Synapse
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Air Quality In Queens County

Opportunities for Cleaning Up the Air in Queens County and Neighboring Regions

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Synapse Energy Economics is a research and consulting firm that specializes in energy, economic and environmental topics. Synapse provides research, testimony, reports and regulatory support to consumer advocates, environmental organizations, regulatory commissions, federal and state agencies, and others. For more information on Synapse, see www.synapse-energy.com.

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Executive Summary

S.1 Introduction

In the interest of protecting the environment and public health of Northwest Queens, the Natural Resource Defense Council (NRDC) and the Citizens Helping Organize for a Klean Environment (CHOKE) participated in the New York State Article X permitting process for several new power plants proposed in Northwest Queens. One of their objectives was to have a study conducted to analyze the contributors to air pollution in Northwest Queens and to identify possible strategies for improving air quality and reducing risks to public health. As part of the Article X permitting process for its 250 MW Ravenswood Combined Cycle project, KeySpan committed to funding such a study as a community benefit. CHOKE and NRDC contracted with Synapse to conduct this study. The conclusions and recommendations are those of the authors but do not necessarily reflect the position of KeySpan.

One of the reasons that Queens County was chosen for this study is that it is home to many sources of air pollution. In the northwest corner of the county there currently are four large power plants, which together house 46 electric generating units. The county also contains an extensive transportation network that includes the Long Island Expressway, the Brooklyn Queens Expressway, the Grand Central Parkway, two highway bridges, a tunnel to Manhattan, and two airports, along with over 400 miles of arterial and local roads. Queens also has several large industries, and some 2.2 million residents, leading to significant economic activity which contributes to air quality problems.

While Queens contains many large sources of air pollution, it is also important to note that a significant portion of the borough's pollution arises from pollution sources located upwind. Similarly, much of the pollution generated within Queens affects the air quality of other regions located downwind of the county. Thus, this report should be informative to policymakers throughout the Northeastern US – as the air quality problems and opportunities that exist throughout this large region are inextricably linked.

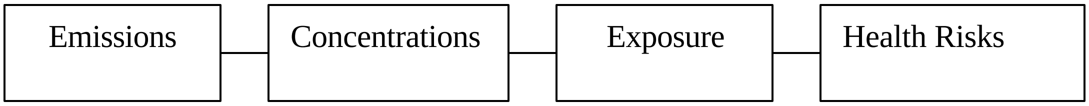
S.2 Overview of Urban Air Pollution

Framework for Assessing Pollution and Health Threats

Like most large urban areas, Queens has numerous pollutants in its air. This can make it difficult to set priorities for improving air quality, since the pollutants come from different sources, have different health effects, and are regulated differently. In addition, since much of the pollution present in Queens blows in from other places, reducing pollution emissions from sources in Queens will only partially address the air quality problem there.

It is important to distinguish between the different types of emissions and pollutants. A pollutant that is emitted and has not been transformed at all in the air is called a *primary pollutant*. A pollutant that leads to the formation of another pollutant is called a *precursor*, and the pollutant that forms as a result of the emissions of the precursor is called a *secondary pollutant*. These distinctions are important to keep in mind, since they may mean that the pollutants we control at a source are not the same as the pollutants for which we want to reduce exposures to people.

It is also useful to point out the several different steps that lead to the health threats caused by air pollution. One can visualize the pathway leading to health risks as follows:



In other words, primary pollutants are *emitted* from a source (such as a power plant or a car) and result in *concentrations* of a pollutant outdoors and indoors. The concentrations of pollutants at any one point in space and time are determined by many factors, including the transport of pollutants from many miles away, and the creation of secondary pollutants through complex chemical processes. Human *exposure* occurs when people spend time in areas with pollutant concentrations. Finally, human exposure leads to public *health risks*, if the exposure concentrations are high enough.

There are three major categories of air pollutants that lead to public health and environmental risks – criteria air pollutants, toxic air pollutants, and greenhouse gases. For each of these categories, we provide a description of the pollutants as well as a discussion of the major health risk that they create for the citizens of Queens County.

Criteria Air Pollutants Defined

In accordance with the Clean Air Act, the US EPA has set uniform, nationwide standards for six pollutants that are considered harmful to human health and the environment at high concentrations. These six *criteria pollutants* are briefly described below. For these pollutants, two types of National Ambient Air Quality Standards (NAAQS) are established. Primary standards are set to protect public health, and secondary standards protect against decreased visibility and building damage, and protect other forms of public welfare. It is important to note that being below a NAAQS does not necessarily mean that there are no health risks, especially when multiple pollutants are present.

<u>Carbon monoxide</u> (CO) is a colorless, odorless gas that is almost entirely due to motor vehicle exhaust in dense urban areas. It is harmful to health because it can displace oxygen in our bloodstream, reducing delivery of this vital substance to the cells of our bodies.

<u>Nitrogen dioxide</u> (NO_2) is a reddish-brown gas that is formed when fuel is burned. NO_2 is a precursor of both ozone and of nitrate particulate matter. Across the US, about half

of the NO_2 comes from motor vehicles, with about a third from power plants. When inhaled, NO_2 can irritate and damage the cells lining the deep regions of our lungs.

Sulfur dioxide (SO_2) is a gas principally formed when fuel containing sulfur (such as coal or oil) is burned, and is a precursor of sulfate particular matter. About two-thirds of the SO_2 in the US comes from fossil-fired power plants. When inhaled, SO_2 deposits and irritates the upper regions of our lungs. SO_2 is also a major contributor to acid rain, which leads to environmental damage to aquatic and forest ecosystems.

Ozone (O_3) is a major component of smog and is a secondary pollutant, formed when nitrogen oxides (NOx, which includes NO_2) react with volatile organic compounds (VOCs) in the presence of sunlight. Ozone is a strong oxidant gas which, upon inhalation, causes damage to the sensitive cells in the deep regions of our lungs. It can lead to decreased lung functions, increased hospitalizations, and possibly increased mortality risks.

Lead (Pb) is a metal that was once principally related to motor vehicles (since tertraethyl lead was used as an antiknock agent in gasoline). Now that unleaded gasoline is used, most of the lead in the air comes from lead smelters or other industrial sources. Lead exposure results in chemical changes in the brain which can reduce intelligence.

Particulate matter is defined as any solid or liquid suspended in the air. Particulate matter can therefore contain a large number of different chemicals or substances, and can vary greatly in size. PM_{10} is the fraction of particles less than 10 µm in diameter (roughly one-seventh the width of a human hair). The US EPA has recently focused on $PM_{2.5}$, the fraction of particles less than 2.5 µm in diameter, since those smaller particles are more likely to get deeper into the lung. Particulate matter is both a primary pollutant (including fly ash, soil, sea salt, and diesel particles) and a secondary pollutant (including sulfate and nitrate particles). Exposures to particulate matter have been associated with a wide range of adverse health impacts, including respiratory symptoms, decreased lung functions, increased hospitalizations, and increased mortality risks.

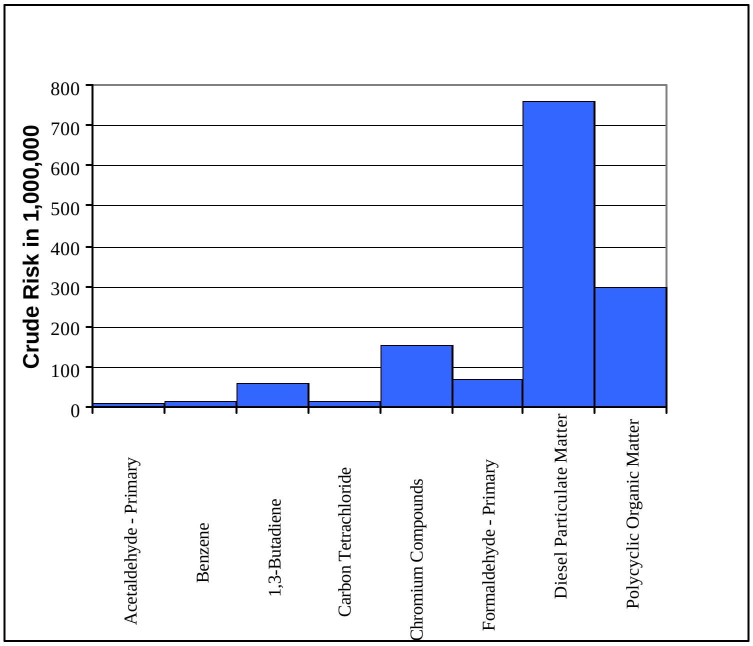
Hazardous Air Pollutants Defined

In addition to the criteria pollutants, the US EPA maintains a list of 188 toxic air pollutants, also known as hazardous air pollutants (HAPs), that are considered detrimental to human health. Unlike the criteria pollutants, HAPs do not have air quality standards, although emissions of some HAPs are regulated under the Clean Air Act. People exposed to air toxics at high levels for long time periods may have an increased chance of getting cancer, damaging their immune system, or suffering from neurological, reproductive (e.g., reduced fertility), developmental, respiratory and other health problems.

US EPA has constructed a list of 34 hazardous air pollutants (33 air toxics and diesel particulate matter) that constitute the greatest public health threat in urban areas. We have further reduced the list to those that create the greatest health risk in Queens. We use estimated concentrations of air toxics in Queens and published cancer risks of these 34 air toxics to pick a subset of pollutants that require closer scrutiny.

Figure S.1 shows the eight pollutants most likely to significantly contribute to cancer risk in Queens, along with their approximate cancer risk rates. In descending order of importance, they are diesel particulate matter, polycyclic organic matter (POM), chromium compounds, formaldehyde, 1,3- butadiene, benzene, carbon tetrachloride, and acetaldehyde. As indicated in the table, the cancer risk from diesel particulate matter is greater than that for all the other eight HAPs combined.

Figure S.1 Estimated Cancer Risks Of Top Eight Air Toxics In Queens



Greenhouse Gases Defined

GHGs include carbon dioxide (CO_2), methane, nitrous oxide, and multiple other pollutants. CO_2 is the greenhouse gas of most concern because of the large volumes of CO_2 emissions relative to other GHGs. While, some of the other GHGs have greater “global warming potential” per unit volume, they are emitted in much smaller volumes.

Although they do not affect human health directly, greenhouse gases (GHGs) contribute to global climate change and associated health problems. Global climate change models predict that worldwide daily mortality and morbidity due to extreme heat events could significantly increase in this century, especially among elderly poor who often have pre-existing health conditions and may lack air conditioning or access to air conditioned spaces. Projected increases in frequency and duration of extreme heat events will exacerbate the "urban heat island effect," which raises daily urban temperatures up to 10 degrees Fahrenheit higher than the surrounding suburbs/exurbs, especially during the nighttime hours.

Other health impacts of climate change include increased rates of secondary air pollutant formation (e.g., O_3 and some $PM_{2.5}$ components), incidence of vector-borne and water-borne diseases, and possibly increased frequency and severity of storms. By as early as the 2020s, there could be significant increases in the sea level in the New York area.

Sea-level rise, combined with more frequent droughts and floods, will pose a significant challenge to urban transportation and drinking water delivery infrastructure. While the vulnerability of Queens to these impacts has not yet been specifically assessed, its highly urbanized structure and extensive coastline suggest a high degree of risk.

S.3 Air Quality and Health Risks in Queens

Criteria Pollutant Levels in Queens

Evaluation of air quality requires analysis of specific data on pollutant concentrations in the air. The air quality in Queens is monitored on a regular basis for a number of pollutants, and data are readily available for these pollutants. The six criteria air pollutants are monitored at numerous locations on a regular basis to evaluate whether the air meets federally mandated ambient air quality standards. Most of these pollutants are measured on a continuous basis, either with daily or hourly average concentrations.

In the past decade, ambient levels for all six criteria pollutants have decreased nationally. However, progress has been slowest for ozone and small particulate matter. Limited progress on the ozone front is largely due to emissions of precursor gases from power plants, especially those in the Midwestern US, and motor vehicles. The highest concentrations of ozone are generally in areas downwind of major urban areas. Limited progress on small particulate matter is due to both vehicle emissions and sulfur dioxide emissions from coal-fired power plants. Concentrations of small particulate matter are particularly high in the Eastern US.

Air quality in Queens itself can be evaluated in comparison to federally mandated ambient air quality standards, air quality indices and other measures. Unhealthy air conditions, as measured using air quality indices, have decreased in the New York metropolitan area in the last decade. For example, sulfur dioxide concentrations in New York City are now well below federal standards, and the EPA has recently redesignated the city to be in attainment of carbon monoxide standards.

However, New York City and Queens County are still burdened with significant air quality problems. Environmental Defense has ranked Queens among the worst 10% of US Counties in terms of its exposure to criteria air pollutants. The greatest remaining threats are caused by ozone and particulate matter, both of which can have severe health impacts. The US EPA has determined that the NY metropolitan area, including Queens is in “severe nonattainment” for ozone; Queens is one of the two city boroughs that violates federal standards. Based on monitoring data, EPA expects that when $PM_{2.5}$ designations are made, most of New York City, including large parts of Queens, will be defined as non-attainment areas.

It is important to note that compliance with National Ambient Air Quality Standards is not necessarily sufficient to eliminate public health risks from air pollution. There is ample evidence of health risks at concentrations below those national standards, especially for particulate matter.

Hazardous Air Pollutant Levels in Queens

Unlike criteria pollutants, data on emissions and air concentrations are more limited for hazardous air pollutants. While individual sources must meet specific emissions standards for certain toxics, there are no air quality standards for air toxics. Estimates of air toxics exposures require alternative data sources and estimation methods than can be used for criteria pollutants.

Based on modeling, ambient air toxics concentrations of several air toxics in Queens derive primarily from on-road mobile sources (cars, trucks, buses) and off-road mobile sources (including airplanes, airports, and trains). Because there are no ambient air quality standards for these pollutants, the importance of the concentrations is best understood in reference to the estimated health risks described above.

For both criteria pollutants and air toxics, it is important to recognize that ambient air pollution concentrations do not necessarily represent the levels of air pollution to which people are exposed. This is due in part to the fact that, on average, Americans spend 90 percent of their time indoors. As a result, indoor exposure, because of either indoor sources or penetration of pollution from outdoors, can be an important source of health impacts. Personal exposure can therefore be considered a combination of exposures from both outside (i.e., ambient) sources and indoor sources. Numerous studies over the past 25 years indicate that for most pollutants, especially VOCs, NO_2 and particulates, personal exposures exceed ambient concentrations. For ozone, personal exposures are usually lower than ambient concentrations.

Moreover, despite the limitations of ambient air quality data, there is a strong correlation between outdoor air pollution levels and certain health outcomes. Epidemiological studies tell us that on days when air pollution levels are high, more people get sick or die. Such correlations lead to the ambient air quality standards set by EPA. Although we have a limited ability to know who is at highest risk because of our lack of personal exposure data and knowledge about population susceptibility, we can still draw population-wide inferences as long as average personal exposures increase when outdoor levels increase. For pollutants that penetrate indoors, even to a limited degree, this is indeed the case.

Greenhouse Gas Contributions From Queens

Information on emissions from specific greenhouse gas sources is limited at present, since GHGs are not currently regulated by federal or state laws. As such, GHG emissions reporting is entirely voluntary and often covers only greenhouse gas reduction efforts, rather than describing overall operational emission inventories.

Americans as a whole contribute far more to climate change on a per-capita basis than the rest of the world's people. The US is responsible for roughly one quarter of the total world's GHG emissions, even though we have only four percent of the world population, indicating that the average American generates 8 times as many greenhouse gases as the average non-American.

New York State is responsible for roughly four percent of US GHG emissions, but has more than 6 percent of the US population, and thus has a slightly lower per-capita green house gas emission rate than the rest of the US. Nonetheless, Queens produces large volumes of CO_2 emissions. For example, the power plants in Queens County produce roughly 15 percent of all the CO_2 emissions from all the power plants in New York State while accounting for about 15 percent of the State's electric capacity. Thus, Queens provides an important opportunity regarding New York City's and New York State's efforts to address global warming.

The NY State Energy Research and Development Authority forecasts that overall GHG emissions in the state will increase by 12% by 2010. This significant increase in emissions, coupled with Queens' substantial contribution to New York State GHG emissions, suggests that the reduction of greenhouse gases should be a high priority in improving air quality in Queens.

The Pollutants that Create the Greatest Health Risks In Queens

In order to identify opportunities for improving the air quality in Queens County and neighboring regions, it is useful to identify those pollutants that create the greatest health risks in Queens. Here we make a broad comparison of the health risks posed by the different criteria pollutants, hazardous air pollutants and greenhouse gases.

Ozone and particulate matter are the two criteria pollutants that currently pose the greatest health risk, both because of their toxicity and because levels of other criteria pollutants have been more greatly reduced in recent years. Thus, we focus our quantitative analysis here on just these two criteria pollutants. Also, remember that we have narrowed the EPA's list of priority air toxics down to eight HAPs that are of most importance to cancer risks in Queens.

In order to rank the health risks of ozone, particulate matter and HAPs, we analyze the premature deaths that might occur in Queens as a result of each pollutant. We assume hypothetically that concentrations of each pollutant are decreased by 10% across all of Queens, and we calculate the resulting reduction in premature deaths. This approach will only capture a fraction of the health benefits due to reduced concentrations, because it does not address health impacts beyond premature deaths. Nonetheless, it provides a useful methodology for creating priorities across the pollutant types.

We estimate that a 10% reduction of the eight priority HAP emissions in Queens would result in four fewer cancers (and associated premature deaths) per year in Queens. We also estimate that a 10% reduction in ozone concentrations would result in roughly 30 fewer premature deaths per year in Queens. Finally, we estimate that a 10% reduction in $PM_{2.5}$ concentrations (to be distinguished from emissions) would result in over 100 fewer premature deaths per year in Queens.

Thus, the health threat from ozone appears to be roughly a factor of ten greater than that of HAPs, and the health threat of $PM_{2.5}$ appears to be roughly a factor of three greater than that of ozone, when ranked on the basis of premature deaths. From this perspective, public policies to reduce air emissions should focus first on $PM_{2.5}$, and then on ozone, with less emphasis on HAPs.

We have not ranked greenhouse gases alongside the other pollutants in this study, due to the long-term timeframe and unpredictable nature of global warming impacts on public health. Nevertheless, it is clear that the potentially dramatic effects of global warming, both in Queens and elsewhere in the world, dictate that greenhouse gases receive substantial attention when addressing air pollution and air quality in Queens and the neighboring regions.

Factors Affecting Air Quality – Transport of Particulates and Ozone

There are a variety of factors that influence air pollution concentrations in a given area. These factors include not only the sources of air pollution and their locations, but also weather-related factors that influence how far pollutants travel and how they change in the air.

Particulate matter consists of many different chemicals and contains components that are directly emitted (primary particles), and components that are formed through reactions in the atmosphere (secondary particles). The most prevalent particle types are sulfate and nitrate particles (which constitute about half of the fine particulates on the East Coast), and elemental and organic carbon (which constitute about one third of the fine particulates on the East Coast).

Concentrations of different forms of particulate matter are determined by a variety of factors. The maximum concentrations associated with any given emission source are generally fairly close to the source. This effect is particularly strong for sources that emit primary particles, such as highways. The effect is reduced for sources that emit primarily precursor gases that will form into small particles, such as power plants. Tall emission stacks on power plants can mean that emissions occur high in the air and can travel long distances before being deposited. However, an individual living near a source will be at greater risk than an individual living hundreds of miles away, because of where the concentration is highest.

Ozone is formed most intensively during the summer months through reaction of NO_x, VOCs, and sunlight. In New York, as for much of the East Coast, the Ozone Season is designated as May 1 through September 30 of each year. This is the period during which ozone formation causes the most significant air pollution problems and health impacts.

Both ozone and particulate matter (and their precursors) can travel long distances in the atmosphere. As a result, pollutant concentrations in a particular area can be affected by sources far away. This characteristic is important in Queens due to meteorological conditions. Queens, and the rest of the New York City area, is affected by weather systems that move from west to east across the country. This predominant west to east weather movement transports air emissions from power plants in the Midwest (as well as other areas to the south and west). The transported pollutants significantly affect pollutant concentrations in the New York area.

S.4 Sources of Emissions Affecting Air Quality in Queens

Introduction and Caveats

Identifying the local sources of emissions that contribute to air quality problems in Queens is a difficult task. First, there is little reliable information to indicate the primary sources of some of the key emissions in Queens. We have reviewed several different data sources only to find that they are incomplete, inconsistent, or not based on data specific to Queens. Second, the formation of pollutants and the transport of pollutants into and out of Queens is a complex process that is difficult to analyze, and yet will have significant implications for the ambient air quality in Queens.

Nonetheless, here we broadly indicate those sources of emissions that are likely to have the greatest impact on the air quality in Queens. While we do not identify many of the specific sources of emissions, we indicate those sectors and those types of sources that are likely to have the greatest impact.

The US EPA recommends dividing sources of air emissions into four main categories, listed below. We use these categories throughout this report to describe the general types of sources in Queens

- <u>Large stationary sources</u>. Sometimes referred to as point sources, large stationary sources are those that emit at least 100 tons per year of any regulated pollutant. This category includes electric power plants, manufacturing, refineries, and steel mills.
- <u>Area sources</u>. This category includes all smaller stationary sources of emissions, such as residential and commercial furnaces and boilers, waste incinerators and miscellaneous small combustion sources. This category also includes non-combustion area sources such as gas stations and dry cleaners.
- <u>On-road mobile sources</u>. This category includes all transportation vehicles that travel on roads, including cars, taxies, buses, trucks, etc., using both diesel fuel and gasoline.
- <u>Off-road mobile sources</u>. This category includes all transportation vehicles that travel off-roads, such as airplanes, marine transportation, recreational vehicles, industrial, construction and mining equipment, using both diesel fuel and gasoline.

Sources of Particulate Matter

Several factors discussed above pertaining to the formation and transport of particulate matter, allow us to make only broad conclusions about the relative impact in Queens of the various sources of particulate matter. We believe that the sources that contribute to ambient particulate matter concentrations in Queens can be described as follows:

- Sources *outside* the metropolitan area contributes the largest portion of ambient of particulate matter in Queens. Much of this transported particulate matter comes from power plants and other industries in upwind states.

- Of the remaining ambient particulate matter in Queens, a large part comes from sources *within* Queens. Most of this particulate matter consists of primary emissions from the transportation sector, the electricity sector, and the area sources (i.e., residential and commercial boilers) within Queens, largely in the PM 2.5 category. Other sources include fugitive dust and natural sources such as suspended salt particles from the ocean and Long Island Sound, which consists mostly of coarser material.
- Another large portion of ambient particulate matter in Queens comes from similar sources *in other parts of the metropolitan area*. Compared with particulate matter from Queens sources, a larger proportion of the particulate matter in this category is secondary rather than primary.

Sources of Ozone and Ozone Precursors

Again, several factors discussed above pertaining to the formation and transport of ozone allow us to make only broad conclusions about the relative impact in Queens of the various sources of ozone. We believe that the sources that contribute to ambient ozone concentrations in Queens can be described as follows:

- Sources *outside* the metropolitan area contribute the largest portion of ambient ozone in Queens. Much of this ozone and ozone precursors come from power plants and other industries in upwind states. Ozone levels are highest in Queens and the Bronx, relative to the rest of New York City, because they are more directly downwind of Northern New Jersey, Newark, and Manhattan.
- Of the remaining ambient ozone in Queens, a large part comes from sources *within* Queens. Most of this ozone is due to ozone precursors from the transportation sector, the electricity sector, and the area sources (i.e., residential and commercial boilers) within Queens.
- Another large portion of ambient ozone in Queens comes from sources in *other parts of the metropolitan area*. Most of this ozone is likely to be due to precursors from the transportation sector, the electricity sector, and area sources.

Sources of Hazardous Air Pollutants (HAPs)

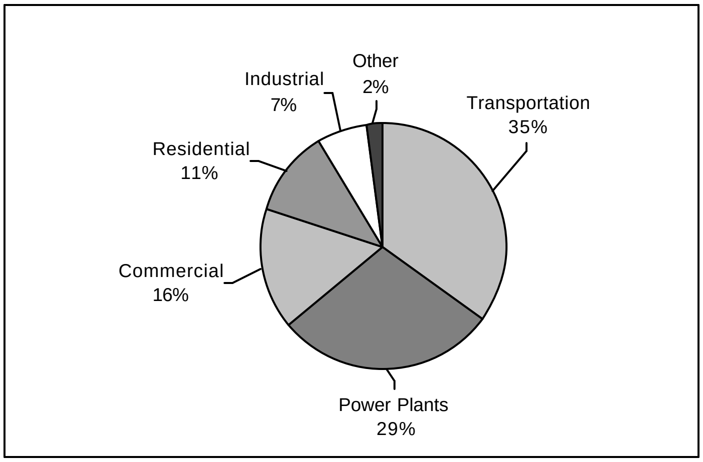
The transportation sector is by far the largest contributor to the health risks created by hazardous air pollutants in Queens. Diesel particulate emissions pose a health risk greater than all of the other seven priority HAPs combined (as described above), and almost all of the diesel particulate emissions are caused by on-road and off-road mobile sources. Furthermore, the transportation sector is responsible for the majority of the emissions of several of the other HAPs, including formaldehyde, benzene, and acetaldehyde.

The power plants in Queens emit several types of HAPs, but they tend to contribute very small portions of the total contributions in the county. For example, roughly three percent of the total chromium compounds emitted in Queens comes from the power plants, and much less than one percent of the polycyclic organic matter (POM) emissions are from power plants. Furthermore, since emissions of these HAPs from sources outside of Queens can contribute to concentrations in Queens, these power plants contribute a relatively small amount to ambient HAP concentrations in Queens. Other HAP emissions from power plants, such as mercury, arsenic, manganese and nickel compounds, were not identified as among the top priority HAPs in Queens, but may have important non-cancer health implications.

Sources of Greenhouse Gases

Figure S.2 provide a breakdown of the sources of CO_2 emissions for the entire state of New York. It indicates that the transportation sector makes the largest contribution to emissions (35%), followed by the electricity sector (29%).

Figure S.2 Sources of CO_2 Emissions in New York State



The breakdown of CO_2 sources in Queens County may be different than that presented for New York State above. Because of the high concentrations of both roadways and power plants in Queens, there may be even greater contributions from the transportation and electricity sectors.

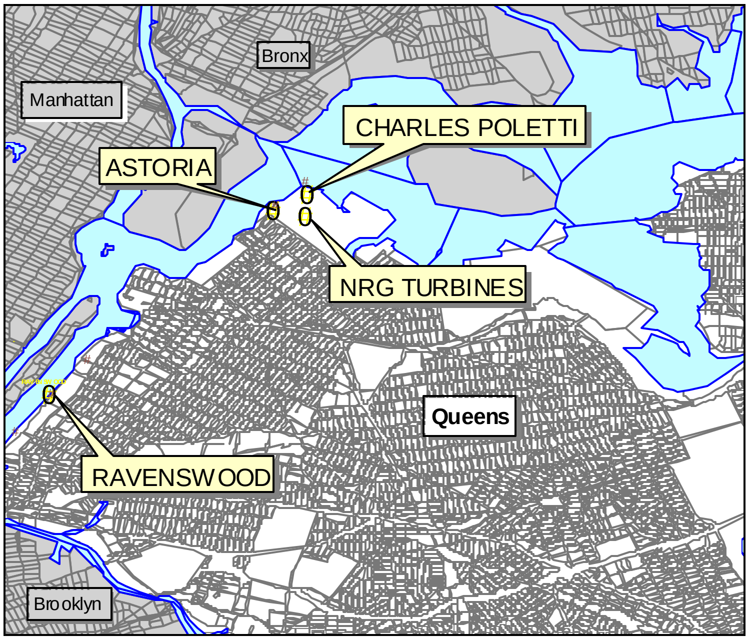
S.5 Reducing Emissions from the Electricity Sector

New York City, like the rest of the nation, gets its electricity from a regional network of interconnected power plants and transmission lines. This means that the residents and businesses of each borough are not served exclusively by power plants within that borough. Rather, the electricity from all the power plants in the Northeast region is commingled in the regional transmission grid. Queens is one of the counties with a large amount of generating capacity relative to its electricity needs, and it consistently exports its surplus electricity to other users in New York City.

Currently, there are four large power plants in Queens, which together house 46 electric generating units. Eight of these are large steam generating units, and 38 are small combustion turbines. All four of these plants are in a small section of Northwest Queens (Astoria). Figure S.3 shows the location of these four facilities in Northwest Queens.

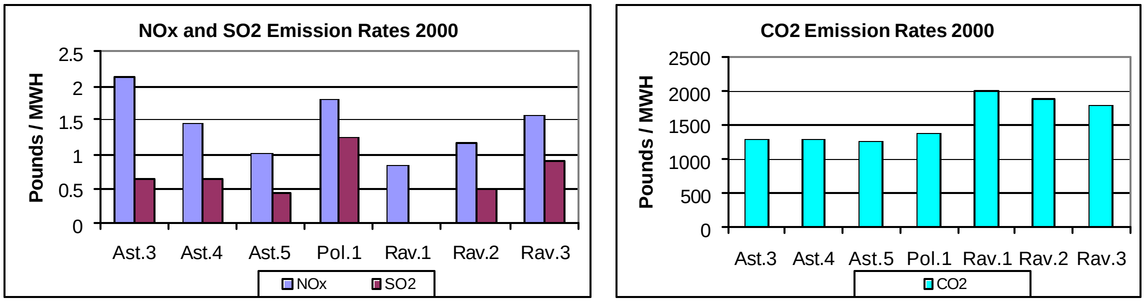
The concentration of generating capacity in Northwest Queens is exceptionally high for such a densely populated area. In addition, this community includes a high percentage of low-income people and persons of color. These demographics suggest that "environmental justice" concepts and policies should be taken into account when considering options for addressing air quality in Queens and in considering the siting of further sources of air pollution.

Figure S.3 The Four Power Plants in Northwest Queens



The steam generating units in Queens are responsible for large percent of the NO_x, SO_2 and CO_2 emitted in Queens. Figure S.4 shows the emission- rates in pounds per megawatt hour produced from these generating units in 2000. It should be noted that the average emission rates of these Queens plants are lower than both the New York State and National averages primarily due to the use of lower-emission fossil fuels (e.g. natural gas and oil, instead of coal).

Figure S.4 2000 Emission Rates from Steam Electric Plants in Queens



As previously mentioned, some Queens generators are already undergoing changes that will result in lower emission rates, such as the Air Quality Improvement Program at the Ravenswood Station that when completed in 2003 will reduce the NO_X emission rate by about 20 percent. At the same time, other older generating units in Queens continue to be of concern, including the recently restarted Astoria Unit 20 plant.

We develop two scenarios to identify the opportunities for reducing emissions from the power plants in Queens. The Base Case scenario is a forecast of power plant operation and emissions assuming "business-as-usual" practices, i.e., without major changes to address air emissions. The Clean Air Plan scenario is a forecast of the electricity sector with several important modifications designed to reduce air emissions.

For the Base Case scenario, we assume that none of the existing generating units in Queens is retired during the study period and that 250 MW of new combined-cycle combustion turbine (CCCT) capacity is added by the end of 2004. Thus, we assume that 250 MW of the currently proposed new CCCT capacity will be installed before 2005, absent the Clean Air Plan. For the purposes of assessing air emissions in Queens it is not necessary to predict which of the currently-proposed projects this will be, or exactly where it will be located within Queens.

For the Clean Air Plan, we modify the Base Case scenario with the following three features:

- Implementation of aggressive energy efficiency measures throughout New York City. We estimate that roughly ten percent of the city's energy load could be saved by 2010 through cost-effective efficiency measures. This would require an annual investment of $131 million, but would result in annual energy savings of $264 million, for a *net savings* of roughly $133 million per year.
- Installation of 50 MW of solar photovoltaics systems throughout New York City, roughly equivalent to 0.5% of the total generation capacity in the city in 2010. This solar power would provide emission-free electricity, assist with transmission and distribution congestion in the city, and provide power during the most expensive hours and seasons of the day – during the summer peak demand periods.
- The retirement of older, inefficient power plants by 2005, including the retirement of Poletti Unit 1; Astoria Units 2, 3 and 4; and Ravenswood Units 1 and 2.[1]
- The installation or repowering of several new units in Queens, including one 500 MW CCCT and two 900 MW CCCTs, resulting in 2,300 MW of new, efficient, gas-fired combined cycle power plants.

Emission Reductions from the Clean Air Plan

The Clean Air Plan results in substantial reductions in emissions from the Queens power plants, as indicated in Table S.1 and Figure S.5 below. These reductions are particularly vital in view of the expected enormous increase 48% by 2010 in electricity generation

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[1] Given the current status of newly-permitted facilities, it is unlikely that these existing facilities would be retired by 2005. Thus, the benefits that our analysis shows for 2005 would actually be achieved in a later year (e.g., 2007), whenever these units are retired.

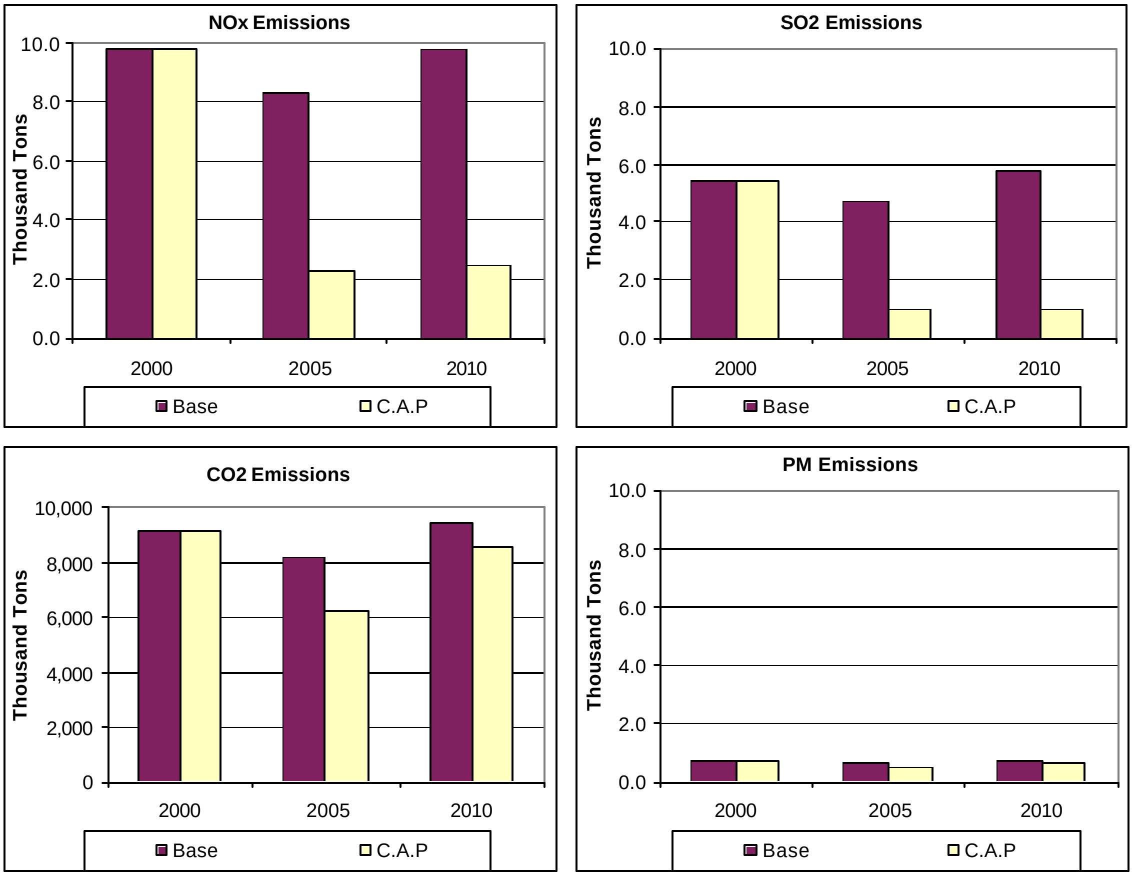
from Queens power plants (48% by 2010), due to the construction of new power plants that will provide increased power to New York City and the region.

Table S.1 Annual Emission Reductions at Queens Power Plants from the Clean Air Plan

	2005	2010
NO_x Reductions (%)	73%	75%
NO_x Reductions (tons)	6,050	7,300
SO_2 Reductions (%)	80%	83%
SO_2 Reductions (tons)	3,760	4,780
CO_2 Reductions (%)	23%	9%
CO_2 Reductions (tons)	1,907,000	895,000
$PM_{2.5}$ Reductions (%)	27%	12%
$PM_{2.5}$ Reductions (tons)	175	91

Emission reductions are relative to the business-as-usual emissions in the relevant years.

Figure S.5 Emissions from Queens Power Plants: Base Case and Clean Air Plan



The NO_X reductions are due to the replacement of the steam generators in Queens with CCCTs with advanced NO_x emission controls. The SO_2 reductions are almost entirely the result of changes in fuel use; because there is negligible sulfur in natural gas, replacing oil combustion with gas combustion reduces SO_2 emissions to near-zero levels. Percentage reductions in CO_2 and $PM_{2.5}$ are not as pronounced as those in NO_x and SO_2

because, while new CCCTs have very low NO_x and SO_2 emission rates, their CO_2 and $PM_{2.5}$ emission rates are more significant.

The Clean Air Plan will also result in significant reductions of emissions in regions outside of Queens. As noted previously, emissions reductions from power plants located outside of Queens can and often will result in air quality improvements in Queens. Table S.2 presents a summary of emissions reductions achieved by the Clean Air Plan in the entire Northeast region.

Table S.2 Annual Emission Reductions at Northeast Power Plants from the Clean Air Plan

	2005	2010
NO_x Reductions (tons)	9,350	15,460
SO_2 Reductions (tons)	13,150	26,240
CO_2 Reductions (tons)	4,324,000	7,078,000

A comparison of the tonnage reductions in Tables S.1 and S.2 demonstrates that a large portion – and in many cases the majority – of emission reductions from the Clean Air Plan occur outside of Queens. This occurs for several reasons: (a) the increased generation in Queens due to the new power plants reduces the emissions from dirtier, less-efficient power plants elsewhere, (b) the efficiency efforts significantly reduce generation from other power plants in the region, and (c) the PV slightly reduces generation from other plants in the region. While these results emphasize the need for regional solutions to address the air quality in Queens, significant reductions can still be realized from efforts at Queens plants.

S.6 Reducing Emissions from the Transportation Sector

Our analysis of the transportation sector assesses (a) current use of roads and vehicles in Northwest Queens; (b) anticipated future use of roads and vehicles under a Base Case scenario; and (c) anticipated future use of roads and vehicles under several different transportation policy scenarios. We evaluate policies that could reduce emissions from the transportation sector by reducing the use of vehicles, reducing the emissions per mile of travel, or both.

The transportation sector study focuses on a 17 square-mile area within Northwest Queens. This area is about 16 percent of the entire Queens County in land area, and contains 25 percent of the population, as well as roughly a third of the expressway miles and a fifth of the arterials and local roads in the county. About one quarter of the total vehicle miles traveled in Queens County were over these roads. In 2000, passenger vehicles accounted for 86 percent of the vehicle miles traveled, commercial vans for eight percent, and large trucks and buses for six percent.

Base Case Emission Forecast

Emissions from the transportation sector in the future will be influenced by three factors: (1) vehicle miles traveled, (2) types of vehicles, and (3) emission rates of vehicles.

During the 1990s, vehicle miles traveled in Queens increased by one-sixth (16.6 percent). The New York State DOT projects a 7.1 percent increase between 2000 and 2005 in Queens County, and an additional 5.7 percent increase by 2010.

Although vehicle use in Queens has been on the rise, emissions of criteria pollutants from vehicles have declined markedly on a per-mile basis over the past several decades, and that trend is expected to continue. Per-mile emissions of volatile organic compounds, carbon monoxide, and nitrogen oxides from vehicles have all decreased on average about 75 percent in the last thirty years. Progress has been less pronounced, however, for two pollutants: particulate emissions from heavy trucks and carbon dioxide emissions from all vehicles.

Over the next 5-10 years, emissions of all of the "conventional" automotive pollutants (VOCs, CO, NO_x, and particulates) are projected to decrease significantly in Northwest Queens, as indicated in Table S.3. These emission reductions will result from developments and policies already in place, including ongoing improvements in engine technology, conversion to cleaner grades of diesel fuel, and large-scale adoption of clean engine and fuel measures by New York City Transit and other bus operators.

The lone but significant exception to these anticipated reductions is that vehicular emissions of CO_2 are expected to increase significantly between 2000 and 2010. This anticipated increase is a product of several factors: an expected 13% increase in vehicle miles traveled; the continuing switch of passenger travel from sedans to less-efficient sport utility vehicles; and the further reduction in fuel efficiency from higher levels of traffic congestion on area roads and highways.

Table S.3 Base Case Changes in Automotive Emissions in Study Area

Pollutant	2005	2010
Volatile Organic Compounds (VOCs)	– 28%	– 51%
Carbon Monoxide (CO)	– 21%	– 33%
Nitrogen Oxides (NOx)	– 24%	– 48%
Particulates (PM-10)	– 14%	– 25%
Fine Particulates (PM-2.5)	– 24%	– 38%
Carbon Dioxide (CO2)	+ 9%	+ 18%

Figures in table denote estimated changes in emissions relative to 2000 from present trends (declining emission factors but rising vehicle miles traveled), absent the pricing or tailpipe/fuel measures discussed directly below.

Our study analyzes several measures to reduce vehicular emissions even further, and to address the potential increase in CO_2 emissions. These measures fall within two broad categories: pricing measures and measures to address heavy-duty diesel vehicles.

Pricing Measures

Cents Per Mile Insurance. Under conventional auto insurance, drivers pay for insurance on a lump-sum basis, and their premiums bear little relationship to the number of miles they drive. An alternative method of charging insurance is to make insurance premiums proportionate to mileage. "Cents-per-mile insurance" would rearrange, not increase, the overall cost of car use, by shifting to a *variable* cost the auto insurance payments that drivers now pay as a *fixed* cost. This cost shift would create a powerful incentive among drivers to economize on driving. Whereas drivers currently save little or nothing on their insurance costs by driving less, cents-per-mile insurance would effectively let drivers pocket 10 cents on average for each mile they did not drive. We estimate that a mandatory cents-per-mile insurance policy could reduce vehicle miles traveled in 2010 by 8.6%. The reduced miles traveled would result in emission reductions of roughly 11% to 15% in 2010, relative to the Base Case emissions in that year. (The emission reductions from all the pricing measures are summarized in Table S.4 below.)

VMT Fees and Weight-Distance Fees. VMT fees charge all motor vehicles a fixed amount per mile driven. Weight-distance fees are a variation on VMT fees in which vehicles are charged per ton-mile, so that two vehicles driven the same amount pay in proportion to their respective weights. This added feature better captures the emissions effects of VMT by different types of vehicles, and appears to be an excellent way to equalize the greater contribution to pollution, especially CO_2, from the increased use of SUVs. We estimate that VMT fees of 10¢ per mile in 2010 would reduce vehicle miles traveled in that year by 8-12%, resulting in emission reductions of 12-16%. Weight-distance fees would have an even greater impact on emissions, because they have a greater influence on high-emission trucks. We estimate that weight-distance fees would reduce emissions from roughly 16-21%.

Bridge Tolls. There is a strong possibility that the bridges connecting Manhattan to Queens and Brooklyn, which have been free to motorists for some 90 years, may again be tolled in the near future, using electronic metering that obviates the need for space-consuming, pollution-generating toll plazas. We estimate that tolls on the East River bridges would result in a roughly 2.8% reduction in vehicle-miles traveled in Northwest Queens in 2010, leading to roughly 6-8% reduction in emissions in that year.

Gasoline Taxes*:* The various transportation policies addressed here will at best only slow, rather than reverse, the increase in vehicular emissions of CO_2. A more targeted policy will be necessary to reduce CO_2 emissions in order to address global warming concerns. An increased gasoline tax could be such a policy. We estimates that a $1/gallon boost in gasoline taxes by 2010 would reduce passenger-vehicle miles traveled by 6.5% and taxi and truck miles traveled by 3.0-3.3%. This reduction in miles traveled, combined with the further effect of customers purchasing more efficient vehicles, would turn an expected 18% *increase* in vehicular CO_2 emissions of into a 25% *reduction*.

Under present policies that “under-price” driving, the increase in vehicular traffic forecast for Northwest Queens will translate into more stop-and-go travel and slower average speeds, both of which tend to raise per-mile and per-vehicle emissions of pollutants. Conversely, this phenomenon creates an opportunity for the pricing measures summarized above to reduce emissions in two ways: directly, by reducing the numbers of miles driven and vehicles on the road; and indirectly, by helping to maintain smoother and faster traffic flows and thus keeping per-mile emission rates from rising.

Our analysis demonstrates that area-wide or even city-wide pricing strategies offer significant opportunities for reducing air pollution and carbon dioxide emissions on a large scale. The effects of the various pricing strategies on emissions in 2010 are summarized in Table S.4

Table S.4 Estimated Changes in Vehicular Emissions in 2010, Relative to 2010 Baseline

	VOCs	PM-2.5	CO2
Cents-per-mile insurance	– 15%	– 11%	– 11%
VMT fees	– 16%	– 13%	– 12%
Weight-distance charges	– 21%	– 19%	– 16%
Gasoline tax increase	– 14%	– 11%	– 25%
Bridge tolls	– 8%	– 6%	– 6%

Emission changes are relative to 2010 baseline. Reductions in CO are similar to those for VOCs; similarly for PM-10 with respect to PM-2.5. NOx reductions tend to be roughly half of those for VOCs.

Measures to Address Heavy-Duty Diesel Vehicles

Heavy-duty diesel vehicles (HDDVs), including mostly 18-wheelers and transit buses, account for only four percent of VMT in the study area but produce 40 percent of vehicular emissions of particulate matter and half of the fine particulates. Currently, a typical HDDV emits particulates at about 20 times the rate of a passenger sedan, and emits fine particulates at around 30 times the rate of a passenger sedan. Because of their disproportionate contribution to emissions, because they are fewer in number than private automobiles, and because they have longer lifetimes than passenger cars or trucks, heavy-duty diesel vehicles are a prime target for emission-control efforts.

Two tailpipe and/or fuel measures are considered here to achieve emission reductions from heavy-duty diesel vehicles. One involves increased use by heavy trucks and transit buses of diesel particulate filters (DPF's); the other accelerates and expands conversion of some of these vehicles to compressed natural gas (CNG) fuel. Both measures would have a modest effect on overall emissions from motor vehicles in the study area, reducing particulate emissions by only 5-8% in 2010, and affecting other pollutants little or not at all. Both measures are extremely effective where used, but they appear to be applicable to only a very small fraction of the vehicle fleet in the study area.

We also estimate potential emission reductions under different emission control scenarios that reflect different usages of low sulfur diesel fuel, diesel particulate filters, and compressed natural gas. We modeled a Base Case (business-as-usual) scenario, a "dump dirty diesel" (DDD) scenario (which includes higher levels of ultra-low sulfur fuel use and diesel particulate filter use than the Base Case scenario), and a "compressed natural gas" (CNG) scenario (which includes higher levels of compressed natural gas use than the Base Case scenario). Our key findings are:

- VOC emissions fall significantly in any event; the DDD and CNG strategies accelerate the reductions only modestly beyond the Base Case, by one-half to one percentage point.
- CO emissions are barely affected by the DDD and CNG strategies, reflecting the fact that CO is overwhelmingly produced by ordinary cars and trucks rather than by heavy-duty diesel vehicles.
- The significant decline in NOx emissions in the Base Case – around 25% in 2005 and 50% in 2010 – can be accelerated slightly, by 1 to 1.5 percentage points – through a strategy to convert more transit buses and some 18-wheelers to CNG.

- Both the DDD and CNG strategies can noticeably affect particulate emissions, reducing them by 3-5 percentage points more than would otherwise occur in the Base Case through the ongoing improvement in engine and emissions-control technology for cars, gasoline-burning trucks and HDDVs.

These impacts may appear small, reflecting the fact that heavy-duty diesel vehicles account for only a small percentage, a little under 4%, of all vehicle miles traveled in the Northwest Queens study area. Nevertheless, either or both of the DPF and CNG measures are worth pursuing because of their ease of implementation and high degree of public acceptability (they would be applied to a relatively small number of buses and 18-wheelers) and their effectiveness in reducing particulate emissions, particularly in industrialized areas with unusually high concentrations of heavy trucks.

S.7 Reducing Emissions from Major Sources and Area Sources

Ideally, this report would have analyzed opportunities for reducing emissions from other "major sources" and "area sources" as well as power plants and mobile sources. Including other major and area sources would provide a complete picture of the contributors to air emissions in Queens County. These other sources may also have a greater impact since the emissions may be closer to ground level than power plants that tend to have very tall emission stacks. However, after assessing the availability and quality of the data for major and area sources, we have concluded that such an analysis is not possible within the scope of this study.

There are two primary sources of emissions data for Queens: the NY DEC and the US EPA. The existing emissions data for the major and area sources in Queens raise several concerns. The largest questions around the emissions inventories arise from the fact that, for most sources, the DEC and EPA estimates of emissions differ significantly. In general, we find that the data available are so unreliable that we are not able to conduct analyses of how these emissions might change over time, nor how these emissions could be reduced through specific public policies.

Nonetheless, major sources and area sources clearly contribute significant portions to some of the key pollution emissions in Queens – especially NO_X, particulate matter, and CO_2. There may also be some significant emissions of hazardous air pollutants that are concentrated in a few major sources. These sources, and opportunities for reducing their emissions, should be given considerable attention in future efforts to study air quality in Queens and other urban areas.

S.8 Potential Improvements to Air Quality in Queens

The final piece of our analysis was to prepare rough estimates of the air quality benefits that might be expected from the emission reduction measures that we studied for the electricity and transportation sectors. We limit our analysis to $PM_{2.5}$ emissions and ambient concentrations, because of the importance of this pollutant on health impacts in Queens.

Local Sources

One important step in this analysis is to identify the extent to which local sources of PM emissions contribute to the ambient concentration of $PM_{2.5}$ in Queens. Recall that the largest portion of $PM_{2.5}$ concentrations in Queens is probably due the transformation and transport of precursor emissions from tens or even hundreds of miles away. By comparing the chemical components that make up $PM_{2.5}$, and the levels of these components that are monitored at several locations around the state, we are able to approximate the extent to which long-range transport of $PM_{2.5}$ and its precursors are likely to affect the ambient concentrations in Queens.

We find that primary emissions from local sources in Queens likely add no more than about 2 to 4 µg/m³ to the overall $PM_{2.5}$ concentration measured at community monitors. This less than one third of the overall $PM_{2.5}$ concentrations in Queens, suggesting that at least two thirds of $PM_{2.5}$ concentrations in Queens are due to $PM_{2.5}$ blown in from upwind regions and, to a much lesser extent, to secondary $PM_{2.5}$ from precursors emitted in Queens. The same conclusion is likely to apply to the contribution of ozone and ozone precursors transported into the area from sources upwind.

The Electricity Sector

To assess the air pollution impacts of our proposals to reduce emissions from the electricity and transportation sectors, we calculate expected pollutant concentrations in Queens using a standard EPA dispersion model. Given the uncertainties involved in our projection of emissions and the absence of an estimate of the contribution of secondary pollution effects, these calculations can only provide a rough guide.

The results of our analysis of the electricity sector are summarized in Table S.5. Under our Base Case scenario, additional demand for electricity over the next ten years would result in an increase of $PM_{2.5}$ emissions from 702 tons to about 745 tons per year. This corresponds to an increase in the maximum annual $PM_{2.5}$ concentration of about 0.04 µg/m³.

Under our Clean Air Plan assumptions, emissions will decrease to about 656 tons per year, and the maximum annual $PM_{2.5}$ concentration in Queens would decrease by about 0.09 µg/m³. The Efficiency Option, which includes all the energy efficiency measures but none of the photovoltaics or supply-side measures, would have similar impacts.

Table S.5 Summary of $PM_{2.5}$ Impacts From the Electricity Sector

	Current 2002	Base Case 2010	Clean Air Plan 2010	Efficiency Option 2010
Annual $PM_{2.5}$ Emissions (ton)	702	745	656	644
Maximum Concentrations (µg/m³)	0.68	0.72	0.63	0.62
Average Concentrations (µg/m³)	0.09	0.09	0.08	0.08

Measurement in Queens have been as high as 16 µg/m³ while the Federal standard in 15 µg/m³

The Transportation Sector

The results of our analysis of the transportation sector are summarized in Table S.6. Currently the 500 tons of $PM_{2.5}$ per year directly emitted from mobile sources in Queens, together with emissions of similar magnitude in the Bronx, Brooklyn, and Manhattan, causes an average (not maximum) annual $PM_{2.5}$ concentration increment in Queens of about 0.86 µg/m³ at community monitors.

We expect regulations adopted by EPA to cut $PM_{2.5}$ motor vehicle emissions by at least one-third over the next ten years. This would lead to a decrease in $PM_{2.5}$ concentrations in Queens of 0.3 to 0.4 µg/m³ at community monitors.

For this purpose we have identified a Clean Air Plan for the transportation sector, which includes a combination of weight-distance charges with either the Dump Dirty Diesel or CNG options. (Recall that weight-distance charges are estimated to result in the greatest amount of emission reductions in criteria pollutants.) We estimate that this Plan would result in a reduction of roughly 0.12 µg/m³ in $PM_{2.5}$ concentrations in 2010, relative to the Base Case.

Table S.6 Summary of $PM_{2.5}$ Impacts From the Mobile Source Sector

	Current 2002	Base Case 2010	Clean Air Plan 2010
Annual $PM_{2.5}$ Emissions (tons)	500	275	210
Average Concentrations (µg/m³)	0.86	0.48	0.36

Measurement in Queens have been as high as 16 µg/m³ while the Federal standard in 15 µg/m³

Conclusions Regarding the Potential Air Quality Improvements

To summarize, the combination of the policies that we recommend for both the electricity and the mobile source sectors would mean a reduction in 2010 $PM_{2.5}$ concentrations of approximately 0.21 µg/m³, relative to Base Case concentrations in 2010. For comparison, recall that some air quality monitors in Queens now have readings as high as 16 µg/m³, and that the federal standard is set at 15 µg/m³. Thus, the $PM_{2.5}$ emission reductions we identify for sources in Queens will have a moderate impact on $PM_{2.5}$ concentrations in Queens.

The air quality improvements might be greater at specific locations most affected by heavy traffic, including areas near major highways. However these improvements alone would be unlikely to reduce the current background $PM_{2.5}$ concentration (16 µg/m³) to below the federal standard (15 µg/m³).

Another way to think of the air quality benefits is relative to the current concentrations. The combination of the policies that we recommend in both the electricity and the mobile source sectors would mean a reduction in 2010 $PM_{2.5}$ concentrations in Queens of approximately 0.55 µg/m³.

While this reduction may appear to be a relatively modest improvement in air quality, it may be significant enough to assist Queens in achieving compliance with the federal standard. Furthermore, the health literature for $PM_{2.5}$ implies that even the relatively small reductions estimated here would provide significant reduced mortality and morbidity effects in Queens. As described in Chapter 3, a reduction of 1.5 $\mu g/m^3$ is estimated to avoid roughly 100 premature deaths per year and avoid numerous other health impacts. Similarly, a reduction of 0.55 $\mu g/m^3$ can be expected to avoid roughly 37 premature deaths per year within Queens, as well as additional premature deaths in populations outside of Queens.

These conclusions on local air quality impacts also suggest that we should take a broad view of pollution control in order to aggressively reduce ambient concentrations in Queens. Controlling sources in Queens will have benefits far greater than the benefits for the population of Queens, and controlling sources well outside of Queens will substantially improve the air quality in Queens.

S.9 Policies to Address the Key Air Emissions

Our findings above suggest that the greatest improvements to air quality in Queens will result from policies targeted to (a) power plants in regions upwind of Queens, and (b) mobile sources inside Queens and New York City. Since many of the health threats in Queens are due to pollution sources outside of Queens, policies must support efforts to control sources in upwind states, such as the several multi-pollutant bills being discussed on the federal level. Policies must also address sources in New York City, as well as in New York State.

At the same time, it is important to address pollution emissions within Queens as well. Many of these emissions do impact the air quality in Queens, and they have a significant impact on the air quality in downwind regions. Queens can act as a model for both upwind and downwind cities, counties, and states – to demonstrate that everyone has a responsibility to address their own air emissions in order to improve air quality for all in the greater Northeast region.

There are many policies that can be used to address the air quality problems in Queens County and the neighboring regions. Here we list those policies that should receive top priority from local and state policy-makers.

Policies to Improve the Efficiency With Which Energy Is Consumed

1) New York State should establish appliance efficiency standards, above and beyond those established by the federal government, as proposed in the recent study from the Northeast Energy Efficiency Partnership (NEEP 2002).

2) New York State should seek a waiver from the central air conditioning standard (SEER 12) recently determined by the US DOE. The New York standard should instead be set at a SEER 13.

3) The existing system benefits charge, used to collect revenue from all New York State electricity customers for energy efficiency programs, should be at least doubled.

4) All federal, state, city and local government agencies should conduct biennial studies to identify efficiency measures that can be implemented at their buildings and facilities. These agencies should be required to implement all cost-effective efficiency measures identified, in order to both save taxpayer dollars spent on long-term energy costs and to reduce the environmental impacts of energy use.

5) The New York Public Service Commission should require electric distribution utilities to "decouple" their revenues from their sales, in order to provide them with the proper financial incentives to promote energy efficiency and distributed generation resources.

6) Architects and builders should be encouraged to adopt green building practices, and to have their building certified using the Leadership in Energy and Environmental Design (LEED) standards established by the US Green Buildings Council.

Policies to Promote the Construction of New, Clean, Efficient Power Plants

7) The New York Public Service Commission should give the distribution utilities a clear mandate to purchase long-term power supplies through a "portfolio management" approach. Under this policy, utilities would sign long-term contracts to support the construction of efficient power plants, but they would also factor in energy efficiency opportunities when determining the appropriate amount of power to contract for.

8) New York State should establish a renewable portfolio standard (RPS), which requires all retail electric suppliers to maintain a certain percentage of new, clean renewable resources in their portfolio of generation sources. The RPS should include a target of 10% renewable generation within ten years, and 20% within 20 years. A specific portion of the RPS should be set aside to promote the development of photovoltaics, in order to encourage the development of renewable resources in urban areas such as Queens.

9) The existing net metering law that currently includes residential solar applications should be expanded to commercial and industrial solar applications, wind turbines, and clean biomass technologies.

10) The New York Public Service Commission should adopt several policies to promote the installation of clean, distributed generation (DG) technologies, including:

    - ♦ policies that require distribution companies to adopt uniform safety and quality standards for DG technologies;
    - ♦ policies that require distribution companies to utilize simple standardized procedures for reviewing and approving applications by customers to connect their DG technologies to the electricity grid;
    - ♦ policies that ensure that utilities do not impose needless and burdensome charges on owners of DG technologies.

11) The New York Department of Environmental Conservation should adopt regulations to ensure that all forms of distributed generation technologies meet stringent air emission standards.

12) New York State should offer tax and other incentives to existing generators to encourage repowering of older, less efficient units.

Policies to Limit Pollution Emissions

13) The New York Legislature should establish a CO_2 standard for vehicles similar to that recently adopted in California. That measure requires automobile makers to achieve the "maximum feasible reduction" in greenhouse gasses for cars and light-duty trucks in model year 2009 and beyond.

14) New York State should promote the adoption of a national, regional or state cap on CO_2 emissions from power plants, and allow power plant owners to trade CO_2 emission allowances within the total cap.

15) The New York Department of Environmental Conservation should establish New York-specific ambient air quality standards for $PM_{2.5}$.

16) New York State should support efforts to establish multi-pollutant regulations to reduce transport of pollutants from upwind sources.

Policies to Promote Environmental Justice

17) Environmental justice issues should be addressed in a comprehensive and equitable fashion through the NY DEC guidance document on environmental justice and permitting (CP-29). Furthermore, when the Article X power plant siting law is reauthorized, it should include all appropriate procedures to address environmental justice issues.

18) When new power plants and other major sources of emissions are proposed to be sited within Queens, the siting and review process should (a) allow for early public input; (b) ensure that there are no disproportionate impacts on low-income populations and people of color; and (c) ensure that the project does not overburden any one community, relative to the benefits provided to that community.

Policies to Address the Transportation Sector

19) New York State should adopt a "cents-per-mile" insurance policy, whereby car-insurance providers would sell their service by the mile rather than by the year.

20) New York State should implement vehicle miles traveled fees, which charge all motor vehicles a fixed amount per mile driven. The best candidate, in terms of efficacy and equity, is weight-distance fees that charge per *ton-mile*, so that two

vehicles driven the same amount pay in proportion to their respective weights, and two vehicles of equal size pay in proportion to their usage.

21) New York State should increase gasoline taxes to induce motorists to purchase and use more-efficient vehicles. Most of the revenues should be rebated to the state's citizens on an equal per-capita basis, to promote equity, although a portion could be reserved to finance other measures to reduce vehicular emissions.

22) New York State should require Heavy-Duty Diesel Vehicles to reduce emissions through use of ultra-low-sulfur fuels and compressed natural gas.

23) New York State should require all heavy-duty construction vehicles to use ultra low-sulfur diesel fuel, and to be fitted with either diesel oxidation catalysts or particulate filters.

24) New York State car dealers should be provided with information and financial incentives to promote the sale of efficient vehicles.

25) New York City should implement tolls at the Queensboro Bridge and the other "free" East River crossings, using high-speed collection systems to obviate the need for toll plazas.

26) New York City should implement policies to reduce truck idling, including establishment of facilities at truck stops to provide air conditioning and electricity for trucks to use instead of their own engines.

27) The Metropolitan Transportation Authority and New York City Transportation Department should accelerate plans to convert diesel bus fleets to cleaner fuels such as compressed natural gas (CNG).

1. Introduction

In the interest of protecting the environment and public health of Northwest Queens, the Natural Resource Defense Council (NRDC) and the Citizens Helping Organize for a Klean Environment (CHOKE) participated in the New York State Article X permitting process for several new power plant proposed in Northwest Queens. One of their objectives was to have a study conducted to analyze the contributors to air pollution in Northwest Queens and to identify possible strategies for improving air quality and reducing risks to public health. As part of the Article X permitting process for its 250 MW Ravenswood Combined Cycle project, KeySpan committed to funding such a study as a community benefit. CHOKE and NRDC contracted with Synapse to conduct this study. The conclusions and recommendations are those of the authors but do not necessarily reflect the position of KeySpan.

Air pollution can have a significant impact on public health and the environment. The severity of these impacts depends on the types and concentrations of pollutants present. The concentration of air pollutants in a given area is the result of contributions from many different sources in many different locations. The objective of this study is to determine the main contributors to air pollution in Queens and identify strategies for improving air quality and reducing risks to public health.

This study should be of interest to residents, local representatives, public health specialists and environmental activists, and should provide a useful basis for policy decisions by lawmakers at the local, state and federal level. It should also be of interest to parties working on air quality in other urban areas in the US, as they are likely to share many of the problems and opportunities identified here for Queens.

It is also important to note at the outset that, while Queens is home to many large sources of air pollution, a significant portion of the air quality problem in Queens is due to pollution sources located upwind of the county. Similarly, much of the pollution generated within Queens affects the air quality of other regions located downwind of the county. Thus, this report should be informative to policymakers throughout the Northeastern US – as the air quality problems and opportunities throughout this large region are inextricably linked.

Air pollution creates environmental problems in a wide variety of ways. As an example, sulfur dioxide (SO_2) and nitrogen oxide (NO_X) can lead to acid rain, which can cause tremendous damage to lakes, forests, and agricultural crops. While these environmental concerns are important, they are not the focus of this analysis. Rather, the current analysis is focused on the consideration of the public health effects of air pollution. Northwest Queens is densely populated and is home to large industrial sources of pollution as well as heavily trafficked roadways. When so many people live in close proximity to so many sources of pollution, it is important to investigate the health impacts on those people.

We begin with a general discussion of the primary health threats caused by air pollution in urban areas such as Queens (Chapter 2). We describe the types of pollutants that pose the greatest risk, and discuss the various health effects of the different pollutants. We then go on to describe the air quality in Queens, and identify those air pollutants that cause the greatest health risk in the county (Chapter 3). We then identify those specific pollution sources in Queens (mobile sources, power plants, area sources) that contribute most to those priority air pollutants (Chapter 4).

We then analyze two sectors that make significant contributions to the air emissions in Queens: the electricity sector (Chapter 5) and the transportation sector (Chapter 6). Here, we estimate the likely patterns of pollution emissions through 2010 under base case, or "business-as-usual," conditions and compare those to potential emission reductions that could occur as a result of clean air policies. We briefly address other major sources and area sources of emissions (Chapter 7), but there is very little data available for those sectors from which to draw many conclusions.

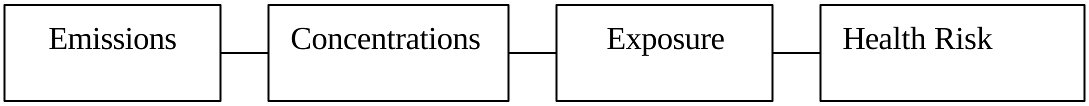
We also prepare rough estimates of the potential improvements in Queens air quality that could be obtained from the clean air policies applied to the electricity and transportation sectors (Chapter 8). Finally, we recommend several policies that can be adopted by local, state, and federal agencies that would lead to improved air quality for the residents of Queens, as well as for citizens across the northeastern United States.

2. Health Threats Due to Urban Air Pollution

2.1 Framework for Assessing Pollution and Health Threats

Like most large urban areas, Queens has numerous pollutants in its air. This can make it difficult to set priorities for reducing those pollutants, since the pollutants come from different sources, have different health risks, and are regulated differently. In addition, since much of the pollution present in Queens blows in from other places, reducing pollution emissions from sources in Queens will only partially address the air quality problem there. In this chapter, we describe the major pollutants present in Queens and provide a method to help decision makers identify the worst of these pollutants.

Our approach involves using the estimated magnitude of health risks to determine the set of pollutants most important to consider in control strategies and in more detailed assessments. One can visualize the pathway leading to health risks as follows:



In other words, *emissions* are released from a source (such as a power plant or a car) and result in *concentrations* of a pollutant outdoors and indoors. If people spend time in areas with pollutant concentrations, human *exposure* will result, which may lead to *health risks.*

This approach has four major implications for how one might set priorities.

1) Whether or not a pollutant is in violation of a health-based ambient air quality standard is a useful criterion for judging potential health risk. However, it should be remembered that some pollutants do not have ambient standards, while others may still affect population health well below the standard.
2) The pollutants emitted in highest volumes may not be the most important ones from a public health perspective, either because people do not get exposed to them or because they are less toxic.
3) Which pollutants and sources are given highest priority will depend on whether health effects within Queens are the primary concern or whether other populations are also considered, since pollution from sources in Queens can travel long distances and affect people outside of Queens (likewise, sources outside of Queens affect people in Queens).
4) Which pollutants and sources are given highest priority will also depend on whether we are most concerned about reducing total population risk (maximum efficiency) or reducing risks for highly exposed and/or highly vulnerable individuals (maximum equity).

In Sections 2.2 and 2.3, we briefly describe the major pollutants and their sources, and we determine the subset of priority pollutants that typically cause health problems in many urban areas.

2.2 Selecting Important Air Pollutants of Concern for This Study

There are three major categories of pollutants we discuss in this report – "criteria" air pollutants, toxic air pollutants, and greenhouse gases. For each of these categories, we provide a description of the pollutants in the category, and identify which of those pollutants pose a particular threat to public health. This chapter identifies which pollutants to focus on in our analysis of air pollution health threats in Queens.

Criteria Air Pollutants Defined

The US EPA has set uniform, nationwide standards for seven pollutants that are considered harmful to human health and the environment at high concentrations, and that result from numerous mobile or stationary sources. These "criteria" pollutants are carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), lead (Pb), and two measures of particulate matter (PM_{10} and $PM_{2.5}$).

Primary National Ambient Air Quality Standards (NAAQS) are established and periodically revised for each of these pollutants to protect against known adverse human health effects. Although the intent of the NAAQS has been to protect public health with an adequate margin of safety, it has become increasingly clear in recent years that being below a NAAQS does not necessarily mean that there are no health impacts (US EPA 1997), especially when multiple pollutants are present. In this chapter, we first describe some characteristics of pollutants important to consider in developing control strategies and provide some basic background about the sources and characteristics of each criteria pollutant.

Criteria pollutants can react in the atmosphere to increase or decrease levels of other criteria (and non-criteria) pollutants. A pollutant that is emitted and has not been transformed at all in the air is called a *primary pollutant*. A pollutant that leads to the formation of another pollutant is called a *precursor***,** and the pollutant that forms as a result of the emissions of the precursor is called a *secondary pollutant***.** These distinctions are important to keep in mind, since they may mean that the pollutants we control at a source are not the same as the pollutants for which we want to reduce exposures to people. We give more detail about these relationships in Section 3.2.

Carbon monoxide is a colorless, odorless gas that is almost entirely due to motor vehicle exhaust. It is harmful to health because it can displace oxygen in our bloodstream, reducing delivery of this vital substance to the cells of our bodies.

Nitrogen dioxide is a reddish-brown gas that is formed when fuel is burned. NO_2 is a precursor of both ozone and of nitrate particulate matter. Across the US, about half of the NO_2 comes from motor vehicles, with about a third from power plants (US EPA 2002a). Area sources such as commercial and residential boilers also emit NO2. When inhaled, NO_2 can irritate and damage the cells lining the deep regions of our lungs.

Sulfur dioxide is a gas principally formed when fuel containing sulfur (such as coal or oil) is burned, and is a precursor of sulfate particles and acid rain. About two-thirds of the SO_2 in the US comes from fossil-fired power plants (US EPA 2002a). When inhaled, SO_2 deposits and irritates the upper regions of our lungs.

Ozone is a major component of smog and is a secondary pollutant, formed when nitrogen oxides (NOx, which includes NO_2) react with volatile organic compounds in the presence of sunlight. ozone is a strong oxidant gas which, upon inhalation, causes damage to the sensitive cells in the deep regions of our lungs. When we are talking about respiratory health and NAAQS, we are interested in ground-level (or *tropospheric*) ozone. This is distinct from *stratospheric ozone*, which is ozone in the upper atmosphere that helps to filter out harmful ultraviolet radiation.

Lead is a metal that was once mainly related to motor vehicles (since tetraethyl lead was used as an antiknock agent in gasoline). Now that unleaded gasoline is used, most of the lead in the air comes from lead smelters or other industrial sources. Lead in soil or paint can also be a health hazard, but those effects are beyond the scope of this report. Lead exposure results in chemical changes in the brain which can reduce intelligence.

Particulate matter is defined as any solid or liquid suspended in the air. Particles can therefore contain a large number of different chemicals or substances, and can vary greatly in size. PM_{10} is the fraction of particles less than 10 micrometers (µm) in diameter (roughly one-seventh the width of a human hair). The US EPA has recently focused on $PM_{2.5}$, the fraction of particles less than 2.5 µm in diameter, since those smaller particles are more likely to get deeper into the lung. Earlier studies and regulations focused on *TSP*, or total suspended particles. Particulate matter is both a primary pollutant (including fly ash, soil, sea salt, and diesel particles) and a secondary pollutant (including sulfate and nitrate particles). Particulates can come from both natural events (forest fires, volcanos, wind erosion) and man-made activities (agriculture, combustion of wood and other fuels, mining). Exposures to particulate matter have been associated with a wide range of adverse health impacts, as described in Section 2.3.

Although all criteria pollutants are known to have health impacts, particularly when NAAQS are exceeded, only a subset are thought to contribute significantly to public health impacts at current ambient levels. In past studies of the benefits of air pollution control (US EPA 1999), improvements in particulate matter and ozone air quality contributed the vast majority of criteria pollutant public health-related benefits. This is not to say that the other criteria pollutants have no importance, or that there are not alternative interpretations of the health literature that would imply greater importance for other pollutants. However, highlighting particulate matter and ozone in this report helps us focus our discussion on the pollutants most likely to impact public health in Queens. In Section 2.3, we discuss why particulate matter and ozone are thought to influence public health so much.

Toxic Air Pollutants Defined

In addition to the criteria pollutants, the US EPA maintains a list of 188 toxic air pollutants, also known as *hazardous air pollutants (HAPs)*, that are considered detrimental to human health. Unlike the criteria pollutants, HAPs do not have air quality standards, although emissions of some HAPs are regulated under the Clean Air Act. People exposed to air toxics at high levels for long time periods may have an increased chance of getting cancer, damaging their immune system, or suffering from neurological, reproductive (e.g., reduced fertility), developmental, respiratory and other health problems.

Because there are so many air toxics, it is particularly important to focus attention on the ones that most influence public health (as we have done for criteria pollutants). As a starting point, the US EPA has constructed a list of 34 pollutants (33 air toxics and diesel particulate matter) that constitute the greatest public health threat in urban areas. This list is given in Table 2.1.

Table 2.1 List of US EPA Priority Air Toxics.

1. acetaldehyde	18. nickel compounds
2. ethylene oxide	19. chloroform
3. acrolein	20. polychlorinated biphenyls (PCBs)
4. formaldehyde	21. chromium compounds
5. acrylonitrile	22. polycyclic organic matter (POM)*
6. hexachlorobenzene	23. coke oven emissions
7. arsenic compounds	24. quinoline
8. hydrazine	25. dioxins/furans**
9. benzene	26. 1, 1, 2, 2-tetrachloroethane
10. lead compounds	27. ethylene dibromide
11. beryllium compounds	28. perchloroethylene
12. manganese compounds	29. propylene dichloride
13. 1, 3-butadiene	30. trichloroethylene
14. mercury compounds	31. 1, 3-dichloropropene
15. cadmium compounds	32. vinyl chloride
16. methylene chloride	33. ethylene dichloride
17. carbon tetrachloride	34. diesel particulate matter

* Also represented as 7-PAH

** Not included in US EPA National Air Toxics Assessment

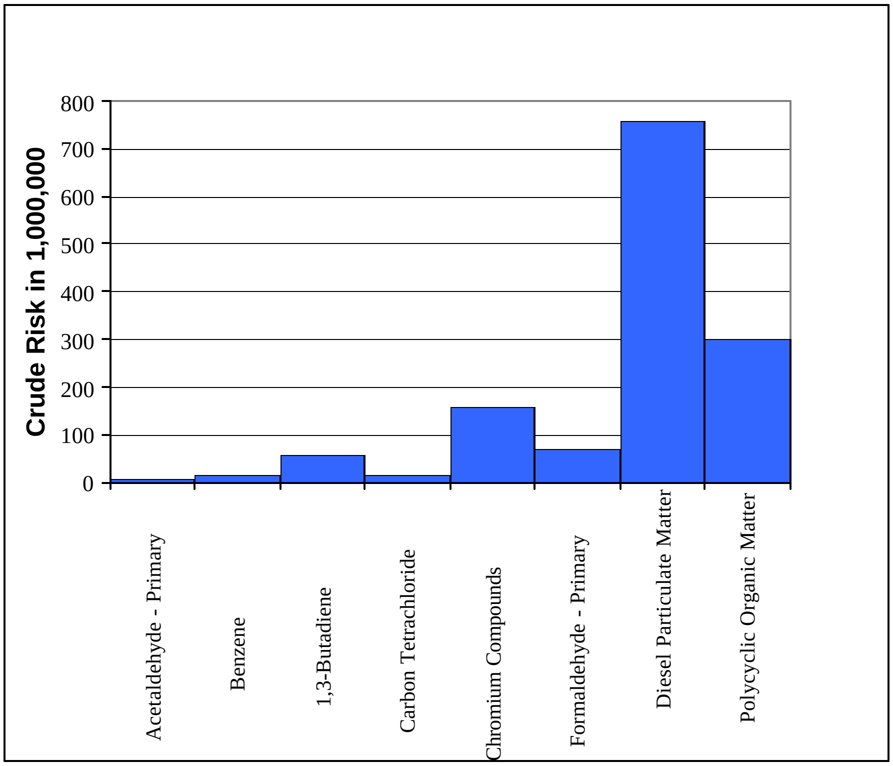
To further reduce this list to the few air toxics that pose the highest public health threat in Queens, we use a similar approach as a national study of air toxic risks (Woodruff 2000). We use estimated concentrations of air toxics in Queens and published cancer risks of these 34 air toxics to pick a subset of pollutants that require closer scrutiny. Although there are numerous non-cancer health impacts (or “endpoints”) associated with hazardous air pollutants, cancer risk arguably provides a common basis for risk comparison and tends to dominate public concern.

We combine the ambient air pollution levels in Queens (US EPA 1996a) with unit cancer risk factors reported by EPA in their Integrated Risk Information System (IRIS) database.[2] The unit risk is the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 µg/m^3 in air. In other words, if a unit risk = 1.5/10^6 per µg/m^3, 1.5 excess tumors are expected to develop per 1,000,000 people if all were exposed daily over their entire lifetimes to 1 µg of the chemical in 1 m^3 of air.

Since no IRIS unit risk was available for polycyclic organic matter (POM) or diesel particulate matter, we use other risk values in these instances. As in Woodruff (2000), we use a fraction of the interim value of benzo[a]pyrene to estimate the POM risk. For diesel particulate matter, we apply a unit risk from a recent occupational study (Dawson and Alexeeff 2001).

When we follow this procedure, we can make a simple estimate of the per-capita risk from each air toxic. Figure 2.1 shows the eight pollutants most likely to significantly contribute to cancer risk in Queens. In descending order of importance, they are diesel particulate matter, polycyclic organic matter (POM), chromium compounds, formaldehyde, 1,3- butadiene, benzene, carbon tetrachloride, and acetaldehyde. In Section 2.3, we provide descriptions of these eight pollutants and discuss the strength of the health evidence supporting our risk estimates.

Figure 2.1 Estimated Cancer Risks Of Air Toxics In Queens: Top Eight Toxics



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[2] The IRIS database, developed by EPA, contains information on human health effects that may result from exposure to various chemicals in the environment (http://www.epa.gov/iris/).

These estimates should be considered as screening calculations rather than definitive quantitative values (telling us simply what is likely enough to be big that it merits closer scrutiny), but they provide some interesting insights. For example, diesel particulate matter yields the largest cancer risk of the air toxics in Queens. Although it is difficult to interpret this risk directly, because of the numerous constituents it might represent, diesel will undoubtedly be an important air toxic in this area where mobile sources contribute greatly to air pollution.

In addition, our screening approach is limited as it results in the omission of air toxics that have significant non-cancer risks but minimal cancer risks. For example, mercury is known to have substantial neurological health effects (generally associated with consumption of contaminated fish) but does not appear to be carcinogenic. Omitting these chemicals likely understates the total air pollution public health effects in Queens, but our approach captures the pollutants with the most substantial effects.

Greenhouse Gases Defined

Although they do not affect human health directly, greenhouse gases (GHGs) contribute to global climate change and associated health problems. GHGs include carbon dioxide (CO_2), methane, nitrous oxide, and multiple other pollutants. CO_2 is the greenhouse gas of most concern because of the large volumes of CO_2 emissions relative to other GHGs. Some of the other GHGs have greater "global warming potential" per volume, but are of less concern because they are emitted in much smaller volumes. Queens contributes a very small fraction of *global* GHG emissions, but trends in CO_2 emissions in Queens are instructive for policy analysis and to compare with trends elsewhere.

2.3 Health Effects of Air Pollutants

Introduction and Definitions

In this section, we briefly define the major types of studies used to draw conclusions about health effects of pollutants. We also present the methods used by US EPA to classify carcinogens. We then describe the health effects of the subset of criteria pollutants and air toxics delineated above. Additional detail about the studies that have demonstrated the health effects of criteria pollutants is provided in Appendix A.

Three major types of studies are used to draw conclusions about health effects of pollutants: toxicological, epidemiological, and human chamber studies.

- *Toxicological studies* involve administering high doses of compounds to lab animals and measuring cancer rates or rates of other health endpoints. Toxicological studies have the advantage of being conducted in controlled laboratory settings, where the exact pollutant exposures can be determined and all other factors, such as temperature, humidity, and diet can be held constant. Because of this ability to control the experimental conditions, results from toxicological studies can demonstrate cause-effect relationships between adverse health effects and individual chemicals or compounds. One obvious problem with these studies is figuring out how to take results from animals and apply them to humans. Scientists must determine which lab animal most resembles a human response to the exposure - are humans more like rats or mice in response to chemical X? Since this is unknown, experiments are generally performed on the most sensitive species. Another problem with toxicological studies involves extrapolating from the very high short-term doses that lab animals are administered to the low long-term exposures that humans experience. Because of the myriad uncertainties associated with toxicological studies, human epidemiological evidence is generally preferred when it is available.

- *Epidemiological studies* are designed to show relationships between exposure to an agent (e.g. a chemical or compound) and the onset of disease in human populations. For example, the relationship between smoking and lung cancer was determined by epidemiology (Doll and Hill 1950). These studies are often criticized for not proving cause-effect relationships due, in part, to the fact that there may be other unknown factors, or *confounders*, that might be responsible for the observed results. Confounders are variables that are independently associated with both exposure and disease and may "cloud" the relationship a study is trying to determine. Finding a correlation between an exposure and disease does not necessarily mean that the exposure caused the disease. Consider the fact that people who carry matches in their pocket have higher lung cancer rates. Obviously, this is because they are smokers rather than because the matches themselves cause lung cancer. This example demonstrates that more information is needed to infer cause-effect relationships from epidemiological studies. Inadequate control of potential confounding factors is a major criticism of some epidemiological studies.
- *Human chamber studies* involve placing healthy or susceptible human volunteers in controlled exposure settings to evaluate how air pollution exposure influences physiological measures (like lung function or heart rate variability). While these studies cannot tell us anything about long-term exposures, severe outcomes, or disease development, they provide important evidence about the mechanisms by which a pollutant can influence health.

For criteria air pollutants, information from all three study types is available, although the primary conclusions are often drawn from epidemiological evidence. In contrast, for cancer risks from air toxics, toxicological evidence is often the only available information. This is in part because it can be difficult to detect the effects of a single air toxic when there are many other causes of cancer and because there is a long delay between exposure to the air toxic (which is difficult to measure) and the development of cancer.

Because what we think about a carcinogen might depend on the type of evidence available, the EPA has developed a classification system to "rank" air toxics. The EPA classifies carcinogens into five categories - A, B, C, D, and E - based upon the strength of the available toxicological and epidemiological evidence. In theory, one should be most concerned about possible exposure to Category A carcinogens and least concerned about Category E carcinogens. Table 2.2 provides the EPA classification scheme.

Table 2.2 US EPA Cancer Classification Scheme.[3]

Category	Description	Toxicological Evidence	Epidemiological Evidence
A	Known	Sufficient, limited, or none	Sufficient
B1	Probable	Sufficient	Limited
B2	Probable	Sufficient	Inadequate or none
C	Possible	Limited	Inadequate or none
D	Not classifiable	Inadequate	Inadequate or none
E	Non-carcinogenic	None	None

Finally, when we consider health effects of air pollutants, we consider both *acute* and *chronic* health effects. Acute health effects are due to short-term exposures, while chronic effects are due to long-term exposures. For the case of premature mortality, these different effects are often referred to as "acute mortality" or "chronic mortality". These short-hand expressions can be somewhat confusing, but they simply refer to the exposure period.

Ozone

As mentioned previously, past studies have found that ozone and $PM_{2.5}$ are the two criteria pollutants that most affect human health at current pollution levels. In this section, we briefly describe the evidence for health impacts of ozone, providing more technical detail in Appendix A.

Ozone exposure has been associated with a variety of respiratory outcomes in both human chamber and epidemiological studies. These effects are plausible because of known chemical properties of ozone. Ozone is able to travel throughout the respiratory tract and cause damage to cells on the surface of the lung, which can lead to inflammation and other pulmonary problems. Human chamber studies and epidemiological studies have demonstrated that short-term exposures to ozone can lead to pulmonary inflammation and decreases in lung function.

Other epidemiological studies have reported acute associations between ozone and a number of health outcomes, including respiratory symptoms, asthma exacerbations, emergency room visits, hospital admissions, and deaths (e.g., Kinney and Ozkaynak 1991; Thurston et al. 1992; Burnett et al. 1994). A recent article (Levy et al. 2001a) summarized this literature and provided estimates for three acute health outcomes that tend to contribute most to the total impacts of ozone – premature deaths, hospital admissions for respiratory causes, and days with minor restricted activities. We present the evidence for premature mortality in this section and discuss the morbidity outcomes in Appendix A.

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[3] The wording EPA uses to classify the categories can lead to confusion and the Agency is in the process of changing the classification scheme. For example, many carcinogens are in the B2 category and labeled "probable carcinogens." In the B2 category, increased tumor rates were found in rodent bioassays, but there is no human cancer data to support this, so these compounds may or may not be "probable" human carcinogens.

Prior to discussing the mortality evidence, it is important to realize that there can be some difficulties in interpreting epidemiological evidence on ozone health effects. Because ozone forms during warmer weather, ozone levels are often strongly correlated with temperature and relative humidity, which can have their own independent effects on health. Similarly, levels of other air pollutants can be higher when ozone levels are high. So, it can be difficult to tell whether associations in epidemiological studies represent effects of ozone alone or ozone in combination with other environmental factors.

In general, studies that controlled statistically for both weather and particulate matter found a significant relationship between ozone exposure and premature death (Moolgavkar et al. 1995; Ito and Thurston 1996; Hoek et al. 1997; Kelsall et al. 1997; Touloumi et al. 1997; Moolgavkar 2000). For the four studies in the US, the average concentration-response function was a 1% increase per 10 part per billion (ppb) increase in daily average ozone (Levy et al. 2001a). This value is applied in Section 3.5 to compare the magnitude of the effect of ozone on premature death in Queens with the effects of other pollutants.

Along with these acute health impacts, there is also limited evidence of respiratory effects of long-term exposure to ozone. For example, studies have shown that children exposed to high levels of ozone who exercised outdoors had greater prevalence of asthma (McConnell et al. 2002) and that young adults living in areas with high ozone concentrations had diminished lung function (Kunzli et al. 1997; Galizia and Kinney 2000).

In summary, the health evidence is strong and relatively consistent for a range of respiratory health effects due to ozone exposure at current ambient levels. As summarized in Appendix A, the strong biological basis and existence of human chamber and animal studies support the epidemiological observations, and recent studies have added to our understanding of the effects of ozone independent from other pollutants.

Particulate Matter

In contrast with ozone, most of the evidence for health effects from $PM_{2.5}$ comes from epidemiological studies. This is partly because $PM_{2.5}$ particles vary widely in size, composition, and origin, unlike ozone, which is a single, uniform pollutant. In addition, relatively few studies to date have focused on $PM_{2.5}$, with more epidemiological evidence existing for PM_{10} or TSP (total suspended particulates). However, because it is known that particles less than 2.5 μm in diameter are capable upon inhalation of reaching the deepest portions of the lung, smaller particles are more likely to influence health than larger particles. It is for this reason that EPA established a human health based NAAQS for $PM_{2.5}$ in 1997.

As for ozone, we can categorize the evidence for $PM_{2.5}$ into studies of acute effects and of chronic effects. The most substantial body of literature is related to premature death (and premature death tends to dominate benefits assessments), so we focus on those studies and discuss the morbidity effects of particulate matter in Appendix A.

Numerous time-series studies of particulate matter mortality risks have been published in settings across the world. In general, these studies suggest that an increase of 10 $\mu g/m^3$ in daily average PM_{10} concentrations results in a 0.5-1% increase in total daily deaths (US EPA 1996c). The deaths tend to be due to either cardiovascular or respiratory disease and appear to result in a loss of life expectancy of at least one month (Schwartz 2001). It has also been shown that mortality risks occur at relatively low particulate matter concentrations, well below both air quality standards and concentrations in Queens (Daniels et al. 2000; Schwartz et al. 2002).

There is also evidence of long-term mortality risks from particulate matter exposure. Two large prospective cohort studies (Dockery et al. 1993; Pope et al. 1995) evaluated the relationship between long-term pollution exposure and mortality risk, controlling for individual risk factors such as smoking, diet, or occupational exposures. In the Six Cities study (Dockery et al. 1993), which focused on over 8,000 white adults living in the eastern half of the US, the risk of death was 26% higher in the most-polluted city when compared with the least-polluted city (controlling for other factors). This corresponded to an approximate 1.3% increase in mortality for every $\mu g/m^3$ of annual average $PM_{2.5}$, substantially higher than the time-series estimates. The American Cancer Society study (Pope et al. 1995; Pope et al. 2002) followed over 500,000 adults in all 50 US states, finding that a 1 $\mu g/m^3$ increase in annual average $PM_{2.5}$ concentrations was associated with a 0.6% increase in mortality rates. Significant effects were seen on both cardiopulmonary and lung cancer death, and there was no evidence of a threshold.

In summary, there is substantial evidence supporting a relationship between particulate matter exposure, especially fine particles, and cardiopulmonary health (including premature death). Because the cohort mortality effect is larger than the time-series mortality effect and theoretically includes some fraction of the acute deaths, we apply the cohort mortality concentration-response function in Section 3.5.

Toxic Air Pollutants

Here we briefly describe the characteristics of each of the eight toxic air pollutants that we consider to be of greatest public health importance in Queens. The method we used to choose this subset from the list of 188 air toxics is described in Section 2.2. Recall that air toxics are pollutants that have the potential to cause serious health effects, but for which no ambient standards exist.

1. Acetaldehyde is mainly used as an intermediate in the synthesis of other chemicals. Acetaldehyde is also formed as a product of incomplete wood combustion in fireplaces and woodstoves, forest and wildfires, pulp and paper production, stationary internal combustion engines and turbines, vehicle exhaust fumes, and wastewater processing.

   The classification of acetaldehyde as a probable human carcinogen (Category B2) is based on increased incidence of nasal tumors in male and female rats and laryngeal tumors in male and female hamsters after inhalation exposure. Epidemiologic evidence for acetaldehyde is lacking.

2. Benzene is found in the air from emissions from oil and natural gas production, petroleum refining, burning coal and oil, gasoline service stations, pulp and paper production, coke ovens, and motor vehicle exhaust. Benzene is used as a constituent

in motor fuels; as a solvent for fats, waxes, resins, oils, inks, paints, plastics, and rubber; in the extraction of oils from seeds and nuts; and in photogravure printing. It is also used as a chemical intermediate. Benzene is also used in the manufacture of detergents, explosives, pharmaceuticals, and dyestuffs.

Benzene is categorized as a known human carcinogen (Category A) and has been linked to increased incidence of leukemia in humans.

3. 1,3-butadiene is found in ambient air from motor vehicle exhaust as well as manufacturing and processing facilities, gasoline distribution, production of synthetic plastics and rubber, wastewater processing, forest and wildfires, or other combustion.

   Inhalation exposure to 1,3-butadiene has been associated with an increase in rates of several tumor types in mice, and 1,3-butadiene is therefore classified as a probable human carcinogen (Category B2).

4. Carbon tetrachloride was produced in large quantities to make refrigerants and propellants for aerosol cans, as a solvent for oils, fats, lacquers, varnishes, rubber waxes, and resins, and as a grain fumigant and a dry cleaning agent. Consumer and fumigant uses have been discontinued and only industrial uses remain. Individuals may be exposed to carbon tetrachloride in the air from accidental releases from production and uses, its disposal in landfills, and wastewater processing.

   Carbon tetrachloride increases rates of hepatocellular carcinomas/hepatomas in hamsters, mice, and rats following inhalation or gavage exposures, and is classified as a probable human carcinogen (Category B2).

5. Chromium sources of emissions include the combustion of coal and oil, electroplating, vehicles, iron and steel plants, and metal smelters. The emissions reflected in this assessment are based on state and local agency reporting of chromium as "chromium and compounds," individual chromium compounds and chromium ions. Because of the inconsistent reporting, all of the chromium was lumped together and modeled as "chromium compounds." When EPA assesses the risk, the Agency will use an estimate of what percentage is hexavalent (which is the most toxic form) based on past inventorying efforts.

   Hexavalent chromium is a known human carcinogen (Category A) when inhaled, and has been linked with the development of lung cancer.

6. Diesel Particulate Matter (PM) is a mixture of particles that represent the main component of diesel exhaust. EPA has recently proposed to list diesel exhaust as a mobile source air toxic due to the cancer and non-cancer health effects associated with exposure to whole diesel exhaust. EPA believes that exposure to whole diesel exhaust is best described, as many researchers have done over the years, by diesel particulate concentrations.

   Diesel particulate matter has not been given a formal cancer classification, in part due to the difficulty in understanding risks of a heterogeneous compound. Epidemiological studies have found that diesel particulate matter increased the rate of lung cancer in railway workers.

7. Formaldehyde is used mainly to produce resins used in particleboard products and as an intermediate in the synthesis of other chemicals. The major sources of emissions to the air are forest and wildfires, stationary internal combustion engines and turbines, pulp and paper plants, petroleum refineries, power plants, manufacturing facilities, incinerators, and automobile exhaust emissions.

   There is some human health evidence for formaldehyde increasing the risk of squamous cell carcinoma, so it has been categorized as a probable human carcinogen (Category B1).

8. Polycyclic organic matter (POM) defines a broad class of compounds that includes the polycyclic aromatic hydrocarbon compounds (PAHs). POM compounds are formed primarily from combustion and are present in the atmosphere in particulate and gaseous forms. Sources of air emissions are diverse and include vehicle exhaust, forest and wildfires, asphalt roads, coal, coal tar, coke ovens, agricultural burning, residential wood burning, and hazardous waste sites. Because of limited emissions data, for this assessment, Polycyclic Organic Matter (POM) data have been limited to either the group of 7 or group of 16 individual PAH species referred to as 7-PAH and 16-PAH, respectively. In this assessment, POM refers to 16-PAH. The 16-PAH group includes the 7-PAH group. The species that make up 7-PAH are probable human carcinogens, and the 16-PAH are those species that are measured by an EPA test method (EPA Method 610).

   Benzo[a]pyrene (a specific compound in the 7-PAH group) is the component of POM generally used for cancer risk estimation. It is categorized as a probable human carcinogen (Category B2). Multiple animal studies in many species demonstrate benzo[a]pyrene to be carcinogenic following administration by numerous routes. It has produced positive results in numerous genotoxicity assays. Exposure to benzo[a]pyrene is suspected to cause lung cancer.

Traffic

Having a separate category for “traffic” may appear redundant, as most of the important traffic-related pollutants are either criteria pollutants or toxic air pollutants, which are described above. However, there are two reasons why it may be useful to consider separately the health effects of traffic exposure, in a detailed air pollution risk calculation:

1) There are multiple published studies documenting health effects of increased exposure to traffic, many of which do not determine the responsible pollutants (or even distinguish between air pollution and other effects, like noise).

2) Much of the pollutant-specific health literature looks at the effect on health of average exposures across the population, while traffic studies capture important spatial patterns.

On the first point, multiple studies have shown that children who live near major roadways have reduced lung function and increased respiratory symptoms (Wjst et al. 1994; Oosterlee et al. 1996; Brunekreef et al. 1997; Venn et al. 2001). Asthmatic children who live near major roadways have increased rates of hospital admissions (Edwards et al.

1994), with high density roads within 200 meters as the strongest traffic-related predictor in a study in New York (Lin et al., 2002). Although these effects are likely related to air pollution, there may be other contributing factors. For example, increased traffic density has been linked with a loss of neighborhood communication and collaboration (Appleyard 1981), which can induce disease through increased stress.

Supporting this evidence for traffic-related health impacts is the potential heterogeneity in traffic-related exposures. If traffic-related air pollution levels were similar across a city, proximity to a major road would not matter. Numerous studies have documented significant differences in traffic-related air pollution levels over small geographic areas. For example, a study in Harlem found that elemental carbon levels (a marker for diesel exhaust) ranged by a factor of four across sites in close proximity to one another, while $PM_{2.5}$ levels were quite similar (Kinney et al. 2000). Similarly, PAH concentrations in an urban center were a factor of three higher on a street than in a park (Nielsen 1996). In the Roxbury neighborhood of Boston, PAH concentrations were close to zero late at night but became higher during rush hour and with proximity to a major bus terminal (Levy et al. 2001b), demonstrating both spatial and temporal variations.

Taken together, these pieces of evidence imply that health impacts from traffic are likely and that they tend to occur in close proximity to major roads. While these impacts are difficult to quantify and may overlap somewhat with pollutant-specific effects, they may make an incremental contribution to air pollution health impacts in Queens. We do not address this dimension further in this report, but this evidence can aid in the interpretation of our findings.

Greenhouse Gases

The worldwide increase in GHG concentrations, beginning in the 1800s with the industrial revolution and accelerating ever since, has put the world on a well-documented trend of increasing temperatures that will become more severe in the current century. Global climate change models predict that worldwide daily mortality and morbidity due to extreme heat events could significantly increase in this century, especially among elderly poor who often have pre-existing health conditions and may lack air conditioning or access to air conditioned spaces. Projected increases in frequency and duration of extreme heat events will exacerbate the "urban heat island effect," which raises daily urban temperatures up to 10 degrees Fahrenheit higher than the surrounding suburbs/exurbs, especially during the nighttime hours.

As temperatures increase, so will summertime energy demand, further increasing CO_2 emissions from power plants – as well as emissions of airborne pollutants like sulfur dioxide, nitrogen oxides and volatile organics (which are precursors of ozone and acid rain). Thus, climate change may lead to a cycle in which increasing CO_2 emissions lead to increased temperatures, which in turn lead to increases in emissions that both exacerbate climate change and threaten public health.

Other health impacts of climate change include increased rates of secondary air pollutant formation (e.g., ozone and some $PM_{2.5}$ components), incidence of vector-borne and water-borne diseases, and possibly increased frequency and severity of severe storms. By as early as the 2020s, there could be significant increases in the sea level in the New York area (US Global Change Research Program 2001). Sea level rise, combined with more frequent droughts and floods, will pose a significant challenge to urban transportation and drinking water delivery infrastructure. While the vulnerability of Queens to these impacts has not yet been specifically assessed, its highly urbanized structure and extensive coastline suggest a high degree of vulnerability.

3. Air Quality And Health Risks In Queens

In this chapter, we move from the general health evidence to specific details about air quality in Queens. This information can tell us something about the types of health effects expected and the sources of important air pollutants in Queens. In Section 3.1, we provide an overview of the population and health profile of the residents of Queens. In Section 3.2, we give an overview of air quality monitoring in Queens. Section 3.3 gives a largely qualitative description of the factors that can influence air pollution patterns in Queens, which can be used to help bridge the gap between emissions and concentrations. We summarize data on outdoor air pollution in Queens in Section 3.4, and conclude with some simple calculations of potential health risks to help prioritize among pollutants in Section 3.5.

3.1 Population and Health Profile of Queens

Any calculation of health risks is based on the demographics and current health status of the community. In this section, we consider basic characteristics of Queens that could be relevant in either estimating health risks or in drawing inferences about the potential burden of air pollution.

Queens, located at the northwestern tip of Long Island, is the second most populous borough of New York City and home to over 2.2 million people. It comprises just over 30% of NY City’s land area (NY Department of City Planning 2001) and includes, along with residential neighborhoods, commercial and industrial zones typical of the New York Metropolitan area, especially along its western waterfront (East River and its tributaries). Queens also includes substantial natural estuarine areas at its northern and southern margins.

The population of Queens grew relatively rapidly between 1990 and 2000 (by 14.2%), largely among its highly diverse immigrant communities. According to the 2000 US Census (US Census Bureau 2002a,b), Queens’ population density averaged over 20,000 persons per square mile and Queens’ residents reported themselves as African-American (20.0%), Asian (17.6%), of some other race (11.7%), or of two or more races (6.1%). The percentage of females was 51.8% and the borough’s median age was 35.4 years. Nearly 36% of Queens households had children under 18, with an average of 2.8 persons per household; 42.8% of residents owned their homes, and the median household income of $35,820 (US Census Bureau 2002b) was only slightly less than NY State’s ($36,369).

In terms of the health status of its residents (see Table 3.1), the 1999 crude mortality rate of Queens County (837 per 100,000 population) was similar to that of New York City as a whole (840 per 100,000) but lower than that of NY State (879 per 100,000) (CDC Wonder 2002). Among the leading causes of death in Queens in 1999 were heart disease (48% of all mortality), neoplasms at all sites (22%), pneumonia and influenza (3%), cerebrovascular disease (3%), and chronic lower respiratory disease (3%). These rankings are similar to those in NY City as a whole, with the exception that deaths due to HIV infections are the fifth leading cause of death in the City, far more so than in Queens.

Comparing Queens to NY State, the leading mortality causes are the same but the rankings are slightly different.

Table 3.1 Current Health Profile of Queens

	Queens		**NY City**		**NY State**	
Yr 2000 Total Pop		2,229,379		8,008,278		18,976,457
Total MORTALITY: 1999		16,744		62,363		159,903
1999 Crude mortality rate (per 100,000 pop)		837		840		879
Among the leading causes of death in 1999 were (% of all annual deaths)…	**Heart Disease**	48%	**Heart Disease**	41%	**Heart Disease**	37%
	Malignant Neoplasms, All Sites	22%	**Malignant Neoplasms, All Sites**	23%	**Malignant Neoplasms, All Sites**	24%
	Pneumonia & Influenza	3%	**Pneumonia & Influenza**	4%	**Cerebrvscular Disease**	5%
	Cerebrvscular Disease	3%	**Cerebrvscular Disease**	3%	**Chronic Lower Resp. Dis.**	4%
	Chronic Lower Resp. Dis.	3%	**HIV infections**	3%	**Pneumonia & Influenza**	3%
Total HOSPITALIZATIONS: 2000		270,511		1,083,821		2,456,658
Among the leading causes of hospitalization in 2000 (% of all admissions) were…	**Cardiovascular (CV) Disease**	15%	**CV Disease**	14%	**CV Disease**	16%
	Health Status/Use of Health Svcs	14%	**Health Status/Use of Health Svcs**	13%	**Health Status/Use of Health Svcs**	12%
	Pregnancy, Childbirth	13%	**Pregnancy, Childbirth**	12%	**Pregnancy, Childbirth**	12%
	Respiratory System	9%	**Mental Disorders**	10%	**Respiratory System**	9%
	Digestive System	8%	**Respiratory System**	9%	**Mental Disorders**	8%

References: 2000 Total Pop from US Census Bureau 2002a, Total Mortality 1999 & 1999 Crude Mortality Rate from CDC Wonder 2002, Leading Causes of Death 1999 for NY State from CDC NCIPC 2002, Leading Causes of Death 1999 for Queens and NY City from NYC DOH 1999b, 2000 Hospitalization Data from InfoShare 2002, NYC Dept of Health 1999b.

Patterns of disease in Queens generally follow those across the city and state. Of the 270,511 hospital admissions in Queens in 2000, 15% were for cardiovascular disease; 14% were attributed to health status/use of health services; 13% were for pregnancy/childbirth; 9% were for respiratory system illnesses; and 8% for digestive system disorders. For the city and state, rankings among leading hospitalization causes were similar except that mental disorder admissions replaced digestive system admissions.

Deaths and illnesses related to respiratory and cardiovascular diseases and asthma are of particular concern when one considers the health impacts of air pollution exposures. Queens has a higher percentage of heart disease deaths (48%) than does the city (41%) or state (37%). The all-age asthma death rate in Queens was 2.15 per 100,000 total population in 1997, slightly higher than the 1998 US average of two per 100,000 population. The 1997 asthma hospitalization rate among children aged 0-14 in Queens was seven per 1,000 total population; this represents a 57% increase since 1988, and was almost three times the NY state average (NYC Dept of Health 1999a). These elevated rates may or may not be due to air pollution, but studies have demonstrated some links between high levels of ozone and greater prevalence and exacerbation of asthma, as described above. In addition, these elevated rates show that there are large numbers of persons who are likely to be susceptible to the effects of air pollution owing to their preexisting cardiovascular disease or asthma.

3.2 Air Quality Monitoring Background

The type of information collected regularly on air quality differs by pollutant type. For the six criteria air pollutants, monitoring is conducted at a number of locations on a regular basis, to help evaluate whether there are NAAQS violations. Data from this monitoring system are contained in the Aerometric Information Retrieval System (AIRS), a database maintained by the U.S. Environmental Protection Agency (http://www.epa.gov/air/data). Most pollutants are measured on a continuous basis, either with hourly or daily average concentrations (depending on the pollutant).

On the other hand, for toxic air pollutants, the US EPA requires different sources to meet a variety of emissions standards, but no ambient concentration standards exist. Thus, the monitoring data available for air toxics are much more limited than for criteria air pollutants, necessitating alternative methods or data sources to estimate exposures to air toxics.

Limitations of Ambient Air Quality Data

Data on ambient air quality can be very useful in understanding overall trends in air quality over space and time and for judging the impacts of sources and compliance with the NAAQS. These data also allow for health risk calculations, since the epidemiological evidence is based on ambient data drawn from central-site monitors.

However, it has long been recognized that ambient air pollution concentrations do not necessarily represent the levels of air pollution to which people are exposed. This is due in part to the fact that, on average, Americans spend 90% of their time indoors. Most ambient pollutants penetrate only partially indoors, with the penetration efficiency depending somewhat on pollutant type and building characteristics (like the presence of air conditioning). Because of its reactive nature, ozone only partially penetrates indoors, with indoor/outdoor ratios ranging from 0.1 to 0.8, depending on the degree of natural ventilation (penetration is greatest when open windows are used for ventilation). On the other hand, outdoor $PM_{2.5}$ particles penetrate readily to the indoor environment (Ozkaynak and Spengler 1996).

In addition, the indoor environment has important sources of many pollutants, including $PM_{2.5}$, NOx, and VOCs. These sources might include gas stoves or new carpets. As a result, higher concentrations of many pollutants occur indoors than outdoors, especially when buildings are tightly sealed for energy efficiency. Another important factor limiting the usefulness of ambient monitoring data for representing population exposures is the fact that monitors are few in number, typically located on roofs two or more stories up, and often do not capture the impact of local sources, e.g., the impact of heavy traffic roadways on nearby residents. For these reasons, in order to fully characterize exposures of the population, it is valuable to supplement the ambient monitoring data with personal monitoring.

Moreover, despite the limitations of ambient air quality data, there is a strong correlation between outdoor air pollution levels and certain health outcomes. As mentioned, above epidemiological studies tell us that on days when air pollution levels are high, more people get sick or die. Such correlations lead to the ambient air quality standards set by EPA. Although we have a limited ability to know who is at highest risk because of our lack of personal exposure data and knowledge about population susceptibility, we can still draw population-wide inferences as long as average personal exposures increase when outdoor levels increase. For pollutants that penetrate indoors, even to a limited degree, this is indeed the case.

Personal Exposure Studies

Personal exposure refers to concentrations of air pollution that are encountered in the breathing zone of persons as they go about their normal activities. Personal exposures are best assessed using miniature, portable air monitoring equipment that can be conveniently carried in a back-, shoulder-, or belt-pack; or by measuring concentrations in a number of specific locations where people are likely to spend time and figuring out how long people spend in those settings.

A large number of personal monitoring studies have been carried out over the past 25 years, though few of them have included people living in NYC, or Queens in particular. The general message that has emerged from these studies is that for most pollutants, especially VOCs, NO_2, and PM, personal exposures generally exceed ambient concentrations, presumably due the impacts of indoor sources along with the tendency for personal activities (such as walking, cooking, or vacuuming) to generate local increases in pollution levels, especially for particles. For ozone, personal exposures are usually lower than ambient concentrations, since there are few important indoor ozone sources and because outdoor ozone does not penetrate indoors very efficiently.

One recent study illustrates personal air toxics exposures to persons living in New York City. The TEACH (Toxic Exposure Assessment, a Columbia/Harvard) study was designed to characterize levels of and factors influencing personal exposures to urban air toxics among 46 high school students living in inner city neighborhoods of New York City (Kinney et al. 2002). In general, the study found that people experience a wide range of exposures to air toxics, that indoor sources are important for some but not all air toxics, and in some cases personal exposures exceed both indoor and outdoor concentrations. Results from the study are summarized in Appendix B.

3.3 Factors Affecting Air Quality in Queens

To interpret data on air pollution concentrations, it is important to understand the factors that can influence concentrations. This includes not only the sources of air pollution and their locations, but also meteorological factors that can affect how far pollutants travel and how they change in the atmosphere. In this section, we briefly describe some of the characteristics of important pollutants and consider factors that can influence the concentrations of these pollutants independent of emission rates. This will allow for a better understanding of the relative influence of local and regional contributors to air quality problems in Queens.

First, we briefly describe meteorological conditions in Queens. We know that Queens (and the New York area in general) is influenced by weather systems that move across the country from a westerly direction. This has the impacts of increasing summer temperatures and lowering winter temperatures when compared with other coastal areas; but the weather pattern also reduces extended periods of stagnant air. For air pollution purposes, this implies that emissions from the Midwest (and other areas to the south and west) are able to be transported to New York and can influence pollutant concentrations.

Particulate Matter

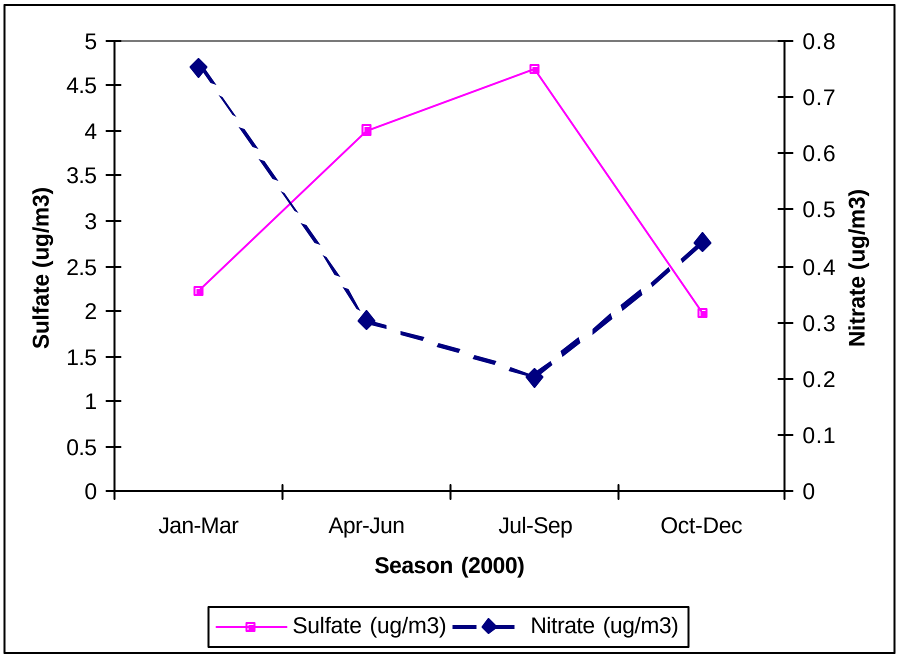
Turning to pollutant characteristics, we focus on particulate matter and ozone, since they appear most important for major health impacts and since they have some complex behaviors worth considering. Recall that particulate matter consists of many different chemicals and contains both primary (directly emitted) and secondary (formed through reactions in the atmosphere) components. As a result, the factors that lead to high concentrations differ somewhat, depending on which form of particulate matter we are discussing.

Two of the most important particle types on a mass basis are secondary sulfate and nitrate particles. Although it depends somewhat on the setting, on average, sulfates and nitrates combined contribute about half of the ambient $PM_{2.5}$ on the East Coast. Sulfates are formed over time in the atmosphere when SO_2 gas reacts with ammonia gas. Sulfate formation tends to be quicker on hot and humid days and slower on cold days or at night. Temperatures in the summer in New York are certainly warm enough for sulfate formation. Thus, concentrations of sulfates are highest in the summer, both because of atmospheric conditions and because power plants generate more electricity in the summer (in response to high air conditioning use). On the other hand, nitrates tend to form on colder days. Figure 3.1 provides seasonal sulfate and nitrate concentrations in Ulster, NY (taken from the EPA’s CASTNET monitoring network). While this is not Queens, sulfates and nitrates follow similar seasonal patterns across New York.

Another important contributor to particulate matter concentrations in Queens is elemental and organic carbon (on average, about a third of $PM_{2.5}$ concentrations in the East Coast). These pollutants do not display as strong a seasonal pattern as sulfates or nitrates, since they are mostly primary pollutants and are predominantly emitted by sources (like diesel vehicles) that emit year-round.

Despite these differences, one important commonality for fine particulate matter is its ability to travel long distances in the atmosphere. Although larger particles settle out of the air more quickly, fine particles ($PM_{2.5}$) can take days to settle out of the air, especially when emitted from tall stacks. Sulfates, nitrates, and elemental and organic carbon are all smaller particles, and they can travel extremely long distances. This is why it is believed that power plants in the Midwest can have an impact on air quality in the East Coast.

Figure 3.1 Seasonal Patterns Of Sulfate And Nitrate Concentrations In New York



This raises an issue that we touch on briefly here and return to throughout this document. Although particulate matter can travel a long distance, the maximum concentrations from a source are generally fairly close to the source (anywhere from less than a mile to tens of miles or more, depending on the height of emission and the type of particulate matter) (Levy et al. 2002; Levy and Spengler, 2002). If the source emits mainly primary particles (e.g., a major highway), this effect will be enhanced. If instead the source emits mainly precursor gases (e.g., a power plant), this effect will be reduced.

The health impacts of a source will differ depending on whether one is concerned about total health risks or individual health risks. If we are concerned about the total health risks of a source, a large fraction of these risks will occur at some distance from the source, simply because only a small fraction of the total affected population lives close by the source. This effect is less pronounced for primary particles and for sources in dense urban areas (like Queens) (Levy and Spengler, 2002). However, an individual living near a source will be at greater risk than an individual living hundreds of miles away, because of where the concentration is highest. This may seem somewhat contradictory at first, but is logical given pollution and population patterns.

Ozone

Turning to ozone, as mentioned above, ozone is a secondary pollutant formed when NOx reacts with volatile organic compounds in the presence of sunlight. Thus, ozone is formed most intensively during the summer. In New York, according to NY DEC, “ozone season” is considered to be from May 1 until September 30. As for particulate matter, ozone can travel a substantial distance in the atmosphere, and many of the ozone episodes in New York can be related to long-range transport of ozone from the Midwest or South. Ozone concentrations often remain elevated late into the evening, especially in regions downwind of major urban areas. As a result, residents of areas downwind of major source areas, such as Queens and Long Island, often experience longer periods of elevated ozone levels than do urban dwellers, such as those living in Manhattan.

An important characteristic of ozone formation to keep in mind is that it is a non-linear phenomenon. In other words, in some circumstances, increases in NOx emissions can increase ozone formation, while in other circumstances, it can lead to lesser ozone formation. When increased emissions lead to lower ozone, it is called *ozone scavenging*. This phenomenon often leads to higher levels of ozone in rural areas than in urban areas (where there are comparatively higher concentrations of NOx).

In conclusion, when we are considering particulate matter and ozone, the complex atmospheric behaviors make it important to understand the setting where the pollutants were emitted in order to estimate the effects on concentrations and public health.

3.4 Summary Description of Air Quality in Queens

Criteria pollutants

Earlier, we discussed the health evidence for criteria pollutants and concluded that particulate matter and ozone were the two most important pollutants in Queens from a health perspective. However, understanding trends of the other criteria pollutants can help understand how different sources can influence air quality in Queens. For example, carbon monoxide (CO) levels are closely linked to motor vehicle pollution patterns, and lead (Pb) levels over recent decades show the influence of unleaded gasoline. Also, as described above, we know that nitrogen oxide (NOx) and sulfur dioxide (SO_2) emissions can influence PM and ozone concentrations. Consideration of ambient concentrations of NO_2 and SO_2 can provide some useful information about these effects.

Nationally, average ambient levels for all six criteria air pollutants decreased from 1991 to 2000 (US EPA 2001). However, air quality progress has been slowest for ground-level ozone and $PM_{2.5}$. Ozone concentrations decreased somewhat in 52 metropolitan regions from 1981-1993, but beginning in 1994 these improvements began to diminish. The limited progress for ozone has been largely due to increases in emissions of precursor gases - national NO_x emissions increased by 20% over the last 30 years, with both power plants and motor vehicles contributing. The highest ambient ozone concentrations are found at suburban and rural sites downwind of urban emission areas (US EPA 2001). From 1991 to 2000, while average ambient PM_{10} concentrations (i.e., particles smaller than 10 micrometers) decreased 19% across the US, $PM_{2.5}$ concentrations decreased nationally by only 5% from 1992-1999. $PM_{2.5}$ levels are higher in the Eastern US, where sulfur dioxide emissions from coal-fired power plants contribute to fine particulate formation (US EPA 2001).

To get a sense of criteria pollutant levels in Queens, we first consider peak concentrations. As indicated in Table 3.2, the New York State Department of Environmental Conservation has monitored ambient air quality at multiple sites in Queens (NY DEC 2002). As in many locations in the US at present, ozone and PM are the two pollutants where levels are close to or exceed the NAAQS.

Queens, as part of the New York Metropolitan Statistical Area (MSA), is within an EPA-designated severe ozone non-attainment area. Over the three years 1998-2000, Queens was one of only two city boroughs to exceed the 8-hour daily maximum NAAQS standard of 0.08 ppm ozone (US EPA 2002b). This has both health implications and practical implications, as violations of air quality standards imply that mitigation measures will be necessary.

Also, readings at some PM 2.5 monitors in Queens show exceedances of the annual federal standard of 15 µg/m³. While the Queens monitors showing exceedances do not use the federal reference method (and will not be used by DEC for non-attainment designations), nearby federal reference method monitors in the South Bronx and northern Manhattan also show exceedances of the annual standard. Before designating PM 2.5 non-attainment areas, DEC must decide whether monitors in the South Bronx and northern Manhattan are more representative of conditions in western Queens than the federal reference monitors in Queens, which are all in the eastern part of the borough.

We can also compare the air quality in Queens with other settings by using the EPA's Air Quality Index (AQI). The AQI is a tool for reporting to the public relative daily pollution levels of health concern, based on a compilation of criteria pollutant concentrations. For example, an AQI from 0 to 50 indicates good air quality, while an AQI over 100 poses unhealthy conditions for those sensitive to air pollution. From 1991 to 2000, the number of days annually with AQI values greater than 100 decreased in the New York MSA, from 49 per year in 1991 to 12 per year in 2000.[4] Since 1996, the primary contributor to high AQI values in New York City has been ozone. Considering the large exposed urban population coupled with significant ambient pollution, Queens has been ranked by Environmental Defense's "Scorecard Pollution Locator" (www.scorecard.org) among the worst 10% of US counties in terms of its criteria air pollutant exposures, and scores only slightly better when compared to NY State counties.

For PM 2.5, AQI levels over 100 correspond to 24-hour PM 2.5 readings greater than 40 µg/m³. Readings higher than 40 µg/m³ occur several times per year at South Bronx monitors close to western Queens.

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[4] For NY MSA: AQI ozone-only at 6 trend sites, and a total of 12 sites; AQI at 29 trend sites and 31 total sites; data at http://www.epa.gov/airtrends/, "Number of Days with an Air Quality Index Over 100 by City" and "Number of Days with an Air Quality Index Over 100 by City, Ozone Only," data at http://www.epa.gov/oar/aqtrnd00/pdffiles/aqioz.pdf

Table 3.2 NY DEC Ambient Air Quality Monitoring Data for Queens, 2000.

Location	CO 2nd Max. 8-hour (ppm)	NO_2 Annual (ppm)	O_3 4th Max. 8-hour (ppm)	$PM_{2.5}$ Annual (µg/m³)	SO_2 2nd Max. Daily (ppm)
Queensboro Comm. College	3.3	0.026	0.088*	13.0	0.025
College Point P.O.		0.030	0.066		
P.S. 29				14.1	
P.S. 214				13.8	
P.S. 199				16.0*	
Maspeth Library				15.1*	
Standards:	CO 8-hour: 2nd highest 8-hour average not to exceed 9 ppm in any year. NO_2 annual: 0.05 ppm. O_3 24-hour: 4th highest 8-hr average not to exceed 0.08 ppm average over last 3 years. $PM_{2.5}$ annual: 15 µg/m³ average over last 3 years. SO_2 24-hour: 2nd highest daily average not to exceed 0.14 ppm in any year.				

** Violation of National Ambient Air Quality Standard (or potential violation in the case of $PM_{2.5}$, which requires three years of data).*

However, violations of NAAQS and AQI levels only provide limited information about air pollution health risks in Queens. For example, an annual average $PM_{2.5}$ concentrations below the NAAQS of 15 µg/m^3 is only helpful if no health effects are documented below this level. As shown in the American Cancer Society study (Pope et al. 2002) and elsewhere, there is ample evidence of health effects below the NAAQS. Thus, if air quality plans are to be based on population health risks rather than simply on violations of NAAQS, it is important to not simply focus on regulatory thresholds.

In summary, the above data (coupled with the earlier health evidence) demonstrate that levels of ozone and $PM_{2.5}$ in Queens are sufficiently high to cause concern. In Section 3.5, we calculate the population health implications of the ambient concentrations of these pollutants, but note that potential non-attainment of the revised NAAQS would inflict additional burdens.

Air toxics

Air toxics may be emitted from major sources (large stationary source emitters), area sources (such as smaller point sources and wildfires), on-road mobile sources (such as cars, trucks, buses), and off-road mobile sources (including airplanes, marine transportation, trains, farm machinery). Alternatively, air toxics may represent background concentrations that result from natural sources, past years' emissions, or long-range transport from distant sources. It is important to recall that while the modeled ambient air toxics concentrations play a role in determining cancer risk, they may not accurately reflect human exposure since people may be exposed to air toxics from a variety of indoor sources as well.

Figure 3.3 Modeled ambient concentrations of 33 air toxics in Queens.

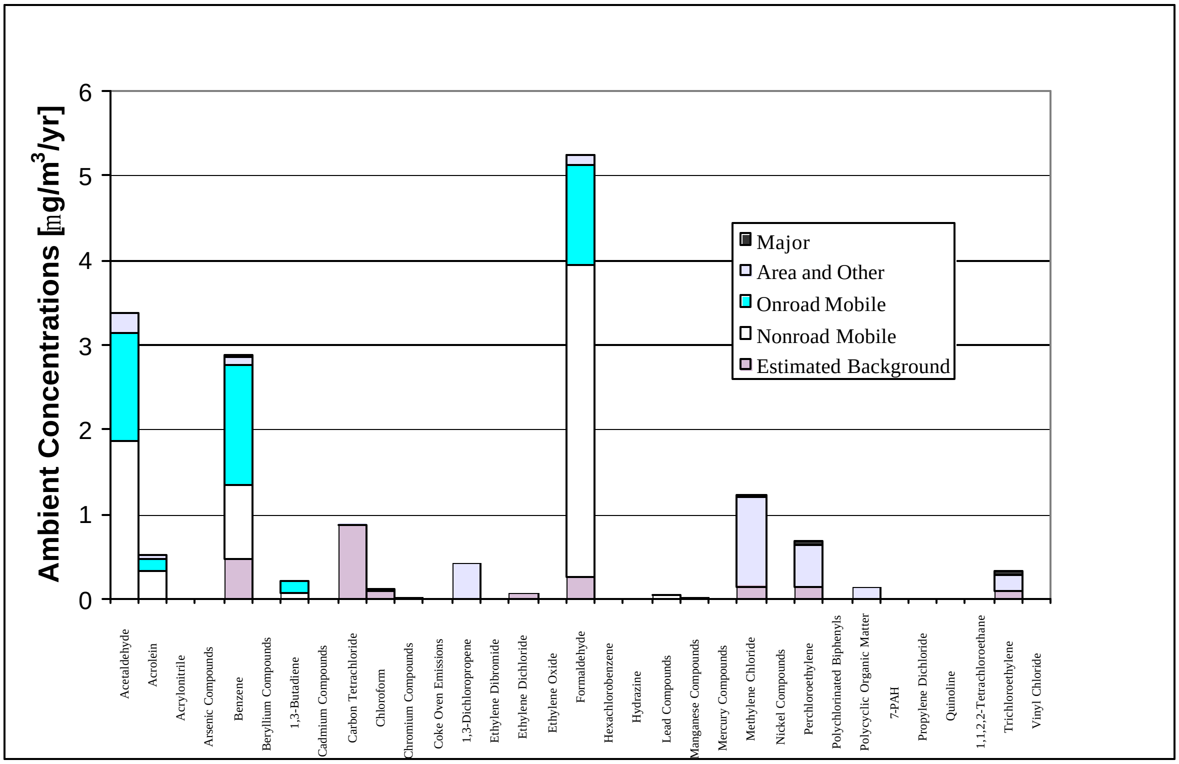

Figure 3.3 shows the modeled ambient air toxics concentrations for 33 compounds in Queens, taken from the National Air Toxics Assessment.[5] Note that PAH represents POM and that diesel particulate matter was not included in the analysis. The tops of the columns represent the total ambient concentration while the shaded areas correspond to the contributions by major, area, and mobile sources. From a health standpoint, it is important to consider the background concentrations, but when trying to reduce emissions, only non-background sources should be considered. Note for carbon tetrachloride, essentially the entire ambient level results from background concentrations. Consequently, efforts to reduce emissions of this compound would have negligible effects upon its ambient concentration. Typically, large power plant emissions would be included in the major source category, which often represents a relatively small fraction of the total ambient concentration of air toxics.

Because there are no ambient air quality standards for air toxics, the importance of these concentrations can only be understood in reference to the resulting health risks. Since we focus on cancer risks from air toxics, this implies that we must multiply the ambient concentrations by the unit cancer risks provided by IRIS, to gain insight about the relative contribution of air toxics to health risks in Queens. In Section 3.5, we make this calculation and compare the cancer risks with the magnitudes of mortality risks associated with PM$_{2.5}$ and ozone.

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[5] See http://www.epa.gov/ttn/atw/nata/

3.5 Potential Health Implications of Air Quality in Queens

In Chapter 2, we outlined the health evidence and concluded that two criteria air pollutants ($PM_{2.5}$ and ozone) and eight air toxics (acetaldehyde, benzene, 1,3-butadiene, carbon tetrachloride, chromium, diesel particulate matter, formaldehyde, and POM) are the most significant contributors to health impacts in their respective categories. In the above sections, we have provided data on the levels of these pollutants in Queens. To use this information to develop an air pollution control policy requires at least two additional questions to be answered:

- How large are the health impacts of $PM_{2.5}$ compared to ozone, and of the criteria pollutants compared to the air toxics?
- What are the primary sources that contribute to ambient concentrations of the most important air pollutants?

Answering the first question in a precise way is well beyond the scope of this study. However, we can make some simple upper bound calculations to help understand which effects are likely to be most significant. First, we focus only on premature mortality (assuming for the sake of argument that all cancers from air toxics are fatal, a reasonable assumption for lung cancer and a bounding assumption for other cancers). We assume that concentrations of each pollutant are decreased by 10% across all of Queens, and we calculate the resulting health benefits. We make this calculation rather than simply calculating the total health burden of current air pollution, because it does not require determining whether there are health effects at very low levels of air pollution and because any near-term air pollution policy would be unlikely to eliminate all air pollution in Queens. We note that the total health burden of current air pollution would be ten times our estimates if no thresholds existed.

Looking first at air toxics, Figure 2.1 depicts the estimated upper-bound cancer risks of the eight selected pollutants. We reproduce those figures in Table 3.3.

Table 3.3 Upper-Bound Cancer Risks of the Eight Selected Pollutants

Pollutant	Lifetime cancer risk per 1,000,000 people
Acetaldehyde	7
Benzene	14
1,3-butadiene	59
Carbon tetrachloride	13
Chromium	156
Formaldehyde	68
POM	300
Diesel particulate matter	760

Adding these risks together, we get a lifetime cancer risk of about 1400 per 1,000,000 people, or 1.4 cancers per 1000 people. There is likely some overlap among the lifetime cancer risks, since POM and diesel particulate matter overlap with one another, but this is a reasonable starting point. According to Scorecard, the added cancer risk per million people from all air toxics in Queens is about 2400, making our estimate from the 8 riskiest air toxics reasonable. Of note, 91% of air toxics cancer risk in Queens was related to mobile sources, and the total air toxics cancer risk ranks Queens fourth among 62 New York counties.

To estimate annual cancer risk, we make two very simple assumptions. First, we assume an average lifetime of about 70 years, which yields a figure equal to 20 cancers per year per million people (i.e., 1400/70). Second, we assume all 2.2 million people in Queens are equally at risk and multiply this by the unit risk, giving about 40 cancers in Queens per year due to air toxics. So, if we reduce levels of all air toxics by 10%, we estimate 4 fewer cancers per year in Queens. Again, this is a crude estimate not meant as the basis of policy decisions, but to help understand what is likely to be big and what is likely to be small among the pollutants we consider.

Now, we consider mortality risks from ozone. Recall that we said that there was about a 1% increase in daily deaths per 10 ppb increase in daily average ozone concentrations. According to NY DEC monitoring data, annual mean ozone concentrations in Queens are 15-24 ppb; we use a value of 20 ppb as a typical value. For our simple calculation, we assume that we reduce ozone levels by 10% (2 ppb) and that the relationship between exposure and mortality risk is linear. Under this assumption, there would be a 0.2% decrease in deaths. Earlier, we stated that there are about 16,700 deaths per year in Queens. Multiplying 16,700 by 0.2% gives us a value of about 30 fewer deaths per year in Queens related to ozone reductions. This value is about an order of magnitude higher than the benefit from reducing air toxics.

We now make a similar calculation for $PM_{2.5}$. Using the American Cancer Society study, there is about a 0.6% increase in premature deaths per $\mu g/m^3$ increase in annual average $PM_{2.5}$ concentrations. Annual average $PM_{2.5}$ concentrations are 13-16 $\mu g/m^3$, so we use a value of 15 $\mu g/m^3$. If we reduce $PM_{2.5}$ concentrations by 1.5 $\mu g/m^3$, there would be a 0.9% decrease in deaths, or over 100 fewer deaths per year in Queens.

These calculations have numerous simplifications and ignore the possibility of thresholds, issues related to cancer and non-cancer latency, variations in exposure and susceptibility, double-counted effects, and any number of other nuances. They ignore non-cancer effects of air toxics and morbidity effects of criteria pollutants. The numbers are only useful in a relative sense and should not be used as the basis of any policy decisions. Nevertheless, they provide us with important insights.

First, the effects of the air toxics appear small in relation to the effects of the criteria pollutants. This disparity is further exacerbated when we consider that diesel particulate matter is a component of $PM_{2.5}$, implying that the cancer effects may already have been counted using the value from the American Cancer Society study. Second, the effects of $PM_{2.5}$ appear larger than those of ozone, especially when we consider the somewhat stronger mortality literature for PM and the fact that the PM effects may represent a greater loss of life expectancy. Nevertheless, the effects of ozone are not trivial and must be considered.

From the above concentration data and discussion about formation of particulate matter, it appears likely that a substantial fraction of $PM_{2.5}$ (especially secondary $PM_{2.5}$) is due to atmospheric transport from outside of Queens. A similar story can be told for ozone. This does not imply that sources in Queens are unimportant, as demonstrated by the substantial contribution of mobile sources to air toxic risks. However, the fact that the two most important pollutants have significant long-range components means that we must take a broader view about pollution control in order to reduce ambient concentrations in Queens. Controlling sources in Queens will have greater benefits to populations outside of Queens, while controlling sources outside of Queens will help the population of Queens. The relative importance of sources requires atmospheric modeling that is beyond the scope of this initial analysis, but is discussed in a qualitative sense in Chapter 4.

In conclusion, in Chapters 2 and 3, we summarized the literature on the health effects of air pollution and we estimated ambient concentrations of key air pollutants. We combined these two lines of evidence to make general inferences about the pollutants likely to contribute substantially to health effects in Queens. We summarize our major conclusions as follows:

- Among the set of criteria air pollutants, ozone and fine particulate matter ($PM_{2.5}$) are the two pollutants of greatest importance from a health perspective. Because ozone and $PM_{2.5}$ can be transported long distances, sources outside of Queens (including power plants and mobile sources) likely contribute a majority of these pollutants.

- Ambient concentrations of both ozone and $PM_{2.5}$ are high enough to be of concern, both from a health perspective and to avoid violating National Ambient Air Quality Standards. Based on simple “order of magnitude” risk calculations, a 10% reduction in $PM_{2.5}$ levels would lead to over 100 fewer deaths per year in Queens, while a 10% reduction in ozone levels would lead to about 30 fewer deaths per year in Queens.

- Among the set of 188 air toxics, diesel particulate matter, polycyclic organic matter, chromium, formaldehyde, 1,3-butadiene, benzene, carbon tetrachloride, and acetaldehyde are the eight pollutants of greatest importance from a health perspective. The upper bound lifetime cancer risk from these eight air toxics at current concentrations in Queens is approximately 1400 per 1,000,000 people, which appears smaller than the mortality risks of ozone and particulate matter but greatly exceeds a “one in a million” cancer risk threshold. Mobile sources are the most important contributors of many of these pollutants.

- An air quality plan for Queens must be specific about the goals of the plan before prioritization can occur. Major sources in Queens will have most of their population health impacts outside of Queens, and sources outside of Queens will have substantial contributions to air quality within Queens.

4. Principal Sources of Emissions Affecting the Air Quality in Queens

4.1 Introduction and Caveats

In Chapter 3 we identify the air pollutants that are likely to lead to the greatest health impacts in Queens. Fine particulate matter appears to cause the greatest health risks, followed by ozone, followed by a set of eight hazardous air pollutants. Greenhouse gasses also pose health and environmental threats to Queens and elsewhere, but it is difficult to rank these threats due to the very different nature and timing of global warming impacts.

In order to develop a plan to improve air quality, it will be useful to identify the primary sources of air emissions that lead to air quality problems in Queens. For example, where does most of the particulate matter come from? How much of it comes from electric power plants, versus mobile sources, versus other sources? How much of it blows in from outside of Queens? How much of the particulates generated within Queens blow outside of the borough to affect populations located elsewhere? Answers to these questions can help identify those sources that have the greatest impact on air quality in Queens, and thus those sources that should be targeted first for emission reductions.

Unfortunately, these questions are quite complex and the answers are very difficult to obtain. First, there is little reliable data to indicate the primary sources of some of the key emissions in Queens. We have reviewed several different data sources only to find that they are incomplete, inconsistent, or not based on data specific to Queens. Second, the formation of pollutants and the transportation of pollutants into and out of Queens is a complex process that is difficult to analyze, and yet will have significant implications for the ambient air quality in Queens.

Nonetheless, in this chapter we broadly indicate those sources of emissions that are likely to have the greatest impact on the air quality in Queens. We present what data are available, and briefly discuss their limitations. We provide some broad generalizations regarding which sources of emissions are likely to be most important and which are likely to be less so. We recommend that additional attention be given to this important issue in future studies of air quality in Queens and elsewhere.

Emission Source Categories

The US EPA recommends dividing sources of air emissions into four main categories, listed below. We use these categories throughout this report to describe the general types of sources in Queens

- Large stationary sources. Sometimes referred to as point sources, large stationary sources are those that emit at least 100 tons per year of any regulated pollutant.

This category includes electric power plants, manufacturing, refineries, and steel mills.

- Area sources. This category includes all smaller stationary sources of emissions, such as residential and commercial furnaces, waste incinerators and miscellaneous small combustion sources. This category also includes non-combustion area sources such as gas stations and dry cleaners.
- On-road mobile sources. This category includes all transportation vehicles that travel on roads, including cars, taxies, buses, trucks, etc., using both diesel fuel and gasoline.
- Off-road mobile sources. This category includes all transportation vehicles that travel off-roads, such as airplanes, marine transportation, recreational vehicles, industrial, construction and mining equipment, using both diesel fuel and gasoline.

4.2 Criteria Air Pollutants

Data Sources and Challenges

There are two primary sources of data regarding the emissions of criteria pollutants in Queens County: the U.S. Environmental Protection Agency (EPA) and the New York Department of Environmental Conservation (NY DEC). The quality of this data varies depending upon the particular emission source. In particular,

- Large stationary sources. State air agencies tend to have relatively good data on emissions from these sources, because the sources are required (by their operating permits) to report annual emissions.
- Area sources. EPA and the NY DEC estimate the emissions from area sources, because the actual emissions are not monitored or reported by anyone. These estimates typically rely upon emission factors and combustion estimates, which may or may not rely upon data specific to Queens County, or even New York State.
- On-road mobile sources. EPA and the NY DEC estimate emissions from mobile sources using computer models that account for the amount and type of traffic in a particular area.
- Off-road mobile sources. As with on-road mobile sources, the emissions from off-road sources are estimated using computer models.

In trying to identify the emissions from different sectors and sources in Queens we have discovered that both the EPA and NY DEC data sources contain substantial problems. For example, the EPA estimates of emissions from area sources are derived by scaling the emissions for the entire state down to Queens County using demographic scaling factors (e.g., population). As a result, some emission sources in other parts of New York State might get allocated to Queens inappropriately. We suspect that this is why the EPA database lists waste incineration as the second largest source of $PM_{2.5}$ in Queens in 1999, even though waste incineration has been banned in New York City for many years.

In addition, a comparison of the EPA and NY DEC data sources indicates that they conflict with each other. We compared the two databases for 1999 emissions from 24 of the largest stationary sources in Queens, across four pollutants (PM_{10}, NO_X, SO_2 and VOC). This comparison found that there were very few cases in which the two data sources were even within ten percent of each other, and in some cases the two data sources deviated by a factor of two or more. The differences between the data in the EPA and the NY DEC sources are so great that we are not comfortable using either of them to draw conclusions about the sources of emissions in Queens.

In the following sections, we provide some general information about what might be the most important sources of emissions in Queens, based partly upon the EPA and NY DEC data, but also upon our understanding of emission sources and air quality implications in general.

Particulate Matter

Identifying the sources of particulate emissions that have the greatest impact on the ambient levels of particulate matter in Queens is very difficult – not only because the data for particulate emissions in Queens is so unreliable, but also because the formation and transport of particulates is a complex process that will significantly affect the air quality in Queens. (See Section 3.3.) Nonetheless, several key points help to inform this issue:

- Electric power plants in Queens generate relatively large amounts of NO_X and (for those that burn oil) SO_2, which are precursors of secondary particulate matter. Because of the relatively slow speed of the chemical reactions, much of this secondary particulate matter will be formed downwind of Queens. Nevertheless, some secondary particulate matter from power plants in Queens will affect the local population, as will secondary particulate matter from power plants in Manhattan, Staten Island, and New Jersey.
- Electric power plants in Queens also generate primary particulate matter. Although tall stacks will cause much of this primary particulate matter to be carried outside of Queens, nevertheless the highest concentrations will probably be within Queens.
- Mobile sources, both on-road and off-road, also generate primary particulate matter. These emissions will have a relatively larger impact on the population in Queens because they are emitted at ground level.
- Area sources (i.e. residential and commercial boilers) also generate primary particulate matter, although the extent of these emissions is difficult to gauge due to the lack of data. They are also likely to have a relatively large impact on the population in Queens, because they are emitted near ground level from short stacks.
- A large proportion of particulate matter in the ambient air is transported into Queens from upwind sources. This includes a mix of primary emissions from

other parts of the metropolitan area, plus secondary particulate matter, mostly from power plants in regions as far away as Midwestern and the Southern states.

These general points allow us to make some broad conclusions about the relative impact in Queens of the various sources of particulate matter. We believe that the particulate matter sources can be described as follows:

- Sources *outside* the metropolitan area contributes the largest portion of ambient of particulate matter in Queens. Much of this transported particulate matter comes from power plants and other industries in upwind states.
- Of the remaining ambient particulate matter in Queens, a large part comes from sources *within* Queens. Most of this particulate matter consists of primary emissions from the transportation sector, the electricity sector, and the area sources (i.e., residential and commercial boilers) within Queens, largely in the PM 2.5 category. Other sources include fugitive dust and natural sources such as suspended salt particles from the ocean and Long Island Sound, which consists mostly of coarser material.
- Another large portion of ambient particulate matter in Queens comes from similar sources *in other parts of the metropolitan area*. Compared with particulate matter from Queens sources, a larger proportion of the particulate matter in this category is secondary rather than primary.

Ozone and Ozone Precursors

Identifying the sources of emissions that have the greatest effect on ambient ozone levels in Queens is also very difficult, for similar reasons. The sources for emissions data are not reliable, and the formation and transportation of ozone and ozone precursors are complex processes that occur over time and depend upon weather and seasonal conditions (See Section 3.3.) Again, several key points can help sort through the complexities of this issue:

- Ozone is a secondary pollutant that is formed through the interaction of NO_X and VOCs in the presence of sunlight. Ozone and its precursors can travel many miles for several days before contributing to the ambient air quality that will affect human health in Queens or elsewhere.
- Electric power plants in Queens generate relatively large amounts of NO_X. Many of these are probably transported out of Queens before they can form ozone and affect ambient ozone levels within Queens. The power plants' tall stacks assist with the transport of NO_X and ozone out of Queens.
- Mobile sources in Queens also generate relatively large amounts of NO_X. Many of these are probably transported out of Queens before they can form ozone and affect ambient ozone levels within Queens. But transport of emissions from mobile sources may be less than for power plants because they are located at ground level.

- Mobile sources in Queens generate the majority of VOC emissions, with the rest coming from some area sources. Again, many of these are these are probably transported out of Queens before they can form ozone and affect ambient ozone levels within Queens.
- The most of the ambient ozone levels in Queens is likely to be due to NO_X, VOC and ozone that are transported in from other regions. These transported pollutants are likely generated from power plants in upwind states as far away as the Midwest and the South, as well as from mobile and area sources located in neighboring regions such as New York State, New Jersey and Pennsylvania.

These general points allow us to make some broad conclusions about the relative impact in Queens of the various sources of ozone. We believe that the ozone sources can be described as follows:

- Sources *outside* the metropolitan area contribute the largest portion of ambient ozone in Queens. Much of this ozone and ozone precursors come from power plants and other industries in upwind states. Ozone levels are highest in Queens and the Bronx, relative to the rest of New York City, because they are more directly downwind of Northern New Jersey, Newark, and Manhattan.
- Of the remaining ambient ozone in Queens, a large part comes from sources *within* Queens. Most of this ozone is due to ozone precursors from the transportation sector, the electricity sector, and the area sources (i.e., residential and commercial boilers) within Queens.
- Another large portion of ambient ozone in Queens comes from sources in *other parts of the metropolitan area*. Again, most of this ozone is likely to be due to precursors from the transportation sector, the electricity sector, and area sources.

The Implications of Pollution Transport

One of the obvious conclusions from this analysis is that efforts to improve the air quality in Queens must also address sources of emissions located in other parts of the state and even the country. In order to make a significant impact on ambient particulate and ozone levels in Queens it will be necessary to reduce the $PM_{2.5}$, NO_X and SO_2 emissions from many power plants, as well as the $PM_{2.5}$, NO_X and VOCs from much of the transportation sector in the neighboring region. It is important that the City and State support initiatives such as the various multi-pollutant bills that would impose strict emission standards on power plants in upwind states.

However, it is also important to keep in mind that the pollution sources located within Queens will still have important air quality implications for other regions that are downwind of Queens. Primary and secondary particulate matter, NO_X, SO_2 and VOCs from power plants and the transportation sector in Queens will contribute to ambient concentrations of particulates and ozone in the New England states and maybe even in Canada. Policy-makers in Queens should recognize that reductions in emissions from Queens sources may be necessary to encourage regional or national actions to achieve similar reductions from regions upwind of Queens. In this way, reductions at Queens emission sources may be necessary to improve the local air quality, even if only because they would indirectly lead to reductions in the upwind emission sources.

4.3 Hazardous Air Pollutants

In Section 2.3 we identified those hazardous air pollutants that are likely to cause the greatest health risk in Queens, using estimated per-capita cancer risk as the ranking criterion. We identified the eight HAPs that pose the greatest risk, and showed that diesel particulate matter poses the greatest health risk of all – with a per-capita cancer risk that is greater than the other seven HAPs combined.

Here we briefly summarize the likely sources in Queens of emissions of these eight top HAPs. We rely in part upon the air toxics emissions inventory compiled by the New York Department of Environmental Conservation (NY DEC 2002). While we expect that this is the best data available for air toxics in Queens, it is not comprehensive and it is not consistent with other sources, as described in Chapter 7.

Where data are not available from the NY DEC, we rely upon the EPA's AIRData data base, which in turn is based on EPA's National Toxic Inventory (NTI) database of HAP emissions for 1996 (EPA NTI 2002).[6] The National Toxic Inventory data base is compiled from several different sources, and in many cases the emissions are estimated based on emission factors and business activity data. The EPA notes, consequently, that the data will vary in quality with regard to pollutants, level of detail and geographic coverage.

Because of the limitations of the data on HAP emissions in Queens, and the inconsistencies between NY DEC and EPA data, we do not present detailed data with regard to emissions from specific sources. Instead, we present some general points to indicate what may be the greatest source of the eight HAPs in Queens. The pollutants are presented separately below in order of health risk.

- Diesel Particulate Matter. Diesel emissions are generated primarily by mobile sources. According to EDF, roughly 60 percent of diesel emissions in Queens are from off-road mobile sources, 27 percent are from on-road mobile sources, and 13 percent are from background sources (EDF Scorecard 2002). Because these data are not provided by the NY DEC, there is a good chance that it more accurately reflects the sources of emissions for all of New York State rather than for Queens County. A more accurate inventory of Queens would probably indicate a greater portion of diesel emissions from on-road and a smaller portion from off-road.
- Polycyclic Organic Matter. Almost all POM emissions in Queens are generated by area sources, while roughly five percent are generated by point sources (EPA

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[6] There are many cases where the NY DEC emissions data differs significantly from the EPA NTI emissions data. We have relied upon the NY DEC data wherever possible, because it is more recent and the emissions are based on data more specific to Queens. The fact that these two data bases are so different suggests that the results presented here should be taken with a great deal of caution.

NTI 2002). Of the point source emissions, only two percent are generated from the power plants in Queens (EPA NTI 2002).[7]

- Chromium Compounds. Roughly 45 percent of the chromium emissions in Queens are generated by point sources, 44 percent by area sources, nine percent by off-road mobile sources, and three percent by on-road mobile sources (EPA NTI 2002). Of the point source emissions in Queens, roughly 89 percent are produced by polishing and plating companies, and seven percent are produced by power plants (EPA NTI 2002).
- Formaldehyde. Roughly 60 percent of the formaldehyde emission in Queens are generated by off-road mobile sources, 39 percent from on-road mobile sources, and the remaining one percent from a variety of area and point sources (NY DEC 2002).
- 1,3-Butadiene. Roughly 65 percent of the 1,3-butadiene emissions in Queens are generated by area sources, 22 percent by on-road mobile sources, and 13 percent by off-road mobile sources (NY DEC 2002). The area source emissions are produced entirely from retail gasoline stations in Queens (NY DEC 2002).
- Carbon Tetrachloride. Nearly all of the carbon tetrachloride emissions in Queens are produced from "background" sources (EDF Scorecard 2002).
- Benzene. Roughly 75 percent of benzene emissions in Queens are generated from on-road mobile sources, 19 percent from off-road mobile sources, and six percent from area sources (NY DEC 2002). Of the area source emissions in Queens, roughly two-thirds are from auto body refinishing shops, and slightly less than one-third are from retail gasoline stations (NY DEC 2002).
- Acetaldehyde – Primary. Roughly 61 percent of acetaldehyde emissions in Queens are generated from off-road mobile sources, while 39 percent are generated from on-road mobile sources (NY DEC 2002).

Table 4.1 presents a summary of the sources of hazardous air pollutants in Queens, indicating the percentages of the pollutants that are generated by point, area, mobile and background sources. The transportation sector is responsible for a large portion of the health threat from HAPs in Queens, partly because diesel emissions create by far the largest health threat, and partly because several of the other HAPs are also generated primarily from mobile sources.

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[7] We are skeptical that the EPA data correctly categorizes the sources of POM. In particular, we would expect mobile sources to be a major contributor because diesels contain significant amounts of PAH.

Table 4.1 Sources of Hazardous Air Pollutants in Queens

	Point	Area	On-Road Mobile	Off-Road Mobile	Background	Total
Diesel Particulate Matter	---	---	27%	60%	13%	100%
Polycyclic Organic Matter	5%	95%	---	---	---	100%
Chromium Compounds	45%	44%	3%	9%	---	100%
Formaldehyde	<1%	<1%	39%	60%	---	100%
1,3-Butadine	---	65%	22%	13	---	100%
Carbon Tetrachloride	---	---	---	---	100%	100%
Benzene	---	6%	75%	19%	---	100%
Acetaldehyde	---	---	39%	61%	---	100%

4.4 Greenhouse Gases

Information on emissions from specific greenhouse gas sources is limited at present, since GHGs are not currently regulated by federal or state laws. As such, GHG emissions reporting is entirely voluntary. Furthermore, whatever reports are voluntarily submitted to federal or state agencies often cover only greenhouse gas reduction efforts, rather than describing overall operational emission inventories. This means that greenhouse gas emissions are typically back-calculated, i.e. using industrial, commercial, and residential fuel purchasing data, estimates are made of fuel usage (taking into account the efficiency of each particular plant), and then associated emissions are computed.

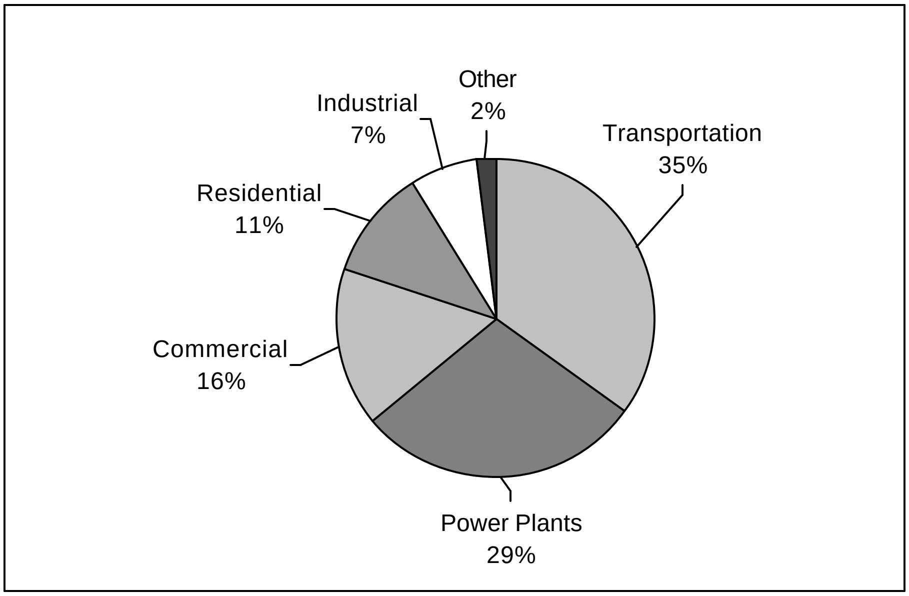
Americans as a whole contribute far more to climate change on a per-capita basis than the rest of the world's people. The US is responsible for roughly one quarter of the total world's GHG emissions, even though we have only four percent of the world' population, indicating that the average American generates 8 times as many greenhouse gases as the average non-American.

New York State is responsible for roughly four percent of US GHG emissions, but has more than 6 percent of the US population, and thus has a slightly lower per-capita green house gas emission rate than the rest of the US. Nonetheless, Queens produces large volumes of CO_2 emissions. For example, the power plants in Queens County alone produce roughly 15 percent of all the CO_2 emissions from all the power plants in New York State while accounting for about 15 percent of the State's electric capacity. Thus, Queens provides an important opportunity regarding New York City's and New York State's efforts to address global warming.

In New York State, CO_2 comprised almost 90% of GHG emissions in 1999, and over 99% of this CO_2 came from fuel combustion. Between 1990 and 1999, primary energy use increased over 8% but New York State's GHG emissions increased by less than 1%, and GHGs emitted from electricity generation decreased by 5%. This slow rate of growth in GHG emissions from electricity generation was mostly due to the introduction of new natural gas-fired power plants with relatively less GHG emissions per kWh produced (NYSERDA 2001).

Figure 4.1 provide a breakdown of the sources of CO_2 emissions for the entire state of New York (EANY 2002). It indicates that the transportation sector makes the largest contribution to emissions (35%), followed by the electricity sector (29%).

Figure 4.1 Sources of CO_2 Emissions in New York State



The breakdown of CO_2 sources in Queens County may be different than that presented in Figure 4.1, because it is more urban than the state of New York as a whole. Queens contains several heavily-traveled transportation arteries, such as the Long Island Expressway, the Brooklyn-Queens Expressway, the Grand Central Parkway, and many other commuter roadways which are major sources of CO_2. Queens also has a relatively large number of power plants, suggesting that the electricity sector probably plays a larger role than for the state as a whole.

The NY State Energy Research and Development Authority forecasts that electricity GHG emissions will rise by only 6% between 1999 and 2010, "due to the addition of highly-efficient natural gas-fired generation which continues to displace oil-fired units (NYSERDA 2001)." However, overall GHG emissions in the state are projected to increase by 12% by 2010, due in part to greater fuel combustion in the transportation sector and increased methane emissions from natural gas systems.

In June 2001, Governor Pataki announced the creation of a New York State Greenhouse Gas Task Force to develop recommendations for reducing emissions of GHGs from New York State. The GHG Task Force is composed of representatives from the business community, environmental organizations, State agencies, and universities.

Also in 2001, New York City agreed to work with the International Council for Local Environmental Initiatives (ICLEI) in developing a city-wide GHG emission inventory. Once completed, this will be a valuable research tool and can help identify local steps to reduce GHG emissions.

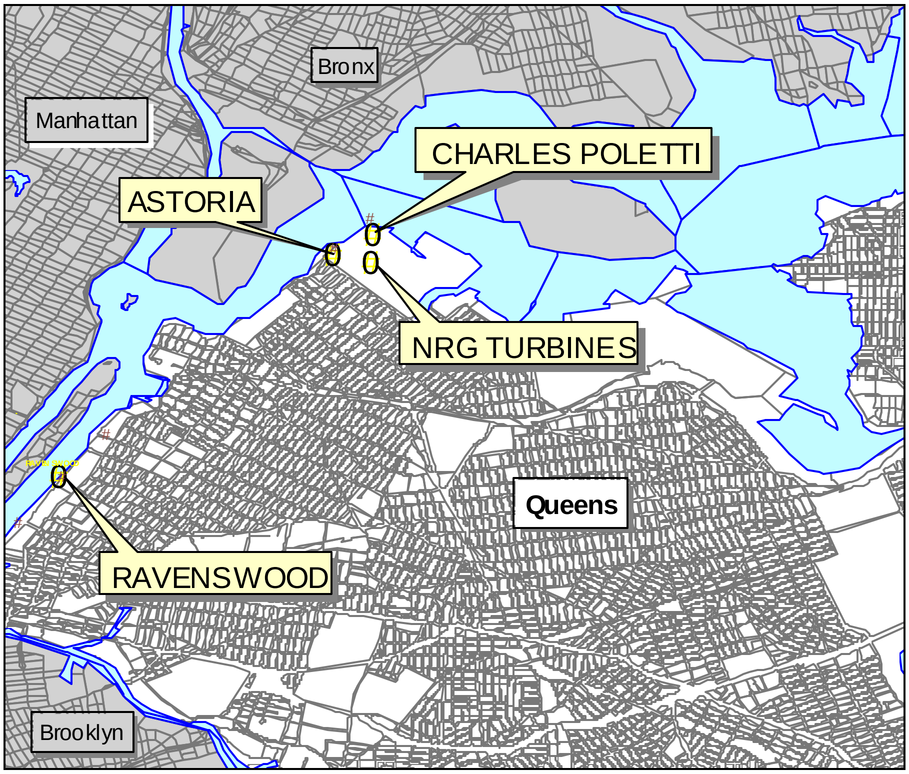
5. The Electricity Sector

New York City, like the rest of the nation, gets its electricity from a regional network of interconnected power plants and transmission lines. This means that the residents and businesses of each borough are not served exclusively by power plants within that borough. Rather, the electricity from all the power plants in the Northeast region is commingled in the regional transmission grid. Some areas of the region have many power plants, and they export electricity to other areas. Some areas of the region are net importers of electricity. Queens is one of the counties with a large amount of generating capacity relative to its electricity needs, and it consistently exports its surplus electricity to other users in New York City, New York State and other parts of the Northeast region.

5.1 Today's Power Plants in Queens

Currently, there are four large power plants in Queens, which together house 46 electric generating units. Eight of these are large steam generating units, and 38 are small combustion turbines. All four of these plants are in a small section of Northwest Queens (Astoria). This concentration of power plants makes a study of the emissions and air quality in Queens especially important. Figure 5.1 shows the location of these four facilities in Queens.

Figure 5.1 The Four Power Plants in Queens



The concentration of generating capacity in Northwest Queens is exceptionally high for such a densely populated area. In addition, this community includes a high percentage of low-income people and persons of color. These demographics suggest that "environmental justice" concepts and policies should be taken into account when considering options for addressing air quality in Queens and in considering the siting of new sources of air pollution.

Table 5.1 below lists these power plants and describes the generating units located at each one. At the units listed as "steam" units, steam is generated first in a large boiler, and this steam is used to drive a turbine to generate electricity. All the steam units in Queens are dual-fueled units; they can burn either natural gas or heavy fuel oil. This oil (also known as residual fuel oil) consists of the final residues in the refining process, left after gasoline, kerosene and other light oils have been extracted from crude oil. The units designated "CT" are combustion turbines. In these units natural gas or kerosene is combusted within a turbine similar to a jet engine, and the turbine drives an electricity generator.

Table 5.1 Current Generating Capacity in Queens by Plant and Unit

Plant/Unit	Owner	Capacity (MW)	Fuel Type	Prime Mover
Poletti	NYPA			
Poletti 1		825	Gas/Resid. Oil	Steam
Astoria	Reliant			
Astoria ST 2[1]		170	Gas	Steam
Astoria ST 3		360	Gas/Resid. Oil	Steam
Astoria ST 4		375	Gas/Resid. Oil	Steam
Astoria ST 5		370	Gas/Resid. Oil	Steam
NRG CTs[2]	NRG			
NRG CTs (21)		650	Gas/Kerosene	CT
Ravenswood	KeySpan			
Ravenswood 1		353	Gas/Resid. Oil	Steam
Ravenswood 2		386	Gas/Resid. Oil	Steam
Ravenswood 3		980	Gas/Resid. Oil	Steam
Ravenswood CTs (17)[3]		415	Gas/Kerosene	CT
Total Queens Capacity		4,884		

[1] Previously retired unit, restarted as part of the now postponed Astoria Repowering Project
[2] The NRG plant consists of 21 combustion turbines, ranging in size from 16 to 50 MW.
[3] The Ravenswood CTs consist of 17 combustion turbines, ranging in size from 10 to 46 MW.

Combustion turbines are far more costly to operate than large steam units, thus they are operated less than steam units.[8] The CTs in Queens are no exception to this rule; the NRG and Ravenswood CTs operate a very small number of hours each year – whenever additional generation is required for a short period, especially on hot summer days, when the use of air conditioners pushes electricity demand to its highest annual levels. In contrast, the large steam units in Queens are operated quite often. In recent years,

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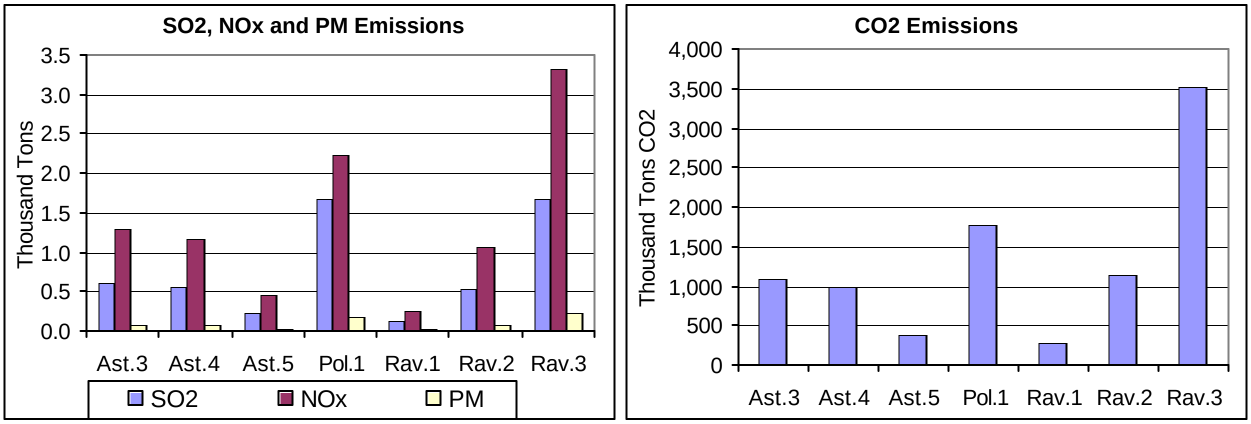
[8] Combustion turbines are also known as "peaking units," because they are only operated during periods of peak electricity demand.

Ravenswood Unit 3 and Astoria Units 3 and 5 have been the most efficient and low-cost steam units in Queens, and they have had the highest utilization rates. Ravenswood 2 and Astoria 2 and 4 have been less efficient and have operated less than these units.

Turning to air pollution, the steam generating units in Queens are responsible for large portions of the NO_x, SO_2, and CO_2 emitted in Queens.[9] They also emit primary fine particulate matter ($PM_{2.5}$) Figure 5.2 below shows the emissions resulting from our simulation of year-2000 operation of these generating units. This is the year we use as the base year against which to calculate changes with and without the Clean Air Plan.[10] Ravenswood 3 has the highest emissions of all three pollutants, primarily because it is larger and more efficient and therefore operates more than other units considered in the study.

Figure 5.2 Total 2000 Emissions from Steam Electric Plants in Queens



Note that the amount of CO_2, SO_2, and primary $PM_{2.5}$ emitted by these steam units in Queens is dependent on which fuel they burn. For example, because there is a negligible amount of sulfur in natural gas, when these units operate on gas their SO_2 emissions are negligible. Residual fuel oil burned in New York, however, contains 0.3 percent sulfur by weight, so when operating on oil, these units can have significant SO_2 emissions.[11] Companies decide when to switch fuels based on the relative prices of gas and oil, permit restrictions and emissions limits.

The combustion turbines in Northwest Queens emit far less pollution on a total annual basis than the steam units, because they are much smaller and operate much less than the steam units. However, the CTs have higher NO_x and CO_2 emission rates per unit of electricity generated than the steam units. The NO_x rates of CTs are five to ten times the

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[9] Here and throughout this Chapter we deal only with "primary" emissions of fine particulates. These are particles with a diameter of 2.5 microns or less that are emitted in particulate form from the smokestack. This category does not include "secondary" fine particulates, which form in the atmosphere from pollutants emitted by power plants and other combustion sources.

[10] The emissions resulting from our simulation of year-2000 operation are very close to the emissions reported by these companies to the U.S. Environmental Protection Agency.

[11] It is worth noting however that units outside the City can burn coal and fuel oil that has significantly higher sulfur levels.

rates of the steam units, and their CO_2 rates are 1.5 to 2 times higher. The combustion turbines' SO_2 and primary $PM_{2.5}$ emission rates are very low. However, these units' NO_x emissions do contribute to the formation of secondary fine particulates.

Thus, while the CT units operate very little, when they do operate, their pollution impacts are significant. These units' contribution to ground-level ozone (smog) health impacts are especially significant because the units are most likely to operate on hot summer days – the same days that ozone pollution levels are the highest.[12] Thus, demand reduction efforts that reduce the need to operate these units can mitigate air quality problems on hot days considerably.

5.2 The Outlook for Power Plants in Queens

We assess the power generation costs and benefits of the Queens Clean Air Plan by modeling power generation in Queens in 2000, 2005 and 2010 with and without implementation of the Plan. We model power generation using the PROSYM electricity market simulation model. This software allows us to model the operation of all the power plants in the northeastern U.S. (New York, New England and the Mid-Atlantic region) under various assumptions about which units are available and how much it costs to operate each plant. See Appendix **B** for a description of the PROSYM model.

One of the challenges in assessing the Clean Air Plan for the power sector lies in predicting the future of the existing power plants in Queens under business-as usual conditions, i.e., without the Clean Air Plan. This is challenging, because there is now considerable uncertainty over what the future holds for the power plants in Queens. To develop a "base case," against which to measure the costs and benefits of the Clean Air Plan, we have carefully reviewed the proposed changes to the electric power sector in Queens and developed a conservative scenario about what will actually happen. The proposed changes to the power plants in Queens that have informed our base-case assumptions are listed below.

- Project 1: A 250-MW combined-cycle combustion turbine (CCCT) developed by KeySpan at the Ravenswood plant;
- Project 2: "Repowering" of the steam units at Astoria by Reliant Energy. This entails removal of the existing steam boilers (totaling approximately 1,400 MW) and replacement with new CCCTs (totaling approximately 1,800 MW);
- Project 3: A 500-MW CCCT developed by NYPA at the Poletti plant; and
- Project 4: A new power plant housing CCCTs totaling 1,000 MW developed by SCS Astoria at a site just east of the Poletti/Astoria site.

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[12] Ozone is not emitted directly from sources. Ozone forms in the air when NO_x molecules react with other molecules called volatile organic compounds (VOCs). NO_x and VOCs are emitted in large quantities from anthropogenic sources. The reaction in which ozone is formed accelerates at higher temperatures. This fact makes hot summer days especially susceptible to high ozone levels, because (a) all available power plants are operating to serve air conditioning loads and (b) high temperatures result in the formation of large amounts of ozone from the available NO_x and VOCs.

As indicated, all four of these projects propose to use CCCT technology. This technology, the cleanest and most efficient generating system available today, brings together a CT and a steam generator in one system. In the first stage of the process, natural gas or light oil is burned in a CT and electricity is generated. In the second stage, hot exhaust gases from the CT are used to generate steam. The steam is then used to generate electricity, as in a traditional steam plant. Generating electricity in two stages from the same fuel combustion results in a much more efficient process. Most existing steam plants have efficiencies in the range of 33 percent (i.e. 33 percent of the energy contained in the fuel is converted to electrical energy), and most existing combustion turbines have efficiencies below 30 percent. This means that 67 percent or more of the energy input is lost as waste heat. In contrast, today's CCCTs can achieve efficiencies approaching 50 percent.

New CCCTs also have much lower air emissions per unit of electricity generated than steam units or CTs. The NO_x emission rate of a new gas-fired CCCT with advanced emission controls is nearly 70 percent lower than the highest emitting steam units in Queens and 30 percent below the lowest emitting units. The CO_2 rate of a CCCT is roughly 33 percent below those of the Queens steam units, and SO_2 emissions from a CCCT are negligible. Thus, the replacement of existing steam generating units in Queens with new CCCTs would provide dramatic reductions in air emissions on a per MWh basis. For example, Reliant Energy calculates that the proposed replacement of the Astoria steam units with CCCTs would reduce annual NO_x emissions by at least 3,726 tons (87 percent), and SO_2 emissions by 1,012 tons (84 percent) (Orion Power 2001).[13] While repowering will significantly reduce emission rates, the project would considerably increase electricity generation at the site.

The Ravenswood, NYPA, and Astoria SCS facilities all have recently received Article X siting certificates, and the reliant facility is still in the process of obtaining a certificate. However, the climate for financing new power plants has become less attractive since the plants were first proposed, putting the future of some, if not all four, of the projects in question. Several delays have been announced in the SCS Astoria plant and the Reliant repowering project at Astoria. Given the increasing skepticism that capital markets are showing toward the power generation sector, additional delays – and potentially project cancellations – would not be surprising.

With so much uncertainty surrounding these projects, it is difficult to predict with any confidence which of the existing steam units will still be operating five years from now and how much new CCCT capacity will exist. Our base case scenario for the power generation sector attempts to balance the fact that changes in this sector are highly likely with the uncertainty about exactly what those changes will be. As shown in Table 5.2 below, in the base case we assume that none of the existing generating units in Queens is retired during the study period and that 250 MW of new CCCT capacity is added by the end of 2004. In effect then, we are assuming that 250 MW of the currently proposed new CCCT capacity will be installed before 2005, absent the Clean Air Plan. For the

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[13] Particulate matter is the only pollutant assessed in this filing for which emissions could rise due to the project.

purposes of assessing air emissions in Queens it is not necessary to predict which proposed project this will be or exactly when it will be added.

The results of our modeling for the base case scenario are shown in Table 5.2. We anticipate that in the base case, operation of the Astoria steam units would decrease significantly in the medium term, immediately after the new CCCT began operation. This is because the new unit would be more efficient and less costly to operate, thus it would be dispatched earlier in the supply curve than the older steam units. Later in the study period, however, the utilization of the older steam units would increase again, to meet growing electricity loads in the region. (We assume that electricity demand grows steadily at about 1.5 percent per year.) Note that generation from the Queens units is higher in 2010 (by over 11 percent) than in 2000. The combustion turbines in Queens show a similar pattern of operation in our base case, although the pattern is less pronounced, because these units operate so little.

Table 5.2 Base Case Generation from Power Plants in Queens

Unit	2000 Generation (GWh)	2000 Capacity Factor	2005 Generation (GWh)	2005 Capacity Factor	2010 Generation (GWh)	2010 Capacity Factor
Astoria ST 3	1,329	42.3%	962	30.6%	1,153	36.7%
Astoria ST 4	1,201	37.2%	823	25.5%	873	27.0%
Astoria ST 5	473	14.8%	526	16.4%	819	25.5%
NRG CTs	1	<0.1%	0	0.0%	1	<0.1%
Poletti 1	2,221	30.7%	2,616	36.2%	2,692	37.3%
Ravenswood 1	301	8.8%	434	13.4%	680	20.9%
Ravenswood 2	1,269	37.2%	871	25.5%	969	28.4%
Ravenswood 3	3,931	45.5%	2,647	30.6%	3,228	37.4%
Ravenswood CTs	0	0.0%	0	0.0%	0	0.0%
New CCCT	---	---	1,506	68.8%	1,539	70.3%
Total	**10,727**		**10,385**		**11,955**	

Capacity factor represents the amount of electricity generated by a unit, relative to the total amount of generation available from the unit. Capacity factors rarely exceed 85% due to scheduled and unscheduled outages.

The air emissions from the future plant utilization estimated in the base case are shown in Table 5.3. Because air emissions from the Queens units are dominated by the emissions from the older steam units, emissions trends will follow the trends in operation of these units. Total emissions of all three pollutants from Queens generating units falls substantially in the medium term, when the new CCCT reduces the use of the older units. Then total emissions rise again as load grows and the older units return to high levels of operation.

Table 5.3 Base Case Emissions from Power Plants in Queens

Emissions	2000	2005	% Change (00-05)	2010	% Change (00-10)
Total NOx (tons)	9,810	8,330	-15%	9,740	-1%
Avg. NOx rate (lb/MWh)	1.83	1.60	-12%	1.63	-11%
Total SO2 (tons)	5,400	4,720	-12%	5,770	7%
Avg. SO2 rate (lb/MWh)	1.01	0.91	-10%	0.97	-4%
Total CO2 (tons)	9,180,000	8,175,000	-11%	9,485,000	3%
Avg. CO2 rate (lb/MWh)	1,712	1,574	-8%	1,587	-7%
Total $PM_{2.5}$ (tons)	702	651	-7%	747	6%
Avg. $PM_{2.5}$ rate* (lb/MWh)	0.13	0.13	0%	0.12	0%

**$PM_{2.5}$ includes primary emissions; it does not include secondary emissions.*

5.3 The Clean Air Plan for the Electric Sector

The Clean Air Plan for Queens' electricity sector is focused on three aspects of electricity production and consumption. The first aspect is the efficiency of electricity *consumption* in Queens. Here we focus on opportunities to make end-use equipment – everything from home appliances to industrial motors – more efficient. The second aspect is the use of renewable sources of energy in Queens. The focus here is on solar electricity, the most feasible renewable energy source available in the New York area. The third is the utilization of the large fossil-fueled power plants in Queens, where we explore a scenario in which a number of the old, steam generating units are retired and new CCCTs begin to operate.

5.3.1 Energy Efficiency

The Many Benefits of Energy Efficiency

In New York City, as in other parts of the United States, there is a vast potential to improve the efficiency with which electricity is consumed. All types of electricity customers – residential, commercial, industrial, institutional, governmental – currently have numerous opportunities to replace aging electric equipment with newer, more efficient models, or to buy a high-efficiency product when purchasing a new piece of electric equipment. There is a long and ever-growing list of new technologies to reduce electricity consumption, including compact florescent lighting; efficient refrigerators; efficient heating, ventilation and air conditioning equipment; efficient motors; water heater improvements and insulation; weather-stripping of houses and businesses; and more. There are also many design and behavioral modifications that allow citizens and businesses to manage their energy use more efficiently.[14]

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[14] For the purpose of this report, we define energy efficiency to include those technologies and measures that reduce the amount of energy needed to provide a given electricity service (e.g., lighting, heating motor power). There are also *additional* efficiency savings that can be obtained through lifestyle changes and other ways to reduce the level of electricity services required.

Many efficiency measures cost significantly less than the costs of generating, transmitting and distributing electricity – i.e., they are highly cost effective. In many cases, efficiency measures have a payback period of two years or less. Thus, energy efficiency offers a huge resource for lowering system-wide electricity costs and reducing customers' electricity bills.

Energy efficiency also has significant environmental benefits. Every kWh that is saved through efficiency results in less electricity generation, and thus less pollution. Unlike other pollution control measures – such as scrubbers, selective catalytic reduction, and allowance trading schemes – energy efficiency measures can reduce air emissions with a *net reduction* in costs. Thus, it should be considered as one of the top priorities when investigating options for reducing air emissions.

Energy efficiency also offers other benefits to electricity customers and society in general. It can help reduce the demand on local transmission and distribution systems, potentially deferring expensive T&D upgrades or mitigating local transmission congestion problems. Efficiency can help reduce reliance upon fossil fuels, with their inherently unstable price and supply characteristics. It can also help promote local economic development and job promotion by increasing the disposable income of citizens and reducing costs to businesses and industries.

New York State has a history of implementing relatively successful energy efficiency programs, and the New York State Energy Research and Development Authority (NYSERDA) is currently sponsoring several energy efficiency programs in New York City and throughout the state. Nonetheless, there remains a lot more efficiency potential to be developed in New York City and in Queens. One recent study finds that, if New York City were to undertake efficiency efforts equivalent to those in California during the electricity market crisis last year, it could reduce peak electricity demand by as much as 8 to 15 percent in a single year (Riverkeeper, Pace and NRDC 2002). Additional time would allow for additional savings as efficiency programs become more mature and inefficient equipment reaches the end of its natural life.

Our Assumptions of Efficiency Potential and Costs in New York City

For the purpose of this study, we assume that energy efficiency measures could be implemented throughout New York City to reduce the electricity demand in 2010 by 10 percent. We also assume that these savings are achieved incrementally over the eight years between now and 2010, and thus three eighths of these savings are achieved by 2005. In other words, efficiency measures can reduce New York City electricity demand by 3.8 percent by 2005, and by 10 percent by 2010.

These assumptions are based on a review of many studies demonstrating the potential for energy efficiency in New York and elsewhere. For example, a 1989 report for NYSERDA found that the energy use in Consolidated Edison's service territory could be reduced by as much as 44 percent through cost-effective efficiency measures (NYSERDA 1989). A more recent, nation-wide study for the US Department of Energy (DOE) found that cost-effective efficiency measures could reduce the energy demand of the residential and commercial sectors by roughly 23 percent in 2010 and 32 percent by

2020, with similar savings available in the industrial sector (Interlaboratory Working Group 2000). Many other studies have shown that cost-effective energy efficient technologies can reduce electricity needs by as much as 15-20 percent in 2010 and 30-35 percent in 2020 (for example, ACEEE 2001; UCS 2001; WWF and EF 1999).

We assume that these efficiency savings are achieved by implementing energy efficiency programs throughout New York City. We have not applied these programs throughout all of New York State because this study is focused on Queens County – although there are many reasons to implement such programs throughout New York State. We have not applied these efficiency savings to just Queens County because that would be too small a region to have the effect on power plant generation and pollution that we seek.

We also assume that this energy efficiency can be obtained at an average cost of 2.5 ¢/kWh, including the cost of purchasing and installing the efficiency measures. In practice, some measures will cost considerably less, while others will cost more. This cost is consistent with the energy efficiency costs assumed in the nation-wide Interlaboratory Working Group study, as well as the costs experienced recently in several states with aggressive efficiency programs such as California and Vermont (NRDC 2001; EVT 2001).

Potential Benefits of Energy Efficiency

Based on the assumptions described above, it will require an efficiency investment of roughly $131 million per year by 2010 to reduce electricity loads in New York City by 10 percent. However, the savings can be expected to reduce fuel and operating costs in the region by roughly $156 million per year, to reduce T&D costs roughly $29 million per year, and to reduce new power plant capacity costs by roughly $79 million per year. Thus, a $130 million investment per year will result in $264 million in savings per year, for a net savings of $133 million per year. In other words, for every dollar spent on efficiency, there will be nearly two dollars in savings due to reduced electricity costs.

Further, we find that the efficiency savings in New York City reduce the generation from power plants throughout the state and even in neighboring states in the Northeast study region. Of the 5,237 GWh of energy saved in New York City in 2010, roughly 50 percent of the reduced energy generation is anticipated to be from plants located within New York City, 36 percent is from plants located outside of New York City but within New York State, and the remaining 14 percent is from plants located in other states in the Northeast.

Table 5.4 shows the emission reductions at the Queens generating plants that could be expected from the energy efficiency described above. Reductions of NO_x, SO_2, CO_2 and primary $PM_{2.5}$ are shown. In percentage terms, emission reductions are very similar across the four pollutants, because they result from the same amount of reduced generation at the Queens plants. Reductions in 2005 are in the range of 18 to 19 percent, and reductions in 2010 are in the range of 14 to 20 percent.

Table 5.4 Emission Reductions at Queens Plants from Energy Efficiency

	2005	2010
NO_x Reductions (%)	18%	15%
NO_x Reductions (tons)	1,530	1,460
SO_2 Reductions (%)	18%	20%
SO_2 Reductions (tons)	830	1,140
CO_2 Reductions (%)	19%	14%
CO_2 Reductions (tons)	1,528,000	1,288,000
$PM_{2.5}$ Reductions (%)	18%	14%
$PM_{2.5}$ Reductions (tons)	113	103

Emission reductions are relative to the base case emissions presented in Table 5.3.
$PM_{2.5}$ includes primary emissions; it does not include secondary emissions.

The Rationale for Public Policies to Support Energy Efficiency

Despite the availability and economic benefits of efficiency measures, customers do not typically adopt efficiency measures on their own. Most customers are not aware of the wide variety of energy efficiency technologies, or of the potential for lowering their electric bills. Some efficiency products are more difficult to obtain than conventional products, and they frequently require higher up-front costs in order to achieve long-term economic savings. In sum, there are many “market barriers” that inhibit customers from adopting cost-effective energy efficiency measures. Other barriers include: high transaction costs for purchasing efficiency measures; split incentives between, for example, a landlord who would make an efficiency improvement and a tenant who pays the electricity bills; purchasing habits that focus on short-term costs or that avoid risks associated with new technologies; and a lack of understanding of the environmental benefits of energy efficiency (as well as the fact that the environmental benefits accrue to society rather than specifically to the individual).

As a result, public policies are necessary to overcome these market barriers and to help make energy efficiency measures become a part of conventional market practices. Chapter 9 describes a set of policies that can help achieve this goal and can lead to the kind of efficiency measures and savings assumed in our Clean Air Plan.

5.3.2 Renewable Electricity Generation

Renewable Energy in New York City

While there are a number of different renewable generating technologies (e.g., wind, hydro, solar, biomass), we assume only the addition of solar energy in New York City in the Clean Air Plan. This is because other renewable technologies face significant barriers to development in heavily urbanized areas. However, photovoltaic (PV) panels, which generate electricity directly from sunlight, are well suited to densely populated areas.

PV panels generate electricity directly from sunlight using the photoelectric effect. The first PV cells used silicon as the active material, and the majority of PV systems in operation today contain silicon cells. However, during the past decade research has focused on other materials, because silicon cell technology requires relatively large amounts of costly silicon. New “thin-film” technologies utilize an extremely thin layer of active material deposited on a lower-cost base material such as glass or ceramic. Minimizing the use of the more expensive active materials lowers costs significantly.

Solar PV systems offer considerable benefits relative to fossil- and nuclear-fueled generation. PV systems are modular, silent, create no pollution in operation, can be operated unattended and require little maintenance. They are usually deployed on a small scale close to the location of electricity consumption, avoiding the need for investments in transmission infrastructure and reducing system line losses. Finally, while PV systems are dependent on the sun—and are therefore not dispatchable—their peak output generally coincides with afternoon peaks in electricity demand, when electricity is most valuable.

The primary hurdle that PV systems face is high up-front cost. While PV units have virtually no operating costs, they are expensive to manufacture. In a sense, users of PV trade operating costs for up-front (capital) costs. When the time value of money is factored in, this can be an expensive tradeoff. However, having some PV in the electricity fuel mix helps insulate consumers against spikes in fossil-fuel prices. Current projections of PV costs range from approximately $4,000 to $7,000 per installed kW. We assume capital costs of $6,000 per kW for PV installed by 2005 and $5,000 per kW for PV installed between 2005 and 2010.

There are many small-scale PV systems currently in operation in the New York area, from large rooftop systems hundreds of kW in size to units a few hundred watts in size used to power highway signs and mobile equipment. While average levels of sunlight are not as high in the New York region as in regions like the Southeast and Southwest, there is ample sunlight in the New York for PV generation, especially during the summer. The amount of PV capacity added over the next decade will be highly dependent on energy policy decisions made at the state and local levels. To the extent that other electricity generators are required to internalize the cost of their pollution emissions, PV will become more cost competitive.

PV Generation in the Clean Air Plan

For the Clean Air Plan, we assume 19 MW of PV capacity are added in 2005, and an additional 31 MW are added between 2005 and 2010, leading to a total capacity of 50 MW in 2010. (50 MW is approximately 0.5% of the total generating capacity in New York City in 2010.) With average annual capacity factors of roughly 22%, this amount of capacity will generate approximately 35,000 MWhs of energy in 2005 and approximately 97,000 MWhs in 2010.

The emission-free PV energy would reduce total emissions relative to the base case, because the energy from the new PV projects would reduce the need for energy from other generating units. Table 5.5 shows a rough estimate of the emission reductions from this PV generation, based on state average emission factors.

Table 5.5 Total Emission Reductions from PV Generation

	2005	2010
NO_x Reductions (tons)	19	57
SO_2 Reductions (tons)	36	115
CO_2 Reductions (tons)	14,500	42,500
$PM_{2.5}$ Reductions (tons)	21	63

Emission reductions are relative to the base case emissions presented in Table 5.3.
$PM_{2.5}$ includes primary emissions; it does not include secondary emissions.
These emission reductions occur throughout our study region; there will be less emission reductions from just the plants located in Queens.

5.3.3 Power Plant Additions and Retirements

The base case includes fairly conservative assumptions about the addition of new power plants in Queens. As discussed in Section 5.2, a number of new CCCTs have been proposed for locations in Queens. Some of these proposed units would replace existing units, while others would simply add to the generating capacity in Queens. This is the type of future our base case envisions. However, the climate for financing new power plants has become less favorable to plant developers in recent months than it was in 2000 and 2001. It is possible that capital markets will see power plants in the Northeast as increasingly risky and continue to seek higher returns from these projects.

Our Clean Air Plan envisions a climate in which regulators, environmental advocates and power plant developers work together to replace the old generating units in Queens with much cleaner, more efficient generating units – a practice called “repowering.” For the Clean Air Plan we envision that seven of the existing eight steam generating units in Queens will be retired and replaced with CCCT units. Specifically, we assume that the Astoria steam units are retired (as proposed by Reliant) and that Poletti 1 and Ravenswood 1 and 2 are also retired.[15]

We also assume that 2,550 MW of new CCCT capacity are built in Queens – about 72 percent of the proposed new CCCT capacity. We do not venture a prediction about exactly which proposed units will come to fruition and which will not. We do not assume that any of the existing CTs in Queens (owned by KeySpan and NRG) are retired, but we do anticipate that they would continue to operate very little in the clean energy scenario because of their high operating costs.

Table 5.6 shows the assumptions about plant repowering that we have modeled in this study. Zeroes or dashes in a cell indicate a new plant that has not been built yet or an old plant that has been retired.

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[15] Given the current status of newly-permitted facilities, it is unlikely that these existing facilities would be retired by 2005. Thus, the benefits that our analysis shows for 2005 would actually be achieved in a later year (e.g., 2007), whenever these units are retired.

Table 5.6 Power Plant Additions and Retirements in the Clean Air Plan

	2000		2005		2010	
Plant/Unit	Capacity (MW)	Type	Capacity (MW)	Type	Capacity (MW)	Type
Poletti						
Poletti 1	825	Steam	0	---	0	---
Astoria						
Unit 2	170	Steam	0	---	0	---
Unit 3	358	Steam	0	---	0	---
Unit 4	369	Steam	0	---	0	---
Unit 5	366	Steam	366	Steam	0	---
NRG						
CTs	650	CT	650	CT	650	CT
Ravenswood						
Unit 1	388	Steam	0	---	0	---
Unit 2	389	Steam	0	---	0	---
Unit 3	986	Steam	986	Steam	986	Steam
CTs	415	CT	500	CT	500	CT
New CCCTs						
CCCT 1	0	---	500	CCCT	500	CCCT
CCCT 2	0	---	900	CCCT	900	CCCT
CCCT 3	0	---	0	---	900	CCCT
CCCT 4	0	---	250	CCCT	250	CCCT
Photovoltaics*	0	---	19	PV	50	PV
Queens Total	5,160		4,530		5,090	

** We assume these PV units are installed throughout New York City.*

To calculate the construction costs of the new power plants in the Clean Air Plan we use data from the US Department of Energy, which assumes capital costs for new CCCTs of $600 per kW (DOE 2001). We use these data rather than relying on information from project developers in order to have cost data from an independent source that is the same for all the new units.[16]

5.3.4 Impacts of the Clean Air Plan for the Electricity Sector

Table 5.7 below shows estimated generation at each Queens unit under the Clean Air Plan for each year evaluated. Dashes in a cell indicate that a unit has not been constructed yet. Again, note that these numbers are not intended to be precise predictions of plant utilization in a future year. The focus should be on relative utilization levels among the plants and trends over time.

A comparison of these numbers to the ones in Table 5.2 indicates the difference between estimated generation in the base case and the Clean Air Plan. Note in Table 5.7 that electricity generation in Queens is projected to increase during the study period even more under the Clean Air Plan than in the base case. Total generation in Queens in 2010

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[16] The capital costs of actual new power plants built in New York City could be higher than DOE's estimate of the capital costs of a "generic" power plant in the Northeast.

is 11,955 GWh in the base case and 17,733 GWh (48 percent higher) under the Clean Air Plan.

It is quite plausible that electricity generation in Queens can increase substantially in the Clean Air Plan, despite the adoption of aggressive energy efficiency. A considerable amount of the generation from the new CCCTs we envision in the Clean Air Plan would displace generation from other high-cost generating units in the region. That is, once these efficient generating units with low operating costs are bidding into the regional power markets, they will take market share from other power plants. Thus, the Clean Air Plan would result in additional emission reductions from displaced power plants in other parts of New York, New England and the Mid-Atlantic.[17]

Table 5.7 Generation From Power Plants in Queens Under the Clean Air Plan

Unit	2000 Generation (GWh)	2000 Capacity Factor	2005 Generation (GWh)	2005 Capacity Factor	2010 Generation (GWh)	2010 Capacity Factor
Astoria ST 3	1,329	42%	Retired	Retired	Retired	Retired
Astoria ST 4	1,201	37%	Retired	Retired	Retired	Retired
Astoria ST 5	473	15%	433	14%	Retired	Retired
NRG CTs	1	<0.1%	0	0%	0	0%
Poletti 1	2,221	31%	Retired	Retired	Retired	Retired
Ravenswood 1	301	9%	Retired	Retired	Retired	Retired
Ravenswood 2	1,269	37%	Retired	Retired	Retired	Retired
Ravenswood 3	3,931	46%	1,726	20%	2,230	26%
Ravenswood CT	0	0%	0	0%	0	0%
New CCCT 1	---	---	1,624	74%	1,589	73%
New CCCT 2	---	---	3,063	70%	3,087	71%
New CCCT 3	---	---	5,498	70%	5,772	73%
New CCCT 4	---	---	---	---	4,958	70%
New PV 1	---	---	35	21%	37	22%
New PV 2	---	---	---	---	60	22%
Total	**10,727**		**12,379**		**17,733**	

Capacity factor represents the amount of electricity generated by a unit, relative to the total amount of generation available from the unit. Capacity factors rarely exceed 85% due to scheduled and unscheduled outages.

Three other aspects of Table 5.7 are worth noting. First, the one existing steam unit in Queens that continues to operate through the study period under the Clean Air Plan (Ravenswood 3) shows the same pattern of operation as it did in the base case. Generation is reduced in the medium term (year 2005) as the new CCCTs effectively "displace" the unit, but generation increases again in the longer term, as demand grows relative to generating capacity. Second, the capacity factors of the new CCCTs remain very high throughout the study period, indicating that we have not assumed an unreasonable amount of new capacity for the New York City area. Finally, this modeling indicates that the existing CTs in Queens would be used very little under the Clean Air

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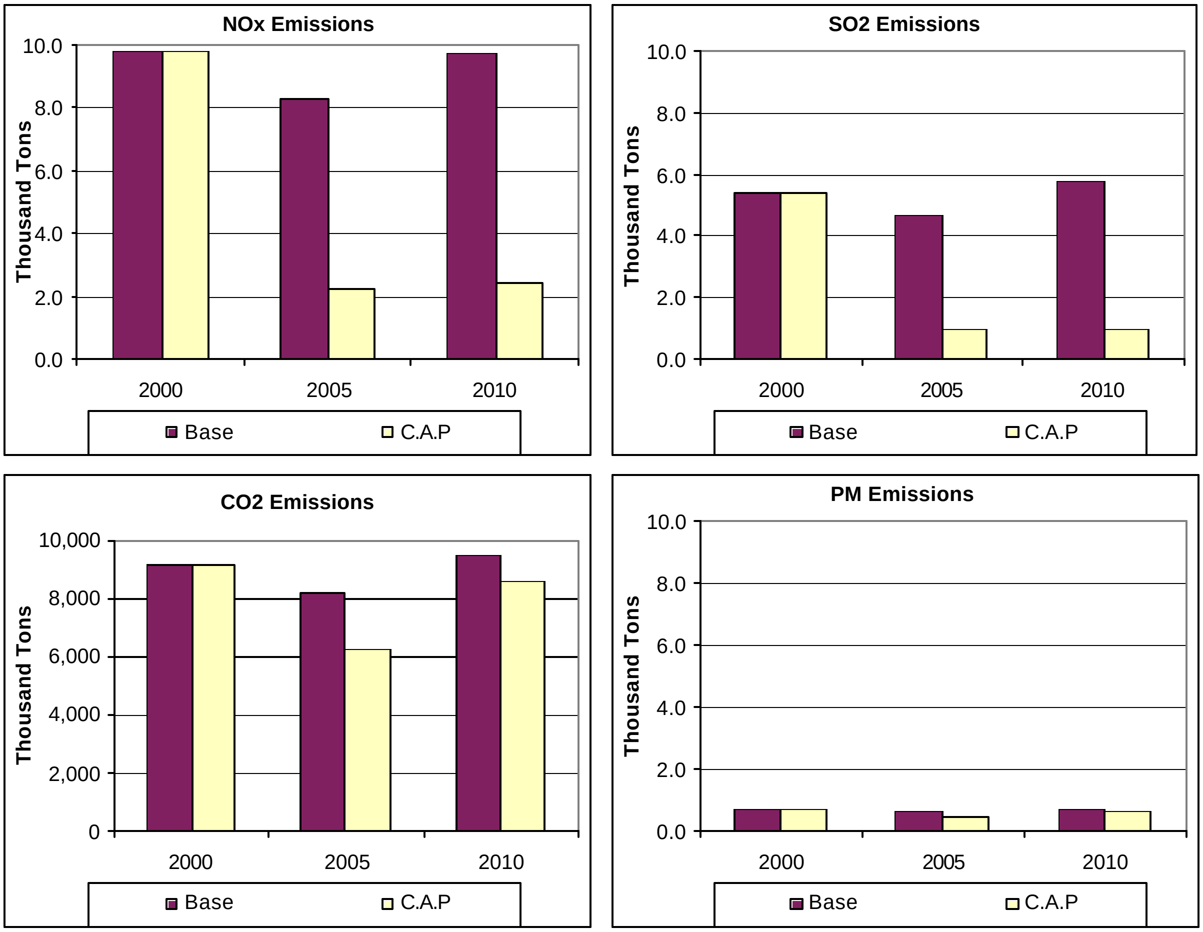
[17] The extent to which Queens power plants will displace emissions in neighboring regions will depend upon amount of energy efficiency that is adopted in Queens and elsewhere. If less efficiency is adopted, then there will be higher load growth and less displaced generation, leading to less displaced emissions.

Plan. This is because new CTs installed in other areas of New York City, combined with the new CCCTs, are anticipated to provide sufficient peaking capacity to serve the City's region's peaking needs.

Together, the three components of the Clean Air Plan for the electric industry reduce emissions from the Queens generating units considerably. Figure 5.3 and Table 5.8 show estimated emissions from the Queens generators in the base case and under the Clean Air Plan.

Figure 5.3 Emissions from Queens Power Plants: Base Case and Clean Air Plan



The Plan reduces NO_x emissions by 73 percent below the base case in 2005 and 75 percent below it in 2010. These reductions are due to the replacement of the steam generators in Queens with CCCTs with advanced NO_x emission controls. In terms of percentage reductions, the Clean Plan reduces SO_2 emissions most. Emissions of SO_2 are 80 percent below base case levels in 2005 and 83 percent below the base case in 2010. These reductions are almost entirely the result of changes in fuel use. Because there is negligible sulfur in natural gas, replacing oil combustion with gas combustion reduces SO_2 emissions to near-zero levels.

The CO_2 reductions from the Clean Air Plan are also considerable. In 2005, CO_2 emissions under the Plan are 1,907,000 tons below base case emissions, and in 2010, they are 895,000 below the base case. Percentage reductions in CO_2 are not as pronounced as those in NO_x and SO_2 because, while new CCCTs have very low NO_x and SO_2 emission rates, their CO_2 emission rates are more significant.

Table 5.8 Emission Reductions at Queens Power Plants from the Clean Air Plan

	2005	2010
NO_x Reductions (%)	73%	75%
NO_x Reductions (tons)	6,050	7,300
SO_2 Reductions (%)	80%	83%
SO_2 Reductions (tons)	3,760	4,780
CO_2 Reductions (%)	23%	9%
CO_2 Reductions (tons)	1,907,000	895,000
$PM_{2.5}$ Reductions (%)	27%	12%
$PM_{2.5}$ Reductions (tons)	175	91

Emission reductions are relative to the base case emissions presented in Table 5.3.
$PM_{2.5}$ includes primary emissions; it does not include secondary emissions.

The Clean Air Plan will also result in significant reductions of emissions in regions outside of Queens. As noted previously, emissions reductions from power plants located outside of Queens can and often will result in air quality improvements in Queens. Table 5.9 presents a summary of emissions reductions achieved by the Clean Air Plan in the entire Northeast region. A comparison of the tonnage reductions in Tables 5.8 and 5.9 demonstrates that a large portion – and in many cases the majority – of emission reductions from the Clean Air Plan occur outside of Queens. This occurs for several reasons: (a) the increased generation in Queens due to the new power plants reduces the emissions from dirtier, less-efficient power plants elsewhere; (b) the efficiency efforts significantly reduce generation from other power plants in the region; and (c) the PV slightly reduces generation from other plants in the region. These results emphasize the need for regional solutions to address the air quality in Queens, as discussed throughout this report.

Table 5.9 Emission Reductions at Northeast Power Plants from the Clean Air Plan

	2005	2010
NO_x Reductions (tons)	9,350	15,460
SO_2 Reductions (tons)	13,150	26,240
CO_2 Reductions (tons)	4,324,000	7,078,000

Emission reductions are relative to the base case emissions.
$PM_{2.5}$ emissions were not modeled for the entire Northeast region..

5.4 Epilogue – the Status of Poletti

As this study was being completed, the New York Power Authority agreed, as part of a settlement with environmental and community groups, to retire the existing 825 MW Poletti generating unit at some point between 2008 and 2010, after construction of a new 500 MW combined-cycle natural gas plant.

In addition to the commitment to retire the Poletti plant, the agreement also includes many restrictions on how the Poletti plant will be operated until its retirement, including:

- in 2003 and 2004 no more than 33% oil can be used on a yearly basis, and no more than 25% oil in the summer;
- in 2005 -2007 no more than 33% oil can be used on a yearly basis and no more than 20% oil during the summer;
- in 2008 (if the plant is not already retired), only 10% gas can be used year round.
- After the new plant is built, operation of the existing Poletti plant will be limited to a capacity factor of thirty percent.

The settlement also provides a $2 million clean air fund for Northwest Queens and increases NYPA's New York City governmental efficiency loan program by $50 million over five years. (Case 99-F-1627, New York State Board on Electric Generation Siting and the Environment, Opinion and Order, Oct. 2, 2002.)

In return for retiring the Poletti plant, the Power Authority will be allowed to proceed with its plan to build a new, 500 MW combined cycle unit (CCCT) at the Poletti site. The new unit will be far more efficient than the existing steam unit, and will mostly rely upon natural gas. It is estimated that the net effect of the retirement and repowering will be to reduce both NO_X and SO_2 emissions by 95%.

In our Base Case, we assume that the existing Poletti unit would continue to operate at least through 2010, and that there would be no CCCT built on that site. In our Clean Air Plan, we assume that the Poletti unit is retired before 2005, and that a new 500 MW CCCT would be installed at the Poletti site.

Thus, one could say that Queens has already taken one very important step towards the Clean Air Plan. Another way to view this development is to consider the new Poletti plans to be a part of the Base Case, and to consider the Clean Air Plan as containing the all the other environmental improvements described in this chapter. From this perspective, the reductions in air emissions between the two cases will be less than those presented in Figure 5.3 and Tables 5.8 and 5.9. In particular:

- In 2005 there will be less air emissions in the Base Case, due to the Power Authority's agreement to burn less oil at Poletti. The reductions will be greatest for SO_2 and NO_X, due to the large difference in emission rates for these pollutants between oil and gas generation. The 2005 emissions in the Clean Air Plan will be unchanged, because the Poletti unit is not included there either way.
- In 2010 there will be significantly less air emissions in the Base Case, due to the retirement of Poletti between 2008 and 2010. Again, the reductions will be greatest for SO_2 and NO_X. The 2010 emissions in the Clean Air Plan will remain unchanged, because the Poletti unit is not included there either way.

In sum, the amount of emission reductions available from the Clean Air Plan will be lower as a result of the Poletti agreement, with the biggest impact on SO_2 and NO_X emissions, and most of the impact occurring in 2010.

6. The Transportation Sector

6.1 The Study Area and the Roadway Network

Our study area, the northwest section of Queens, is bounded by the East River on the north and west, the Grand Central Parkway on the east and the Long Island Expressway on the south. It comprises approximately 17 square miles, about 16% of the entire borough. However, its shares of population, economic activity and traffic are considerably greater.

Some 564,106 people, or 25% of the borough population of 2,229,400 (2000 census), live in the study area. At its center is Long Island City, New York City's leading industrial district and a major generator of goods movement and truck activity. Another generator, LaGuardia Airport, is located on the northern boundary.

Major expressways in the area — the Long Island Expressway (LIE), the Brooklyn Queens Expressway (BQE) and the Grand Central Parkway (GCP) — connect Manhattan, the Bronx, Long Island and Brooklyn. Also connecting the area to Manhattan are the Queens Midtown Tunnel, the Queensboro Bridge and the Triborough Bridge, as well as eight subway lines and two branches of the Long Island Railroad.

All told, the roadway network in the study area has some 20 miles of expressways (limited access highways typically spanning six to eight lanes), 80 miles of arterials (typically, four-lane roads) and 350 miles of local roads (two lanes).[18] These account for roughly 27%, 20% and 18% of the county-wide mileage of the respective roadway types.

6.2 Traffic Levels and Mode Splits

In 2000, an estimated 2.16 billion miles of vehicle travel (VMT) took place within the study area.[19] This is just over one-quarter of all vehicle-miles of travel in Queens County in that year. We estimate that half of this VMT, or 50%, occurred on expressways, with 36% on arterials, and the remaining 14% on local roads. The estimated division of total VMT by vehicle type ("mode split") for the Northwest Queens study area in 2000 is as follows:

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[18] Roadway mileage for Queens County was provided by the NYSDOT. Roadway mileage for the study was estimated utilizing the NYCMAPS provided by the NYCDCP and ARCVIEW GIS software.

[19] Based on daily vehicle volumes on Queens expressways, we calculated that each linear mile of expressway within the study area carries an average of 18.9% more vehicle traffic than each comparable mile within the borough. This supports the inference that study-area arterials also carry more vehicles per mile than do arterials in all of Queens, and we estimated this differential as 2/3 of 18.9%, or 12.6%). We similarly estimate the increment of per-mile volumes on local roads in the study area as 1/3 x 18.9%, or 6.3%. With these adjustment factors, we prorated borough-wide VMT for the three roadway types to the study area, resulting in the VMT estimate given in the text.

Table 6.1 Mode Split for Northwest Queens

Vehicle Type	Share of VMT, 2000[20]
Sedans (conventional autos)	59.0%
Taxis	1.7%
"Light trucks" (SUV's, pick-ups, minivans)	25.5%
Commercial vans	8.2%
Large gasoline-powered trucks	1.7%
Large diesel trucks (18-wheelers) and buses	3.9%

Passenger vehicles, making up the first three categories, accounted for 86% of VMT, or somewhat more than 6 of every 7 miles driven. Large trucks, the last two categories, were responsible for just 5-6% of VMT, but their share of emissions was much larger, particularly for NOx and particulates, as we see below.

These mode splits vary somewhat across the three roadway types. For example, a disproportionately high share of travel by commercial vans and taxis takes place on arterials and local roads, while large trucks travel disproportionately more on expressways. (These distinctions enter into our pollution estimates, since vehicle speeds and, hence, emission factors differ for the three roadway types.)

For VMT growth in the study area, we have used county-wide forecasts by New York State DOT of a 7.1% increase from 2000 to 2005 (an average annual growth rate of 1.39%), with a further 5.7% increase to 2010 (equivalent to 1.11% per year). By comparison, VMT in Queens grew from 1990 to 2000 at an average annual rate of 1.55%.[21] We have applied the 2000 vehicle mode splits to future years, except that for 2005, and again for 2010, we reduced the VMT share for sedans by two percentage points and increased the share for light trucks commensurately to reflect the growing market share of SUV's.[22]

6.3 Emissions and Emission Factors

The US EPA maintains extensive databases of emission factors – pollutant emissions per mile of travel – for a wide range of automotive pollutants, vehicle types and driving conditions. We have used EPA data, except that in several instances we tempered the agency's optimism regarding the rate at which tighter regulations and improved technology will reduce emissions in the future.

Per-mile emission rates for vehicular pollutants have declined markedly over the past several decades. Over the past dozen years in particular, micro-electronics and catalytic

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[20] "Project Environmental Guidelines, Air Quality," Chapter 1.1, New York State Department of Transportation, Environmental Analysis Bureau, January 2001.

[21] Ibid., Table 17 for 2002, 2005 and 2007; with 2000 and 2010 levels extrapolated linearly from those levels.

[22] In the higher gas tax scenario discussed further below, we keep the 2005 sedan/light truck mode split in 2010, on the assumption that higher prices at the pump will arrest the shift in passenger travel from autos to SUV's.

after-treatment have made pollution-control systems not only more efficient and reliable but also more responsive in real time to changing combustion conditions.

Even factoring in the tendency of pollution control systems to degrade over time, average per-mile emissions for today's on-road car and truck "fleet" appear to have fallen around 80% for volatile organic compounds, 75% for carbon monoxide, and 70% for nitrogen oxides and particulate matter, compared to averages from 30 years ago.[23]

Because of these improvements, nationwide emissions of vehicular pollutants have fallen considerably from 1970 levels, even as vehicle miles traveled increased 2½-fold and the vehicle mix shifted heavily toward sport utility vehicles and other "light trucks," which are permitted to pollute substantially more than conventional automobiles. In New York City, where VMT has risen much more slowly, net reductions in emissions have probably been even more marked.

Progress has been less pronounced, however, in two areas: carbon dioxide emissions from all vehicles, and particulate emissions from heavy trucks. CO_2 emissions are inversely related to fuel efficiency (miles per gallon), which has retreated slightly since 1995 after improving steadily through the 1980s and early 1990s. In our analysis we have assumed that car and truck gas mileage increases only slowly — by one-half of one percent annually from 2000 to 2010, or just a third to a half of the rate at which vehicle miles traveled are projected to increase. Accordingly, absent policy measures to dampen growth in VMT (or to actually reduce miles traveled in absolute terms), or to achieve greater improvements in fuel efficiency, vehicular CO_2 emissions in the NW Queens study area will increase by 2005 and again by 2010.

In addition, per-mile emissions of particulate matter and NOx by heavy-vehicle diesel engines (primarily 18-wheelers and transit buses) have fallen noticeably only quite recently, as the tighter regulations effective on 1994 and later model vehicles have begun working their way through the vehicle fleet. Accordingly, as emissions of CO and VOCs and NOx from passenger cars have declined considerably, particulate emissions from heavy trucks and buses have come to assume a larger share of the automotive pollution problem in New York City.

6.4 Base Case Emissions in 2005 and 2010

Good news on automotive emissions is on the way. As the next table illustrates, over the next 5-10 years emissions in the study area of all of the "traditional" automotive pollutants (volatile organic compounds, carbon monoxide, nitrogen oxides and particulates) are projected to decline significantly. Total vehicular emissions of VOCs, CO, NOx and fine particulates are expected to fall by roughly one-fourth by 2005 (from 2000 levels), and by a third to a half by 2010, due to the continued ratcheting down of emissions from new vehicles and the ongoing retirement of older, higher-emitting vehicles. Vehicular emissions of total particulate matter are also projected to decline,

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[23] We say "appear to" because we have had to piece together these percentages from U.S. EPA data that are not 100% consistent.

though by somewhat lesser percentages. Only CO_2 emissions will rise in the study area, by 9% by 2005 and by another 9% by 2010, in the absence of policies to reduce VMT or shift motorists toward more efficient vehicles.

Table 6.2 Base Case Changes in Total Automotive Emissions in Study Area

Pollutant	2005	2010
Volatile Organic Compounds (VOCs)	– 28%	– 51%
Carbon Monoxide (CO)	– 21%	– 33%
Nitrogen Oxides (NOx)	– 24%	– 48%
Particulates (PM-10)	– 14%	– 25%
Fine Particulates (PM-2.5)	– 24%	– 38%
Carbon Dioxide (CO_2)	+ 9%	+ 18%

Figures in table denote estimated changes in emissions from present trends (declining emission factors but rising vehicle miles traveled), absent the pricing or tailpipe/fuel measures discussed directly below.

6.5 The Speed-Emissions Connection

Our emission forecasts account for the likelihood that rising traffic congestion (due to higher VMT) will lower average engine efficiencies, undercutting somewhat the gains from technological advances in emission controls. In general, vehicular emission rates (pollution per mile) are lowest at speeds of 35-45 miles per hour, and rise significantly at progressively lower speeds. Compared to emission rates at 30 mph, emissions from cars and trucks traveling at 10 mph are roughly 2½ times greater for VOCs and CO, and 1½-2 times higher for particulates and CO_2. (NOx emission rates are relatively unaffected by vehicle speed.) Even relatively small reductions in speed can have a noticeable effect: when a typical vehicle slows to 25 mph from 30 mph, its emissions per mile rise by 15% for VOCs, 20-25% for CO, and 10% for particulates and CO_2.

As noted, NY State DOT is forecasting 7.1% traffic (VMT) growth from 2000 to 2005, and an additional 5.7% from 2005 to 2010, for a combined (compounded) growth of 13.2% over the 10-year period. This generalized increase in VMT will slow traffic appreciably, although the precise effect will be extraordinarily dependent on place and, more importantly, time of day. On uncongested roads, the effects of higher traffic volumes on vehicle speeds will be barely noticeable; but on roads that are already highly congested, any increment in traffic will translate disproportionately into more stop-and-go movement and lower average speeds.

To average these disparate situations, we have adopted a rule-of-thumb that each 1% increase in VMT in the Northwest Queens study area results in a 1.5% decrease in average speeds (see Appendix D).[24] Accordingly, the assumed 13.2% growth in VMT in the study area during 2000-2010 translates into a nearly 20% reduction in average traffic speeds (since 13.2% x 1.5 = 19.8%), which in turn offsets somewhat the reduction in

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[24] With virtually no new roads, road widenings or “spot improvements” planned for the study area to 2010, we have assumed zero increase in roadway capacity that might otherwise mitigate the effects on speed (and emissions) of increased VMT.

emission rates due to vehicle turnover. Only NOx, for which emissions are more or less invariant over a wide range of speeds, is exempt from this effect.

This “speed-emissions” effect has major implications for emissions in the study area. For one thing, it means that increased traffic congestion can significantly undercut the ongoing reduction in emissions of VOCs, CO and particulates from improved pollution controls. (That is, the reductions shown in the previous table would have been even greater, were it not for the slower average speeds due to higher traffic volumes.) It also suggests that efforts to reduce vehicle miles driven carry extra “bang for the buck,” due to the synergy between traffic and emission rates.

6.6 Measures to Accelerate Reductions in Vehicular Emissions

We have analyzed seven different policy measures to accelerate the ongoing reduction in vehicular emissions in the Northwest Queens study area over the next 5-10 years. We say “accelerate” because even without any additional concerted anti-pollution effort, and despite increases in the amount of driving, the steady replacement of older cars and trucks by newer, cleaner vehicles is projected to yield net reductions in emissions.

Five of the measures employ different types of economic incentives to induce motorists to economize on the amount of driving they do or to drive lower-emission vehicles. The other two measures expand the use of emission-control devices or special fuels to curb emissions of particulates and other pollutants from 18-wheelers and transit buses.

6.6.1 Pricing Measures

The five pricing measures operate by rearranging the “price signals” given to motorists so as to encourage more efficient use of cars, trucks and fuels. One measure, cents-per-mile insurance, is internally “revenue-neutral” — it converts auto-insurance premiums from a largely fixed to a variable basis while keeping overall insurance costs constant. The other pricing measures do increase the overall cost to drive, through road fees based on miles driven, or higher gasoline taxes, or new bridge tolls. Since the resulting revenues would be collected by municipal government, they could be used either to reduce existing taxes (e.g., sales taxes), or to finance other public functions, ranging from transportation to schools to social services. Insofar as these services would otherwise be financed from general revenues (or would go unmet), the revenue-neutral label applies to the pricing measures discussed here as well.

Precisely how the revenues from the various measures would be allocated is beyond the scope of this report, as are the larger questions of implementation and political feasibility. Suffice it to say that no technical barriers stand in the way of any of the pricing measures discussed here.

Pricing Measure 1: Cents-Per-Mile Insurance

Discussion and Assumptions

Under conventional auto insurance, drivers pay for insurance on a lump-sum basis, and their premiums bear little relationship to the number of miles they drive. An alternative method of charging insurance would be to make insurance premiums proportionate to mileage. Because vehicular accidents overall are proportional to miles driven, this would be rational from the perspective of the main purpose of insurance — coverage for personal and property damage.

Under "cents-per-mile insurance," car-insurance providers would sell their service by the *mile* rather than by the *year*. Drivers would be billed according to their individual *insurance rate* times their *miles driven*. A driver's insurance rate would be so many cents per mile, rather than so many dollars per year.

Cents-per-mile insurance rates can be adjusted to reflect an individual driver's safety record (of accidents and infractions) as well as age and gender. Rates therefore would vary widely, from a few cents per mile for the safest drivers to as much as 20 cents for very unsafe drivers. In the New York area, the likely average rate would be around 10 cents a mile, and we have used this figure in our analysis.[25]

The idea behind cents-per-mile insurance is to rearrange, not increase, the overall cost of car use, by shifting to a *variable* cost the auto insurance payments that drivers now pay as a *fixed* cost. This cost shift would create a powerful incentive among drivers of non-commercial vehicles — the assumed target group for cents-per-mile insurance — to economize on driving. Whereas drivers currently save little or nothing on their insurance costs by driving less, cents-per-mile insurance would effectively let drivers pocket 10 cents on average for each mile they did <u>not</u> drive. Travel demand models calibrated to California metropolitan areas suggest that 10¢/mile rebates for "driving less" would cut driving by some 15%, as drivers re-prioritized their travel to consolidate, shorten or eliminate trips that aren't worth the additional 10¢/mile cost.[26]

If 15% seems a high estimate of the likely cutback in non-commercial travel, consider that adding 10 cents to the cost to drive each incremental mile packs the same pocketbook wallop as adding $2 to the cost of a gallon of gasoline (assuming a 20 mpg car). Still, to reflect higher "background" driving costs (for parking, tolls, etc.) in the New York metropolitan area, we trimmed the effect on driving predicted by the California models by one-fourth, yielding an estimated 11.4% reduction in miles traveled by drivers who opt to purchase insurance by the mile.

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[25] New York State drivers paid an average of $1,040 per automobile for insurance in 2000. We increase this by 25%, to $1,300, to reflect higher in-city costs. We estimate that 75% of this annual figure, or just under $1,000, is due to costs that vary with miles driven, which we estimate to be 10,000 miles per vehicle per year. This yields an average of 10 cents per mile in variable auto insurance costs.

[26] Todd Litman, Victoria Transportation Policy Institute, http://www.vtpi.org/tdm/tdm10.htm, based on extensive modeling work by Greig Harvey for the California Air Resources Board and other CA agencies.

Cents-per-mile insurance should be especially attractive to drivers who drive less than average (but whose annual premiums aren't downsized accordingly) and to drivers with good driving records (which current premiums don't fully credit). We assume that 25% of drivers will choose it by 2005, if it is made available in the next year or two, resulting in an overall 2.9% cutback in driving (since 25% x 11.4% = 2.9%), relative to the growth in VMT projected for that year.

Insofar as high-volume drivers (who as a group are heavily subsidized by present-day insurance pricing) have little or no incentive to switch, the market share for cents-per-mile pricing may never rise much above 50% unless it is made mandatory. Because the potential social benefits of cents-per-mile insurance are so great,[27] we assume in our 2010 cents-per-mile insurance scenario that it is made mandatory for that year. With 100% "participation" in cents-per-mile insurance, VMT by passenger vehicles —sedans and "light trucks" such as SUV's — is predicted to be 11.4% less than it would have been otherwise.

However, we must account for the phenomenon by which reduced traffic congestion entices some drivers into taking more and/or longer trips. Precisely forecasting the level of "bounce-back," as we call it, would require travel-demand models that predict mode choice and miles traveled as a "function" of car ownership rates, out-of-pocket costs, travel times, and preference factors such as comfort. In lieu of such elaborate models, we use our professional judgment to estimate that bounce-back will equal 25% of the gross reduction in miles driven. Accordingly, the 2.9% reduction in passenger-vehicle trips in 2005 becomes 2.1%, and the 11.4% reduction in 2010 becomes 8.6%.[28] (Both reductions are relative to projected growth.)

Results

For 2005, cents-per-mile insurance produces 2-4% reductions in emissions (vs. "base case" emissions for that year). These reductions are caused about equally by the fewer vehicle miles traveled in the study area and the improvement in average speeds resulting from the shrinkage in VMT. The effect is considerably greater by 2010, when cents-per-mile insurance is assumed to be universal for non-commercial vehicles: 15-17% reductions (vs. base case 2010 emissions) in VOCs and CO, and 11% for particulates and CO_2. (The relatively smaller reductions in particulates are because cents-per-mile insurance affects only passenger-vehicle use, leaving unchanged heavy truck traffic.) Because NOx emission rates don't improve with the smoother traffic flow, NOx emissions decline by just 6% relative to base case levels. (The results for each of the pricing measures are summarized in Table 6.3 below).

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[27] The benefits of cents-per-mile insurance include not just reduced driving (and lower traffic congestion and emissions) but disproportionate reductions in driving by motorists with poor driving records, since their cents-per-mile insurance rates will be unusually high, with correspondingly higher incentives to economize on driving.

[28] Some of the trips induced via the bounce-back effect would be by commercial vehicles, i.e., taxis and trucks. However, specifying this level of precision would not materially change the results and is beyond the scope of this analysis.

Pricing Measures 2 and 3: VMT Fees and Weight-Distance Fees

Discussion and Assumptions

VMT fees charge all motor vehicles a fixed amount per mile driven. Weight-distance fees are a variation on VMT fees in which vehicles are charged per *ton-mile*, so that two vehicles driven the same amount pay in proportion to their respective weights. This added feature better captures the emissions effects of VMT by different types of vehicles, and appears to be an excellent way to equalize the greater contribution to pollution, especially CO_2, from the continuous increase in use of SUVs.

Both types of fees are attractive because they capture many of the societal costs associated with driving — "externality costs" such as air and noise pollution and endangerment of other road users, as well as direct governmental costs to provide, maintain and police roads. Weight-distance fees are particularly attractive because these costs tend to rise directly with vehicle weight: compared to a 3500-pound sedan, a 5000-pound SUV is noisier, more demanding of fuel, more air-polluting, more consuming of road space,[29] and more likely to injure or kill other vehicle users. Similarly, compared to a car or smaller truck, an 18-wheeler inflicts vastly more damage on public health, other travelers' time and the road infrastructure.

We assumed VMT fees of 5¢ per mile for all vehicles in 2005 and 10¢ in 2010 — "round-number" rates that at the high end match the incremental effect of cents-per-mile auto insurance. The California travel demand models noted earlier suggest that these charges would cut passenger-car driving by 8.2% and 15.2%, respectively. That is, in areas whose travel-cost characteristics mirror those of California metropolitan areas, a 10 cent a mile charge would be expected to reduce passenger-car driving by 15 percent, as drivers find that some trips for which the net utility is marginal at today's driving "prices" are no longer worth taking at all (or are converted to shorter journeys) now that each mile driven incurs a fee of 10 cents.

However, these figures (8.2% reduction for 5¢ fee in 2005; 15.2% for 10¢ fee in 2010) must be reduced by 25% *twice*: first, to better approximate NYC conditions, and second, to allow for the "bounce-back" effect noted above. Moreover, taxi and truck travel generally is less price-sensitive than passenger-car travel; accordingly, we further reduce the above price effects by one-half for taxis and vans, by three-quarters for large trucks, and by seven-eighths for 18-wheelers. This produces a range of VMT reductions in 2005, from 4.6% for passenger cars and light trucks down to 0.6% for 18-wheelers. For 2010,

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[29] That SUV's generate more pollution and danger than ordinary cars is well known. Equally clear, but less publicized, is their exacerbation of traffic congestion due to poorer maneuverability, slower responsiveness and sheer bulk. Researchers at the University of Texas have estimated that each large SUV contributes as much congestion effect as 1.4 sedans. See *The New York Times*, January 16, 2000, Week in Review section, "Heavy Traffic; No Wonder S.U.V.'s Are Called Light Trucks," by Keith Bradsher. For the source document, "Effect of Vehicle Type on the Capacity of Signalized Intersections: The Case of Light-Duty Trucks," by Kara M. Kockelman and Raheel A. Shabih, go to http://www.ce.utexas.edu/prof/kockelman/public_html/ASCELDTShabih.pdf.

when the stipulated per-mile charge doubles from 5 cents a mile to 10, the estimated decreases in driving are almost twice those figures.[30]

This nearly 8-fold range in VMT reductions is itself an argument for charging mileage fees according to vehicle weight, via weight-distance fees. Assuming an average weight for sedans of 3,400 pounds, a VMT fee of 5 cents per mile converts to a weight-distance fee of *2.94 cents per ton-mile* (since 2.94 x 3,400 / 2,000 = 5.00). The same charge of 2.94¢/ton-mile applied to an average 4,600-pound minivan or SUV yields a per-mile fee of 6.8 cents, which is some 36% greater than the sedan's per-mile fee.

At that same per ton-mile rate, a 6,500-pound commercial van, an 18,000-pound large truck and a 38,000-pound 18-wheeler will pay approximately 10¢, 26¢ and 56¢ per mile, respectively, or roughly two, five and eleven times the per-mile charge applied to a sedan. These ratios are in reasonable proportion to the relative societal costs imposed by each vehicle class. For 2010, when the charges are doubled, the sedan will pay 10¢ per mile driven, while the 18-wheeler will pay $1.12, or eleven times as much.

Applying the same New York City and bounce-back adjustments (25% each) and elasticity factors (ranging from one-half to one-eighth the rate for sedans) already noted yields a more narrow range of reductions in miles driven in 2005 — 4.4% to 6.4% (except that taxi VMT falls by just 2.6%). For 2010, the VMT reductions range from 8% to 12%, except that taxi VMT decreases by only around 5%.

Results

In 2005, "straight" VMT fees yield 6-7% reductions in emissions of particulates and CO_2, 9-10% reductions in VOCs and CO, and 4% for NOx. The reductions almost double in 2010, reflecting the assumed doubling in the per-mile charge from 5¢ per mile in 2005 to 10¢; particulates and CO_2 fall by 12-13%, VOCs and CO by 16-18%, and NOx by 7%. (All reduction estimates are relative to the base case for the year stated.)

The impact of weight-distance fees is both more uniform across the different pollutants, and greater in absolute terms. In effect, the far higher per-mile charges that weight-distance fees impose on heavy vehicles, especially 18-wheelers, acts to counteract the lesser price-sensitivity of these vehicles, resulting in more nearly equal VMT reductions for all vehicle classes, which in turn yield level reductions in the various pollutants. In 2005 emissions decline (relative to the base case for that year) by 6% for NOx, 8% for CO_2 and 10-12% for the other four pollutants; in 2010 the reductions relative to that year's base case are 12% for NOx and 16-21% for the other pollutants.

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[30] The law of diminishing returns dictates that a 10¢/mile fee will not produce twice the impact on driving of a 5¢/mile fee; the travel demand model used here indicates that the effect will be 85% rather than 100% greater.

Pricing Measure 4: Higher Gasoline Taxes

Discussion and Assumptions

New York motorists already pay approximately half-a-dollar in federal and state fuel taxes for each gallon of gasoline or diesel fuel they purchase.[31] These taxes act as an incentive to purchase and use more-efficient vehicles and to economize on driving, since they augment the monetary savings from using higher-mpg cars and trucks and from driving fewer miles. Raising gasoline taxes would enlarge these incentives, bringing them closer to the levels in other "advanced" industrial nations in Europe and the Far East.

We have estimated the effects of a 50 cent a gallon increase in gasoline taxes in 2005, and $1.00 in 2010. These are substantial increases, respectively doubling and tripling the current gasoline tax rate in New York State. Nevertheless, a 50 cent a gallon tax hike falls within the range of normal "market" fluctuations in gas prices.[32] As well, 50 cents is a reasonable approximation of the per-gallon cost of maintaining U.S. military forces to ensure access to Middle Eastern crude oil that supplies much of the gasoline used by American vehicles.[33] Moreover, on a per-mile basis for a 20 mpg sedan, even the $1.00 per-gallon tax increase hypothesized for 2010 equates to only 5¢/mile, the same as the per-mile VMT charge assumed here for 2005. In any event, we would expect that gas tax increases of these magnitudes would be phased in, for example, in 15 or 20 cent annual increments, rather than imposed all at once.

The effects of gasoline price changes on both gasoline consumption and miles driven have been studied extensively. The long-term price elasticity of gasoline use by passenger vehicles has been established at approximately 0.6, such that a 1% price increase brings about a 0.6% decline in usage (holding all other factors, e.g., income and number of vehicles in service, constant) over a 5-10 period. The elasticity of *driving* is about one-third of this figure, i.e., over the long haul a 1% increase in gasoline prices

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[31] Taxes on gasoline include a federal levy of 18.3¢/gallon (22.3¢, or 4 cents, higher, for diesel fuel) and NY State charges of 30.4¢/gallon. See http://www.energy.ca.gov/fuels/gasoline/gas_taxes_by_state.html. On the other hand, motor fuels are exempt from state and local sales taxes, an effective 8¢/gallon subsidy (calculated on a nominal $1 base price).

[32] For example, the average U.S. retail price of regular gasoline was $1.17/gallon for the week ended Nov. 5, 2001, down from $1.65 six months earlier (May, 2001). See http://www.eia.doe.gov/oil_gas/petroleum/data_publications/wrgp/mogas_history.html.

[33] US passenger cars (including light trucks) consume an average of 7,855,000 barrels of gasoline and diesel fuel a day, and commercial trucks another 2,460,000. (Komanoff, *Ending The Oil Age*, KEA, 2002, p. 8) Combined, these volumes equate to 123 billion gallons of fuel annually. American military expenditures associated with the Middle East have been estimated at $50 to $100 billion. Allocating these amounts to car and truck petroleum consumption yields a range of roughly 40 to 80 cents per gallon. While this calculation is non-conservative — for example, it does not allow for non-oil strategic considerations in the Middle East — it also ignores the costs of "homeland security" that are at least partly occasioned by U.S. dependence on oil imports.

brings about only a 0.2% drop in VMT (since the lion's share, some two-thirds, of the decline in gas usage occurs through shifts to more-efficient vehicles).[34]

To reflect the time required to "turn over" the vehicle fleet, we have reduced these rates by one-third for the year-2005 analysis. We have also halved them for both years (2005 and 2010) for commercial vehicles (taxis, commercial vans, large trucks), usage of which is less price-sensitive than passenger vehicles. We have also applied our 25% "bounce-back" factor to reflect the fact that the time savings from more freely-flowing highways will attract some drivers to take more and/or longer trips, offsetting somewhat the "original" reductions in traffic. We also assume that the second stage of the gas tax increase, from 50 cents to a dollar for 2010, arrests the ongoing shift in the passenger-vehicle fleet from sedans to light trucks.[35]

Results

At the amounts hypothesized, higher gasoline taxes reduce driving only modestly in 2005, by an estimated 2.8% for cars and light trucks, and 1.2-1.4% for taxis and commercial trucks. The reductions in 2010 are more than twice these levels, however, due to not only the doubling of the assumed gasoline tax but also higher prioritization of *proximity* in decisions on where to live and work by individuals and businesses. Our model indicates a 6.5% reduction in passenger-vehicle miles traveled in 2010, and 3.0-3.3% reductions in taxi and truck miles in the same year.

The reductions in emissions exceed the reductions in driving, largely because of the improvements in vehicle speeds caused by the reductions in traffic levels. Relative to base case levels for the year in question, particulate emissions decline by 4% in 2005 and 10-11% in 2010; VOCs and CO fall by 6% in 2005 and 14-15% in 2010; and NOx by 3% in 2005 and 7% in 2010. Of course, the big payoff from higher gas taxes is in the reduced CO_2 emissions: an estimated 11% decline in 2005 and a whopping 25% in 2010 (relative to base case levels for the same years), reflecting reductions in fuel consumption. These result from decisions by thousands of drivers to buy or otherwise select more-efficient vehicles in response to the higher cost to fill the tank.

Pricing Measure 5: East River Bridge Tolls

Discussion

There is a strong possibility that the bridges connecting Manhattan to Queens and Brooklyn, which have been free to motorists for some 90 years, may again be tolled in the near future. New York City Mayor Bloomberg's budget statement for FY-2006 includes revenues of $800 million in "congestion pricing and E-Z Pass revenues," an

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[34] See Douglas R. Bohi, *Analyzing Demand Behavior*, Johns Hopkins / Resources for the Future, 1981, p. 117. We use Bohi's short-run price elasticity of gasoline usage as a proxy for the effect on VMT, since almost all of any immediate reduction in gasoline usage is effected through driving fewer miles.

[35] While there may be an element of double-counting in our eliminating the 2005-2010 increase in light trucks *and* applying standard price-elasticity factors, we believe this assumption better captures the likely real-world effects of higher gas taxes.

amount that could be generated only (in this time frame) by tolling the four East River bridges.[36] Not coincidentally, the technology to charge motorists "at speed," without space-consuming, pollution-generating toll plazas, is finally available, making tolls far more palatable to motorists and nearby residents alike. Indeed, a web site devoted to advancing the cause and timetable for East River bridge tolls was inaugurated recently (June 2002),[37] and as this report was being finalized there was widespread speculation that bridge tolls, collected electronically without traffic-slowing toll booths, would be seriously considered after the November elections.

Tolls on the East River bridges would affect traffic in the Northwest Queens study area in two major ways. First, thousands of cars and trucks now divert daily through Long Island City to reach the free Queensboro Bridge (via 21st Street from the Grand Central Parkway, and via Van Dam Street and the Queens Boulevard viaduct from the LIE). We assume that once the Queensboro Bridge is tolled, all of these diverters would switch to the more direct route, resulting in a 3% transfer of Queensboro Bridge traffic to the Queens Midtown Tunnel, and a 2% transfer to the Triborough Bridge. Second, apart from this "re-sorting" of traffic, we estimate that the disincentive to driving due to tolling the Queensboro Bridge would eliminate an additional 5% of current trips on the bridge, resulting in a total 10% drop in bridge usage — half through transfer to other routes, and half through outright elimination.

These assumptions translate to a roughly 1.4% decline in total VMT in the study area for 2005, most of which would be observed on arterial roads. We double this effect for 2010 on the assumption that the success of bridge tolls in generating revenue and speeding traffic flow will inspire city officials to increase tolls from the initial levels.[38]

Results

Bridge tolls have the smallest effect among the price-based measures treated here: 3-4% reductions in emissions in 2005 (except 2% for NOx), and double those figures in 2010. The localized impacts would be much greater at the Queensboro's eastern terminus in Long Island City, and far less in other parts of the study area (indeed, the areas around the Queens Midtown Tunnel and the Triborough Bridge could experience slight increases in emissions due to the transfer of trips now "diverting" to the free Queensboro Bridge).

These figures support the position of some transportation-reform advocates that the greatest benefits of bridge tolls lie in revenue generation and traffic-flow improvement, and not necessarily in air pollution reduction. To be sure, bridge tolls would reduce emissions; however, the emission reductions would likely be steeper in Brooklyn, with three untolled bridges (the Brooklyn, Manhattan and Williamsburg) to Queens' one.

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[36] See, for example, *New York Times*, " Mayor Looks at Tolls for Bridges on East River," by Randy Kennedy, February 15, 2002.

[37] The web site is www.bridgetolls.org.

[38] These effects do not include the added benefits of utilizing toll revenues to subsidize transit operations and capital improvements which would result in additional travelers choosing transit over cars for some trips.

Pricing Measures — Summary

The analysis here demonstrates that area-wide or even city-wide pricing strategies offer significant opportunities for reducing air pollution and carbon dioxide emissions on a large scale. The effects of the various pricing strategies on emissions are summarized in the next table. (We have chosen just one year and three pollutants to simplify the discussion.)

Table 6.3 Estimated Changes in Vehicular Emissions, 2010 vs. 2010 Base Case

	VOCs	PM-2.5	CO_2
Cents-per-mile insurance	– 15%	– 11%	– 11%
VMT fees	– 16%	– 13%	– 12%
Weight-distance charges	– 21%	– 19%	– 16%
Gasoline tax increase	– 14%	– 11%	– 25%
Bridge tolls	– 8%	– 6%	– 6%

Emission changes are relative to 2010 base case. Reductions in CO are similar to those for VOCs; similarly for PM-10 with respect to PM-2.5. NOx reductions tend to be roughly half of those for VOCs.

The values in the table suggest that weight-distance charges are most effective in reducing emissions of “traditional” pollutants, especially particulates, while increased gasoline taxes are the best route for reducing carbon dioxide. These results are precisely what one would expect, since weight-distance charges exact a severe toll on the heavy vehicles such as 18-wheelers that are the most prolific generators of particulates, while gasoline taxes nudge drivers toward buying and driving less gasoline-consuming cars and trucks.[39]

In another sense, however, most of the measures discussed here and summarized above should be viewed as “both/and” rather than “either/or” policies. Cents-per-mile insurance is essentially a consumer-reform measure that happens to have considerable potential to reduce driving by shifting insurance costs from a fixed to an incremental basis. VMT fees and weight-distance charges are means of weaning drivers from their least-essential trips while also generating municipal revenues to offset some of the fiscal and “external” costs of car and truck use. A boost in the gasoline tax is at least as much of an energy-policy reform as a transportation measure, since it would reduce petroleum usage more and faster than miles driven. And bridge tolls are primarily a tool for improving traffic flow, raising revenue, and rationalizing the regional transportation system.

In fact, leaving aside real-world limitations on legislative time and citizen attention, the above five measures could be regarded as potentially complementary, save for VMT fees and weight-distance charges, the latter of which is essentially a more finely-tuned and comprehensive version of the former.

The synergistic effects of combined measures can roughly be estimated through a simple multiplicative process involving the “complements” of the emission reductions. To calculate the combined effect on PM-2.5 emissions in 2010 of cents-per-mile insurance

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[39] Note that cents-per-mile insurance was evaluted only for passenger vehicles, whereas the other pricing measures extend to commercial traffic as well.

and weight-distance charges, for example, multiply 89% (the complement, from 100%, of the 11% reduction from cents-per-mile insurance) by 81% (the complement of the 19% reduction from higher gas taxes). This yields 72%, indicating a combined reduction in PM-2.5 emissions of 28% (the complement of 72%).

The same procedure may be used to estimate the combined effects of any two or more measures for any pollutant analyzed here. The result in each case will be the percentage change in emissions relative to the base case for 2010. To calculate the change relative to current (2000) emissions, the process just described must be repeated, using the corresponding percentage figure in Table 6.2. Continuing the example just above, since emissions of PM-2.5 are projected to decrease by 38% from 2000 to 2010, absent any of the policies discussed here, the combined effect of cents-per-mile insurance and increased gasoline taxes is estimated by multiplying 72% (derived just above) by 62% (the complement of the 38% decline from 2000 to the 2010 base case), yielding 45%, and indicating that the two measures combined will yield a 55% net reduction in PM-2.5 emissions in 2010, measured relative to 2000.

For completeness, Table 6.4 shows changes in emissions in the Northwest Queens study area for individual measures, relative to current (year-2000) emissions.

Table 6.4 Estimated Changes in Vehicular Emissions, 2010 vs. 2000

	VOCs	PM-2.5	CO_2
2010 Base Case (no measures)	– 52%	– 34%	+ 18%
Cents-per-mile insurance	– 59%	– 42%	+ 5%
VMT fees	– 59%	– 43%	+ 4%
Weight-distance charges	– 61%	– 47%	– 1%
Gasoline tax	– 58%	– 41%	– 11%
Bridge tolls	– 55%	– 39%	+ 11%

Emission changes are relative to 2000 base case.

The top row of the table makes clear that emissions of conventional vehicular pollutants will decline markedly, even without implementing any economic incentives to reduce driving. Still, the various incentives discussed here will deepen the reductions, by up to 10 percentage points (and more, in the case of weight-distance charges and fine particulates). Conversely, CO_2 emissions will rise by 18% with no policies, will fall 11% if gasoline taxes are increased significantly, and will either stay roughly constant or increase somewhat under the other policies discussed here.

6.6.2 Fuel And Tailpipe Emission Control Measures

Heavy-duty diesel vehicles (HDDVs) — largely 18-wheelers and transit buses — account for only 4% of vehicle miles traveled in the study area but produce 40% of vehicular emissions of particulates (PM-10) and fully half of the fine particulates (PM-2.5). Although these shares are projected to decline by 2010, this disproportion argues for focusing emission-control efforts on these HDDVs

There are other reasons as well: heavy-duty diesel vehicles are far fewer in number than private automobiles, or even commercial vans. Accordingly, retrofitting emission-control devices on a meaningful percentage of the HDDV fleet in Northwest Queens appears far more feasible than converting a comparable share of cars and small trucks to electric propulsion or natural gas fuels. HDDV's also have longer lifetimes than ordinary cars or trucks, and will therefore keep polluting longer, absent active intervention.

Ongoing Progress in Reducing Heavy-Duty Diesel Vehicle Emissions

Currently, a typical HDDV emits particulates (PM-10) at almost 20 times the per-mile rate of an ordinary sedan (based on U.S. EPA emission factors); the disparity in emission rates for fine particulates (PM-2.5) is even greater, around 30-fold. By 2010, however, these relative ratios will be trimmed by half, to around 10 (for PM-10) and 15 (for PM-2.5), or roughly proportional to the respective vehicle weights. The disparity in emissions of VOCs and CO (but not NOx or CO_2) will shrink similarly, according to EPA projections.

Three efforts already underway have been reducing emissions from 18-wheelers and transit buses for some time. First, to comply with federal regulations taking effect in 1994 and subsequent model years, manufacturers added electronic fuel injection with feedback while modifying combustion chambers and pre-chambers to optimize combustion and keep emissions below smoke limits. With each passing year, substantial reductions in emissions of particulates, VOCs and CO have been propagating through the HDDV "fleet"; according to EPA estimates, by the end of this year nearly two-thirds of the miles traveled by HDDV's will be from this cleaner, post-1993 vintage, with the figure reaching 90% by the end of 2010.

Second, the sulfur content of diesel fuel burned by HDDVs is scheduled to plunge, to 15 or lower parts of sulfur per million, from the current 350-500 ppm, a change that is estimated to reduce per-mile emissions of particulates by roughly one-tenth. All New York City Transit (MTA) buses converted to this cleaner fuel as of late 2000. All other buses, 18-wheelers and other diesel-burning vehicles, not only in New York City but throughout the United States, are required to do the same beginning on January 1, 2007.

Third, a smaller number of buses in Queens and some other boroughs, primarily operated by private "franchise" lines, have converted to compressed natural gas (CNG). Use of this fuel is estimated to cut particulate emissions from "uncontrolled" diesel fuel tailpipes by twenty-fold,[40] while also reducing VOC emissions by 90% and NOx emissions by 40%. (However, CO emissions from CNG are around 10% *higher* than those from diesel fuel.)

Pollution-Control Progress at NYC Buses

The use of cleaner fuels by buses just noted is particularly significant for the study area, insofar as transit buses account for around 14-15% of all HDDV (heavy-duty diesel vehicle) miles traveled in Northwest Queens. (This share is apportioned roughly 4-to-1 between "city buses" operated by New York City Transit (NYCT), and private buses

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[40] Motor vehicles also emit particulates from brake lining and tire wear. Taking those sources into account, "total" particulate emissions decline around 10-fold from switching to CNG from conventional diesel fuel.

operating under City franchises.[41]) These vehicles are undergoing significant changes in pursuit of cleaner air, as follows:

- The entire NYCT fleet of buses (approximately 4,500) was converted to low-sulfur fuel as of late 2000, as noted above.
- As of last year (2001), 5% of the NYCT fleet (221 buses) were operating on compressed natural gas (CNG); those figures are scheduled to rise to 14% (646 buses) by 2006.
- Also by 2006, 9% of NYCT buses (390 buses) are scheduled to use hybrid-electric propulsion.
- By the end of 2003, all other NYCT buses, close to 3,500 in number (77% of the fleet) are to be outfitted with an add-on device known as a catalyst-based diesel particulate filter, or CB-DPF (DPF for short), which funnels exhaust gases through a ceramic filter where gases and particles in the gas stream are burned ("oxidized"). DPFs destroy an estimated 90% of particulate matter, along with approximately 90% of VOCs and CO.[42]
- Of the roughly 1,250 franchise buses, approximately one-quarter currently run on CNG, and that share is expected to rise.[43]

Assumptions

Table 6.5 shows the estimated effect on emission rates (pollutant emissions in grams per mile) from the fuel and tailpipe measures being considered for heavy-duty diesel trucks:

As the table indicates, the use of low-sulfur diesel fuel reduces particulate emissions from heavy-duty diesel vehicles by close to 10%, while the use of diesel particulate filters (which requires low-sulfur fuel) reduces HDDV emissions of all of the key vehicular pollutants except NOx by around 90%. Compressed natural gas achieves roughly 90% reductions in VOCs and particulates and 40% for NOx while unfortunately increasing CO emissions by 10%.

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[41] City-wide NYC transit buses currently log 102 million "revenue miles" annually. (MTA/NYCT, Dept. of Transit Buses, "NYCT Experience With Clean Fuel Technologies," slide presentation, May 2, 2002, p. 3), 9% of which we apportion to the Study Area, based on its share of all NYC VMT (we also add 10% for "deadheading" and divide twice by 1.02 to adjust to year-2000 miles), resulting in 9.7 million miles. A similar procedure applied to the estimated 26.3 million miles by franchise buses citywide yields an estimated 2.4 million miles in the Study Area. HDDV's — primarily 18-wheelers and transit buses — traveled an estimated 83-84 million miles in the Study Area in 2000.

[42] Diesel particulate filters require low-sulfur fuel to function, since anything more than trace levels of sulfur dioxide in the gas stream prevents the catalyst from provoking the necessary chemical reactions. Accordingly, conversion of diesel vehicles to low-sulfur fuel, whether on a fleet basis as the NYC Transit Authority has already implemented on its buses, or on the nationwide level that EPA is requiring in 2007, is a prerequisite to installing and operating DPF's.

[43] Data on NYCT bus conversions is from MTA/NYCT slide presentation, op. cit. Franchise bus statistic is from Tri-State Transportation Campaign, *Mobilizing the Region*, Issue 369, June 10, 2002.

Table 6.5 Effects of Fuel & Tailpipe Measures on HDDV Emissions

	Percent Reduction in Emissions		
	Low-S Fuel	Low-S + DPF	CNG
Volatile Organic Compounds (VOCs)	0%	– 90%	– 90%
Carbon Monoxide (CO)	0%	– 90%	+ 10%
Nitrogen Oxides (NOx)	0%	0%	– 40%
Particulates (PM-10)	– 8%	– 92%	– 91%
Fine Particulates (PM-2.5)	– 9%	– 92%	– 91%

DPF = Diesel Particulate Filter. CNG = Compressed Natural Gas. Percentages for VOCs, CO and NOx are approximate and are drawn from the technical literature. Percentages for particulates are calculated from US EPA Mobile 6 model and are relative to uncontrolled levels (high-sulfur fuel without particulate filters) for 2010. Particulate reduction percentages fall to around 80% when non-tailpipe emissions from tire wear and brake lining are included (as they are in the area-wide emission calculations in this report). CO_2 *emissions are largely unaffected by the measures shown.*

As a base case assumption for 2000, we assumed that low-sulfur fuel was used for 11.1% of all VMT by heavy-duty diesel vehicles in the Northwest Queens study area (this is the share accounted for by NYCT buses, less the small amount using CNG); and that 1.3% uses CNG, reflecting NYCT use of compressed natural gas along with a quarter of franchise buses.

Table 6.6 Penetration Rates among Heavy-Duty Diesel Vehicles for 2005 and 2010

	’05 Base	’05 DDD	’05 CNG	’10 Base	’10 DDD	’10 CNG
% low-Sulfur fuel	11.4%	22.8%	11.4%	96.9%	96.9%	80.0%
% DPF	10.0%	19.9%	10.0%	19.0%	38.0%	19.0%
% CNG	3.1%	3.1%	14.5%	3.1%	3.1%	22.1%
% uncontrolled	85.5%	74.2%	74.2%	0%	0%	0%

Percentages are assumed shares of VMT by HDDV’s. DPF = Diesel Particulate Filter. CNG = Compressed Natural Gas. Uncontrolled means high-sulfur diesel fuel. DDD denotes a “dump dirty diesel” strategy described in text directly below. Figures ignore hybrid-electric vehicles (buses), whose small share is subsumed under low-sulfur fuel.

The base case assumptions for 2005 shown in Table 6.6 are similar, except that the CNG share of HDDV VMT rises to 3%, and all NYCT buses not burning CNG (accounting for 10.0% of VMT by heavy-duty diesel vehicles) are assumed to be equipped with diesel particulate filters. Under this base case scenario, 14.5% of all HDDV mileage in the study area is “controlled” (uses low-sulfur fuel or CNG), while the remaining 85.5% continues to use high-sulfur fuel.

We also analyzed two “pro-active” scenarios for 2005, in which the share of VMT by heavy-duty diesel vehicles in the study area that is controlled in some fashion increases from 14.5%, to 25.8%. In the scenario we have dubbed “dump dirty diesel” or “DDD” (the name is borrowed from NRDC’s long-standing campaign with the same objective), the share of HDDV VMT using low-sulfur fuel doubles, from 11.4% to 22.8%; at least as importantly, most of those vehicles are assumed to be equipped with diesel particulate filters. The share using CNG remains 3.1%. The other, “CNG” scenario uses the business-as-usual assumptions about low-sulfur fuel and DPF’s but increases the share of HDDV mileage using CNG to 14.5%.

For 2010, all heavy-duty diesel vehicles except those using CNG are assumed to be fueled by low-sulfur diesel. In addition, U.S. EPA forecasts that 38% of all HDDV mileage will be by trucks and buses using diesel particulate filters. To be conservative, we have applied this figure only to the dump-dirty-diesel scenario, while halving it, to 19%, for the business-as-usual and CNG cases. For the latter, we upped the share of VMT using CNG to 22%, to equalize the two pro-active scenarios (dump dirty diesel and CNG) as to use of CNG or DPF's.

Results

Table 6.7 summarizes the reductions expected in vehicular emissions in the study area in 2005 and 2010 relative to 2000, under three different sets of assumptions as to the types and extent of pollution control measures applied to 18-wheelers, transit buses and other heavy-duty diesel vehicles (HDDVs). The effectiveness of the dump-dirty-diesel or compressed natural gas strategies can be estimated as the net difference between each entry in those columns and the base case entry to the left.

Table 6.7 Impacts of HDDV Fuel & Tailpipe Controls on Total Vehicular Emissions

	'05 Base	**'05 DDD**	**'05 CNG**	**'10 Base**	**'10 DDD**	**'10 CNG**
Volatile Organic Compounds (VOCs)	28.5%	28.9%	28.9%	51.5%	52.4%	52.4%
Carbon Monoxide (CO)	20.9%	21.2%	20.9%	33.2%	33.7%	33.1%
Nitrogen Oxides (NOx)	24.1%	24.1%	25.2%	48.3%	48.3%	49.7%
Particulates (PM-10)	14.4%	17.0%	17.3%	20.8%	24.6%	24.5%
Fine Particulates (PM-2.5)	24.1%	27.6%	28.0%	34.4%	39.4%	39.3%

All percentages are reductions from all study-area vehicles combined from year-2000 levels, in the absence of any pricing measures such as VMT fees or higher fuel taxes. Figures are given to one decimal point to reveal (small) differences between columns, and should not be considered definitive as absolute levels. Carbon dioxide (CO_2) changes are not shown since these are uniform across the three scenarios. Base = Business-As-Usual Scenarios summarized in preceding table. Similar for DDD (Dump Dirty Diesel Strategy) and CNG (Compressed Natural Gas Strategy).

Following are the key findings from the table:

- VOC emissions fall significantly in any event; the dump-dirty-diesel (DDD) and compressed natural gas (CNG) strategies accelerate the reductions only modestly, by one-half to one percentage point;
- CO emissions are barely affected by the DDD and CNG strategies, reflecting the fact that they are overwhelmingly produced by ordinary cars and trucks rather than by heavy-duty diesel vehicles;
- The already significant decline in NOx emissions — around one-quarter in 2005 and one-half in 2010 — can be accelerated slightly, by 1 to 1½ percentage points — through a strategy to convert more transit buses and some 18-wheelers to CNG;
- Both the DDD and CNG strategies can noticeably affect particulate emissions, reducing them by 3-5 percentage points more than would otherwise occur "automatically" through the ongoing improvement in engine and emissions-control technology for cars, gasoline-burning trucks and HDDVs.

Note that the measures to reduce emissions from HDDVs will have their greatest impacts in those parts of Queens with the highest concentrations of heavy-truck traffic.

6.6.3 Pricing Measures vs. Tailpipe/Fuel Measures

The title of this section may be a misnomer, insofar as pricing measures such as weight-distance fees or per-mile insurance can be pursued side-by-side with, rather than as alternatives to, measures to reduce emissions by changing engines or fuels. Nevertheless, in pursuing policy changes it is often necessary to compare the effectiveness of different measures, if only because limits on citizen and official "attention" often turn potentially complementary options into mutually exclusive choices.

It is also helpful to focus on a single pollutant; we have selected PM-2.5, a pollutant that has come to dominate expert and public concern about air pollution, and which is amenable to both sets of measures — pricing and tailpipe/fuel. Table 6.8 shows the estimated reduction in PM-2.5 emissions from vehicular sources in the Northwest Queens study area for 2010, compared to base case estimates for 2000.

Table 6.8 Reductions in Total Vehicular Emissions of PM-2.5, 2010 vs. 2000

	Base	DDD	CNG
2010 Base Case (no pricing measures)	34%	39%	39%
Cents-per-mile insurance	42%	46%	46%
Weight-distance charges	47%	51%	51%
Gasoline tax	41%	46%	46%
Bridge tolls	39%	43%	43%

Base = Base Case scenarios summarized in preceding table. Similar for DDD (Dump Dirty Diesel Strategy) and CNG (Compressed Natural Gas Strategy). Impacts of VMT fees are not shown, since it is assumed that "smarter" weight-distance charges would be implemented instead.

Each entry in the table gives the expected reduction in emissions of fine particulates in the study area in 2010 (vs. 2000) from *combining* a single pricing measure with a single diesel-tailpipe or fuel strategy. For example, the "51%" entry in the center of the table indicates that combining weight-distance charges for all vehicles with a "dump dirty diesel" strategy for heavy-duty diesel vehicles brings about an expected 51% reduction in PM-2.5 emissions.

The effectiveness of the various pricing policies can be calculated by subtracting any entry from the corresponding entry in the first data row; similarly, the effectiveness of the dump-dirty-diesel or compressed natural gas strategies can be calculated by subtracting any entry from the corresponding entry in the first data column.

The table indicates that the most-effective pricing measure, weight-distance charges, adds around a dozen percentage points to the naturally-occurring percentage reduction in PM-2.5 emissions from motor vehicles from 2000 to 2010, while either of the tailpipe/fuel measures adds 4-5 percentage points to the impacts of any of the pricing measures. Considering that the dump-dirty-diesel and CNG strategies have virtually no effect on overall vehicular emissions of the other pollutants (VOCs, CO and NOx, not to mention CO_2), whereas weight-distance charges reduce them by an average of a dozen percentage points, it is clear that the strongest pricing measure has the potential to reduce emissions by considerably more than the tailpipe/fuel measures.

However, this is hardly the end of the discussion. The DDD and CNG strategies are far more attainable politically than any of the pricing measures. Stated differently, it could be argued that enacting any of the pricing measures would require watering them down (i.e., reducing the cents-per-mile or cents-per-gallon charge) to the point where their effect on pollutant emissions would be no greater than that of the tailpipe/fuel measures. On the other hand, insofar as the two types of measures are technically and administratively complementary, there is no inherent reason that they could not be pursued and achieved in tandem.

6.7 Summary of Results

Following are the key findings from our analysis of vehicular emissions, and of the leading potential strategies for reducing them, in the Northwest Queens study area:

- *Ongoing Emission Reductions:* Policies already in place, including ongoing improvements in engine technology, conversion to cleaner diesel fuel, and large-scale adoption of clean engine and fuel measures by New York City Transit and other bus operators, make it a virtual certainty that emissions of pollutants considered harmful to human health from motor vehicles in the study area will decline significantly in 2005 and 2010, relative to current (2000) levels. The anticipated reductions (calculated for all on-road motor vehicles in the study area, in 2010 vs. 2000) range from 21% for total particulates (PM-10) to 52% for volatile organic compounds (VOCs).

- *Greenhouse Gases:* The lone exception to these impressive expected reductions is that vehicular emissions of carbon dioxide (CO_2), the greenhouse gas that results automatically from burning petroleum and all other fossil fuels, are expected to increase by 18% from 2000 to 2010. This anticipated increase is a product of several factors: an expected 13% increase in vehicle miles traveled; the continuing switch of passenger travel from sedans to more-inefficient sport utility vehicles; and the further reduction in fuel efficiency from higher levels of traffic congestion on area roads and highways.

- *Pricing Measures:* The ongoing reductions in health-damaging emissions can be accelerated, and the expected increase in CO_2 emissions reduced and perhaps even reversed, by adopting "pricing" policies designed to encourage motorists to conserve fuel or miles driven or both. One such policy, switching the basis for purchasing car insurance from "per-year" to "per-mile" pricing, has the potential to reduce emissions of most automotive pollutants by 11% to 15%, simply by rearranging (without increasing) auto insurance premiums. Another measure, weight-distance fees, is estimated to have an even greater impact on most pollutants, reducing them by 16% to 21% in 2010 (compared to expected emissions in 2010 absent any pricing measures).[44]

- *Speed-Emissions Connection:* The increase in vehicular traffic expected for the study area will translate into more stop-and-go travel and slower average speeds, both of which tend to raise per-mile and per-vehicle emissions of pollutants. This phenomenon means that pricing measures will reduce emissions in two ways: directly, by reducing the numbers of miles driven and vehicles on the road; and indirectly, by helping to maintain smoother and faster traffic flows and thus keeping per-mile emission rates from rising.
- *Diesel Emissions:* Two "tailpipe" and/or fuel measures are considered here, both applying only to heavy-duty diesel vehicles (HDDV's). One involves increased use by heavy trucks and transit buses of diesel particulate filters (DPF's); the other would accelerate and expand conversion of some of these vehicles to compressed natural gas (CNG) fuel. Both measures would have a modest effect on overall emissions from motor vehicles in the study area, reducing particulate emissions by only 5-8 percent in 2010 (vs. base case levels for that year), and affecting other pollutants little or not at all. Both measures are extremely effective where used, but they appear to be applicable to only a very small fraction of the total car and truck vehicle "fleet" in the study area.
- *Gasoline Taxes:* Neither tailpipe/fuel measure will reduce CO_2 emissions, and, with one exception, the various pricing policies will only slow the increase in vehicular emissions of this greenhouse gas or, at best, offset the increase. The exception is that a $1/gallon boost in gasoline taxes by 2010 would turn an expected 18% *increase* in study-area vehicular emissions of CO2 into an 11% *reduction*.
- *Targeting Heavy Truck Fuels and Tailpipes:* Either or both of the DPF and CNG measures are worth pursuing because of their ease of implementation and high degree of public acceptability (they would be applied to a relatively small number of buses and 18-wheelers) and effectiveness in reducing particulate emissions.
- *Targeting Heavy Trucks through Pricing:* The pricing measures have the advantage of reducing vehicle-miles driven (and, thus, improving traffic flow), but would nevertheless almost certainly encounter widespread opposition as "new taxes." Thus, implementing any of the pricing measures will require an energetic and well-financed campaign. The most attractive among them may be weight-distance fees; not only would they reduce emissions of each pollutant substantially, they would also impinge most heavily on the largest (and least politically popular) vehicles, heavy trucks. Conversely, per-mile insurance for passenger vehicles may also be attractive because it involves restructuring rather than increasing auto insurance premiums and could be packaged as a consumer reform.

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[44] The percentage figures in this paragraph and throughout the executive summary are just that — percent reductions. In some other parts of this report, however, the effectiveness of different measures is discussed in terms of *percentage point* reductions in emissions. The reader is urged to be mindful of the difference.

7. Other Major Sources and Area Sources

7.1 Data Sources and Problems

As discussed in Chapter 4, the U.S. EPA directs states to divide sources of air emissions into four main categories: major sources (also called point sources), area sources, on-road mobile sources and off-road mobile sources. Chapter 5 analyzes emissions from the large electric generators, which fall into the category of major sources. Chapter 6 analyzes emissions from mobile sources. This Chapter presents the existing data on emissions from other major sources and from area sources.

There are two primary sources of emissions data for Queens: the New York DEC and the U.S. EPA. These two agencies both publish data on major sources and area sources. These data, which estimate or quantify emissions from different sectors, are called emission inventories. As discussed in Chapter 4, the existing emissions data for Queens sources other than electric generators raise significant questions. The largest questions around the major and area source inventories arise from the fact that, for most sources, the NY DEC and EPA estimates of emissions differ significantly.

Other uncertainties stem from the fact that current data are not available from DEC for area sources. The NY DEC is currently revising its state emissions inventory. The last inventory, published in 1995, quantifies emissions for the year 1990. The revision in progress will quantify emissions in 1999. At this writing, the 1999 data for major sources were available from the NY DEC, but the 1999 data for area sources were not. In general, a significant amount of review and quality assurance work needs to be performed on the Queens emissions inventories before they can be viewed as credible assessments of emissions within the county.

In this chapter, we describe the major sources and area sources in Queens, and we present the available data on air emissions from these sources. We find that the data available are so unreliable that we are not able to conduct any analyses of how these emissions might change over time, or how these emissions could be reduced through specific policies.

7.2 Emissions from Major Sources in Queens

Criteria Pollutants

The NY DEC's 1999 inventory of criteria pollutants from major sources includes data from 36 sources. Four of these are electric generation facilities, and are addressed in Chapter 5. For the other 31 sources, shown in Table 7.1, the NY DEC provides 1999 emissions of NO_x, SO_2, PM_{10} and VOC. (Emissions of CO_2 from these sources are not available.) These emissions numbers were reported by these sources to the NY DEC.

The U.S. EPA provides data on major source via the AIRData system on the EPA website. With this system, users can search for emissions data by facility, by source sector and by pollutant. EPA provides data on emissions of carbon monoxide (CO) and $PM_{2.5}$ as well as the four pollutants for which the NY DEC provides data. Like the NY DEC, EPA does not provide emissions of CO_2 from these sources. In Table 7.1, we indicate whether EPA's inventory includes data for each source included in the NY DEC inventory.

Table 7.1 Facilities Listed in NY DEC Major Source Emissions Inventory

Source in NY DEC Inventory	Also in EPA Inventory
103-00 Shorefront Parkway Building	No
Astoria Tunnel Headhouse	No
Barker Bros. - Ridgewood	Yes
Big Six Towers Inc	Yes
Creedmoor Psychiatric Ctr.	Yes
Dayton Beach Park # 1 Corporation	Yes
Dayton Towers Corporation	No
Elmhurst Hosp-79-01 Broadway	No
Fink Baking Corp, LLC.	Yes
Grace Asphalt	No
Grand Basket-53-06 Grand Ave	Yes
Hugo Neu Schnitzer East-Queens Yard	No
Interstate Brands Corporation	No
Kew Gardens Hills Association	Yes
Kiac Cogeneration Plant-JFK Airport	Yes
Long Island Jewish Medical Center	Yes
Mary Immaculate Hospital	Yes
Mt. Hope Asphalt	Yes
N. Shore Towers Apt.	Yes
New York Hospital Medical Ctr.	Yes
NY DEC Tallman Island WPCP	No
Parker Towers - Parman Corp	No
Poly Plastic Packaging	No
Queens Fresh Meadows Facility	Yes
Rochdale Village	Yes
Sirmos Div. Of Bromante	No
St. Johns University	Yes
Std. Folding Carton Inc.	No
Steinway & Sons	Yes
Trans World Airlines	No
Con Ed-Vernon Ctr.	No

For 1999, the most recent year for which data are available, the NY DEC reports that these facilities together emitted approximately 4,320 tons of NO_x, 1,280 tons of SO_2, 420 tons of VOCs and 390 tons of PM_{10}.

As shown in Table 7.1, many facilities appear on both the NY DEC and EPA inventories. However, the NY DEC and EPA emissions numbers for almost all of these facilities differ by considerable amounts. For many facilities, the numbers differ by a factor of two or three. Because of these differences, we do not present either inventory in full. More work is needed to review these two data sets before an estimate of total emissions from major sources in Queens can be made with confidence.

These two data sets may, however, provide a sense of which major sources in Queens are likely to be the biggest emitters of various pollutants. In Tables 7.2 through 7.4 we show the facilities that appear to be the largest emitters of each pollutant along with the facility's emissions from the NY DEC inventory and the EPA inventory. There is considerable overlap on these three tables, indicating that, despite the questionable data, these facilities are probably among the largest major sources of emissions in Queens.

Table 7.2 Major Source NO_X Emissions in Queens: NY DEC and EPA

Major Source	DEC NOx (tons)	EPA NOx (tons)
Con Ed-Vernon Ctr.	3,022	6,984
Con Ed-Rainey Substation	522	ND
N Shore Towers Apt.	246	244
Rochdale Village	133	30
Big Six Towers Inc	94	72
Kiac Cogeneration Plant-JFK Airport	78	292
Fink Baking Corp., LLC.	61	142

"ND" indicates that no data were provided.

Table 7.3 Major Source SO_2 Emissions in Queens: NY DEC and EPA

Major Source	DEC SO_2 (tons)	EPA SO_2 (tons)
Con Ed-Vernon Ctr.	1,012	1,968
Queens Fresh Meadows Facility	61	63
Creedmoor Psychiatric Ctr.	40	22
Dayton Beach Park # 1 Corp.	19	16
Big Six Towers, Inc.	13	11
N. Shore Towers Apt.	11	14
St. Johns University	10	30

Table 7.4 Major Source PM_{10} Emissions in Queens: NY DEC and EPA

Major Source	DEC PM_{10} (tons)	EPA PM_{10} (tons)
Con Ed-Vernon Ctr.	250	ND
Con Ed-Rainey Substation	44	ND
Kiac Cogeneration Plant-JFK Airport	16	ND
Rochdale Village	5	ND
Fink Baking Corp., LLC.	5	ND
Long Island Jewish Medical Ctr.	3	15
Kew Gardens Hills Association	2	13

"ND" indicates that no data were provided.

It is important to note that the DEC made an error in compiling the data for the Con Ed Vernon Center and the Con Ed Rainey Substation. When breaking up the Con Ed permits when KeySpan purchased Ravenswood, the 1999 emissions of Ravenswood Units 10-30 were incorrectly assigned to the Vernon Center permit, and the 1999 emissions from the Ravenswood GTs were incorrectly assigned to the Rainey Substation. This error was carried over into the DEC databases used in preparing the tables above. As a result, the emissions for these two sources in Tables 7.2 through 7.4 are dramatically overstated.

Toxic Air Pollutants

The most recent NY DEC inventory of toxic emissions includes data for the year 1999. This inventory does not list emissions by specific source for major sources. Rather, emissions are listed by source category (i.e., major source, area source, mobile source, etc.).[45] The NY DEC inventory quantifies emissions from major sources for seven toxic pollutants, as shown in Table 7.5. Presumably, this means that this sector's emissions of other toxic air pollutants are much less significant.

The most recent EPA data on toxic emissions are for the year 1996. In contrast to the NY DEC, EPA does list emissions by source for major sources. Further, EPA includes emissions from major sources of far more than seven chemicals. Finally, as with criteria pollutants, the numbers in these two databases for a given chemical are dramatically different.

To provide a sense of the differences in these databases, in Table 7.5 we show the NY DEC and EPA figures for the seven chemicals included in the NY DEC inventory.[46] (Again, the EPA inventory includes data on additional chemicals.) Note that the numbers for three of the chemicals differ by an order of magnitude. Because of these differences, we do not make assessments or predictions of toxic air emissions from major sources in Queens. Because the NY DEC inventory does not include data by source, we do not speculate on which facilities might be the largest emitters.

Table 7.5 Major Source Toxic Emissions in Queens: NY DEC and EPA

Toxic Air Pollutant	DEC Data (pounds/year)	EPA Data (pounds/year)
Toluene	33,991	514,544
Xylenes ISO	12,237	249,537
Formaldehyde	1,390	29,701
Perchloroethylene*	28,065	69,020
Ethylbenzene	3,180	4,518
Acrolein	3,445	ND
Ethylene Oxide*	244	5

"ND" indicates that no data were provided.

7.3 Emissions from Area Sources in Queens

Criteria Pollutants

As with the major source inventories, the NY DEC and EPA area source inventories for Queens raise significant questions. First, the area source inventory of criteria pollutants currently available from the NY DEC provides estimates of 1990 emissions.[47] The

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[45] Note that the DEC inventory uses the term "Point Sources" rather than "Major Sources."

[46] The DEC data did not include information on the eight HAPs that we focus on in this study, with the excpetion of formaldehyde, so we are unable to compare the two data bases for those HAPs.

[47] DEC is currently updating this inventory, but new data were not available for this report.

composition of area sources and quantities of pollution from a given source may have changed significantly since 1990. Second, the NY DEC only provided to us inventories of ozone precursors – NO_x, CO and VOCs. And third, there are significant differences between the numbers in these two inventories. Therefore, we do not present either inventory as more credible than the other.

An equally important point about these inventories is that they were developed using different methodologies. The EPA began with data on total state fuel use and activity levels, and then allocated fuel use or activity to counties and then applied emission factors to the fuel use or activity. In contrast, the NY DEC estimated area source emissions starting with fuel use or activity by county and then applied emission factors. The use of two different methodologies is not a problem – in fact it can be useful. Where the numbers from the two inventories are relatively close, this might increase our confidence in the estimates. Where numbers in the two inventories are far apart, we might consider which methodology is likely to lead to the most credible estimate for that source category. However, the fact that these estimates are for emissions in periods separated by nine years – and the fact that there are considerable differences in the estimates – makes comparison of the two inventories difficult.

The 1990 NY DEC area source inventory is shown in Table 7.6 below and the EPA 1999 inventory is shown in Table 7.7. A quick review of these tables demonstrates the many differences that exist between these data bases.

Regarding nomenclature, EPA includes a category called “Incineration,” while NY DEC includes a category called “Apartment Incineration.” In these tables, we have used EPA’s title, however, there is some question as to whether these categories refer to the same thing. Municipal incineration has been banned in all of New York City since June, 1993. While the NY DEC numbers may reflect the situation in 1990,. the EPA number may not reflect this law. That is, EPA may inaccurately allocate a portion of statewide incineration — much of which is municipal — to Queens.

Table 7.6 Area Source Criteria Pollutants in Queens: NY DEC 1990

Source Category	NO_x	SO_2	CO	VOC	PM_{10}
Incineration	113	ND	113	5.7	ND
Waste Management	ND	ND	ND	4	ND
Wastewater Treatment	ND	ND	ND	ND	ND
Residential Combustion	3,414	ND	11,408	2,274	ND
Comm/Institut. Combustion	758	ND	233	61	ND
Industrial Combustion	1,712	ND	614	38	ND
Other Combustion	ND	ND	ND	ND	ND
Structural Fires	21	ND	891	163	ND
Petroleum Products*	ND	ND	ND	1,394	ND
Solvent Evaporation	ND	ND	ND	15,690	ND
Other	ND	ND	ND	242	ND
Total	6,018	ND	13,259	19,871	ND

**In the NY DEC inventory, this category is called “Transportation Fuels Evaporative Losses.” In this table, we use “Petroleum Products” for consistent comparison with the EPA inventory. “ND” indicates that no data were provided.*

Table 7.7 Area Source Criteria Pollutants in Queens: EPA 1999

Source Category	NO_x	SO_2	CO	VOC	PM_{10}
Incineration	98	143	98	ND	1,311
Waste Management	ND	ND	2,512	ND	254
Wastewater Treatment	ND	ND	ND	ND	ND
Residential Combustion	8,456	2,641	1,771	452	196
Comm/Institut. Combustion	68	269	13	456	245
Industrial Combustion	1,361	6,529	525	35	161
Other Combustion	1	<1	5	2	11
Structural Fires	ND	ND	ND	ND	ND
Petroleum Products	ND	ND	ND	1,284	ND
Solvent Evaporation	ND	ND	ND	21,230	ND
Other	ND	1	ND	309	ND
Total	9,984	9,583	4,924	23,768	2,178

"ND" indicates that no data were provided.

The numbers themselves raise more questions, most of which are beyond the scope of this report. Nonetheless, several general conclusions can be drawn from the two data sets:

- Fuel combustion (residential, commercial and industrial) is probably the largest area source of NO_x, SO_2 and CO emissions
- Solvent evaporation is probably the largest area source of VOC emissions.
- Incineration appears to be the largest area source of PM_{10} emissions, but this conclusion would need to be confirmed by additional research on waste incineration in Queens. We believe it is more likely that fuel combustion is the largest area source of $PM_{2.5}$ emissions.
- Residential combustion is probably the largest area source of NO_x.
- Industrial combustion may be the largest area source of SO_2. However, EPA's inventory methodology is likely to misstate SO_2 emissions in Queens considerably.[48]
- Waste management and residential fuel combustion appear to be the largest area sources of CO, although this conclusion is not certain given the lack of NY DEC data on CO and the difference between the NY DEC and EPA estimates of CO from residential combustion.

Toxic Air Pollutants

As discussed in Section 7.2, the data in the 1999 NY DEC inventory of toxic air pollutants in Queens are considerably different from the data in EPA's most recent inventory. As an example of these differences, in Table 7.8 we show the data from both sources for the eight toxic pollutants that pose the greatest health risk in Queens. The

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[48] For example, it is possible that there is very little industrial coal combustion in Queens and that EPA has allocated a portion of statewide industrial coal combustion to the county.

data from these two sources are so different that we do not have confidence in using either one of them for this study.[49] Clearly, more work needs to be done to compile better data and to better characterize toxic emissions from area sources in Queens.

Table 7.8 Area Source Toxic Emissions s in Queens: NY DEC and EPA

Toxic Air Pollutant	DEC Data	EPA Data
Diesel Particulate Matter	ND	ND
Polycyclic Organic Matter	ND	218,478
Chromium Compounds	0 or ND	3,748
Formaldehyde	10,052	92,252
1,3-Butadine	489,196	180
Carbon Tetrachloride	0 or ND	1,249
Benzene	95,579	36,556
Acetaldehyde	0 or ND	8,590

“ND” indicates that no data were provided.

7.4 Conclusion

Ideally, it would be useful to analyze the opportunities for reducing emissions from “major sources” and “area sources,” as well as power plants and mobile sources. Including major and area sources would provide a complete picture of the contributors to air emissions in Queens County. However, after assessing the availability and quality of the data for these sources, we have concluded that such assessments are not possible within the scope of this study.

Nonetheless, major sources and area sources clearly contribute significant portions to some of the key pollution emissions in Queens – especially NO_X, particulate matter, CO_2 and VOCs. There may also be some significant emissions of hazardous air pollutants that are concentrated in a few major sources. These sources, and opportunities for reducing their emissions, should be given considerable attention in future efforts to study air quality in Queens and other urban areas.

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[49] It is possible that part of the difference arises from different ways of categorizing area sources. However, this does not make it any easier to use either data base.

8. Measuring the Potential Improvements to the Air Quality in Queens

In Chapter 2 on health threats due to air pollution and Chapter 3 on air quality in Queens we showed that the major air pollution-related health threats in Queens are associated with fine particulate matter and ozone. In Chapter 4 we identified power plants and motor vehicles as two major sources of fine particulate matter and ozone precursors that might be subject to reduction measures. In this chapter we prepare rough estimates of the air pollution benefits that might be expected from the emission reduction measures proposed in Chapters 5 and 6.

8.1 The Intake Fraction

An evaluation of risks from air pollution requires an atmospheric dispersion model, i.e., a computer program that calculates pollutant concentrations using mathematical equations that describe dispersion under a variety of atmospheric conditions. Results of the dispersion analysis can then be linked with epidemiological or toxicological evidence to estimate health impacts. Using dispersion models researchers have developed rules of thumb for the amount of exposure people have from different pollutants from typical sources. They have done so by defining a concept known as an *intake fraction* (Bennett et al. 2002; Evans et al. 2002).

Intake fraction is simply defined as the fraction of material emitted from a source that is eventually inhaled or ingested by someone, somewhere. It is therefore a unitless measure within which detailed information about pollutant fate and transport and population patterns are summarized. An intake fraction is not an inherent property of a pollutant, but rather varies as a function of pollutant release height, meteorology, climate, population patterns, and a number of other factors. Thus, deriving the intake fraction associated with a specific source can be somewhat challenging, but provides quite plausible bounding estimates for the exposure per unit emissions from similar sources.

As an example, researchers at Harvard School of Public Health have calculated intake fractions for primary particulate matter and for secondary sulfate and nitrate particles, which are presented in Table 8.1. These calculations are based on Abt Associates' source-receptor matrix often used in regulatory impact assessments (US EPA, 1997; US EPA, 1999). The intake fractions were calculated for all power plants in the U.S. for which data were available, using a SAS program created for a recent analysis (Levy et al. 2002).

Table 8.1 Intake Fractions for Emissions From Power Plants

	Primary $PM_{2.5}$	Sulfate/SO_2	Nitrate/SO_2	Nitrate/NOx
Mean	1×10^{-6}	3×10^{-7}	-5×10^{-8}	5×10^{-8}
Minimum	4×10^{-7}	7×10^{-8}	-2×10^{-7}	4×10^{-9}
Maximum	9×10^{-6}	7×10^{-7}	-4×10^{-9}	2×10^{-7}
Standard deviation	8×10^{-7}	1×10^{-7}	3×10^{-8}	3×10^{-8}

A few points will help to interpret these intake fractions:

- If we look at the mean value for primary PM (1×10^{-6}), it implies that of every million particles emitted by a power plant in the U.S., one is eventually inhaled by someone in the U.S. The magnitude of this value is in close agreement with past findings. For example, Wolff (2000) estimated an average value for 40 randomly selected power plants across the U.S. of 2×10^{-6}.
- The secondary pollutants require more complex definitions. "Sulfate/SO_2" refers to the number of sulfate particles inhaled per unit of SO_2 emissions. On average, this number is about a factor of 3 lower than the primary PM estimate. "Nitrate/SO_2" reflects the fact that decreases in SO_2 emissions can free up ammonium to react with gaseous nitrate and form particulate ammonium nitrate. This is the so-called "nitrate bounce-back" phenomenon. The magnitude of this figure shows that the bounce-back is, on average, about 13% of the initial benefit.
- For secondary pollutants, there is a greater deal of climate-related dependence, so the relative magnitudes of these numbers can vary somewhat. In spite of this, there is more variation (as measured by the standard deviation) in the primary PM estimate than the secondary PM estimates, largely because primary PM intake fractions are more closely tied to local population patterns.

We would also like to have similar values for mobile sources or other pollution sources. However, the available information is somewhat more limited. Wolff (2000) modeled highway stretches in urban and rural settings using the same approach as for power plants. He found essentially identical values for secondary pollutants for power plants and mobile sources, but values about four or five times higher for primary PM from mobile sources.

8.2 The Intake Fraction for Queens Sources

As a first step in evaluating the air pollution impacts, we calculated the intake fraction for primary PM emission from typical power plants and mobile sources in Queens. In this exercise we use a different dispersion model than the one used to obtain the results described above. The model we use, EPA's Industrial Source Complex model, gives a more exact estimate of the intake fraction near the source, since the source-receptor matrix only provides county-level resolution. As a typical power plant, we took the proposed New York Power Authority combined cycle plant, which will be located in Astoria. To model mobile sources, we assumed a street segment approximately one-block long, located in the same area.

The results show that the intake fraction within a 31-mile radius is 8.4 $\times 10^{-6}$ for primary emissions from a stationary source located in Queens and 3.2 x 10^{-5} for primary emissions from mobile sources in Queens. These values are near the high end of the estimates for sources in various areas, probably because of the very high population density within 31 miles of Astoria. Notice that the ratio of mobile source to stationary source intake fraction is again four, confirming the four to one ratio for benefits from reduction of primary mobile source emission vs. primary power plant emissions.

8.3 The Relative Importance of Local Sources

The analysis of Chapter 2 concluded that the two air pollutants affecting Queens of most health concern are ozone and $PM_{2.5}$. Because both of these pollutants involve atmospheric chemical transformation and long-range transport from distant sources, it is difficult to accurately assess the impact of our proposals on air quality in Queens.

To calculate pollutant impacts, mathematical models of atmospheric dispersion are generally used. Dispersion models that include chemical transformation and long-range transport are much more complicated and are beyond the scope of this report. Thus in this report we do not model ozone concentrations, since ozone is entirely a secondary pollutant with distant sources. While the largest proportion of $PM_{2.5}$ contributing to concentrations in Queens comes from chemical transformation of precursor emissions tens or even hundreds miles away, some proportion is primary particulate matter, emitted by motor vehicles, power plants, building boilers, and other local sources.

To get an idea of the relative proportions contributed by long-range transport as opposed to local sources, we can examine measurements of the chemical compounds that make up $PM_{2.5}$. NY DEC measures the chemical components of $PM_{2.5}$ at several locations around the state. One site is located at Queens College and two others are located at the Bronx Botanical Garden and at IS 52 in the South Bronx. In addition, NY DEC has two monitors in remote locations, one at Pinnacle State Park in a rural area near the Pennsylvania border southwest of Corning, New York and one at Whiteface mountain in the Adirondacks. NY DEC describes the Pinnacle State Park site as having few local sources of pollution; the same is true of the site at Whiteface Mountain (NY DEC 2002).

A comparison of NY DEC's data for a one-year period are shown in the following table. For each monitoring station, Table 8.2 presents the annual average $PM_{2.5}$ concentrations at four NY DEC monitoring stations, as well as the three categories of chemical components that contribute to the annual average: total carbon, ammonia sulfates and nitrate, and metals.

From this data we can see the major contribution that long-range transport makes to $PM_{2.5}$ concentrations. Sulfates and nitrates, almost entirely due to long-range transport, are a large fraction of the $PM_{2.5}$ concentration at all sites. The fact that sulfate and nitrate concentrations at Queens College and the Bronx Botanical Garden are higher than at Pinnacle State Park and Whiteface Mountain can be attributed to the mix of sources that affect New York City, including coal-burning power plants in the Tennessee Valley, and the Hudson Valley, rather than to sources local to New York City.

Table 8.2 NY DEC Speciation Data for $PM_{2.5}$ (µg/m³)

Monitoring Station	$PM_{2.5}$ Annual Average	Total Carbon	Ammonia Sulfates and Nitrate	Metals
Queens College	13.8	4.3	8.9	0.6
Botanical Garden	15.6	6.2	8.7	0.7
Pinnacle State Park	8.9	2.5	6.2	0.3
Whiteface Mountain	5.9	2.0	3.8	0.2

Data is for April 1, 2001, to March 30, 2002, except data from Whiteface Mountain, which is for May 25, 2001, to May 5, 2002.

Concentrations of elemental and organic carbon and metals are also higher in New York City than at Pinnacle State Park and Whiteface Mountain, contributing about 5 to 7 µg/m³ to the totals. For these portions of total $PM_{2.5}$ mass, however, local sources are much more important because both carbon and metals are directly emitted. Nevertheless if we assume that concentrations of carbon compounds and metals at Pinnacle State Park represent the long-range transport portion of concentrations in New York City, only the difference, about 2 to 4 µg/m³ (at Queens College or the Bronx Botanical Garden), can be due to primary emissions from local sources.

Of course $PM_{2.5}$ concentrations at some monitors in New York City are higher than the one at Queens College. As shown in Table 3.2, annual $PM_{2.5}$ concentrations at Maspeth Library and PS 199 in western Queens reach 15 to 16 µg/m³, roughly the same concentration that NY DEC measured at the Bronx Botanical Garden. (In Manhattan annual average $PM_{2.5}$ concentrations are about 17 or 18 µg/m³.) The higher concentration in western Queens is due in part to a higher concentration of sources in that area, including both mobile sources and power plants, but also is an example of a typical pattern in which air pollutant concentrations in New York City tend to peak near the East River as a result of the concentration of sources in Manhattan, the densest part of the city.

8.4 Primary $PM_{2.5}$ Impacts of Selected Clean Air Policies

Primary $PM_{2.5}$ emissions from power plants in Queens amount to about 700 tons per year, while primary $PM_{2.5}$ emissions from motor vehicles amount to about 500 tons per year. However, the impact of mobile source emissions is much greater than power plant emissions because they are released at street level rather than through a relatively tall stack. Fuel combustion for space heating probably also contributes a significant amount to the primary $PM_{2.5}$ emissions in Queens. Unfortunately, it is not clear how much $PM_{2.5}$ is emitted by this area source, as explained in Chapter 7.

To assess the air pollution impacts of our proposals to reduce emissions from these two sources, we calculate expected pollutant concentrations in Queens using a standard EPA dispersion model. Given the uncertainties involved in our projection of emissions and the absence of an estimate of the contribution of secondary pollution effects, these calculations can only provide a rough guide.

Electricity Sector

Our calculations show that the maximum annual $PM_{2.5}$ concentration from primary power plants emissions in Queens is now about 0.7 µg/m³ with the average concentration about 0.1 µg/m³.

Under our Business-As-Usual scenario, additional demand for electricity over the next ten years would result in an increase of $PM_{2.5}$ emissions to about 745 tons per year. This corresponds to an increase in the maximum annual $PM_{2.5}$ concentration of about 0.04 µg/m³. Under our Clean Air Plan assumptions, emissions will decrease to about 656 tons per year despite a substantial increase in electricity generated, and the maximum annual $PM_{2.5}$ concentration in Queens would decrease by about 0.09 µg/m³. Table 8.3 presents a summary of the $PM_{2.5}$ impacts of the two scenarios modeled in this study, as well as a summary of the Efficiency Option (which includes all the energy efficiency measures but none of the photovoltaics or supply-side measures), which has similar impacts.

Table 8.3 Summary of $PM_{2.5}$ Impacts From the Electricity Sector

	Current 2002	Business-As-Usual 2010	Clean Air Plan 2010	Efficiency Option 2010
Annual PM2.5 Emissions (ton)	702	745	656	644
Maximum Concentrations (µg/m³)	0.68	0.72	0.63	0.62
Average Concentrations (µg/m³)	0.09	0.09	0.08	0.08

While the average $PM_{2.5}$ concentration is an indication of the health impact of power plants in Queens generally, the maximum $PM_{2.5}$ concentration due to power plants indicates that the impact on Astoria and surrounding neighborhoods is higher, as reflected in the higher total $PM_{2.5}$ background concentrations in western Queens. Our policy recommendations for the electricity sector offer a slight improvement in $PM_{2.5}$ concentrations in Queens while allowing for a substantial increase in electricity generated. In particular, the Clean Air Plan and Efficiency Option at least ensure that $PM_{2.5}$ concentrations do not worsen in the future, as would occur under the Business-As-Usual scenario.

Transportation Sector

As mentioned above, changes in mobile source emissions are expected to have a larger effect. Currently the 500 tons of $PM_{2.5}$ per year directly emitted from mobile sources in Queens, together with emissions of similar magnitude in the Bronx, Brooklyn, and Manhattan, causes, according to our calculations, an *average* (not maximum) annual $PM_{2.5}$ concentration increment in Queens of about 0.9 µg/m³ at community monitors.[50] To that we must add a certain amount to account for re-suspension of road dust, although there is a great deal of uncertainty about the magnitude. Measurements on Madison

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[50] We included the impact of emissions from other boroughs in mobile source calculations because the policies we propose for this sector would be applied city-wide. Emissions from other boroughs on average add about 20% to concentrations from Queens sources alone.

Avenue in 1993 showed that road dust could add perhaps 4.5 µg/m³ to PM_{10} concentrations, or about 1.1 µg/m³ to concentrations of $PM_{2.5}$,[51] although the concentration at community monitors would undoubtedly be less.

As discussed in Chapter 6, we expect regulations adopted by EPA to cut $PM_{2.5}$ motor vehicle emissions by at least one-third over the next ten years. This would lead to a decrease in $PM_{2.5}$ concentrations in Queens of 0.3 to 0.4 µg/m³ at community monitors. (There may also be some reduction in road dust.)

In this context the effect of the additional traffic-related measures we discuss in Chapter 6 may seem small. For example, even the policy that would have the largest impact would mean an additional reduction of only 0.1 to 0.2 µg/m³ in $PM_{2.5}$ concentrations. This is shown in Table 8.4, where the column labeled "Clean Air Plan" represent the combination of weight-distance charges with either the Dump Dirty Diesel or CNG options.

Table 8.4 Summary of $PM_{2.5}$ Impacts From the Mobile Source Sector

	Current 2002	Business-As-Usual 2010	Clean Air Plan 2010
Annual PM2.5 Emissions (tons)	500	275	210
Average Concentrations (µg/m³)	0.86	0.48	0.36

However, the concentrations we have been comparing are those at community monitors, which are located away from the street on the roofs of buildings. While impacts on $PM_{2.5}$ concentrations at community monitors may be small, impacts could be much larger in areas with higher concentrations of heavy-truck traffic, including areas near the major highways.

As an example, we return to NY DEC's 1993 measurements on Madison Avenue. There the portion of $PM_{2.5}$ concentrations due to diesel buses was found to be over 20 µg/m³.[52] Of course diesel emissions are lower now than they were in 1993 (60% lower based on EPA's Mobile 6 emission factors for heavy-duty diesel trucks), and will be still lower in 2010 (85% lower based on Mobile 6 emission factors). If we apply the percent reduction in heavy-duty diesel emissions by 2010 to the diesel $PM_{2.5}$ concentration measured on Madison Avenue in 1993, the $PM_{2.5}$ concentration in 2010 due to buses would still be about 3 µg/m³.

In fact, however, assuming New York City Transit Authority completes its ambitious emission-reduction program described in Chapter 4, diesel $PM_{2.5}$ concentrations on Madison Avenue due to bus emissions will be much lower by 2010, probably in the

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[51] NY DEC1995, p. 11, assuming that half of the iron concentration was from road dust and that 25% of PM_{10} road dust is $PM_{2.5}$ (see Appendix A-3). See also EPA, "Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources. Fifth Edition," AP-42, Sect. 13.2.1.

[52] NY DEC 1995, p. 11, applying the diesel fraction (52.8%) to the 1993 annual average PM_{10} concentration of 47 µg/m³ (Table 2.3) and assuming that 90% of diesel PM_{10} emissions are $PM_{2.5}$.

neighborhood of 1 µg/m³.[53] While modeling the impact of our transportation proposals on specific highway segments is beyond the scope of this report, this calculation gives a sense of the maximum impact that might be achieved, for example, by extending a particulate-trap retrofit program to other heavy-duty diesel vehicles.

Summary and Conclusion

To summarize, the combination of the policies that we recommend for both the electricity and the mobile source sectors would mean a reduction in 2010 $PM_{2.5}$ concentrations of approximately 0.21 µg/m³, relative to Base Case concentrations in 2010. For comparison, recall that some air quality monitors in Queens now have readings as high as 16 µg/m³, and that the federal standard is set at 15 µg/m³. Thus, the $PM_{2.5}$ emission reductions we identify for sources in Queens will have a moderate impact on $PM_{2.5}$ concentrations in Queens.

The air quality improvements might be greater at specific locations most affected by heavy traffic, including areas near major highways. However these improvements alone would be unlikely to reduce the current background $PM_{2.5}$ concentration (16 µg/m³) to below the federal standard (15 µg/m³).

Another way to think of the air quality benefits is relative to the current concentrations. The combination of the policies that we recommend in both the electricity and the mobile source sectors would mean a reduction in 2010 $PM_{2.5}$ concentrations in Queens of approximately 0.55 µg/m³.

While this reduction may appear to be a relatively modest improvement in air quality, it may be significant enough to assist Queens in achieving compliance with the federal standard. Furthermore, the health literature for $PM_{2.5}$ implies that even the relatively small reductions estimated here would provide significant reduced mortality and morbidity effects in Queens. As described in Chapter 3, a reduction of 1.5 µg/m³ is estimated to avoid roughly 100 premature deaths per year and avoid numerous other health impacts. Similarly, a reduction of 0.55 µg/m³ can be expected to avoid roughly 37 premature deaths per year within Queens, as well as additional premature deaths in populations outside of Queens.

These conclusions on local air quality impacts also suggest that we should take a broad view of pollution control in order to aggressively reduce ambient concentrations in Queens. Controlling sources in Queens will have benefits far greater than the benefits for the population of Queens, and controlling sources well outside of Queens will substantially improve the air quality in Queens.

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[53] This is based on the use of diesel particulate filters to reduce tailpipe PM emissions to 0.04 g/mi., as described in Thomas Lanni, *et. al*., 2001. Added to the EPA Mobile 6 emission factor of 0.012 g/mi for tire and brake wear, the overall bus emission factor would be 0.052 g/mi, about one-third the 2010 Mobile 6 emission factor for heavy-duty diesel trucks.

9. Policies to Address the Key Air Emissions

In Chapter 3 we identify small particulate matter as the creating the greatest health threat from air quality in Queens, and ozone as the next greatest threat. Air toxics are also an important risk factor in Queens, with diesel particulates the leading cause of concern. Carbon dioxide and other greenhouse gases pose long-term health risks at both a local and global level.

In Chapter 4 we identify the major sources of pollutants that contribute to the air quality conditions in Queens. In sum, we find that:

- With regard to small particulate matter in Queens, the greatest contributions come from power plants outside of Queens, followed by mobile sources both outside of Queens and inside of Queens.
- With regard to ozone levels in Queens, the greatest contributions come from power plants and mobile sources outside of Queens, followed by mobile sources within Queens.
- The majority of air toxics in Queens are produced by mobile sources, especially the diesel particulate matter.
- With regard to CO_2 emissions in Queens, more than one third comes from mobile sources, slightly less than one third come from power plants, and the remainder come from area sources.

Our findings suggest that the greatest improvements to air quality in Queens will result from policies targeted to (a) power plants in regions upwind of Queens, and (b) mobile sources inside Queens and New York City. Since many of the health threats in Queens are due to pollution sources outside of Queens, policies must support efforts to control sources in other upwind state, such as the several multi-pollutant bills being discussed on the federal level. Policies must also address sources in New York City, as well as in New York State.

At the same time, it is important to address pollution emissions within Queens as well. Many of these emissions do impact the air quality in Queens, and they have a significant impact on the air quality in downwind regions. Queens can act as a model for both upwind and downwind cities, counties, and states – to demonstrate that everyone has a responsibility to address their own air emissions in order to improve air quality for all in the greater Northeast region.

There are many policies that can be used to address the air quality problems in Queens County and the neighboring regions. Here we list those policies that should receive top priority from local and state policy-makers.

Policies to Improve the Efficiency With Which Energy Is Consumed

1) New York State should establish appliance efficiency standards, above and beyond those established by the federal government, as proposed in the recent study from the Northeast Energy Efficiency Partnership (NEEP 2002).

2) New York State should seek a waiver from the central air conditioning standard (SEER 12) recently determined by the US DOE. The New York standard should instead be set at a SEER 13.

3) The existing system benefits charge, used to collect revenue from all New York State electricity customers for energy efficiency programs, should be at least doubled.

4) All federal, state, city and local government agencies should conduct biennial studies to identify efficiency measures that can be implemented at their buildings and facilities. These agencies should be required to implement all cost-effective efficiency measures identified, in order to both save taxpayer dollars spent on long-term energy costs and to reduce the environmental impacts of energy use.

5) The New York Public Service Commission should require electric distribution utilities to "decouple" their revenues from their sales, in order to provide them with the proper financial incentives to promote energy efficiency and distributed generation resources.

6) Architects and builders should be encouraged to adopt green building practices, and to have their building certified using the Leadership in Energy and Environmental Design (LEED) standards established by the US Green Buildings Council.

Policies to Promote the Construction of New, Clean, Efficient Power Plants

7) The New York Public Service Commission should give the distribution utilities a clear mandate to purchase long-term power supplies through a "portfolio management" approach. Under this policy, utilities would sign long-term contracts to support the construction of efficient power plants, but they would also factor in energy efficiency opportunities when determining the appropriate amount of power to contract for.

8) New York State should establish a renewable portfolio standard, which requires all retail electric suppliers to maintain a certain percentage of new, clean renewable resources in their portfolio of generation sources. The RPS should include a target of 10% renewable generation within ten years, and 20% within 20 years. A specific portion of the RPS should be set aside to promote the development of photovoltaics, in order to encourage the development of renewable resources in urban areas such as Queens.

9) The existing net metering law that currently includes residential solar applications should be expanded to commercial and industrial solar applications, wind turbines, and clean biomass technologies.

10) The New York Public Service Commission should adopt several policies to promote the installation of clean, distributed generation (DG) technologies, including:
    - policies that require distribution companies to adopt uniform safety and quality standards for DG technologies;
    - policies that require distribution companies to utilize simple standardized procedures for reviewing and approving applications by customers to connect their DG technologies to the electricity grid;
    - policies that ensure that utilities do not impose needless and burdensome charges on owners of DG technologies.

11) The New York Department of Environmental Conservation should adopt regulations to ensure that all forms of distributed generation technologies meet stringent air emission standards.

12) New York State should offer incentives to existing generators to encourage repowering of older, less efficient units.

Policies to Directly Limit Pollution Emissions

13) The New York Legislature should establish a CO_2 standard for vehicles similar to that recently adopted in California. That measure requires automobile makers to achieve the “maximum feasible reduction” in greenhouse gasses for cars and light-duty trucks in model year 2009 and beyond.

14) New York State should promote the adoption of a national, regional or state cap on CO_2 emissions from power plants, and allow power plant owners to trade CO_2 emission allowances within the total cap.

15) The New York Department of Environmental Conservation should establish New York-specific ambient air quality standards for $PM_{2.5}$.

16) New York State should support efforts to establish multi-pollutant regulations to reduce transport of pollutants from upwind sources.

Policies to Promote Environmental Justice

17) Environmental justice issues should be addressed in a comprehensive and equitable fashion through the NY DEC guidance document on environmental justice and permitting (CP-29). Furthermore, when the Article X power plant siting law is reauthorized, it should include all appropriate procedures to address environmental justice issues.

18) When new power plants and other major sources of emissions are proposed to be sited within Queens, the siting and review process should (a) allow for early public input; (b) ensure that there are no disproportionate impacts on low-income populations and people of color; and (c) ensure that the project does not overburden any one community, relative to the benefits provided to that community.

Policies to Address the Transportation Sector

19) New York State should adopt a "cents-per-mile" insurance policy, whereby car-insurance providers would sell their service by the mile rather than by the year.

20) New York State should implement vehicle miles traveled fees, which charge all motor vehicles a fixed amount per mile driven. The best candidate, in terms of efficacy and equity, is weight-distance fees that charge per *ton-mile*, so that two vehicles driven the same amount pay in proportion to their respective weights, and two vehicles of equal size pay in proportion to their usage.

21) New York State should increase gasoline taxes to induce motorists to purchase and use more-efficient vehicles. Most of the revenues should be rebated to the state's citizens on an equal per-capita basis, to promote equity, although a portion could be reserved to finance other measures to reduce vehicular emissions.

22) New York State should require Heavy-Duty Diesel Vehicles to reduce emissions through use of ultra-low-sulfur fuels and compressed natural gas.

23) New York State should require all heavy-duty construction vehicles to use ultra low-sulfur diesel fuel, and to be fitted with either diesel oxidation catalysts or particulate filters.

24) New York State car dealers should be provided with information and financial incentives to promote the sale of efficient vehicles.

25) New York City should implement tolls at the Queensboro Bridge and the other "free" East River crossings, using high-speed collection systems to obviate the need for toll plazas.

26) New York City should implement policies to reduce truck idling, including establishment of facilities at truck stops to provide air conditioning and electricity for trucks to use instead of their own engines.

27) The Metropolitan Transportation Authority and New York City Transportation Department should accelerate plans to convert diesel bus fleets to cleaner fuels such as compressed natural gas (CNG).

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Appendix A: Studies Demonstrating the Health Effects of Air Pollutants

In this appendix, we provide more detail about the health effects of ozone and particulate matter (discussed briefly in Section 2.3).

Ozone

Ozone is a strong oxidant gas which, upon inhalation, deposits throughout the respiratory system. Because ozone is poorly water soluble, it does not simply diffuse into lung tissue, but rather reacts easily with molecules at the surface of the lung. Epithelial cells lining the respiratory bronchioles and alveoli are especially vulnerable to oxidant damage, both because the delivered dose of ozone is greatest in the deep lung and because these cells lack a protective mucous layer. It has been documented that ozone can lead to damage in the lung such as epithelial cell destruction, pulmonary edema, and inflammation (US EPA 1996b). This provides a strong biological basis to believe that ozone can influence human health

Health evidence for ozone comes from both human chamber studies and observational epidemiological studies. As we discuss below, controlled chamber experiments have shown that brief, ambient-level exposures cause acute, reversible drops in lung volumes, increases in non-specific bronchial responsiveness, and pulmonary inflammation. Epidemiology studies have confirmed many of these findings, and further have demonstrated associations with asthma exacerbations, emergency room visits, hospital admissions, and deaths. Populations most at risk include children and adults who are active outdoors, especially those with asthma.

First considering acute pulmonary effects from ozone, these effects have been demonstrated extensively in human and animal chamber studies as well as in epidemiological studies. Human chamber studies have shown that brief ozone exposures at or above 80 ppb cause reversible drops in lung volumes, increases in non-specific bronchial responsiveness, and pulmonary inflammation (US EPA 1996; Horstman et al. 1990; Devlin et al. 1991). There is a broad distribution of responsiveness across human subjects for all of these effects, with some individuals exhibiting responses several-fold higher than the average response, and others showing no response. The epidemiological literature has also documented these effects on lung function in children and adults (Kinney et al. 1989; Spektor et al. 1991; Hoek et al. 1993).

As mentioned in Section 2.3, three acute health outcomes tend to contribute most to the total impacts of ozone – premature deaths, hospital admissions for respiratory causes, and days with minor restricted activities. This is because of the magnitude of the concentration-response functions derived from the epidemiological literature, the frequency of the health outcomes, and the economic values placed on those health outcomes. For example, in the US EPA's benefit-cost analysis of the Clean Air Act (US

EPA 1999), premature death is given an economic value of approximately $5 million in 1990 dollars, more than an order of magnitude greater than any morbidity valuation. In contrast, minor restricted activity days were only valued at $38 per day, but the per-capita incidence of minor restricted activity days was 7.8/year (versus a per-capita mortality risk of approximately 8/1,000 per year).

For premature mortality, there have been numerous published studies. However, many of these studies may not have accurately estimated the effects of ozone, if they did not account for weather and other pollutants appropriately in the analysis. The summary report by Levy and colleagues (2001a) concluded that there were four studies in the US (Moolgavkar et al. 1995; Ito and Thurston 1996; Kelsall et al. 1997; Moolgavkar 2000) and two in Europe (Hoek et al. 1997; Touloumi et al. 1997) that adequately controlled for both weather and particulate matter. All of these studies found a significant relationship between acute ozone exposure and premature death. The average value of the US studies was a 0.5% increase in premature deaths per 10 $\mu g/m^3$ increase in daily average ozone concentrations, or roughly a 1% increase per 10 ppb increase in daily average ozone (Levy et al. 2001a).

Similarly, hospital admissions for respiratory illnesses increased up to 35% in association with 100 ppb increases in daily maximum one-hour ozone concentrations. When we look across a number of published studies (in New York, Canada, and across the US), the average is an 18% increase in all-age respiratory hospital admissions per 100 ppb increase in daily maximum one-hour ozone concentrations (Thurston and Ito 1999).

Evidence for minor restricted activity days (MRAD) is drawn from a single national cross-sectional survey (Ostro and Rothschild 1989). This study used information from the annual Health Interview Survey to compare reported days with minor restricted activities with ozone concentrations for 50,000 households. Ostro and Rothschild reported a 0.2% increase in MRAD per $\mu g/m^3$ increase in two-week average 1-hour maximum ozone concentrations. Although the recent summary report (Levy et al., 2001a) concluded that an estimate of 0.1% might be more appropriate, the above evidence of the ability of ozone to influence lung function and respiratory symptoms supports the plausibility of this relationship.

There is also concern about possible chronic pulmonary effects of ozone in humans associated with long-term exposures. These effects have been demonstrated in long-term toxicological studies and are also suggested in some recent epidemiological studies. However, more studies are needed to better understand chronic pulmonary effects of ozone. Recent epidemiological studies have reported decreases in lung function in young adults who have lived for long periods in areas with high ambient ozone concentrations (Kunzli et al. 1997; Galizia and Kinney 2000), and have demonstrated increased risk of asthma development associated with ozone exposure and outdoor exercise (McConnell et al. 2002). Associations appear most pronounced for measures of small airways function such as FEF_{25-75} (forced expiratory flow at 25%-75% of maximal lung volume), consistent with a hypothesis of small airway narrowing secondary to chronic pulmonary inflammation. It is not clear whether these epidemiological findings are due to ozone exposure alone or ozone in combination with other co-pollutants. In addition, studies of mortality from long-term air pollution exposure (Dockery et al. 1993; Pope et al. 1995; Krewski et al. 2000) did not find a significant role of ozone.

Particulate Matter

For $PM_{2.5}$, the evidence for health effects derives largely from epidemiological studies, which have reported associations with premature death both from short-term and long-term exposures. Other effects associated with ambient particulate matter include increases in cardiovascular and respiratory hospitalizations, respiratory symptoms, and decreases in lung function. Populations at greatest risk of $PM_{2.5}$ effects include the elderly and those with pre-existing cardiopulmonary disease. Although the evidence is quite strong for $PM_{2.5}$ health effects, important questions remain, including the nature of the PM component(s) responsible, the biological mechanism(s) involved, and the host factors that promote greater susceptibility. These are currently areas of active research.

Due to limited exposure data until recently, only a handful of epidemiological studies have examined the effects of $PM_{2.5}$ specifically; much more evidence exists for PM_{10} or TSP. However, known characteristics of particles help inform our focus on $PM_{2.5}$. For example, particles less than 2.5 µm in diameter are capable upon inhalation of reaching the deepest portions of the lung, while larger particles tend to deposit in the higher airways. Some scientists are concerned about even smaller particles known as *ultrafine particles* (less than 0.1 µm in diameter), since most $PM_{2.5}$ particles are less than 0.1 µm and this fraction is more likely to deposit in the deep lung (Spengler and Wilson 1996). We do not discuss ultrafine particles further, focusing on the growing body of evidence on $PM_{2.5}$

Focusing first on acute mortality evidence for particulate matter, a large number of recent time series observational studies have reported small, statistically significant associations between particulate matter (usually TSP or PM_{10}) and daily mortality. Quantitative results from studies of this kind have been remarkably consistent, suggesting a 0.5-1% increase in total daily deaths associated with increases of 10 $\mu g/m^3$ in daily average PM_{10} concentrations (US EPA 1996c). The National Morbidity, Mortality, and Air Pollution Study (NMMAPS) of the 90 largest cities in the US (Samet et al. 2000) found that mortality rates increase on average by approximately 0.3% for every 10 $\mu g/m^3$ in daily average PM_{10} concentrations, with somewhat higher rates in the Northeast. Literature review studies have yielded similar values. A recent summary article (Stieb et al. 2002) found well over one hundred published studies and documented that this magnitude of effect has been found in numerous locations. This extraordinary consistency, along with the fact that the effect remains significant when other criteria pollutants are considered simultaneously, provides substantial evidence that short-term particulate matter exposure leads to premature death.

These deaths tend to accrue among the most vulnerable members of society, such as the elderly and those with pre-existing cardio-pulmonary disease (e.g., Pope et al. 1992; Schwartz 1993; Kinney et al. 1995; Katsouyanni et al. 1997). Cause-specific analyses usually have observed larger relative effects for deaths attributed to respiratory and cardiovascular causes than for other causes of death. Although it has been asserted that this effect represents “harvesting”, killing individuals who would have otherwise died in a matter of days, a recent study concluded that the effect represents a loss of at least a month of life expectancy (Schwartz 2001). Another difficult question is whether there is a level below which no health effects are seen (known as a *threshold*). Although this is as yet unresolved, an investigation of a subset of NMMAPS cities (Daniels et al. 2000) found that if there were a threshold, it would be well below both air quality standards and average ambient levels in Queens. Another recent study focused on six US cities concluded that time series mortality risks of $PM_{2.5}$ occurred at levels as low as 2 $\mu g/m^3$ (Schwartz et al. 2002).

Several important uncertainties remain in the interpretation of the acute mortality literature. This includes the precise identity of the population subgroups that are most at risk, the unique impact of PM distinct from other co-pollutants, the PM sub-component that is most important, the impact on life expectancy of these findings, and the pathophysiologic mechanism(s) responsible. These are all areas of active research. Nevertheless, the strength of the acute mortality literature is substantial and demonstrates a consistent and significant relationship between short-term particulate matter exposure and premature death.

Briefly considering acute morbidity, a more limited body of evidence is available across a wide range of outcomes, ranging from cardiovascular and respiratory hospital admissions to asthma exacerbation to respiratory symptoms and reduced lung function. For example, observational time series studies similar to those addressing acute mortality have reported increases in hospitalizations or emergency room visits for respiratory complaints in association with $PM_{2.5}$ and/or sulfate particles (e.g., Thurston et al. 1992; Burnett et al. 1994; Schwartz 1994). Repeated measures studies in small cohorts of subjects have reported small but statistically significant declines in FEV1 and increases in lower respiratory symptoms associated with ambient PM_{10} and sulfate concentrations (Hoek and Brunekreef 1993; Pope and Kanner 1993). As a group, findings from these studies reinforce the plausibility of the acute mortality results noted earlier, and suggest a possible role of acute pulmonary irritation in the mechanistic pathway leading to mortality in susceptible individuals.

We now turn to the potential influence of long-term particulate matter exposure on risk of premature death. Epidemiological studies correlating mortality rates and PM concentrations across metropolitan areas represent the oldest and most extensive evidence for chronic PM effects (Lave and Seskin 1970; Evans et al. 1984). However, interpretation of early cross-sectional observational studies was seriously hindered by uncertainties regarding potential confounding by cigarette smoking, occupational exposures, and other factors (Evans et al. 1984).

Confirmatory results have emerged from two large prospective cohort studies which, based on individual questionnaire data on smoking and other risk factors, were able to control for major potential confounders at the individual level in the analyses (Dockery et al. 1993; Pope et al. 1995). These studies are known as the Six Cities study and the American Cancer Society study. While other cohort studies exist (e.g., McDonnell et al. 2000; Lipfert et al. 2000), the Six Cities and American Cancer Society studies are most often cited because of their generalizability and the fact that they have undergone extensive scrutiny and reanalysis (Krewski et al. 2000). These two recent studies are also important because they analyzed multiple, alternative PM measures, including $PM_{2.5}$.

In the Six Cities study (Dockery et al. 1993), Dockery and colleagues followed a cohort of 8,111 white adults in six cities in the eastern half of the US for 15-17 years. After controlling for potential confounders (including smoking, education, obesity, and occupational exposures), they reported a significant association with mortality rates for three different measures of particulate matter (PM_{10}, $PM_{2.5}$, and sulfates). The risk of death was increased by 26 percent for an exposure difference of 18.6 $\mu g/m^3$ of $PM_{2.5}$ across cities, for an approximate 1.3% increase in mortality for every $\mu g/m^3$ of annual average $PM_{2.5}$. However, this study was somewhat limited in its ability to distinguish between pollutants, given the relatively small number of cities evaluated.

The American Cancer Society study conducted by Pope and colleagues (Pope et al. 1995) expanded on this work by considering a larger number of individuals (552,138 adults) and a broader geographic area (151 metropolitan areas in all 50 states). The study population was drawn from a previously defined cohort being followed for the development of cancer. A recent publication (Pope et al. 2002), with a longer period of follow-up than the original analysis, concluded that a 1 $\mu g/m^3$ increase in annual average $PM_{2.5}$ concentrations was associated with a 0.6 percent increase in mortality rates. Significant effects were seen on both cardiopulmonary and lung cancer death, and there was no evidence of a threshold. The primary critiques of this study are that the population studied was somewhat older and better educated with more non-smokers than the US average (US EPA 1996c). However, the two follow-up analyses (Krewski et al. 2000; Pope et al. 2002) considered numerous key confounders and used advanced statistical techniques to account for spatial patterns, and the large sample size and geographic coverage enhance the representativeness of the findings. For these reasons, many studies use the American Cancer Society estimate to calculate mortality risks from particulate matter (Abt Associates 2000; Levy and Spengler 2002).

Viewed in total, the epidemiological evidence for health impacts of exposure to ambient PM (including acute and chronic effects, and both mortality and morbidity) is quite strong. Epidemiological evidence implicating $PM_{2.5}$ specifically is more limited at present, especially for acute mortality. However, plausibility arguments based on pulmonary penetration and deposition, as well as the known concentration of toxic chemical species in the fine particle fraction, argue that $PM_{2.5}$, or a subcomponent of $PM_{2.5}$, is likely to be the correct metric of PM-related mortality risk. In addition, the chronic mortality risk is larger than the acute mortality risk and theoretically includes some portion of the acute deaths, making the chronic mortality estimates (if causal) the primary estimates used in risk calculations. Although some major areas of uncertainty remain, including the nature of the PM component(s) responsible for adverse health effects, the biological mechanism(s) involved, and the host factors that promote greater susceptibility, the evidence for health effects of PM is substantial.

Appendix B:
Results of A Personal Exposure Study

To illustrate personal exposures to persons living in New York City, we summarize one recent example of a personal exposure study. The TEACH (Toxic Exposure Assessment, a Columbia/Harvard) study was designed to characterize levels of and factors influencing personal exposures to urban air toxics among 46 high school students living in inner city neighborhoods of New York City (Kinney et al. 2002). The study included personal, indoor, and outdoor measurements of a wide range of air toxics, including 15 VOCs, $PM_{2.5}$ and 28 associated metals and elements, and 2 aldehydes. Study subjects were high school students from the A. Philip Randolph Academy, a magnet public high school located in the West Central Harlem section of NYC. Students attending the school lived primarily in Northern Manhattan and the South Bronx, with additional students coming from the boroughs of Queens and Brooklyn.

The 46 study subjects ranged from 14 to 19 years of age, with 31 (67%) female and 15 (33%) male. The racial distribution was 43% black, 50% Hispanic, and the remaining 7% either Asian or not reported. Most students lived in apartment buildings (76%).

Concentrations (means and standard deviations) of air toxics monitored on personal samples, and corresponding home indoor and outdoor samples, are given in Table B.1 (particles) and Table B.2 (VOCs). These results demonstrate the wide range of exposures to air toxics, the importance of indoor sources for some but not all air toxics, and, in some cases, personal exposures that exceed both indoor and outdoor concentrations.

Table B.1 Personal Exposure Results for $PM_{2.5}$

Means and standard deviations of $PM_{2.5}$, absorbance, and particle-associated elements for personal, home indoor, and home outdoor locations: (a) Summer, (b) Winter. Limits of detection are also given.

a) WINTER Concentrations (ng/m^3) unless otherwise stated

		Home Outdoor			Home Indoor			Personal		
Analyte	LOD	N	Mean	STD	N	Mean	STD	N	Mean	STD
PM 2.5 (µg/m^3)	0.90	37	11.9	3.8	38	20.9	16.9	35	17.0	6.8
Abs (1/m * 10^5)	0.23	37	1.94	0.91	38	1.62	0.78	35	1.65	0.70
Aluminum (Al)	2	36	40	17	26	41	23	8	86	30
Antimony (Sb)	0.01	36	1.48	1.04	38	5.29	22.82	35	4.32	16.03
Arsenic (As)	0.03	0			0			0		
Beryllium (Be)	0.0003	0			0			0		
Cadmium (Cd)	0.010	36	0.157	0.092	38	0.207	0.164	35	0.287	0.239
Calcium (Ca)	3	36	65	31	38	92	105	35	129	76
Cesium (Cs)	0.0002	36	0.0105	0.0052	38	0.0087	0.0057	35	0.0089	0.0043
Chromium (Cr)	0.40	0			0			0	.	.
Cobalt (Co)	0.00	36	1.59	0.78	38	1.76	3.39	35	1.26	0.77
Copper (Cu)	0.60	36	6.0	3.0	38	7.0	4.7	35	10.5	7.1
Iron (Fe)	22	36	107	41	38	84	40	35	633	588
Lanthanum (La)	0.00	36	0.81	0.49	38	0.72	0.56	35	0.62	0.31
Lead (Pb)	0.03	36	6.96	3.27	38	22.40	70.25	35	16.09	36.43
Magnesium (Mg)	1	36	30.0	14.0	38	30.7	17.4	35	44.4	65.7
Manganese (Mn)	0.20	36	2.35	0.94	38	2.20	1.15	35	7.35	5.15
Nickel (Ni)	0	36	32.3	22.4	38	31.6	54.5	35	49.6	114.2
Platinum (Pt)	0.0001	36	0.0008	0.0008	38	0.0010	0.0008	35	0.0008	0.0004
Potassium (K)	3	36	44	17	38	84	66	35	80	56
Scandium (Sc)	0.0010	36	0.006	0.004	29	0.006	0.004	0		
Selenium (Se)	0.20	0			0			0		
Silver (Ag)	0.001	36	0.059	0.043	38	0.096	0.113	35	0.124	0.128
Sodium (Na)	2	22	117	70	30	153	135	27	142	79
Sulfur (S)	2	36	840	352	38	983	1077	35	947	628
Thallium (Tl)	0.0000	27	0.0142	0.0094	38	0.0149	0.0099	35	0.0133	0.0081
Tin (Sn)	0.01	36	0.79	0.56	38	1.01	0.53	35	1.21	0.66
Titanium (Ti)	0.30	36	2.45	1.65	38	2.94	2.22	35	4.75	2.02
Vanadium (V)	0.01	36	7.68	3.14	38	9.49	20.66	35	6.56	3.67
Zinc (Zn)	0	36	35.8	29.0	38	120.7	370.6	35	80.3	143.7

b) SUMMER

		Home Outdoor			Home Indoor			Personal		
Analyte	LOD	N	Mean	STD	N	Mean	STD	N	Mean	STD
PM 2.5 (µg/m^3)	0.90	38	13.6	4.5	40	19.0	21.5	40	18.5	17.7
Abs (1/m * 10^5)	0.23	38	1.79	0.71	40	1.66	0.62	40	1.71	0.61
Aluminum (Al)	2	36	37	18	39	39	31	40	50	20
Antimony (Sb)	0.01	36	1.05	0.45	39	0.90	0.40	40	2.87	12.68
Arsenic (As)	0.03	36	0.37	0.18	39	0.40	0.20	40	0.45	0.37
Beryllium (Be)	0.0003	15	0.0032	0.0025	18	0.0016	0.0007	33	0.0019	0.0008
Cadmium (Cd)	0.010	36	0.118	0.055	39	0.145	0.110	40	0.215	0.293
Calcium (Ca)	3	36	47	23	39	54	26	40	70	41
Cesium (Cs)	0.0002	36	0.0046	0.0018	39	0.0044	0.0020	40	0.0042	0.0018
Chromium (Cr)	0.40	34	0.46	0.41	39	0.55	0.29	39	1.99	1.98
Cobalt (Co)	0.00	36	0.78	0.46	39	0.72	0.48	40	0.68	0.42
Copper (Cu)	0.60	36	12.6	44.0	39	10.3	30.6	40	8.5	13.0
Iron (Fe)	22	36	114	56	39	95	47	40	519	556
Lanthanum (La)	0.00	36	0.59	0.37	39	0.55	0.53	40	0.46	0.27
Lead (Pb)	0.03	36	6.61	5.08	39	5.83	4.38	40	88.85	525.56
Magnesium (Mg)	1	1	16.9		32	25.2	12.8	40	25.2	10.5
Manganese (Mn)	0.20	36	2.06	0.93	39	1.81	0.81	40	5.78	5.26
Nickel (Ni)	0	36	11.7	6.3	39	12.6	8.4	40	17.3	24.7
Platinum (Pt)	0.0001	36	0.0016	0.0008	39	0.0014	0.0010	40	0.0017	0.0014
Potassium (K)	3	0			32	64	58	40	59	34
Scandium (Sc)	0.0010	33	0.007	0.004	39	0.005	0.003	40	0.006	0.003
Selenium (Se)	0.20	34	0.58	0.34	39	0.52	0.28	40	0.51	0.19
Silver (Ag)	0.001	36	0.043	0.031	39	0.062	0.041	40	0.098	0.074
Sodium (Na)	2	36	103	69	39	122	98	40	104	38
Sulfur (S)	2	36	1756	1164	39	1226	687	40	1104	498
Thallium (Tl)	0.0000	36	0.0064	0.0024	39	0.0079	0.0060	40	0.0081	0.0072
Tin (Sn)	0.01	20	0.90	0.48	39	1.42	1.92	40	1.59	1.98
Titanium (Ti)	0.30	36	3.54	1.28	39	3.46	1.36	40	4.14	2.13
Vanadium (V)	0.01	36	4.62	1.63	39	4.17	1.68	40	3.81	1.46
Zinc (Zn)	0	36	34.8	40.5	39	86.2	187.5	40	76.6	143.3

Table B.2 Personal Exposure Results for VOCs.

Means and standard deviations of VOCs and aldehydes for personal, home indoor, and home outdoor locations: (a) Summer, (b) Winter. Limits of detection are also given.

a) WINTER

		Home Outdoor			Home Indoor			Personal		
Analyte	LOD	N	Mean	STD	N	Mean	STD	N	Mean	STD
1,1,1-Trichloroethane	0.13	36	0.51	0.29	36	5.43	22.78	36	2.01	4.18
1,3-Butadiene	0.06	36	0.13	0.28	36	1.18	1.54	36	0.87	1.29
1,4-Dichlorobenzene	1.29	36	5.03	7.11	36	54.9	105	36	43.4	77.4
Acetaldehyde	1.27	36	2.78	0.87	38	15.6	9.7	38	13.0	7.7
Benzene	1.66	36	2.55	1.40	36	5.97	7.29	36	4.70	3.33
Carbon Tetrachloride	0.1	36	0.75	0.16	36	0.75	0.16	36	0.67	0.13
Chloroform	0.12	36	0.23	0.21	36	3.83	3.12	36	3.00	2.74
Ethylbenzene	0.22	36	1.27	0.57	36	3.57	6.91	36	2.24	2.37
Formaldehyde	0.96	36	2.11	0.85	38	12.1	5.0	38	11.5	4.9
Methylene Chloride	0.25	36	1.96	3.68	36	6.19	13.8	36	3.80	5.95
MTBE	0.46	36	11.9	6.0	36	21.0	32.6	36	15.5	11.7
Styrene	0.17	36	0.43	0.25	36	1.25	0.70	36	1.01	0.46
Tetrachloroethylene	0.12	36	2.42	1.93	36	7.53	14.71	36	7.98	19.28
Toluene	1.98	36	6.50	3.08	36	17.7	14.4	36	15.5	12.9
Trichloroethylene	0.15	36	0.36	0.26	36	1.26	3.59	36	2.62	8.30
o-Xylene	0.29	36	1.52	0.81	36	3.36	6.09	36	2.24	2.09
m,p-Xylene	0.78	36	4.46	2.16	36	10.4	20.1	36	6.71	5.69

b) SUMMER

		Home Outdoor			Home Indoor			Personal		
Analyte	LOD	N	Mean	STD	N	Mean	STD	N	Mean	STD
1,1,1-Trichloroethane	0.13	35	0.76	1.84	40	1.21	3.03	41	1.11	1.37
1,3-Butadiene	0.06	35	0.14	0.41	40	1.01	2.56	41	1.16	1.95
1,4-Dichlorobenzene	0.14	29	4.31	6.04	36	108	503	40	41.1	88.2
Acetaldehyde	0.33	36	4.15	1.53	41	14.98	16.70	42	20.2	15.9
Benzene	1.9	35	1.31	1.01	41	1.75	1.17	41	3.09	1.94
Carbon Tetrachloride	0.1	33	0.49	0.25	39	0.53	0.24	41	0.59	0.29
Chloroform	0.12	33	0.33	0.73	40	2.01	2.02	41	2.80	2.73
Ethylbenzene	0.17	29	1.88	1.75	36	1.99	1.08	40	3.37	2.02
Formaldehyde	0.15	36	5.28	2.27	41	20.9	11.0	42	28.5	13.8
Methylene Chloride	1.84	35	1.10	1.33	40	8.80	32.32	41	9.3	29.1
MTBE	0.13	35	12.7	14.0	40	21.1	50.9	41	29.5	67.7
Styrene	0.08	30	0.32	0.25	37	0.80	0.70	40	1.68	1.76
Tetrachloroethylene	0.17	30	9.46	34.33	36	6.45	11.69	40	9.18	15.49
Toluene	0.28	31	7.48	3.84	37	14.9	19.8	40	37.4	60.5
Trichloroethylene	0.15	31	0.24	0.31	38	0.32	0.52	40	0.51	0.93
o-Xylene	0.37	30	2.00	1.99	36	2.27	1.38	40	3.93	2.33
m,p-Xylene	0.94	30	5.77	6.18	36	6.44	4.11	40	10.9	6.8

Appendix C:
The PROSYM Electricity Market Simulation Model

The PROSYM Model

Our analysis is focused on two reliability regions, NPCC and MAAC. We use Henwood's PROSYM model (version 3.5.08, EMSS version 4.4.01) to simulate the operation and costs of the NPCC and MAAC electricity markets. This model is a detailed simulation model in which individual generating units are dispatched to meet hourly system demand for electricity in particular control areas. We used the NERC version 5.9.0 database for the default assumptions in the model.

PROSYM is a complete electric utility/regional pool analysis and accounting system. It is designed for performing planning and operational studies, and as a result of its chronological structure, accommodates detailed hour-by-hour investigation of the operations of electric utilities and pools. This hour-by hour simulation, respecting chronological, operational, and other constraints in the case of cost based dispatch, and relevant pool or independent system operator (ISO) rules in the case of bid based dispatch, is the essence of the model. Because of its ability to handle detailed information in a chronological fashion, planning studies performed with PROSYM closely reflect actual operations.

Electric utilities and generation pools operate generation resources, energy storage devices, and load control systems to match generation and load on an instantaneous basis. This real-time operation entails using highly sophisticated control systems, which match generation levels with load virtually instantaneously. It is not analytically necessary to represent this level of time detail in performing planning studies, which have a time horizon of weeks to years. What is necessary is a level of time detail that allows the planning study to obtain a reasonable approximation of actual system operation.

PROSYM is the central component of the proprietary HESI Simulation Software Suite from Henwood Energy Services[54]. In addition to PROSYM, and its multi-region equivalent MULTISYM, the suite includes a variety of database files along with the EMSS data management software, and additional packages for specialized analyses and reporting.

General Assumptions

We have conducted numerous PROSYM model runs to come up with the final results presented in this study. These runs can be categorized as Base Case and Clean Air Plan

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Case runs. The Base Case runs includes Henwood default data for the electricity system cost and operating performance. The Base Case runs also include some additional assumptions made by the authors to reflect more recent, or more appropriate, data.

In general, the Clean Air Plan Cases assume that several steam plants retire early, that new cleaner capacity is built, and that end-uses consumption is reduced through energy efficiency. These Clean Air Plan assumptions are described in the main body of this report.

We assumed that the wholesale power market is deregulated with generators bidding into the market. That is, all generators get paid the market clearing price for a given transmission area. This structure is now in place in California and the Northeast. We also assumed the market is competitive such that all generators bid their marginal cost of production.

This is a commonly used simplification that overlooks the complexity of the actual electricity markets in terms of high levels of concentration and anti-competitive behavior. We believe that the assumption of an “ideal competitive market” would be problematic if the goal were to project market prices. Since this analysis is focused on fuel mix and emissions, however, the assumption should not be a problem. The most common forms of exercise of market power (i.e., raising bid prices above margin costs of production) will have a direct and potentially large impact upon the market prices, but will leave the loading order and dispatch largely unchanged so long as the practice is employed as a general practice in the market place. It may be that anti-competitive bidding is being employed by one or several companies, but we leave exploration of this for future analyses.

We used PROSYM to simulate the electricity market in the years 2000, 2005 and 2010. These years provide “snapshots” of the current system, as well how the system will operate in the short-term and medium future. We rely upon Henwood’s data base for forecasts of key assumptions such as electricity load growth and increases in fuel prices.

One of the more challenging aspects of the electricity market forecast is identifying the addition of new power plants over the next five to ten years. There has recently been a great deal of uncertainty regarding proposals for financing and developing new power plants in the Northeast region. In order to obtain the most up-to-date information on new power plant development, we modified some of the PROSYM default assumptions, based on the NY Department of Public Service’s website and NY ISO’s 2000 Load & Capacity Data.

Appendix D:
The Speed-Traffic Relationship

Because emissions of most automotive pollutants increase as speeds drop below a range of 35-45 mph, a key issue in analyzing economic incentives for driving less is the extent to which reducing the number of vehicles in the traffic stream increases vehicular speeds. Indeed, the effect in the opposite direction is equally critical, since the projected increases in base case traffic levels can be expected to reduce average speeds on highways and local roads in the study area, thus adding to emission rates.

Traffic engineers have long understood that roadway delays rise disproportionately as the traffic level approaches, and then equals or even exceeds, the roadway's design capacity. This understanding has been codified in a set of equations that simulate average speeds as varying with the inverse of the fourth or fifth power of the ratio of vehicle volumes (V) to highway capacity (C). The fourth power of this "V/C" ratio is generally applied to urban or suburban streets, while the fifth power is employed for highways.

Here we take an example of a highway with a design speed of 60 miles per hour and, for simplicity's sake, a design volume of 1,000 vehicles per hour. Traffic-flow models indicate that average speeds of 59-60 mph are readily achievable up to volumes of 400-500 vehicles per hour, i.e., for V/C (volume divided by capacity) ratios up to 0.4 or 0.5. However, average speeds degrade progressively as the V/C ratio rises, as the table shows:

Table D.1 Illustrative Example: Highway Speeds as a Function of Traffic Level

Vehicles per hour	V/C Ratio	Average speed, mph
200	0.2	60.0
300	0.3	59.9
400	0.4	59.5
500	0.5	58.5
600	0.6	56.5
700	0.7	52.9
800	0.8	47.5
900	0.9	40.8
1000	1.0	33.3
1100	1.1	26.2
1200	1.2	20.1
1300	1.3	15.1
1400	1.4	11.3

In this hypothetical example, the highway design capacity is 1000 vehicles per hour.

The vast majority of vehicle trips in the study area take place on roads and highways for which the V/C (vehicle/capacity) ratio is 0.5 or higher, up to ratios of 1.4 corresponding to the hyper-congestion often experienced in the region and in northwest Queens in particular. For each V/C ratio in that range, and across the range of road conditions in the study area (expressways, arterials and local roads), we calculated the rate of decline in average speeds relative to the rate of increase in the V/C ratio. The average of these rates was roughly 1.5, i.e., for each 10% increase in the V/C ratio (across a V/C range of 0.5 to 1.4), average traffic speeds fell by an average of 15%. Accordingly, throughout our analysis we used this 1.5 figure to estimate the extent to which increases (or decreases) in VMT translate to decreases (or increases) in average speeds.