INTERNATIONAL GAS UNION
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CASE STUDIES IN IMPROVING URBAN AIR QUALITY

Contents

Introduction

In the run up to the United Nations Framework Convention on Climate Change negotiations culminating in Paris in December 2015, there has been a great deal of high-level global political focus on the issue of climate change. As air quality problems in cities from Beijing to New Delhi become increasingly severe, the links between action to address climate change and to curb local air pollution have attracted increasing attention as a means to mobilize political support.

This paper highlights the interconnection that exists between reducing greenhouse gas emissions and reducing emissions of other air pollutants. It presents case studies of efforts in four cities— New York, Istanbul, Toronto, and Beijing—to improve urban air quality. These cities can provide lessons for other cities seeking to reduce the potentially severe health consequences of urban air pollution.

Background on Air Pollution and Climate Action

Outdoor air pollution is among the most significant environmental threats to human health. According to the World Health Organization, air pollution contributed to 3.7 million premature deaths each year—and this may be an underestimate since it does not include deaths from exposure to long-term pollutants other than particulate matter. As more people move to cities around the world, deaths from urban air pollution will increase substantially.

The current world population is approximately 7.3 billion people, with just over half residing in urban areas.[1] By 2050, the world population is expected to grow to over 9 billion, and the share of those residents living in cities is projected to boom from 50 to 70% - up to 6.3 billion people.[2] This rapid growth in urban population is expected to occur primarily in middle-income and developing countries. As cities in developing countries grow, the demand for energy and transportation will rise accordingly. As a result, the OECD projects that, absent policy changes, deaths from outdoor air pollution will double from current levels by 2050, with urban outdoor air pollution becoming the top environmental cause of mortality worldwide (moving ahead of dirty water and lack of sanitation).[3]

Addressing urban air quality will increasingly emerge as among our most urgent environmental challenges, along with issues like climate change and water availability. This report provides useful case studies of measures taken by cities in the recent past to make improvements to their air quality. Cities in emerging economies can learn lessons from the experiences of those in more developed countries about how to expand access to needed energy services while improving air quality. Experiences in both developed and developing countries demonstrate that air quality improvements can be made while still promoting economic growth, energy services, and even industrial growth.

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1 UN, "World Urbanization Prospects 2014 Revision," p. 2, available at:

2 Ibid.

3 OECD, "Environmental Outlook to 2050: The Consequences of Inaction, Key Findings on Health and Environment," available at: http://www.oecd.org/newsroom/environment actnoworfacecostlyconsequenceswarnsoecd.htm.

Common Air Pollutants and Their Health Impacts

The major components of outdoor air pollution are a combination of gases and dust particles (particulate matter, or "PM") that have deleterious human health and environmental consequences. Health impacts include lung disease, cardiac disease, cancer, and more. Outdoor air pollution has a variety of human and natural sources, but the most significant human contributor to outdoor air pollution is the combustion of fuels – primarily fossil fuels. [4]

A few of the main components of outdoor air pollution, including their health impacts and primary sources are:[5]

Particulate Matter (PM): PM consists of sulfate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water. The most health-damaging particles are those with a diameter of 10 microns or less (PM_{10}), especially fine particles of 2.5 microns or less ($PM_{2.5}$). PM is generated from human and natural sources, with PM_{10} and above often coming from dust generated in the environment. Combustion of fossil fuels, particularly coal, fuel oil, and diesel, are a significant source of $PM_{2.5}$.

There is a close relationship between exposure to high levels of PM and impacts on human health. Long-term exposure to $PM_{2.5}$ is associated with increased mortality due to lung diseases and cardiac events. The WHO has recognized PM matter as a carcinogen since 2013.6 Exposure to PM has health impacts even at very low levels.

Sulfur Dioxide (SO2): SO_2 is produced from burning fossil fuels (coal and oil) that contain sulfur. It is one of a group of sulfur oxides that are highly reactive gases.[7] SO_2 has harmful health effects and is a major contributor to the formation of acid rain.

SO_2 can impact the respiratory system, impair lung function, and cause eye irritation. Studies have found that hospital admissions for cardiac events and mortality increase on days of high SO_2 concentration.

Nitrogen Dioxide (NO_2): NO_2 is one of several nitrogen oxides (NOx) produced during combustion processes, particular higher temperature combustion associated with burning fossil fuels. NOx are harmful pollutants that have direct health consequences in humans and contribute to the formation of ground-level ozone and acid rain. NO_2 is linked to reduced lung function and respiratory issues in asthmatic children.

Ozone (O3): Ground-level ozone is a major component of smog and should not be confused with the ozone layer that filters out UV radiation from the sun. Ground-level (or "tropospheric") ozone is produced when gases such as NOx or volatile organic compounds are exposed to sunlight.

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4 S. Icecik, U. Im, "Air Pollution in Megacities: A Case Study of Istanbul," in Air Pollution – Modeling, Monitoring and Health, InTech, Ed. M. Khare, 2012, available at: http://cdn.intechopen.com/pdfs-wm/33882.pdf.

5 Information for this overview of air pollutants is drawn from the World Health Organization, http://www.who.int/mediacentre/factsheets/fs313/en/; and the U.S. Environmental Protection Agency, http://www.epa.gov/air/urbanair/.

6 WHO, "IARC: Outdoor Air Pollution a Leading Environmental Cause of Cancer Deaths," available at: http://www.iarc.fr/en/media-centre/iarcnews/pdf/pr221_E.pdf.

7 Both SO2 and NO2 are considered indicators of the presence of the other sulfur oxides and nitrogen oxides, respectively. Rather than set standards for each of the separate gas individually, regulatory bodies typically set standards just for SO2 and NO2. Reports of emissions and concentrations of pollutants in the air are sometimes done just for SO2 or NO2, and other times are done for the broader group of SOx and NOx.

Excessive ozone in the air can cause breathing problems, trigger asthma, reduce lung function and cause lung diseases. Increased episodes of mortality are associated with high-ozone days in cities.

In addition to the specific pollutants identified above, in 2013 the WHO concluded that outdoor air pollution is a leading environmental cause of cancer deaths. This recent conclusion is just one example of the growing scientific consensus that air pollution has more severe health consequences than previously understood.

Given these harmful health effects (as well as harmful environmental effects), governments have set limits on emissions and have also set limits on the average level of pollutants allowed in the atmosphere. These limits are typically expressed as micrograms per cubic meter (μg/m^3).

Separate guidelines are given for both short-term and long-term exposure levels. These guidelines are based on scientific studies that have linked different levels of air pollution and exposure times to different health risks. WHO Guidelines for air pollution levels are in Table 1.[8]

Table 1: WHO Guidelines for Ambient Air Pollution Concentrations

$PM_{2.5}$	10 μg/m^3 annual mean 25 μg/m^3 24-hour mean
PM_{10}	20 μg/m^3 annual mean 50 μg/m^3 24-hour mean
Ozone (03)	100 μg/m^3 8-hour mean
NO_2	40 μg/m^3 annual mean 200 μg/m^3 1-hour mean
SO_2	20 μg/m^3 24-hour mean 500 μg/m^3 10-minute mean

SOURCE: World Health Organization

Comparison of Fossil Fuel Emissions

The amount of pollutants produced from burning fossil fuels depends on a number of factors, including the type of facility (industrial/commercial scale versus residential), the type of combustion (boiler versus internal combustion engine), the type of emissions control technology employed (if any), and the type of fuel burned (including, in particular, the sulfur content of the fuel).

In the case studies below, there are two primary sources of air pollution examined: large-scale combustion for electricity generation or industrial use, and smaller-scale combustion for residential/commercial heating and other use.[9]

8 WHO, "WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide; Global update 2005; Summary of risk assessment," available at: http://www.who.int/phe/health_topics/outdoorair/outdoorair_aqg/en/. There are other health- damaging air pollutants (such as lead and other heavy metals, and carbon monoxide). Some of these other pollutants may not be as widespread or as well monitored. This paper focuses on the pollutants listed in the WHO guidelines.

9 Transportation is a major source of urban air pollution. Addressing pollution from mobile sources will inevitably have to be part of overall strategies to address urban air pollution. The case studies in this review focus on the policies to address emissions from stationary sources.

The emissions from burning coal or natural gas in electricity generation can vary greatly based on the age and efficiency of the generating plant(s) and the emissions controls that are used at the plant. Control technologies could include technologies to capture SO_2 during combustion or to remove it from exhaust gases, to lower combustion temperatures to reduce the amount of NO_2 produced during combustion, or to filter some of the PM from exhaust gases. Table 2 provides an estimate of the average emissions per megawatt hour of generation from the U.S. electricity sector in 2005. These averages reflect the variety of emissions controls technologies that are deployed across the U.S. electricity sector.

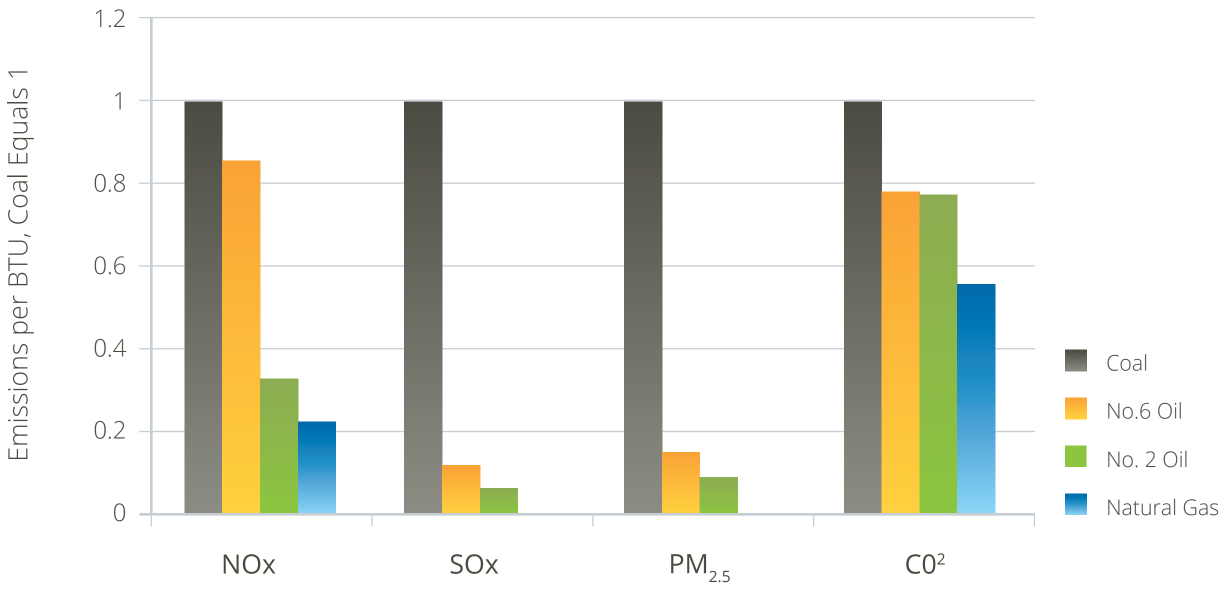
Table 2: Average Pounds of Pollutant-Forming Emissions per MWh for U.S. Coal and Natural Gas Power Plants, 2005

	Coal	Natural Gas
SO_2	12	.045
NO_2	4.1	2.3
$PM_{2.5}$	.59	.11
PM_{10}	.72	.12

SOURCE: Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use, National Academies Press, 2010, Tables 2-11, 2-16.

Figure 1 shows a comparison of emissions from residential or commercial combustion of different heating fuels – coal, No. 6 (heavy) fuel oil, No. 2 (light) fuel oil, and natural gas. These are emissions from much smaller-boilers or space heaters than the electricity generating fleet in the U.S. and operate with many fewer, if any, control technologies to reduce emissions.

Figure 1: Comparison of Emissions from Different Fuels



SOURCE: EPA AP-42 Compilation of Air Pollutant Emission Factors; CenSARA Area Combustion Emissions Inventory Enhancement Project – Final Report 2011

Co-Benefits of Reducing Greenhouse Gas Emissions and Air Pollution

There are many connections between climate change and health-damaging air pollution. For example, climate change is likely to exacerbate local air pollution problems, meaning even more stringent air pollution controls may be necessary going forward.[10] More importantly, the burning of fossil fuels predominantly causes both greenhouse gas emissions and local air pollution. As a result, many efforts to reduce GHG emissions can also reduce emissions of health-damaging pollutants, and vice-versa. As shown in Figure 1, the fuel switching that reduces health-damaging air pollutants also has a tendency to reduce CO_2 emissions.

The most common strategies for reducing GHG emissions and emissions of health-damaging air pollutants are to:

1. Improve end-use energy efficiency;
2. Increase combustion efficiency (reducing or eliminating black carbon and other products of incomplete combustion);
3. Encourage fuel switching; and
4. Increase use of non-combustion renewables. [11]

The impacts of air pollution are felt primarily locally, while the impacts of greenhouse gas emissions are global. A ton of GHG emission in New York contributes to climate change just as much as a ton in Beijing. As a result, free-rider concerns pose a barrier to action to mitigate carbon emissions. Concerns about local pollution have thus often been a greater motivation for urban areas to reduce emissions, and those actions often (though not always) have climate benefits as well.[12] Switching from fossil fuels to non-emitting renewables such as wind or solar electricity generation (or nuclear) would eliminate such emissions, although even in the most aggressive climate policy scenarios run by the International Energy Agency and others, fossil fuels remain a significant part of the global energy mix for decades to come.

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10 D. Jacob, D. Winner, "Effect of climate change on air quality," Atmospheric Environment, 43(1), 51-63, available at: http://dash.harvard.edu/bitstream/handle/1/ 3553961/Jacob_EffectClimate.pdf?sequence=2.

11 K. Smith, A. Woodward, et al., "Human health: impacts, adaptation, and co-benefits," Climate Change 2014: Impacts, Adaptation, and Vulnerability, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, p. 737, available at: http://www.ipcc.ch/pdf/assessment-report/ar5/wg2 /WGIIAR5-Chap11_FINAL.pdf.

12 M. Kojima, M. Lovei, "Urban Air Quality Management: Coordinating Transport, Environment, and Energy Policies in Developing Countries," World Bank Technical Paper No. 508, September (2001), p. 5; available at: http://elibrary.worldbank.org/doi/abs/10.1596/0-8213-4948-1.

13 New York City Department of Health and Mental Hygiene, "New York City Trends in Air Pollution and its Health Consequences," 2013, p. 2, available at: http://www.nyc.gov/ html/doh/downloads/pdf/ environmental/air-quality-report-2013.pdf.

CITY CASE STUDIES

The cities reviewed in these following case studies, New York, Istanbul, Toronto, and Beijing, each has implemented targeted policy initiatives to address its urban air pollution problems. They were selected because they each provide an example of an effort to reduce emissions from stationary sources. They represent both developed and emerging economies and represent varying degrees of regulatory capacity. Although effective policies to combat urban air pollution are highly dependent on the context in any given city (e.g., the level of development, climate patterns, regulatory capacity, economic activity, etc.), the efforts in these cities can provide lessons in addressing urban air pollution.

NEW YORK: Targeted Reforms in Residential and Commercial Heating

Although New York City's air quality has been improving for several decades, air pollution remains a serious concern. In 2007, the levels of Ozone and $PM_{2.5}$ exceeded United States Environmental Protection Agency standards. That same year, New York City launched PlaNYC, its first long-term sustainability plan. PlaNYC included the goal of making New York City's air the cleanest of any large city in the United States, as measured by levels of PM2.5.

A comprehensive air-quality monitoring program was launched with PlaNYC. The initial results from that air quality program showed that not only were $PM_{2.5}$ and ozone levels above national standards, but also that $PM_{2.5}$ and SO_2 levels were particularly elevated in areas with a high density of buildings burning heavy fuel oil (Grades No. 4 or No. 6) for heat and/or power.[13] The neighborhoods with higher traffic or higher density buildings burning heavy fuel oil had annual average $PM_{2.5}$ levels that were 30% higher than areas with less traffic or fewer buildings burning those dirty fuels.[14]

14 The City of New York, PlanNYC update April 2011, p. 122, available at: http://www.nyc.gov/html/planyc/downloads/pdf/publications/planyc_2011_planyc_full_report.pdf The local PM2.5 pollution from heavy fuel oil was particularly acute. The City estimated that in 2005 the 10,000 buildings burning heavy heating oil produced more PM2.5 than all on-road vehicle transportation in the city. New York City Department of Health and Mental Hygiene, "New York City Trends in Air Pollution and its Health Consequences," 2013, p. 2. In 2008, the heavy-heating oil buildings burned 27% of the heating oil burned in New York (the remainder burned No. 2 heating oil) but accounted for 86% of the particulate matter emissions from buildings. EDF, 'The bottom of the barrel: How the dirtiest heating oil pollutes our air and harms our health," p.3 n.9, available at: http://www.edf.org/sites/default/files/10086_EDF_BottomBarrel_Exec_Summ.pdf. The SO2 emissions from the heavy heating oil buildings were also disproportionately high because of the high sulfur content of the fuel oil.

The city concluded that although more than half of the PM2.5 originated outside of the city, health benefits could be achieved by reducing the consumption of heavy heating oil within city limits.

To address this challenge, New York City initiated and supported a number of state and local regulatory reforms and incentive programs, including:

- Working with other groups to get the State of New York to reduce the allowed sulfur content in No. 2 fuel oil to 15 ppm, a 99% reduction;[15]
- Passing a local law in 2010 to cut in half the sulfur content allowed in No. 4 heating oil (from 3,000 ppm to 1,500 ppm) and requiring all heating oil to contain 2% renewable biodiesel by October 2012;[16]
- Issuing regulations in 2011 to phase out No. 4 and No. 6 heating oil; first by requiring all boilers in the City to burn No. 4 oil (or cleaner) by 2015, then by requiring all boilers to transition to the cleanest available fuels (natural gas, ultra-low sulfur No. 2 oil or equivalent) by 2030;[17]
- Launching a voluntary "Clean Heat Program" in 2011 to encourage early adoption of cleaner fuels by providing technical and financial assistance to building owners.[18]

The city also noted it would try to accelerate the heating oil phase-out by aiding in the development of natural gas transmission pipelines and working with utilities and neighborhoods to try to cluster buildings in underserved neighborhoods where additional gas distribution could have the greatest air quality benefits.[19]

As a result of these policies, by the fall of 2013, approximately 30% of heavy fuel-burning buildings (2,700 out of 9,000) in New York City converted to cleaner fuels. Approximately 75% of those that made the switch converted to natural gas or ultra-low sulfur No. 2 oil. The conversion to natural gas was particularly strong because of market factors such as the increased natural gas supply to the New York area and lower prices.[20] By mid-2015, the phase-out of No. 6 fuel oil was complete, and all buildings had converted to No. 2 heating oil or natural gas.

A September 2013 air quality report found that the SOx concentration in the winter of 2012-2013 was down 69% compared to the winter of 2008-2009, while the PM2.5 level from burning fuel oil was down 35 percent. [21] The benefits were greatest in the areas that had the highest concentrations of these pollutants because of their proximity to buildings burning heavy fuel oil. (See Figure 2).

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15 New York City Department of Health and Mental Hygiene, "New York City Trends in Air Pollution and its Health Consequences," p.3.

16 New York City Local Law No. 43 (2010), available at: http://www.nyc.gov/html/ dep/pdf/air/ll43.pdf.

17 New York City Department of Environmental Protection, Promulgation of Amendments to

Chapter 2 of Title 15 of the Rules of the City of New York Rules Governing the Emissions from the Use of #4 and #6 Fuel Oil in Heat and Hot Water Boilers and Burners, 2011. http://www.nyc.gov/html/dep/pdf/air/heating_oil_rule.pdf.

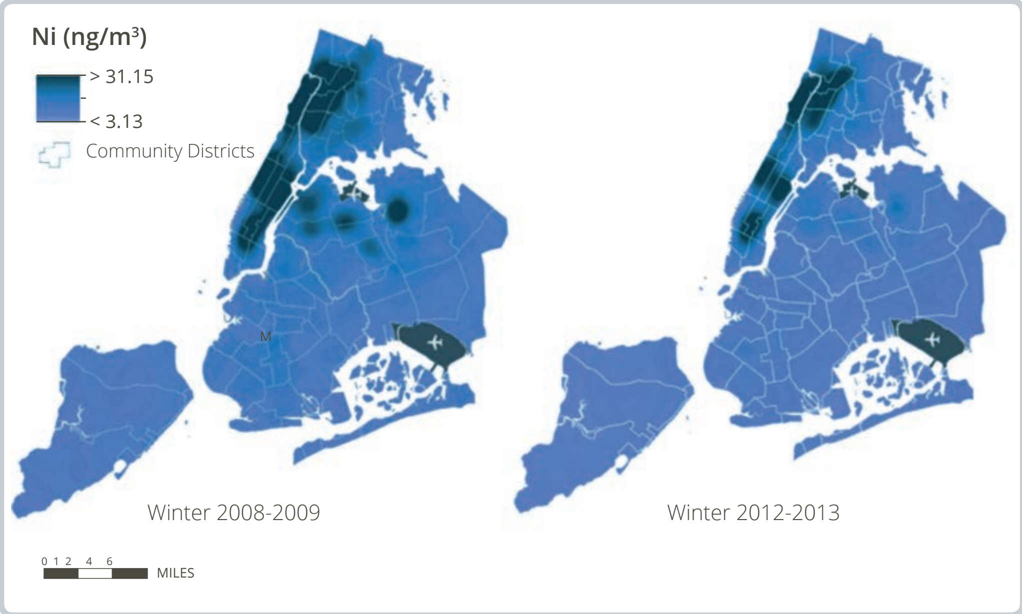
18 New York City Clean Heat, available at: https://www.nyccleanheat.org/content/what-nyc-clean-heat.

19 The City of New York, PlanNYC update April 2011, p.106.

20 New York City Department of Health and Mental Hygiene, "New York City Trends in Air Pollution and its Health Consequences," 2013, p.3.

21 http://www.nyc.gov/html/planyc2030/downloads/pdf/140422_PlaNYCP-Report_FINAL_Web.pdf, p. 26. The winter of 2012-2013 was slightly warmer than that in 2008- 2009, which would mean there were fewer heating days. The warmer temperature in 2012-2013 was not substantial enough to account for the observed emissions reductions. New York City Department of Health and Mental Hygiene, "New York City Trends in Air Pollution and its Health Consequences," p. 7.

Figure 2: Comparison of Estimated Nickel Concentrations in PM2.5



SOURCE: New York City Department of Health and Mental Hygiene

The measures to eliminate No. 6 heating oil, along with other city and state regulatory measures (such as reducing the sulfur content of on-road diesel in New York) and market trends (such as displacing fuel oil from power generation with cheaper natural gas in the New York City area), helped New York City meet the EPA standards for PM2.5 levels in 2014 for the first time since the standards were promulgated in 1997.[22] The City estimated that the overall improvement in PM2.5 levels in New York City contributes to 780 fewer deaths in the city and over 2,000 fewer emergency room visits each year. [23]

From 2005 to 2013, New York City buildings also reduced their GHG emissions by 19%. The city noted that the two main factors in this improvement were the decrease in the carbon intensity of the electricity used by buildings and the buildings' switching from fuel oil to natural gas.[24]

New York's combination of local and regional regulatory measures on fuel oil quality, combined with the voluntary Clean Heat program, enabled it to achieve important reductions in emissions in the city. The comprehensive air-quality monitoring program was an additional significant measure that allowed the city to not only identify the strategy that could have the biggest impact on air quality, but also to determine how the emissions reductions contributed to changes in air quality at a very localized level.

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22 http://www.dec.ny.gov/press/96759.html. From 2005 to 2008, local power plants that could burn either fuel oil or natural gas increasingly burned natural gas because it was cheaper. In that time, the percentage of heavy oil used for electricity generation in New York decreased from 30% to 2%. These gains occurred before the detailed air quality monitoring program was implemented, so are not reflected in the 2008-2012 improvements. But they are gains that helped the New York metro area meet PM2.5 standards. http://www.nyc.gov/html/doh/downloads/pdf/environmental/air- quality-report-2013.pdf, p.3.

23 New York City, "PlaNYC Progress Report 2014," p. 26, available at: http://www.nyc.gov/html/planyc2030/downloads/pdf/140422_PlaNYCP- Report_FINAL_Web.pdf. These estimates were based on the scale of improvement measured between the 2005-2007 timeframe, and the 2012-2013 time frame.

24 New York City, "Inventory of New York City Greenhouse Gas Emissions," 2014, p. 13, available at: http://www.nyc.gov/html/planyc/downloads/pdf/NYC_GHG_Inventory_ 2014.pdf.

ISTANBUL: Eliminating the Dirtiest Fuels in Residential Use

Beginning with the oil crisis in the 1970s, households in Istanbul switched from fuel oil to coal for domestic heating. Throughout the 1970s and 1980s Istanbul experienced worsening air quality coinciding with population growth and increasing use of coal for domestic heating. The coal being used was primarily a Turkish lignite coal that was relatively low quality and high in sulfur.[25]

The high sulfur content of the lignite contributed to very high levels of SO_2 in Istanbul. In 1992, the annual mean SO2 concentration in Istanbul peaked at above 220 μg/m3.[26] This concentration is approximately 11 times higher than the current WHO guidelines for 24-hour concentration.

Istanbul's primary strategy in addressing its air pollution problem was to provide an alternative residential heating fuel. In the late 1980s, the city formed a gas distribution company, IGDAS, that began installing the necessary infrastructure to distribute gas to Istanbul residents. Although Turkey has no significant domestic natural gas production, Istanbul and other cities in Turkey were able to take advantage of Turkey's growing role as an energy hub at that time, as several major pipelines from Central Asia, Russia, the Caucuses, and Iran began transmission through the country to supply part of Europe's gas in the 1980s[27]

In 1992, the Istanbul city government banned the most polluting lignite coal. IGDAS started to distribute natural gas in January 1992.[28] By 1998, natural gas was supplying approximately half of the residential heating needs in Istanbul.[29] In addition, the city and IGDAS established an international research center in 1999 to adapt the technical norms to the local market and train the IGDAS staff.[30]

25 Around 68% of the total lignite reserves in Turkey have very low heat content, below 2000 kcal/kg. The remaining reserves have 23.5% between 2000-3000 kcal/kg, 5.1% between 3000- 4000 kcal/kg, and 3.4% above 4000 kcal/kg. Republic of Turkey Ministry of Energy and Natural Resources available at: http://www.enerji.gov.tr/en-US/Pages/Coal.

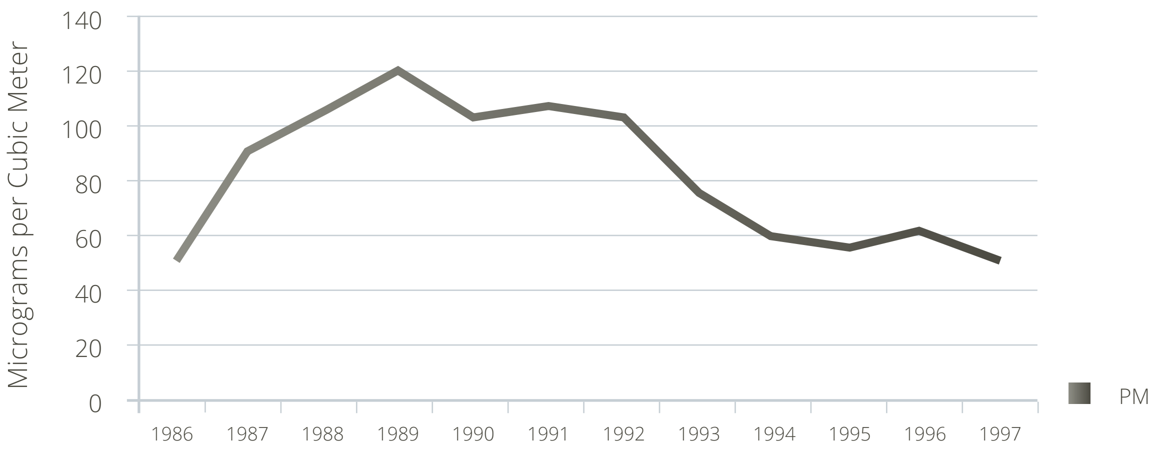
26 OECD, Environmental Performance Reviews, Turkey 1999, p. 71.

27 E. Verdeil, et al., "Governing the transition to natural gas in Mediterranean Metropolis: The case of Cairo, Istanbul and Sfax (Tunisia)," Energy Policy 78 (2015), p. 238.

Over approximately 20 years from 1992, when the first gas was distributed, to 2012, the distribution network in Istanbul expanded to cover 97% of urbanized territory in the metropolitan municipality and to supply nearly 5 million residential customers.

As a result of these changes, Istanbul's air quality has improved dramatically. First, as shown in Figure 3, particulate matter declined from over 100 micrograms per cubic meter in the early 1990s, to just above 50 by 1997.[31]

Figure 3: Istanbul Annual Average Particulate Matter Concentrations 1986-1997



SOURCE: OECD Environmental Performance Reviews, Turkey 1999

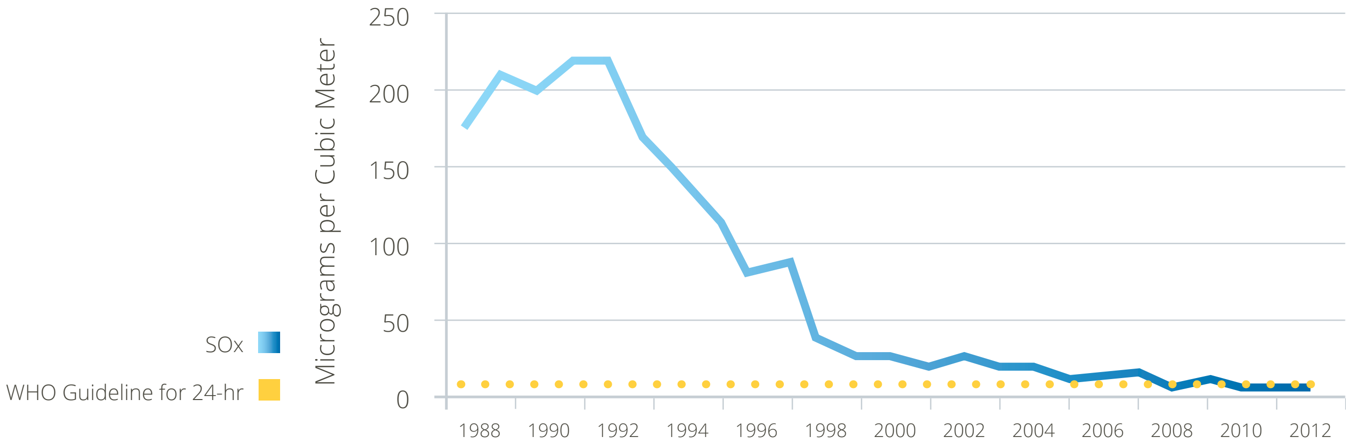
Second, as shown in Figure 4, SO_2 concentrations also began an immediate decline in the early 1990s. By the end of the 1990's SO_2 had fallen nearly 90%, but the annual average concentration remained above the WHO standard daily average of 10 μg/m^3. The concentrations have continued to decline and were approximately 5 μg/m^3 in 2011 and 2012.

28 S. Icecik, U. Im, "Air Pollution in Megacities: A Case Study of Istanbul," in Air Pollution – Modeling, Monitoring and Health, InTech, Ed. M. Khare, 2012, p. 92.29 A. Durmayaz, et al., "An application of the degree-hours method to estimate the residential heating energy requirement and fuel consumption in Istanbul," Energy 25 (2000), p. 1255.

30 E. Verdeil, et al., "Governing the transition to natural gas in Mediterranean Metropolis: The case of Cairo, Istanbul and Sfax (Tunisia)," Energy Policy 78 (2015), pp.238-240.

31 OECD, Environmental Performance Reviews, Turkey 1999, p.71.

Figure 4: Istanbul Annual Average SO2 Concentrations 1988-2012



Source: IGDAS

Levels of other pollutants – NO_2, PM, and Ozone – remain elevated, largely due to the increased traffic in Istanbul over the past twenty years. But the concentrations of these pollutants are lower than they would have been had Istanbul not engaged in the aggressive measures to promote fuel switching.[32]

The experience in Istanbul shows how long-term planning is essential to deploy the necessary infrastructure to support emissions reduction strategies. IGDAS was formed in the late 1980s but it took 25 years to provide near-universal access to natural gas for Istanbul residents. Istanbul also demonstrates that important gains in emissions reductions can be achieved relatively quickly, even before the full infrastructure network is deployed, as the combination of eliminating the dirtiest coal and beginning fuel-switching to natural gas produced the biggest gains in the early years of the policy.

32 S. Icecik, U. Im, "Air Pollution in Megacities: A Case Study of Istanbul," in Air Pollution – Modeling, Monitoring and Health, InTech, Ed. M. Khare, 2012.

33 Toronto Public Health. "Path to Healthier Air: Toronto Air Pollution Burden of Illness Update. Technical Report," 2014, p. 1, available at: http://www1.toronto.ca// City Of Toronto/Toronto Public Health/Healthy Public Policy/Report Library/PDF Reports Repository/2014 Air Pollution Burden of Illness Tech RPT final. pdf, p.1. The Ontario Medical Association had published an influential report in 2000, which estimated that province-wide the health impacts of ozone and PM2.5 would contribute to 1,900 premature deaths and 9,800 hospitalizations in Ontario in 2000. IISD, "The End of Coal: Ontario's coal phase-out," 2015, p. 11, available at: https://www.iisd.org/sites/default/ files/publications/end-of-coal-ontario-coal-phase-out.pdf.

TORONTO: Province-Wide Coal Phase-out

While air pollution, unlike GHG emissions, has predominantly local causes and impacts, it can still spread over wide areas that span multiple governmental jurisdictions. Toronto faced this challenge in addressing its urban air quality problems.

In 2004, Toronto Public Health estimated (based on 1999 data) that air pollution in the city contributed to 1,700 premature deaths and 6,000 hospitalizations per year.[33] In 2014, Toronto Public Health estimated that improved air quality over the subsequent decade (based on 2009 data) resulted in premature deaths and hospitalizations being reduced to 1,300 and 3,550 respectively.

These improvements in the health statistics were based on improvements in air quality in Toronto over the first decade of this century: SO2 went down 79% and NOx went down 36% from 2000- 2011; CO dropped 78% from 2001-2011; and PM2.5 dropped 30% from 2003-2011.

The air quality improvements were driven by reductions in emissions in Toronto, Ontario, and the U.S. Great Lakes states that are substantial sources of upwind pollution for Toronto and Ontario. Toronto Public Health estimated in 2014 that 51% of the premature deaths and 45% of the hospitalizations were attributable to sources outside of Toronto. [34]

As with the previous case studies, the air quality improvements in Toronto were driven by a variety of policies, but Toronto's story is unique in that a key policy was the decision by Ontario to eliminate coal from its electricity generation.[35] The Toronto Board of Public Health, on several occasions in the early 2000s, advocated for converting Ontario's coal-fired generators to natural gas.[36] The political support for such a policy extended beyond Toronto to much of the rest of Ontario. Concerns about the health impacts of air pollution were a key driver of the move to phase out coal.

34 Toronto Public Health. "Path to Healthier Air: Toronto Air Pollution Burden of Illness Update. Technical Report," 2014, p. 3.

35 IISD, "The End of Coal: Ontario's coal phase-out," 2015, p. 11.

36 Toronto Public Health. "Path to Healthier Air: Toronto Air Pollution Burden of Illness Update. Technical Report," 2014, p. 20.

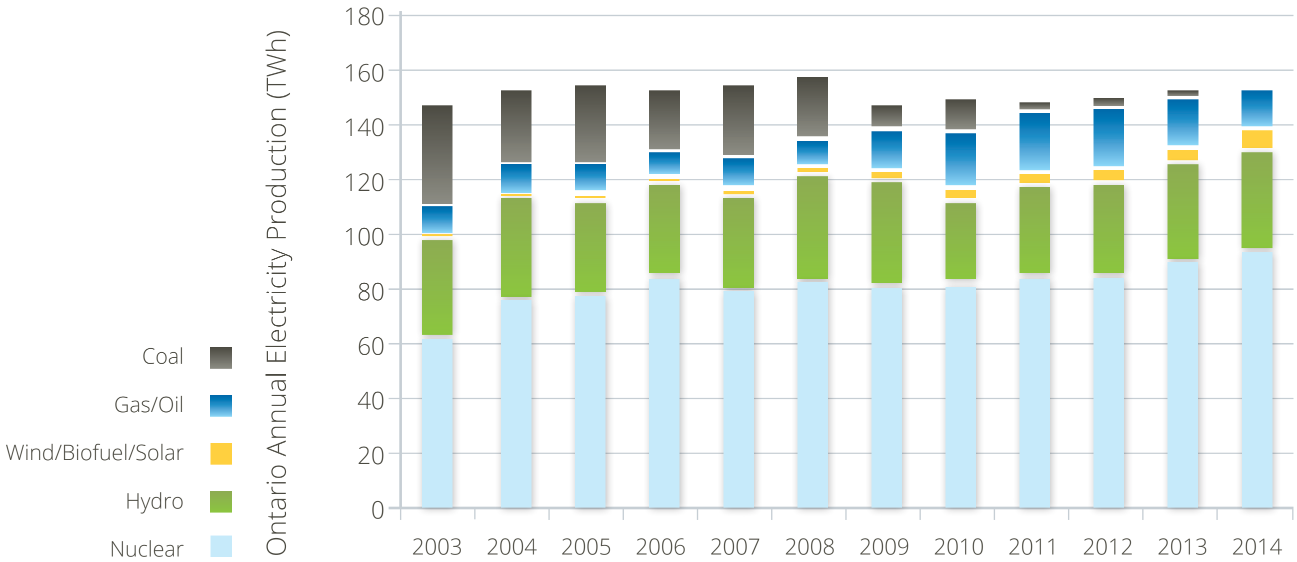
37 IISD, "The End of Coal: Ontario's coal phase-out," 2015, p. 5.

Several factors made such a phase-out easier in Ontario than it might be in other jurisdictions. First, in 2000 when the phase-out movement was gaining steam, coal-fired generation only accounted for approximately 25% of Ontario's energy supply. Nuclear and hydro provided most of the remainder. Second, all of the coal was imported to the province, meaning there were fewer job impacts from and less intense political opposition to a phase-out. Finally, Ontario owned the generation facilities, meaning it could make the decision to phase out coal and absorb any extra costs. [37]

When the plan to phase out coal was first considered in 2001-2002, the focus was on replacing the lost generating capacity with renewables. Concerns about cost and reliability of supply led the Ontario government to commission a feasibility study. In 2005, that study recommended a combination of expanded nuclear generation and additional natural gas generation as the most cost-effective way to phase out coal and reduce emissions. [38]

The phase-out began with the shut down of a generating station directly southeast of Toronto in 2005. From 2010 to 2013, three more coal plants were taken offline and the last plant in the province stopped using coal in 2014. Over this time period, coal generation was replaced by increased generation from natural gas, expansion of nuclear generation, and, in recent years, the deployment of renewables. [39]

Figure 5: Fuel Mix in Ontario's Electricity Sector 2003-2014



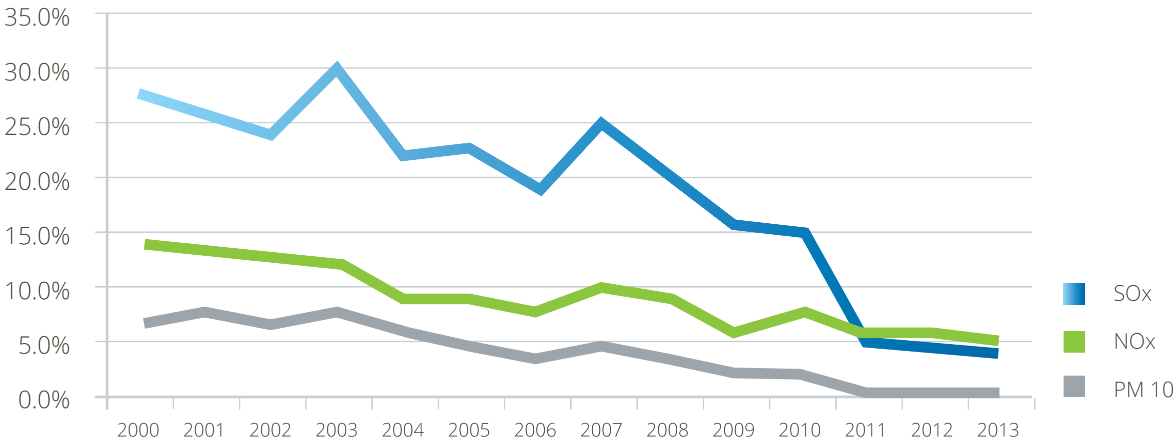
SOURCE: Ontario Independent Electricity System Operator; IISD

38 Ibid., p. 11.

39 Ibid., p.4.

The emissions reductions from the electricity sector during this time were substantial. Between 2004 (the year before the first coal plant was retired) and 2013, PM10, SO2, and NO2 emissions from electricity generation declined by 90%, 91%, and 65%, respectively. Phasing out coal in electricity generation was the most significant among the many policies Toronto and Ontario adopted during this time frame to reduce local air pollution. In 2013, the Ontario electricity sector emitted less than 4 % of the SOx in the province, down from around 30% a decade earlier. NOx and PM10 emissions also dropped sharply (from 12 to 5% and 7 to less than 1%, respectively).

Figure 6: Emissions from Electricity Generation as a Percent of Total Ontario Emissions



SOURCE: Canada National Pollutant Report Inventory, Author's Analysis
(PM10 emissions exclude open sources such as road dust, agriculture, and construction)

The coal phase-out in Ontario was a key part of improving Toronto's air quality over the past decade. The unique circumstances in Ontario allowed it to pursue a strategy that might not be possible everywhere – a complete coal phase-out. It nonetheless highlights the benefit of flexibility in pursuing a fuel-switching strategy. The decommissioned coal capacity has been replaced by increased capacity from nuclear, natural gas, and renewables. The ability of additional natural gas capacity to be built and deployed rapidly helped accelerate the timeframe for, and reduce any impact from, the coal phase-out. This allowed emissions reductions to begin earlier without having to wait for the additional capacity from nuclear and renewables to become available.

BEIJING: Aggressive Policies Aimed at Tackling Some of the Worst Urban Air Pollution in the World

The problem of air pollution is widespread throughout Chinese cities, but is particularly severe in and around Beijing.[40] For years, the exact scope of the air quality problems was difficult to assess because there was not sufficient publicly available monitoring data. Beginning around the time of the Beijing Olympics in 2008, the U.S. Embassy in Beijing began publicizing daily measurements of local air quality. After initially resisting the publication of this information, in 2012 the Chinese government began putting in place a system of air quality monitoring throughout the country.

The monitoring has highlighted the poor air quality in Chinese cities. The average $PM_{2.5}$ levels in China's urban areas are often 6 times higher than WHO standards. This level of air pollution is estimated to contribute to approximately 1.2 – 1.6[41] million deaths per year in China. The high end of this range would mean air pollution is responsible for 1 out of every 6 deaths in China.

Around 50% of this air pollution burden is attributable to coal.[42]

These estimates of the impact of air pollution are from years after which China had already made progress in improving urban air quality. For example, China reduced sulfur dioxide concentrations by more than 50% in many of its major cities by utilizing an emissions trading system.[43] Also, from 2006-2010, China closed 76.8 gigawatts of the most polluting coal-fired power plants.[44] Despite this progress, pollution continued to worsen as the economy and coal use expanded.

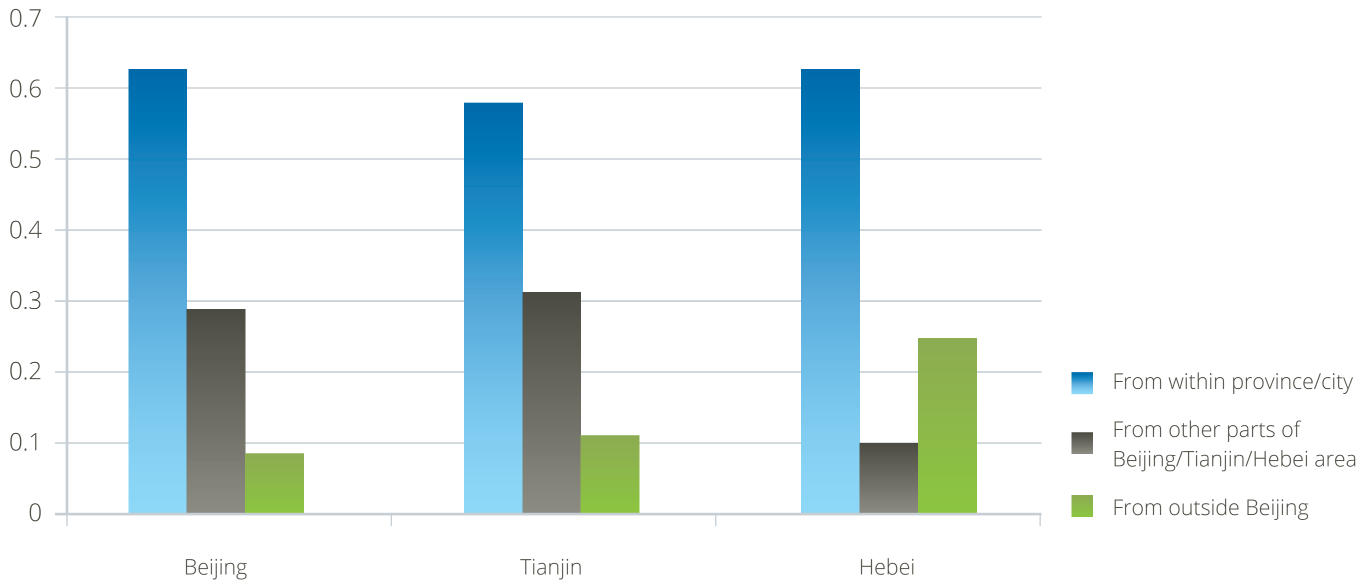
As with Toronto, air pollution in the Beijing area highlights the need for regional coordination. Approximately 40% of Beijing's $PM_{2.5}$ pollution comes from outside of Beijing, primarily from Tianjin and Hebei areas. (Figure 7) On high haze days, it is estimated that up to 90% of Beijing's $PM_{2.5}$ pollution may originate elsewhere. (Some of Beijing's pollution has even contributed to air quality problems in California.[45])

40 R. Rohde, R. Muller, "Air Pollution in China: Mapping of Concentrations and Sources," PLoS ONE 10(8), 2015. Available at: http://berkeleyearth.org/wp-content/uploads/2015/08/China-Air- Quality-Paper-July-2015.pdf.

41 R. Rohde, R. Muller, "Air Pollution in China: Mapping of Concentrations and Sources," PLoS ONE 10(8), 2015.

42 A 2014 study estimated that coal combustion contributed to 670,000 premature deaths in 2012 in China. L. Jing, "670,000 smog-related deaths a year: the cost of China's reliance on coal," South China Morning Post, Nov. 4, 2014, available at: http://www.scmp.com/news/china/article/1632163/670000-deaths-year-cost-chinas-reliance-coal.

Figure 7: Origin of $PM_{2.5}$ Pollution in Beijing/Tianjin/Hebei Area, 2010



SOURCE: Paulson Institute, Climate Change, Air Quality and the Economy: Integrating Policy for China's Economic and Environmental Prosperity

Recognizing the need to improve urban air quality, China has promulgated a number of new laws and regulations in recent years. The Beijing-Tianjin-Hebei region has been identified as one of the priority areas in which China is seeking to make the most substantial improvements. In 2013 and 2014 the average $PM_{2.5}$ levels in that area were more than 10 times greater than the WHO recommended levels.

The revised laws and regulations contain several key initiatives, many of which involve particularly ambitious goals for the most polluted areas, such as the Beijing-Tianjin-Hebei region:[46]

- China has toughened its ambient air quality standards and emissions limits. For example, in 2012-2013, for the first time, the government issued standards for PM2.5 levels.
- China has increased the enforcement powers of its environmental agencies, which had previously been criticized for lax enforcement;

43 Bloomberg Brief, "China's Smog: Clearing Skies Without Killing Growth," 2015, p.7, available at: http://www.bloombergbriefs.com/content/uploads/sites/2/2015/05/China-Smog.pdf.

44 Ibid.

45 J. Lin, et al., "China's international trade and air pollution in the United States," Proceedings of the National Academy of Science, 111(5), 2014, pp. 1736-1741.

46 Paulson Institute, "Climate Change, Air Quality and the Economy, Integrating Policy for China's Economic and Environmental Prosperity," 2015, available at: http://www.paulsoninstitute.org/wp-content/uploads/2015/06/Climate-Change-Air-Quality-and- the-Economy-Integrating-Policy-for-China's-Economic-and-Environmental-Prosperity.pdf.

- Chinese leadership has made achieving the new environmental standards a political priority, such that there is more incentive for local officials to take actions that may adversely impact GDP numbers by reducing excess production capacity in order to improve environmental measures;[47]
- China has adopted a variety of policies and goals to promote increased generation from renewables, increased supply and infrastructure to distribute natural gas, and increased nuclear generation.[48]

The current goal for the Beijing-Tianjin-Hebei region is to reduce $PM_{2.5}$ levels 25% by 2017. The specific action plan includes decommissioning the highest emitting vehicles, prohibiting construction of any new heavy polluting industries, and replacing coal with renewables and natural gas.[49] The plan also provides that local officials will be judged not only by the usual quantitative performance measures (such as meeting $PM_{2.5}$ standards), but also on specific initiatives they undertake, such as fostering cleaner production or green buildings.[50] The goal is to reduce coal consumption in Beijing by 57% by 2017, and in the Beijing-Tianjin-Hebei region overall by 16%.[51] In early 2015, the government announced that the last of Beijing's four coal power plants would shut down in 2016. The plan is to replace the generating capacity with four new natural gas power plants that would have 2.6 times greater capacity.[52]

There are several factors that make it difficult to judge how effective these policies will be. First, the policies and goals have only recently been developed and are still in early stages of implementation. Second, air quality monitoring data for major Chinese cities only dates back a few years (to 2012 or 2013). Third, lack of enforcement of environmental measures has been a problem previously. Nonetheless, there are signs that the air in Beijing may be improving.

During the first half of 2015, Beijing's PM2.5 levels decreased. A preliminary analysis from the Paulson Institute indicates that the decrease is not attributable to natural factors such as having fewer cold days requiring heating or a change in wind patterns. (Figure 8).

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47 E. Spegele, "China War on Pollution Benefits From Economic Slowdown," Wall Street Journal, July 20, 2015, available at: http://www.wsj.com/articles/china-war-on-pollution-benefits-from- economic-slowdown-1437410558.

48 Paulson Institute, "Climate Change, Air Quality and the Economy, Integrating Policy for

China's Economic and Environmental Prosperity," 2015, pp. 16-17.

49 Ibid., p. 20.

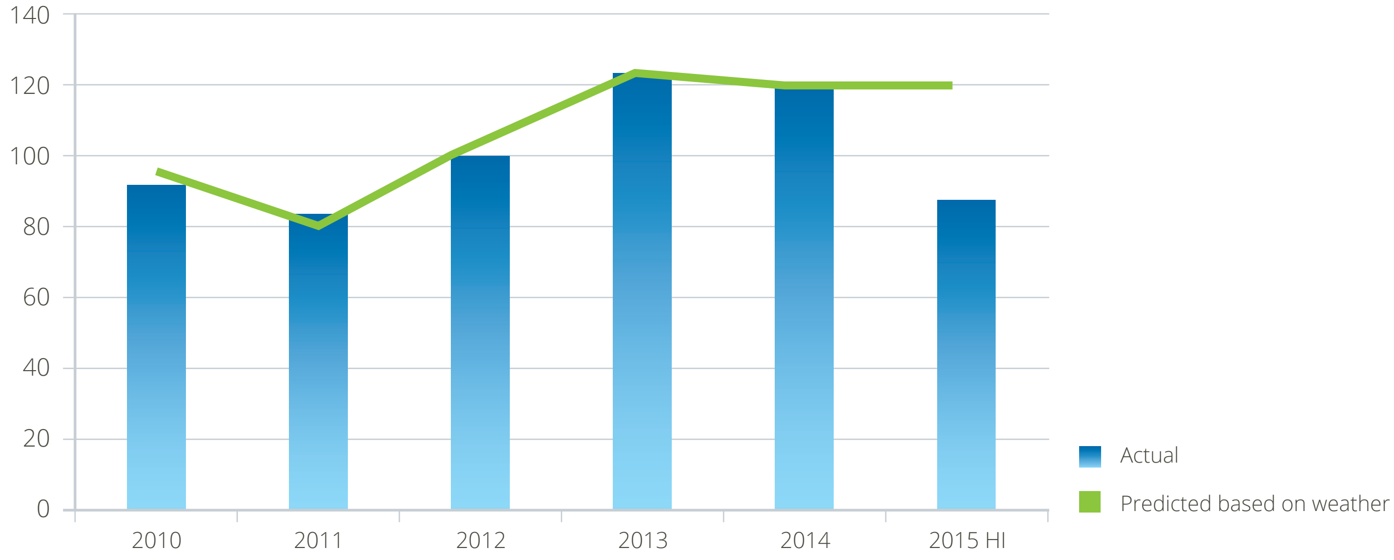
50 Ibid., p. 20.

51 Ibid., p.51.

52 Bloomberg, "Beijing to Close All Major Coal Power Plants to Curb Pollution," Mar. 23, 2015, available at: http://www.bloomberg.com/news/articles/2015-03-24/beijing-to-close-all-major-coal- power-plants-to-curb-pollution.

53 A. Hove, et al., "Beijing Blue Skies, Is This the New Normal?" Paulson Institute, June 24, 2015, available at: http://www.paulsoninstitute.org/paulson-blog/2015/06/24/beijing-blue-skies-is-this- the-new-normal/.

Figure 8: Beijing Actual PM2.5 Levels Compared to Predicted Levels Based on Weather



SOURCE: Greenpeace; Paulson Institute, "Beijing Blue Skies – Is This the New Normal?"

It is too early to tell exactly what is driving the improved air quality, but there are several trends that could be contributing to reduced emissions. First, from January to April coal consumption in China was down 8% compared to the previous year.53 Second, production from some particularly polluting industrial sectors, such as steel, were flat or down through the first four months of the year.[54] Whether the emissions reductions are a result of the pollution control policies, a general economic slowdown in China, a continued restructuring of the Chinese economy away from heavy industry, or some other factor will likely not be known for several years.

54 Ibid.

CONCLUSION

Addressing urban air pollution is one of the most important environmental/health challenges the world currently faces. With a growing global urban population, particularly in middle-income and developing countries, the challenge of addressing this air pollution problem will only increase.

Many of the policies that can address urban air pollution also reduce GHG emissions (and vice- versa). Recognizing the connections between the health-damaging pollutants and climate-damaging pollutants can help maximize the benefits and efficiency of policy actions.

The city case studies examined in this paper demonstrate that tackling air pollution does not have to mean sacrificing economic growth and the expansion of energy services. New York, Istanbul, and Toronto each faced different pollution challenges. Each was able to enact a comprehensive set of policies – including promoting fuel switching—to make real progress in reducing the air pollution burden without harming economic growth. In the Beijing area, which currently faces some of the worst urban air pollution in the world, there are early hopeful signs of progress, although uncertainty remains about what exactly is driving improved air quality. Continuing to examine and monitor the impact of policies in these cities can help define a path for other developing cities and countries to meet their air quality and climate goals.

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