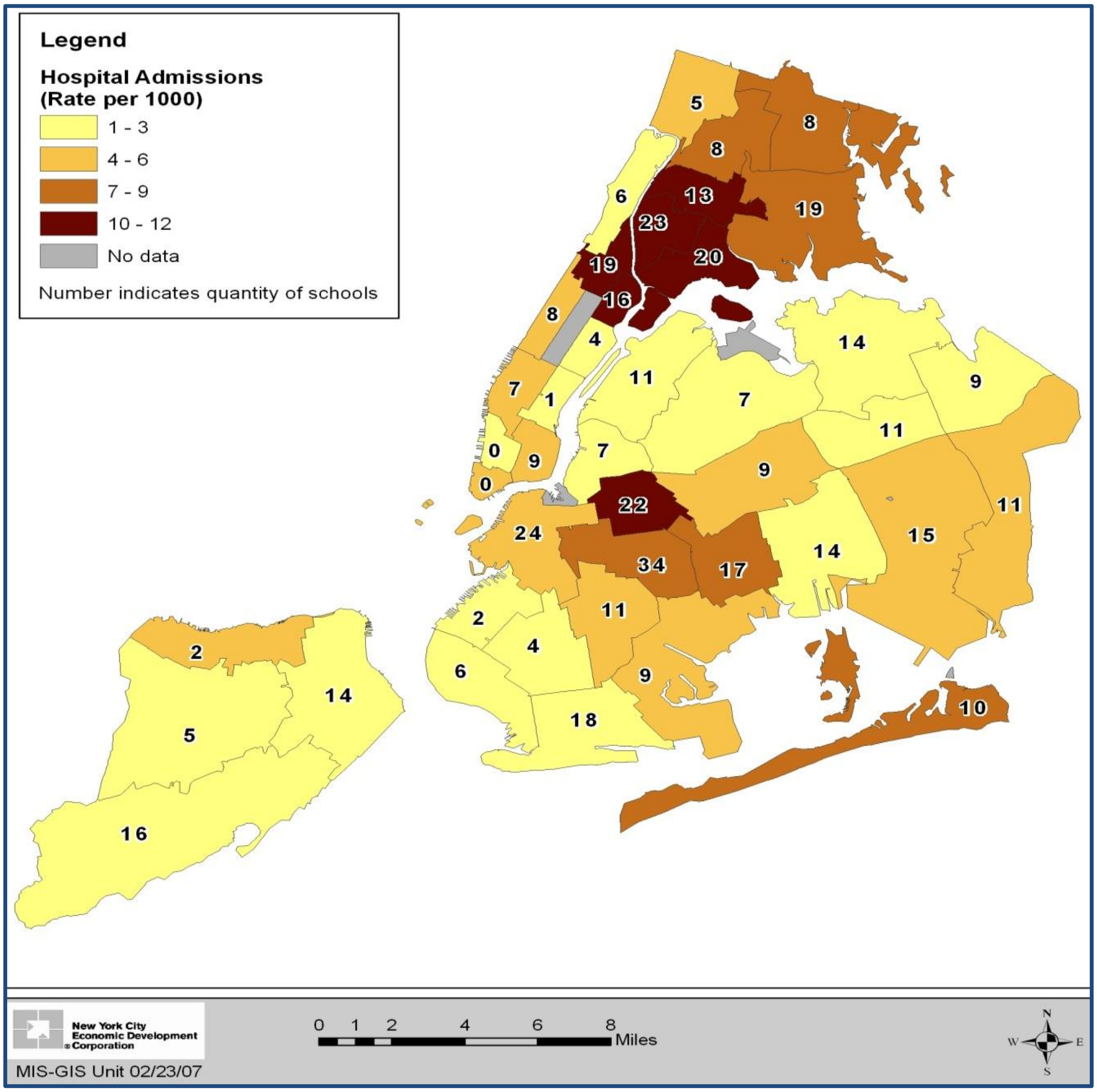
In 2007 in New York City, 420 schools—roughly one-third of them—had old, inefficient, Number 4 or 6 heating oil boilers to provide heat and hot water to the school buildings. Schools house the City's most sensitive demographic when it comes to health impacts from air pollution, and their boilers were a source of neighborhood-level air pollution. Thus, through PlaNYC, the City made a commitment to upgrade and replace the boiler systems of at least 100 of these schools to enable the boilers to burn cleaner fuels, which occurred well before the enactment of any City or State legislation.

PlaNYC set aside $285 million to be made available over a 10 year period and the Mayor's Office of Long Term Planning and Sustainability and New York City Department of Health and Mental Hygiene conducted an analysis of the locations of all New York City schools that combusted residual oil in order to identify and rank neighborhood clusters. At that time, many of the schools burning residual oil were located in neighborhoods where asthma hospitalization rates were at least twice as high as the national average.[217] Through this epidemiology analysis, the City prioritized neighborhoods by grouping them into two categories. Category 4 areas had childhood asthma hospitalization rates of 10-12 asthma-related hospital admissions per 1,000—the city's highest, while Category 3 areas had childhood asthma hospitalization rates of 7-9 per 1,000. The schools were then geocoded using ArcView GIS and schools located in Category 4 neighborhoods (those with the highest child asthma hospitalization rates) were prioritized for boiler upgrades or conversion to achieve the maximum local health benefits. These neighborhoods were concentrated in the Bronx, Harlem, Central Brooklyn, and along Jamaica Bay (see figure 18).

Since the launch of PlaNYC, the City has already replaced boilers at 13 facilities, leading to a 50% reduction in CO_2 emissions and a 44% reduction in $PM_{2.5}$ emissions from these schools, as well as improved boiler efficiency, and reduced fuel consumption and maintenance costs. Planning for the additional boiler replacements are underway and the City will complete conversions at 15 additional facilities by 2013. Conversions of the 100 targeted schools are expected by 2017.[218] To date, the New York City Department of Education, in partnership with the Department of Citywide Administrative Services' Division of Energy Management, has developed a comprehensive greening plan for NYC schools which includes upgrading and improving the efficiency of heating and lighting systems and the replacement of Number 4 and Number 6 fuel oil boilers in up to 287 schools by 2030. The plan, the 2011 NYC Schools Comprehensive Plan: Greener, Healthier Schools for the 21st Century, was announced in 2011,[219] and outlines a strategy to prioritize schools with the greatest need for environmental improvements due to equipment age and low energy efficiency scores.[220]

Figure 18. 2005 Asthma-Related Hospital Admissions, Children 0-14 years by United Hospital Fund Neighborhoods (UHF), and Distribution of NYC Schools Using Number 4 or Number 6 Heating Oils.

NYC neighborhoods with the highest distribution of schools using oil grade 4 or 6 are also neighborhoods with highest asthma-related hospital admissions**.**



Source: Mayor's Office of Long Term Planning and Sustainability.

These improvements are not only expected to significantly improve local air quality across New York City neighborhoods, but they are an integral part of the City's strategy to reduce greenhouse gas emissions by more than 200,000 metric tons of CO_2e. The City's goal is to reduce greenhouse gas emissions by 30% by 2017 and with 13% of the City government's total CO_2e emissions coming from government buildings burning Number 4 and Number 6 heating oils,[221] boiler upgrade strategies are critical and have a high level of government support.

Because it will take years until all school boilers have been upgraded and replaced and are able to combust cleaner fuels, the strategy to reduce air emissions from school boilers was expanded in 2009 to include the installation of fuel catalysts and economizers. These technologies complement boiler conversions because they are fuel treatment devices that improve boiler efficiency to reduce fuel consumption. In previous trials and pilots, the City attained a minimum 5% decrease in fuel use at facilities equipped with boiler catalysts and a 17% to 62% decrease in fuel consumption at facilities equipped with economizers.[222] In all trials, improved combustion led to less soot and other combustion by-products, improving boiler performance and lowering maintenance costs.

The City set aside funds to pilot these technologies in 19 schools across New York City neighborhoods. Given the schools' fuel use for the 2008 heating season, the City projected a significant reduction in fuel, and a cleaner, more efficient operation. Reducing residual oil use by just 17%—the lower range of the estimate at 1,855,587 gallons—would attain significant air quality benefits including: 23,290 metric tons of CO_{2e}, 116 metric tons of NOx, 548 metric tons of SOx, 33 metric tons of PM, 61 metric tons of CO and 10 metric tons of VOCs removed from the atmosphere.

Using this data, and given the premise that fuel not burned is pollution not emitted, the City applied for Federal Stimulus funding to install these technologies in boilers not yet slated for conversions. In 2009, the City was awarded $4 million from the Federal American Recovery and Reinvestment Act's (ARRA's) Energy Efficiency and Conservation Block Grants to expand the pilot program and install fuel catalysts and economizers at 200 more schools.[223] Installations of these technologies were prioritized based on the fuel type and age of the boilers not yet slated for replacement and the location of the schools—that is, schools with newer Number 4 or Number 6 heating oil boilers in areas of the city with higher-than average pediatric asthma hospitalization rates.[224] To date, this ARRA project is over 50% complete and the installation of these technologies has allowed the city to reduce its fuel costs as it felt the impacts of the national economic recession.[225] At the same time, the City began implementing best maintenance practices for all school boilers.

Overall, by preventing the unnecessary combustion of fuel due to residual fuel use, system inefficiencies and poor maintenance, these technologies have also proportionally allowed the city to reduce its emissions of air and greenhouse gas pollutants. The comprehensive way in which New York City school boilers are being replaced and upgraded will lead to reducing the City's fuel costs and proportionately reducing emissions of greenhouse gases and other air pollutants. This initiative, along with other previously described policies and regulations, made for a comprehensive process to reduce emissions from burning dirty heating oil. Table 9 below summarizes the main components and major milestones of the policy process, listed in chronological order.

Table 9. Summary of Policies, Regulations, and Initiatives Related to Heating Oil in NYC, 2007-2012

2007	• PlaNYC 2030 launched. • City commits to replacing boiler systems at 100 NYC schools, to be completed by 2017. • MANE-VU agrees to pursue strategies to reduce SO_2 emissions, particularly from fuel oils. • NYC Mayor's Office begins conversation with MANE-VU, NESCAUM, NYC DEC concerning New York State legislative strategies. • U.S. Energy Independence and Security Act provides a sustainability standard for "biomass-based diesel." • Intro 594 and 599 introduced regarding biodiesel mandate and biodiesel sustainability definition.
2008	• Governor Elliot Spitzer resigns in March. • New York Community Air Survey (NYCCAS) launched by NYC DOHMH and OLTPS in December.
2009	• Analysis performed of DEP's boiler database that revealed the 10,000 buildings in NYC that burn No. 4 or No. 6 heating fuel. • Hearing regarding Intro 104-A takes place on February 25. • City awarded $4 million from ARRA's Energy Efficiency and Conservation Block Grants to expand boiler technology program in NYC schools. • Strategy to reduce emissions from school boilers expanded to include installation of fuel catalysts and economizers.
2010	• The State of Maine enacts a sulfur cap in April. • Hearing regarding Intro 104-A takes place on May 28. • Connecticut state sulfur cap is enacted in June. • Governor David Paterson passes NY State Local Law 43 that caps No. 2 oil sulfur level at 15 ppm in June. • Mayor Bloomberg signs Intro 194-A into law that caps No. 4 oil at 1,500 ppm and adds biodiesel requirement, August. • DOE Fund and METRO Fuels contract a partnership to collect vegetable grease from restaurants and create biodiesel fuel.
2011	• Clean Heat Program launched as part of new PlaNYC goal to reduce soot pollution by 50% by 2013. • DEP regulations proposed after much research and analysis, January 27. • Public hearing regarding proposed DEP regulations takes place on February 28. • 2011 NYC Schools Comprehensive Plan: Greener, Healthier Schools for the 21st Century was announced regarding improving efficiency of heating and lighting systems and replacing fuel oil boilers in 287 schools by 2030.
2012	• NYC Local Law 43 goes into effect on July 1. • DEP regulations go into effect on July 1. • Intro 194-A goes into effect on October 1.

Part III. Application of Results: Science, Environmental Monitoring and Public Policy

The regulations implemented by New York City and New York State to reduce soot pollution and improve air quality will have significant impacts on the public's exposure to pollution hazards that have been linked to a myriad of adverse health effects. Whether this improvement stems from promoting cleaner heating fuel, implementing a sulfur cap in fuel, promoting the use of biodiesel, or converting specific school boilers, the result will be reductions in $PM_{2.5}$ concentrations that will have extensive public health benefits for New York residents in terms of reductions in deaths, hospitalizations, and emergency room visits. The environmental monitoring data from the NYC Department of Health and Mental Hygiene's NYCCAS (described under strategy 1) was an important component in informing regulations enacted by the city and state. This section will summarize some of the fundamental connections among science, environmental monitoring, and public policy, and will review various examples while linking basic concepts to the NYCCAS project.

Review of Health Benefits of Air Quality Regulations

Researchers have sought to assess the public health impacts of a variety of air quality regulations, actions, and policies. These assessments have been performed with respect to both indoor and outdoor air quality, on local and national scales, and have quantified the extent to which specific initiatives decrease health impacts and improve quality of life. Monitoring data is often the first piece of evidence in determining that improvements have been made at all, and "air quality monitoring has demonstrated that historical air pollution abatement programs have been effective in reducing ambient levels of air pollution."[226] The second piece of evidence stems from the measured health benefits of a given pollution abatement.

For example, numerous studies have examined the health benefits related to the implementation of indoor smoking bans. A study in New York City utilized monitoring data from a small air quality survey to show that ambient aerosol concentrations have indeed declined after the implementation of a ban on smoking in restaurants and bars.[227] Studies around the U.S. have found decreases in adverse health effects due to laws that reduce indoor air pollution, such as with decreases in hospital admissions for heart disease by 27%,[228] decreases in acute myocardial infarction by 8%,[229] and reductions in the prevalence of coronary heart disease/angina.[230] One study in Ireland directly measured indoor air in restaurants and bars pre and post ban of smoking, and found statistically significant improvements in pulmonary function in workers post-ban with median exhaled breath CO and salivary cotinine levels decreased by 79% and 81%, respectively.[231]

Various studies on outdoor air quality initiatives, whether they constitute overarching policy or local action, also provide evidence of health benefits. A steel mill closure in Utah resulted in a reduction in air pollution, especially PM_{10}, and one study found that women who were pregnant around the time of its closure were less likely to deliver prematurely compared to those who were pregnant before or after.[232] Another situation that acted as a natural experiment, quantified by researchers at Brigham Young University, took place in four southwest states in which workers from a copper smelter went on strike for 8.5 months. The strike resulted in a 60% decrease in concentration of suspended sulfate particles and a subsequent reduction of 2.5% in mortality rates.[233]

Similarly, a study in London that looked at the effects of a congestion charging scheme found a decrease of 25% in average daily traffic for cars, and modeled reductions in NO_2 concentrations for a predicted life gain of 26 years per 100,000 in the Greater London area.[234] Another study in Mexico City looked prospectively at the possible effects of implementing five specific air pollution control measures, and models estimated overall reductions of 1% PM_{10}, 3% ozone, and 1.5 Mtons per year CO_2, for a savings of 100 lives, 700 cases of chronic bronchitis, and 500,000 minor restricted activity days per year.[235] Finally, a 1999 analysis of the Clean Air Act performed by the U.S. EPA using emissions data and computer models, estimated that the stricter requirements established by the Act's 1990 amendments would prevent 23,000 premature deaths, 1,700,000 incidences of asthma attacks, 22,000 respiratory-related hospital admissions, and 4,100,000 lost work days by 2010.[236] Overall, these studies provide a wide range of examples in which researchers have quantified the public health benefits of air quality policies or local actions that led to air pollution reductions. Regulations related to changes in heating oil sources in New York are also expected to have measurable health benefits once fully implemented.

Monitoring Data and Policy

The City's success in enacting regulations on heating oil during the second term of Mayor Michael R. Bloomberg is due to a comprehensive policy approach to clean up heating oil systematically in the state, as well as the timely data provided by NYC Department of Health and Mental Hygiene's environmental monitoring efforts. The street-level monitoring data from the NYC Community Air Survey allowed policy makers to identify neighborhoods with the worst air pollution and correlate areas of high pollutant concentration with specific sources. Such causal patterns are often discovered through accumulation of information via modeling and gathering of data.[237] The NYCCAS data then allowed for the development and implementation of a series of strategies to target the sources that have the most potential for cost-effective pollution reduction. Quantitative analyses from monitoring data have commonly shown to play a large role in prioritizing measures especially when resources are limited.[238]

Nationally, environmental monitoring has provided important information for the formulation of public policy, resulting in regulations or initiatives that are comprehensive, data-driven, and cost-effective. Such monitoring data has been shown vital in a variety of environmental fields apart from air pollution, such as ecological forecasting,[239] agriculture and water resource management,[240] and land use policy.[241] The Clean Air Act, Clean Water Act, and Endangered Species Act each required monitoring data to determine specific standards and observe ongoing progress.[242] The NYCCAS air monitoring data was significant in enacting regulations on heating oil in New York City and State, and other air pollution monitoring efforts around the U.S. have also proven significant in contributing to final regulatory decisions. For example, the U.S. EPA has used various human exposure and toxicological studies that are based on air monitoring data to develop and regularly amend the National Ambient Air Quality Standards. Specifically, studies looking at the adverse health effects of measured ozone concentrations prompted the EPA to change the daily maximum 8 hour standard of 80 ppb and phase out the daily hourly maximum standard of 120 ppb in 1997,[243] and new standards were adopted for $PM_{2.5}$ based on two large prospective cohort studies done in 1993 and 1995 that also utilized extensive monitoring data.[244,245]

Environmental monitoring data has also shown to drive regional and local regulatory efforts. For example, the Acid Rain Program, an SO_2 cap and trade from electricity sources, and the NO_x Budget Trading Program, a rate based standard limitation by boiler type, were adopted in the eastern U.S. after the implementation of comprehensive monitoring, reporting, and verification requirements.[246] The U.S. Supersites program, which involved eight regional air quality monitoring projects around the country, helped policy makers develop data for state implementation plans to create risk management preparations.[247] In NYC, Smoke-Free Air Acts were driven by monitoring data performed by the DOHMH that showed that $PM_{2.5}$ and PM_{10} levels were higher in bars that allowed smoking than in outdoor high traffic areas.[248]

In another local effort, West Harlem Environmental Action (WEACT), a NYC advocacy group, collaborated with the Children's Environmental Health Center in a community based participatory research project that utilized backpack air pollution monitors to measure $PM_{2.5}$ concentrations and diesel exhaust particles at certain intersections around the Harlem community. These types of portable monitors were used to obtain a measure of actual human exposure to diesel bus pollution, and the results from the monitoring suggested spatial variation in relation to traffic density.[249] These findings prompted the EPA to establish permanent air monitoring in specific hot spots, and led to eventual local policy changes in the use of clean diesel in NYC bus fleets and adoption of state environmental justice policies such as the Childhood Asthma Initiative.[250] These examples portray how monitoring data often has a necessary role in environmental policy in both initial formulation and in measuring ensuing effectiveness, yet they also show the complementary manner that such data works with information from other stakeholders to drive policy processes, as will be discussed shortly.

The Role of Science and Collective Action in Policy Processes

Although various stakeholder groups have different ideas about the role of science in regulation,[251] the above examples provide evidence for the integral role monitoring data plays in environmental public policy making. The literature on environmental policy making largely agrees concerning the significance of such scientific data, but only if that data is the best available science and is incorporated effectively.[252] Scientific advisors have often been called the 'fifth branch' of government because of the growing importance of science in decision making, even if that role is not always positive.[253] Environmental policy in particular has increasingly relied on analysis of monitoring data, and such data has especially contributed to the current air quality environment.[254,255] A summary of five meetings of the Network for Environmental Risk Assessment and Management stated that "a wide range of air quality measurements and exposure analyses is essential for epidemiological research aimed at uncovering the current risks posed by air pollution and for subsequent risk assessment exercises."[256] Policies require a quantitative understanding of the burden of public health risk.[257,258] Some studies have even been devoted to discerning policy-relevant background concentrations of pollutants because of the implications for air quality policy.[259] Information concerning background or ambient pollutant levels is necessary to determine human exposure as well as to compare with later data to measure and track improvements.

There are various debated theories surrounding the necessary components of a successful science-policy interface. Engel-Cox & Hoff introduced a science-policy data compact, citing that scientific data must meet certain criteria in order to be capitalized by environmental policymakers to reduce the value gap between scientists and regulators. The authors proposed five criteria, based on the overlapping ideas of relevant literature, and state that data must contain relevance, timeliness, clarity, integrity, and visualization in order to be utilized effectively in the policy arena.[260] Others reiterate the importance of some these criteria. For example, Policansky describes the need for relevant data pertaining to each particular policy situation.[261] Similarly, Cash et al. describes the need for information that is salient, credible, and legitimate in order to be utilized in policy action.[262] With respect to air quality, the idea of relevant/salient data is increasingly moving from ecologic measures of air pollutant concentration, which may not accurately represent day-to-day human exposure, to examining individual exposure at a range of geographic locations.[263] The monitoring site location relative to the population should represent actual exposure, and should be weighted to the size of the surrounding population if possible.[264]

NYCCAS was the first comprehensive street-level air monitoring survey in New York City performed by a credible and recognized city agency, and provided information that exemplified possible human exposure for multiple neighborhoods. Policies should target the pollutant sources with the greatest effect on health, that pose the greatest risk of human exposure, and that can be most effectively controlled,[265,266] and NYCCAS provided specific enough spatial information to help discern patterns regarding the most dangerous pollutants and target specific sources that had the greatest potential for pollution reductions. This validates why priorities were given to school boilers in neighborhoods with greatest pediatric asthma hospitalization rates, and to the 1% of NYC buildings that burn Number 4 or 6 heating fuel, as those few buildings contribute more to $PM_{2.5}$ emissions than do NYC vehicles and therefore can play a large role in overall City pollution abatement.

Other debates about the relationship between science and policy involve the contrast between a technocratic approach, which emphasizes the science community in decision making, and a democratic approach, which emphasizes the need for nonscientific components of accountability, such as a wider mode of citizen participation.[267] Jasanoff articulates a combination of the two in what she calls a 'negotiation' and 'boundary work' model, in which there exists a sharp boundary between science and policy in a way that the boundary can be negotiated while incorporating different viewpoints in the process.[268] The implications for policy are that while science and monitoring may be a vital part of the outcome, it is only a part of the solution; the process should involve a multi-pronged approach. Policansky and others argue the need for consensus decision-making that is informed not only by science, but also by political and social understanding, especially in issues related to the environment. [269,270] Much of the literature also describes the need for multi-stakeholder and trans-disciplinary networks, including from local knowledge and capacity,[271,272] and emphasizes the inevitable multi-faceted, multi-directional process in the knowledge transfer for successful policy implementation.[273] Especially regarding public health, issues should be addressed within a process that considers knowledge outside of the scientific arena, with contributions from other experts, community members, and engaged groups of civil society.[274]

The comprehensive monitoring initiative under NYCCAS was just one strategy under PlaNYC, and the data contributed to the development of a variety of strategies and tools to allow for easier compliance. The focus was on reducing pollution rather than on eradicating a specific fuel type, additionally allowing for a variety of ancillary benefits, and the plan was systematic and included specific milestone goals and timelines for each initiative. For example, the strategy to convert school boilers involved specific goals at precise and realistic time intervals (15 additional schools by 2013 and 100 by 2017). In addition, both state and city-wide bills, as well as DEP regulations laid out specific timelines for when each specification was to go into effect, providing advantages for early compliance. It is important to have a decision making process that is transparent and rationally explained, within an appropriate time interval for the policy in question.[275]

Maintaining cost effectiveness was also an important strategy in implementing initiatives under PlaNYC; the goal was to achieve maximum reduction of key pollutants at the most reasonable cost. The emissions model developed by the Mayor's Office assessed capital and operating costs separately with respect to each fuel conversion option in order to discern the most effective strategies. The installation of fuel catalysts and economizers in school boilers improved efficiency and reduced amount of fuel needed, which was estimated to reduce maintenance costs. The statewide bill that put a cap on the amount of sulfur in No. 2 heating oil and the City bill that capped sulfur levels in No. 4 oil would result in a similar outcome. The emissions model helped elucidate the ease with which buildings that use Number 2 heating fuel can easily switch to ULSD #2, which would reduce sulfur content from 2,000 ppm to 15 ppm with no capital expense. The added biodiesel mandate in the local City law also reflects the increased cost effectiveness that comes with lowered maintenance costs, and increased biodiesel production was seen as a way to create local jobs and increase energy independence. Under the Clean Heat Program, buildings that were ready to convert to natural gas were often aggregated in order to create economies of scale and thereby reduce cost. And of course, each of these initiatives can also be related to reduced costs due to improved health outcomes.

Other researchers note that the inclusion of a wide range of stakeholders can result in more effective, timely, and responsive policies,[276] and that societal participation can increase legitimacy, problem solving capacity, and competent decision-making.[277,278] The development of coalitions in which community organizations, government agencies, and other institutions come together to address pressing social and environmental issues, has been a particular strength of the PlaNYC policy process. The relevance of environmental and quality of life issues in New York City has been greatly increased via collaboration efforts among various parties, and the policies and strategies that resulted from PlaNYC included a number of such alliances. The statewide legislation on heating fuel was enacted with the help of environmental, industry, and public health advocates at both City and State levels, and partners in City Council and others in the environmental and business communities helped enact NYC's local law. The City-wide school greening plan occurred as a result of a partnership between the City's Department of Education and the Department of Citywide Administrative Services' Division of Energy Management. Education efforts like "Quit Six" under the Clean Heat Program that informed building owners about health risks of burning number 6 heating oil and about financial benefits of switching to cleaner fuels, were performed via collaboration among various stakeholders such as the Environmental Defense Fund, National Grid, the Mayor's Office of Long-Term Planning, and Department of Environmental Protection, among others. Private-public partnerships were also formed with banks, industry and local utilities to help finance some of the conversions to cleaner fuel for low and moderate income residences. These types of coalitions have been touted by researchers because they recognize the importance of combining community agencies and institutions, public and private stakeholders, and other members of civil society in policy processes, especially those that are public health related.[279]

Many experts stress the importance of effective communication among stakeholders, including the public.[280,281,282,283] This may involve translating monitoring data into a form that not only policymakers can understand and utilize,[284] but also that the public can easily comprehend.[285] Craig et al. succinctly summarize this idea by asserting that "the key to effective science-policy interface is through interactive dialogue among the scientific community, policy makers, stakeholders, and the public."[286] This is where the criteria of clarity and visualization come into play; visual techniques clarify the information by reducing the complexity of the data.[287,288] This communication strategy is especially important when considering that the way air pollution is perceived may affect whether or not the public accepts an environmental policy;[289] for example, the NYC Smoke Free Air Act received less opposition when framed as a worker health and safety issue.[290]

The framing of the regulatory and legislative changes as issues of public health were largely made possible by the public reports released by NYC DOHMH in 2009 and 2010 based on NYCCAS data, which provided clear maps that depicted geographic variation in concentration of pollutants and allowed people to relate the issue to their personal lives. People could visualize the quality of air in where they lived, worked, went to school, etc. Public awareness is often vital in the decision-making process because an informed public can influence policy changes, sometimes better than can the content and scientific basis of the policy itself.[291] In fact, researchers have concluded that problems can be more efficiently overcome through collective action, which involves a strong overall social network based on the voice and perception of the public.[292] That perception often stems from the data that comes from trusted sources, which further portrays the need for effective collaboration in a multi-directional process.

Conclusion

New York City has made great strides in measuring air quality, in legislating emissions reductions from heating oil at both City and State level, and in reducing pollution from school buses, ferries, private trucks, and construction vehicles. Yet despite decades of progress, air pollution in New York City remains a significant concern. Current levels of $PM_{2.5}$ are estimated to contribute to over 3,000 premature deaths and over 8,000 hospital admissions and emergency room visits annually in New York City. Various private and public actors are collaborating to help NYC achieve the best air quality possible in any large American city.

In efficient policy decisions, the inclusion of economic considerations, effective communication, and multiple strategies is largely due to the availability of scientific data. It is not only necessary to have data to examine the effectiveness of air pollution abatement, but also to provide a measure of possible human exposure and therefore possible health effects. Monitoring efforts have shown that the air pollutants with the greatest public health impact in New York City result mainly from fuel combustion emissions of on-road and-off road vehicles, heating oil, other building sources, and electric power generators. Local monitoring data has greater implications for interventions that target specific neighborhood-level populations or specific sources than does ecologic-level monitoring data. The New York City Community Air Survey was an extremely comprehensive effort that contributed to the resulting State and City policies, and continues to inform the focused strategies in PlaNYC that reduce citywide air pollution levels and reduce variability across neighborhoods. Finally, the issue-based coalitions and consistent civil society and industry engagement have strengthened the ability of government to develop and enact comprehensive approaches to improving New York City's air quality.

In summary, the following factors played a role in the successful enactment of the most comprehensive air quality policy New York City had seen in over 30 years: 1) the existence of a cost effective technical solution; 2) the role of science in framing the issue and bringing about collective action and policy networks; 3) the role of regulation and institutions (governance); 4) ancillary benefits (combinations of the stick and carrot approaches); 5) the framing of the issue. This policy process contributes to a deeper understanding of the role of science and people in natural resource management and policy by illustrating these relationships in practice. Better integration of science, monitoring data and modeling analysis and also increased stakeholder engagement before, during and after the policy development process would contribute to win-win environmental strategies that can be implemented in the short, intermediate and long term.

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