STRONGER MARKETS, CLEANER AIR

CLIMATE CHANGE, AIR QUALITY AND THE ECONOMY

Integrating Policy for China's Economic and Environmental Prosperity

June 2015

保尔森基金会
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More integrated policy could allow China to deliver clear skies, like this Beijing sunset, without damaging the economy.

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Cover photo: A coal power station at night in China

Preface

Dear Reader,

We are pleased to launch the Paulson Institute Climate Change and Air Quality Program's activities for 2015 with this background report, Climate Change, Air Quality and the Economy: Integrating Policy for Economic and Environmental Prosperity.

Air quality and climate change are two of the most important issues facing China today—and both issues must be addressed in the context of the country's economic agenda. At the same time, China's economic growth strategy must take key environmental issues into account if that growth is to be truly sustainable, in all senses of the word.

The Paulson Institute's Climate Change and Air Quality Program believes that China can and should address air quality, climate change and economic growth together, with integrated policy and regulatory strategies. In this background paper, we demonstrate the urgency of China's air quality and climate issues, make the environmental and economic case for addressing these issues together rather than in separate and disconnected policies and argue that there are ways in which markets can be strengthened to more efficiently allocate resources within the country to lower emissions.

While this paper is a scene-setter rather than a set of specific policy recommendations, it kicks off a series of more detailed papers to be released throughout 2015 focused on the theme of strengthening markets to create cleaner air, looking at policies related to power sector reform, electric power demand response, carbon emissions trading and building energy disclosure.

Ultimately, the Climate Change and Air Quality Program believes that economic prosperity and a clean environment go hand in hand. Cities like Los Angeles, which had smog levels in the 1950s similar to Beijing's today, have demonstrated that it is possible to clean the air while promoting economic growth. While it took L.A. and the surrounding region decades to fully address these environmental issues, China has the benefit of that policy experience, plus access to newly commercialized technologies including low-carbon energy sources, to overcome its environmental issues in less time while also creating millions of new jobs.

Over the coming months, the Climate Change and Air Quality Program will be researching and publishing recommendations on policy and technology mechanisms to support China, and especially the Beijing-Tianjin-Hebei region, to achieve its economic and environmental goals. We look forward to collaborating with industry executives, policymakers, and other experts who care about China and its role in the world as we start along this journey.

Kate Gordon
Vice Chair, Climate and Sustainable Urbanization, Paulson Institute

Elle Carberry
Managing Director, China Office and Climate Change & Air Quality Program, Paulson Institute

June 2015

At the Climate Change and Air Quality Program of the Paulson Institute, we believe that China can address its air quality and climate issues while simultaneously pursuing economic prosperity.

Dispatching coal plants in order of efficiency instead of allocating each an equal number of hours would reduce emissions while saving money.

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At the Climate Change and Air Quality Program of the Paulson Institute, we believe that China can address its air quality and climate issues while simultaneously pursuing economic prosperity.

At the Climate Change and Air Quality Program of the Paulson Institute, we believe that China can address its air quality and climate issues while simultaneously pursuing economic prosperity. This proposition is being tested today in China, where economic growth has long been predicated on investment in heavy industries that are central contributors to the country's current air quality and climate issues. We believe there is a different way forward in China, and particularly in the heavily industrialized Beijing-Tianjin-Hebei (also known as Jing-Jin-Ji or JJJ) region, that will allow the country to address air quality and mitigate climate change while continuing to promote economic growth.

Both climate change and air quality are urgent problems that China needs to address immediately, as both are directly affecting the health and welfare of China and its economy. The Paulson Institute recommends addressing these issues together, in part through more focus on energy efficiency and fuel-switching away from coal. Taking this approach would also help address other urgent policy priorities related to energy, innovation and economic transformation. For example, increased energy efficiency not only helps reduce air emissions, it also reduces water consumption by power plants and coal mines.

This paper provides a brief background and literature review on the current state of air quality, carbon emissions and environmental policies in China. The paper aims to provide context to policymakers and advocates from both the environmental and the financial sectors on the urgent question of how the country can simultaneously accomplish its economic and environmental goals. In the months to come, the Paulson Institute's Climate Change and Air Quality Program will publish papers that dive deeper on specific sectors of the economy, focusing in particular on the Jing-Jin-Ji region as a key demonstration area for a broader sustainable economic growth strategy.

Double impact: In China, air pollution is a highly visible problem relative to climate change, and the two issues are often thought of separately both in terms of urgency and solutions. Putting more focus on energy efficiency and fuel-switching away from coal would lead to reduction of conventional air pollutants as well as greenhouse gas emissions.

EXECUTIVE SUMMARY

Climate change and air pollution are both urgent problems for China today. Air pollution is a serious challenge for China, with most large Chinese cities experiencing levels of pollution far above those considered acceptable by international health experts. For example, only eight of China's 74 largest cities met national standards for air quality in 2014[1]. China also faces enormous short- and long-term risks from climate change, including increased extreme weather events, more frequent and longer droughts affecting the country's food supply and rural economy. In addition, China has as many as 60 million people living in low-lying coastal areas that are vulnerable to flooding – more than any other country.[2]

Economic and health data confirm the urgency of air pollution and climate change in China: Ambient air pollution from coal consumption caused an estimated 670,000 excess deaths in China in 2012, according to a 2014 study by Tsinghua University and Peking University.[3] Increased mortality and illness caused by pollution leads to estimated annual economic losses of between US$ 100 billion and US$ 300 billion.[4]

To fully address both climate change and air quality, China must reduce multiple emissions sources in parallel. Scientific analysis of air pollution sources, including particulate matter under 2.5 micrometers in aerodynamic diameter (PM2.5), nitrogen oxides (NO_X) and sulfur dioxide (SO_2), shows that air pollution is a highly complex issue. While coal is the largest contributor to ambient PM2.5 by fuel, and industry is the largest contributor by sector, the complex air chemistry and China's changing weather conditions mean that all sectors play a contributing role at different times and seasons. Addressing these pollutants separately through smokestack and tailpipe emissions technologies (sometimes called "end-of-pipe solutions") is insufficient for several reasons. First, as a quantitative analysis by Ma Jun, now chief economist at the People's Bank of China, has shown, using the maximum technically achievable emissions control technologies for these pollutants, combined with other policies now underway, would still be insufficient to reach the government's target for ambient PM2.5 of 30 micrograms per cubic meter by 2030.[5] Second, controlling individual pollutant emissions often increases emissions of other pollutants.[6] In some cases, as with sulfur and ammonia, reducing emissions of one pollutant (such as sulfur) without changing emissions of another (such as ammonia) can also lead to increased formation of other pollutants.[7] Third, implementation of emissions controls is costly and tends to lock in present production patterns, whereas policies that jointly control all emissions categories—such as energy efficiency or non-fossil energy sources—often better optimize investment for the long-term.

China can best address climate change and air quality together by focusing its policy initiatives in two specific areas: energy efficiency and fuel-switching away from coal. Emissions policy and enforcement

STRONGER MARKETS, CLEANER AIR

In summer 2015, the Paulson Institute's Climate Change and Air Quality Program will publish a series of papers on the role that markets can play in China in encouraging lower emissions and greater energy efficiency.

POWER SECTOR:
Deepening Reform to Reduce Emissions, Improve Air Quality and Promote Economic Growth

DEMAND RESPONSE:
A High-Reward Solution to Reduce Energy Use, Emissions and Costs

BUILDING ENERGY DISCLOSURE:
How Energy Reporting for Buildings Can Reduce Costs and Improve Efficiency

CARBON EMISSIONS TRADING:
Rolling Out a Successful Carbon Trading System

China has as many as 60 million people living in low-lying coastal areas that are vulnerable to flooding – more than any other country.

have typically focused on implementing industry-specific end-of-pipe solutions, such as NO_X emissions standards for power plants or tailpipe standards for automobiles. These solutions often address only one or a few pollutants at a time; they can lock in existing energy production patterns; and they may even lead to higher emissions of other pollutants. In contrast, policies that promote energy efficiency and fuel-switching away from coal accomplish many policy goals while reducing emissions across all pollutants. Often energy efficiency investments or operational changes have low cost or actually save money—for example, LED lighting and better building insulation pay for themselves in cost savings, while simply changing the way existing power plants are utilized to favor cleaner, more efficient units could save China billions of RMB annually.[8]

In addition to policy efforts, market forces can play an important role in efficiently allocating energy resources to reduce emissions, in line with the goals of the Third Plenum of the 18th Party Congress. Specific areas of focus for the Climate Change and Air Quality Program include:

Power sector: Dispatching coal plants in order of efficiency instead of allocating each an equal number of hours would reduce emissions while saving money. Changing the rules of how power plants are dispatched can also increase the amount of renewable energy reaching the grid, often without adding costly new power lines.

Cities by the sea: As many as 60 million people—more than in any other country—are living in China's low-lying coastal areas, which are vulnerable to flooding.

Electricity demand response: Demand response refers to increasing or reducing electric power use to meet the needs of the grid—often done to reduce peak load, but also to shift load to times when wind or solar are providing excess energy. Electric utility demand response programs helped Southern California to retire the San Onofre nuclear power plant with little additional investment in new generation.[9]

Carbon emissions trading: Emissions trading programs in the U.S. and EU have shown how such systems can enable policymakers to achieve long-term emissions reduction goals while giving businesses and other market participants flexibility on how to reduce emissions cost-effectively. China is already piloting emissions trading and working toward introduction of a national carbon emissions trading system.

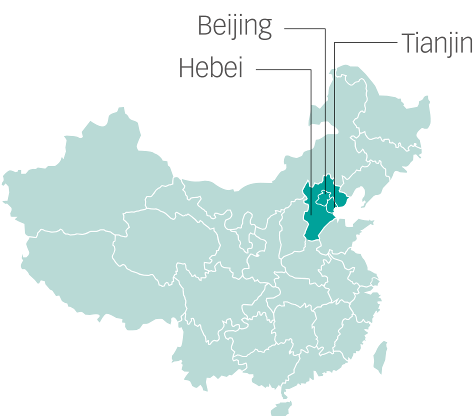
Building energy disclosure: Building energy disclosure—requiring building owners to disclose the energy use of residential, commercial or government buildings on a publicly-available website—is a new policy experiment being tried in the EU and in certain U.S. cities such as New York, Austin and Seattle. It appears to offer policymakers new information to make decisions about how to promote energy upgrades for buildings, while also providing tenants and building owners with valuable data about how their own building compares to its peers.

Economic prosperity and a clean environment go hand in hand: Cities like Los Angeles, and in fact the entire state of California under its sweeping carbon trading system, have demonstrated that it's possible to address local air quality issues and more global carbon emissions while growing the economy and maintaining quality of life. Furthermore, aggressive policies to promote lower emissions, low-carbon energy generation and energy efficiency have contributed to innovations and development of new industry in both the U.S. and China—a process that creates jobs and transforms the economy toward higher technology and better quality growth. Finally, the dramatically declining cost of renewable energy systems, particularly solar and wind, makes these switches more economically viable than they were even five years ago. While some cities in the U.S. and Europe took decades to clean up their air and transform their economies, China can use already commercial technologies—including emissions control technology, renewable energy, energy efficient building technology and electric vehicles—to overcome its air quality and climate change problems while creating millions of new jobs.

> China can best address climate change and air quality together by focusing its policy initiatives in two specific areas: energy efficiency and fuel-switching away from coal.

BACKGROUND: URGENCY OF ADDRESSING AIR QUALITY AND CARBON EMISSIONS IN CHINA

Air pollution and climate change are devastating for China's economy and the health of its citizens



Ambient air pollution resulting from coal consumption caused an estimated 670,000 excess deaths in China in 2012 according to a 2014 study by Tsinghua University and Peking University.

1.1 Introduction: Economic consequences of air pollution and climate change

As a developing country, China has long struggled to balance the need for rapid economic development with environmental protection, but until recently arguments for faster action on air and greenhouse gas emission reductions had received little attention. China's position on climate change has been that developed countries bear most of the responsibility,* and China as a developing-world nation lacks the financial and technical capability to take the lead.[10] In the past three years China's views and actions have begun to shift, especially on air quality. Following a several-week-long period of heavy haze in January 2013 in Beijing, the general public has become much more aware of the negative consequences of air pollution, and the government has made efforts to increase transparency of pollution data and also address air pollution and climate change through better laws, policies and enforcement. The government is taking more aggressive action on climate change as well, evidenced by the joint China-U.S. agreement on climate change in November 2014, in which China for the first time announced its intention to peak absolute carbon emissions around 2030.

This chapter provides a brief overview of what China and international researchers have learned about the cost and immediacy of air pollution and climate change in China. Ultimately, the present urgency of both problems is one of the major reasons why it makes sense for China's policymakers to address climate change and air quality in an integrated fashion. Other factors driving the need for policy integration, such as the sources of emissions that contribute to climate change and air quality problems, and the need for greater attention to policies that address both problems together, are discussed in the next section.

1.2 Air pollution has immense health consequences

Numerous Chinese and international studies have concluded that air pollution in China is deadly, and on a vast scale. In many cases, the numbers are so large that they are difficult to fully grasp—on a national scale, the toll is greater than the most deadly earthquakes and floods. For example, a 2013 Global Burden of Disease study published in *The Lancet* suggested air pollution resulted in 1.2 million premature deaths in China in 2010.[11] The study noted that particulate matter pollution was the fourth leading risk factor for disability-adjusted life years, with a total impact only moderately lower than

* China is the world's largest emitter of greenhouse gases and is set to surpass the U.S. as the largest cumulative emitter of carbon dioxide since 1990. Its per capita emissions are above those of Europe but below those of the U.S.

that of smoking, high blood pressure and poor diet.[12] A 2013 study of mortality north of the Huai River, the boundary of China's coal-fired central heating region, found that particulate matter north of the river was significantly higher, reducing life expectancy by 5.5 years on average.[13]

Chinese studies have shown similar results. Ambient air pollution resulting from coal consumption caused an estimated 670,000 excess deaths in China in 2012 according to a 2014 study by Tsinghua University and Peking University.[14] Some 355,000 of these excess deaths were in the heavily polluted North China Plain. The study's authors note that the number of chronic illnesses to which pollution contributes is likely much higher.

Chinese public health experts agree that air pollution is one of the primary killers in China. According to Yang Wei, Director of the National Natural Science Foundation of China and member of the National People's Congress (NPC) Standing Committee, lung cancer is the top killer of men and the second largest killer of women in China; pollution is a key contributor, along with smoking.[15] According to Aaron Cohen of the Health Effects Institute, a 30 microgram/m^3 long-term increase in PM2.5 levels is associated with a 1-5 year decrease in lifespan, and each 10 microgram/m^3 increase is associated with an annual increased mortality rate of 0.25-0.6%. Even with these high uncertainty levels, the impact of increased pollution on mortality is clear.[16]

The human health impact of air pollution is more complex than simple mortality numbers reflect. PM2.5 haze can cause respiratory and cardiovascular disease, stroke, as well as cancer.[17] Studies released in 2015 showed that air pollution in Beijing lowers the birth weight of children.[18] Air pollution has also been shown to affect the physical development of children as well as lead to slow cognitive impairment in adults.[19] Air pollution is linked to the so-called "Beijing Cough," according to Song Guojun, Director of Environmental Policy and Environmental Planning Institution of Renmin University, who also noted the connection between air pollution and respiratory disease.[20]

China will need to realize major cuts in pollution levels in order to alleviate these health impacts. The 2013 Global Burden of Disease study suggested that reducing PM2.5 to 35 micrograms/m^3—a reduction of 50% versus current levels for most of China and 67% lower than current levels in the Jing-Jin-Ji region[21]—would reduce annual excess mortality from today's number of over 670,000 deaths per year to 519,000 such deaths. Reducing all the way down to 15 micrograms/m^3 would still result in excess mortality of 236,000 deaths per year—suggesting that modest reductions in air pollution are insufficient to address this major national health issue.[22]

1.3 **Air pollution is holding back the Chinese economy**

The economic cost of pollution is rising, whether considering health effects, lost productivity, or damage to ecosystems. According to estimates from the World Bank's China 2030 report published in 2012, increased mortality and illness caused by pollution leads to estimated annual economic losses of between US$ 100 billion and US$ 300 billion.[23] In 2011, Greenpeace estimated that public health-related economic losses for the period between 2005 and

Health hazards: Ambient air pollution resulting from coal consumption caused an estimated 670,000 excess deaths in China in 2012, according to a Tsinghua University study.

PM2.5 haze can cause respiratory and cardiovascular disease, stroke, as well as cancer.

2010 caused by air pollution surpassed RMB 600 billion.[24]

Public health is not the only cost of pollution. In 2010, the Ministry of Environmental Protection's Academy of Environmental Planning estimated that pollution causes China to suffer RMB 1.1 trillion in direct economic losses each year, or 2.5% of GDP in 2010. Including indirect losses such as ecosystem damage to forests, wetlands and grasslands raises the estimate to RMB 1.54 trillion, or 3.5% of 2010 GDP.[25] Other impacts range from reduced agricultural output to business interruptions, worker absences, school closures, and lower real estate prices. Reduced sunlight due to haze and fog in the North China Plain may reduce crop yields by 30%, or even more when estimates include the effect of ozone, according to a 1999 study.[26] Worker absences in China due to air quality-related health problems lead to reduced productivity.[27] The same is true for school suspensions.[28] A 2012 Peking University study measured the impact on air pollution on local real estate prices in China, finding a significant reduction in real estate prices in China due to smog.[29]

Many of these negative impacts of pollution can be traced back to coal, which is the largest contributor to air pollution in China.[30] A 2014 study, "The True Cost of Coal" by Peking University and Tsinghua University, found that each ton of coal consumed in 2012 cost the country approximately RMB 260 due to damage to the environment and public health as measured by excess mortality from such illness as cardiovascular disease, lung disease and stroke.[31] This estimate did not include the negative economic impacts of chronic illnesses, which are more difficult to estimate. The same study estimated that current PM2.5 levels cost the Chinese economy RMB 530 billion per year in health care costs.[32]

The economic cost of pollution is rising, whether considering health effects, lost productivity, or damage to ecosystems.

Health effects and health care costs, lost productivity, wasted resources on air filters and masks, road traffic and air travel disruptions, interruptions in work and schools, lower real estate values and tourism revenue—all represent real and likely increasing costs due to air pollution. If China invests in a cleaner environment, the economic benefits will be huge. In addition to the direct environmental benefits, the economy will thrive from healthier workers and students.

THE ECONOMIC COST OF POLLUTION

¥ 1.1 trillion

Pollution causes RMB 1.1 trillion in direct economic losses each year

1.4 **China is uniquely vulnerable to climate change**

Just as air pollution is harming China today, so increasingly will climate change. With its low-lying cities, water resources, and arable land—combined with a low GDP per capita—China is one of the most sensitive countries to the impacts of climate change. In addition, China's industrial development to date has relied on high-emitting industries. Keeping the country's economic growth and wealth improvement on track, while also addressing its serious short- and long-term environmental issues, is one of the greatest social and economic challenges of the 21st century.

In 2007, China fed more than 22% of the earth's population on just 9% of the earth's cultivated land,[33] which occupies just 13% of China's total land area.[34] Of these factors, water scarcity is one of the most prevailing issues limiting agricultural production. Water consumption in the agricultural sector reached 392 trillion cubic meters in 2013, or 63.4% of total water resources used nationwide that year, equivalent to 1.07 trillion cubic meters of water per day.

Industry, agriculture and changing climate have contributed to severe water shortages. According to government statistics, land area affected by drought has increased by a factor of five, and agricultural losses caused by droughts have risen by a factor of 18 since the 1950s.

Climate change is an increasingly urgent problem for China, especially given its rapid development and urbanization. The country's developed coastal areas face threats from flooding and natural disaster, while its food supply is at risk of drought, lower river runoff and climate change-induced natural disasters. Because of its geographic position, adapting to climate change will likely be costly and painful for China, and especially for its most economically vulnerable citizens—making it even more imperative for the country to take strong actions now to mitigate future climate impacts.

China's climate has already warmed significantly in the past half century. A study of daily temperatures across China from 1961 to 2007 found that the hottest days of the year saw a temperature increase of about 1 degree Celsius, while the coldest days recorded a temperature increase of 2-4 degrees Celsius—increases that resulted from human greenhouse gas emissions.[35]

Climate change in China will also exacerbate extreme weather events, such as droughts, storms and floods. According to Professor Xu Yinlong of the Chinese Academy of Agricultural Sciences, climate change has already resulted in worsening of super-typhoons and droughts. Droughts, severe snowstorms and super-typhoons have caused tens of billions of RMB in damage to crops and livestock, and have been associated with outbreaks of crop and livestock pests that lead to additional spending on pesticides.[36] China's most recent National Communication on Climate Change notes that land area affected by drought has increased by a factor of five and agricultural losses affected by droughts have risen by a factor of 18 since the 1950s.[37]

Droughts, severe snowstorms and super-typhoons have caused tens of billions of RMB in damage to crops and livestock, and have been associated with outbreaks of crop and livestock pests that lead to additional spending on pesticides.

China's coastal provinces, home to 40% of the nation's population and responsible for 56% of GDP, are at greatest risk from climate impacts, particularly from sea-level rise. China's local sea levels have been rising faster than the global average, at roughly 2.6 millimeters per year, compared to 1.7 millimeters per year globally.[38] Many of China's mega-cities are located in low-lying areas vulnerable to rising seas. Tianjin and Shanghai are two prominent examples: both have undergone rapid economic development and have reclaimed low-lying areas to construct massive new economic zones. A quantitative study of various coastal cities that combined city-provided data into a Coastal City Flood Vulnerability Index ranked Shanghai as most vulnerable overall to the effects of climate change-related coastal flooding, above such other cities as Manila in the Philippines and Dhaka in Bangladesh.[39] A similar study by the World Wildlife Fund (WWF) ranked Shanghai as less vulnerable than Manila or Dhaka, but projected that a 30 centimeter rise in sea levels by 2050 would flood half the city's land area.[40] The Shanghai Meteorological Association has also found that the Yangtze River Delta region, of which Shanghai is part, is likely to suffer more frequent and intense typhoons due to global warming.[41]

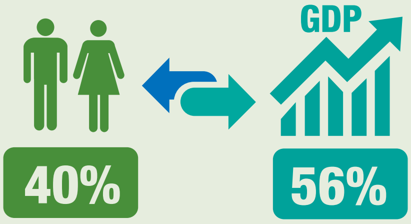
Shanghai and Tianjin are not alone: major coastal cities like Xiamen, Ningbo, Dalian and Shenzhen all have millions living in areas vulnerable to sea-level rise or flooding during storms. According to an analysis by Climate Central using a 2014 projection of local sea level rise to 2100, satellite data on elevation, and population data from LandScan, China has 40-60 million people living in low-lying coastal areas vulnerable to flooding, more than any other country. [42]

Keeping the country's economic growth and wealth improvement on track, while also addressing its serious short- and long-term environmental issues, is one of the greatest social and economic challenges of the 21st century.

Elsewhere, higher temperatures associated with climate change will likely accelerate water scarcity. Temperatures are rising more rapidly in the Tibetan plateau than elsewhere in China, leading to accelerated glacial melting, which is likely to reduce river flow among some of Asia's most critical river systems—the Yangtze River, for example, could see annual flow drop by 25% due to such changes.[43] Higher temperatures will also result in greater surface evaporation and less runoff.[44] Most of China's population lives in regions with water shortages and the country has only 25% of the world's average fresh water resources per capita.[45] In recent decades, rainfall has been increasing in South China and decreasing in North China, precisely the region with the most serious water shortages.[46] Both agriculture and urban populations will be affected by water shortages, as will the manufacturing and utility sectors, which rely on water for both consumptive and non-consumptive purposes. While some problems can be countered by increased spending on water infrastructure, these expenditures would be unnecessary in the absence of climate change.

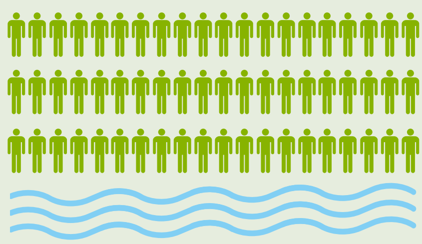
Ultimately, both air pollution and climate change are urgent issues for China. Air pollution puts millions of lives at risk with real economic damage that accumulates year after year. Climate change threatens the country's vulnerable coastal areas like Tianjin and Shanghai, while endangering China's water and food supply. Given China's size, and the large role of its emissions in global air pollution and climate change, China should view both air pollution and climate change as urgent threats to the nation's well-being, and take action accordingly.

CLIMATE CHANGE AND AIR QUALITY ARE BOTH URGENT ISSUES FOR CHINA



China's coastal provinces, home to 40% of the nation's population and responsible for 56% of GDP, are at greatest risk from climate impact

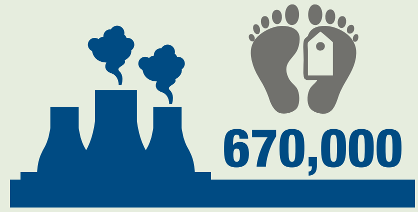
60 million



Over 60 million people live in coastal areas in China that are directly vulnerable to sea-level rise

8 out of 74

Only eight of China's 74 largest cities met national standards for air quality in 2014



Ambient air pollution caused by coal consumption caused an estimated 670,000 excess deaths in China in 2012

POLICY GAP ANALYSIS

Climate change and air quality require better enforcement, multi-pollutant control, regional coordination, and greater integration of energy and emissions policy

Given the urgency of addressing both climate change and air quality, the next step is to understand how to best address each problem. The following sections of this report illustrate how China's environmental and energy policies are already rapidly evolving to respond to the need to address climate change and air quality. But some policy gaps still remain. The most important of these is the need for China to take an integrated approach to climate and air quality, so that progress on one of these issues does not hamper the other. Ultimately, China's overall approach to its economic growth must also be balanced with its approach to these critical energy and environmental challenges.

Other important policy gaps include the need for greater regional coordination, better multi-pollutant control, and more effective enforcement of energy and environmental policies. In addition, China needs to take significant steps toward moving away from a heavily industrial and thus heavily polluting economy to one that is more efficient, and more grounded in low-carbon energy and fuel sources.

While China has made significant progress on controlling emissions from the power sector, industry and transportation, enforcement remains a weak point.

2.1 Introduction: The case for integrated air quality, climate change and economic policy in China

In China, air pollution is a highly visible problem relative to climate change, and the two issues are often thought of separately both in terms of urgency and solutions. This chapter outlines why it makes both practical and economic sense for China to invest in resolving the two issues together. While some "end-of-pipe" solutions—those that control emissions after energy has been consumed—can effectively control individual air pollutants, China also needs to invest more in energy efficiency and fuel switching away from coal. At the same time, China should avoid risky investments in massive coal gasification projects that waste scarce water, coal and financial resources, create water and air pollution, and hinder China's ability to meet its new carbon policies.

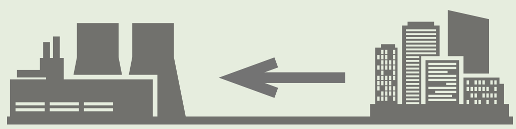
There are five broad options for China to address ambient air quality problems: Technologies that reduce emissions after energy has already been consumed (sometimes called "end-of-pipe solutions"), fuel-switching away from high-emissions fuels, improved energy efficiency, shifting high-emissions facilities out of zones with high ambient air pollution, and transforming the structure of the economy by reducing distortions that favor energy-intensive heavy industry. While China is pursuing a mixture of all of these strategies, we suggest that policymakers place an increasing priority on fuel-switching away from coal as well as energy efficiency, for several reasons:

- End-of-pipe solutions are insufficient in themselves to resolve the problem. While China has made significant progress on controlling emissions from the power sector, industry and transportation, enforcement remains a weak point. In addition, emissions control alone can only go so far toward resolving the country's significant air pollution issue. In addition, such emissions-control technologies typically do not reduce greenhouse gas emissions, which would then require additional investment.

- Energy efficiency is one of the most economically effective ways to reduce emissions from both conventional pollutants and greenhouse gas emissions. Steps to increase energy efficiency in many cases have negative cost, though they may face institutional or market barriers.
- Fuel-switching away from coal is consistent with broader energy policies: China's energy policy recognizes that coal is a high-emissions fuel and there is value in finding alternatives, including natural gas, renewable energy and nuclear. In many cases, alternative fuels are not only cleaner, but also use less water, addressing another critical national priority. Lastly, innovation in clean energy production is itself an important economic objective for both employment and technology policy.

THERE ARE FIVE BROAD OPTIONS FOR CHINA TO ADDRESS AMBIENT AIR QUALITY PROBLEMS

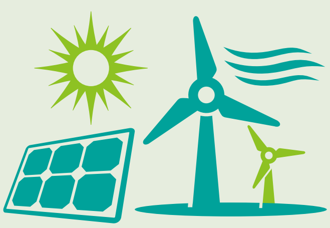
Technologies that reduce emissions after energy has already been consumed (sometimes called "end-of-pipe solutions")



Shifting high-emissions facilities out of zones with high ambient air pollution

Our Focus

[WE SUGGEST THAT POLICYMAKERS PRIORITIZE FUEL-SWITCHING AWAY FROM COAL AND ENERGY EFFICIENCY]



Fuel-switching away from high-emissions fuels (such as coal and coal-derived gas)

Improved energy efficiency

Transforming the structure of the economy by reducing distortions that favor energy-intensive heavy industry.

- Finally, China can benefit from policies that reduce economic and financial distortions that favor large, heavy industry over other sectors such as services and clean industries. Administrative actions to clean up industry and set explicit energy goals have achieved much over the past ten years, but a recent analysis shows that existing policies in these areas would be insufficient in themselves to bring ambient PM2.5 levels down to 30 micrograms per cubic meter by 2030.[47] Distortions that favor energy-intensive industries range from cheap industrial land costs, subsidies to heavy industry, and low-cost financing available to large SOEs in heavy industry.

2.2 Policy progress to date

China has made progress on multiple levels to address its air pollution and climate challenges. Recent laws and policies, such as the newly revised Environmental Protection Law, are driving improvements across sectors by providing enforcement officials with the tools needed to hold polluters responsible for their actions. Key policy developments since 2012 include the following:

- In October 2012, China published the **12th Five-Year Plan for Air Pollution Prevention and Control in Key Regions,**[48] which outlines ambitious targets for renewable energy development and PM2.5 reduction in regions suffering from severe haze.
- Passed a year after the 12th Five-Year Plan, the **2013 Action Plan for Air Pollution Prevention and Control** sets out more ambitious ambient PM2.5 reduction targets for key regions, with more aggressive deadlines. This Action Plan has led to the establishment of regional and provincial action plans for achieving ambient air quality improvements.
- China's 2014 revision of the **Environmental Protection Law** strengthens the authority of environmental protection agencies, requires key emitters to disclose emissions data, increases penalties for violations, and enhances the role of NGOs in environmental governance. China is also in the process of revising its Air Pollution Prevention and Control Law, which should be finalized in 2015.[49] These policies are expected to help the nation achieve its goals for air quality improvement nationwide, and particularly in the Jing-Jin-Ji region.
- The **National Climate Change Plan (2014-2020)** outlines China's strategy for achieving its 2020 carbon intensity reduction goals and sets a target to stabilize CO_2 emissions from energy-intensive industries to 2015 levels by 2020. In particular, the Plan aims to reduce the carbon intensity of the economy by up to 45% compared with 2005 levels by 2020,[50] and to stabilize CO_2 emissions from the steel and cement industry at 2015 levels by 2020. The plan includes carbon reduction obligations for provinces, cities and ministries; detailed carbon emissions standards for individual industries will follow.[51]
- Other national energy policies are focused on directing China's energy development toward lower-carbon sources; these include policies to

China can benefit from policies that reduce economic and financial distortions that favor large, heavy industry over other sectors such as services and clean industries.

rapidly scale up renewable energy such as wind and solar, improve natural gas supply and infrastructure, and increase the role of nuclear energy. The government is also prioritizing new energy vehicle deployment, demand-side management and building energy efficiency.

These policy developments coincide with government leadership in raising public awareness on ambient air pollution. Print and television news now regularly cover air pollution issues, and media reporting on heavy haze periods in large cities has intensified. For example, the government provides advanced warnings on heavy pollution days more regularly.[52] Top national leaders have also raised the profile of the air quality issue, such as when Premier Li Keqiang declared war on air pollution at the opening of the National People's Congress in March 2014.[53]

Across broad areas of environmental and energy policy, China is now making rapid progress. However, there are several areas for potential improvement.

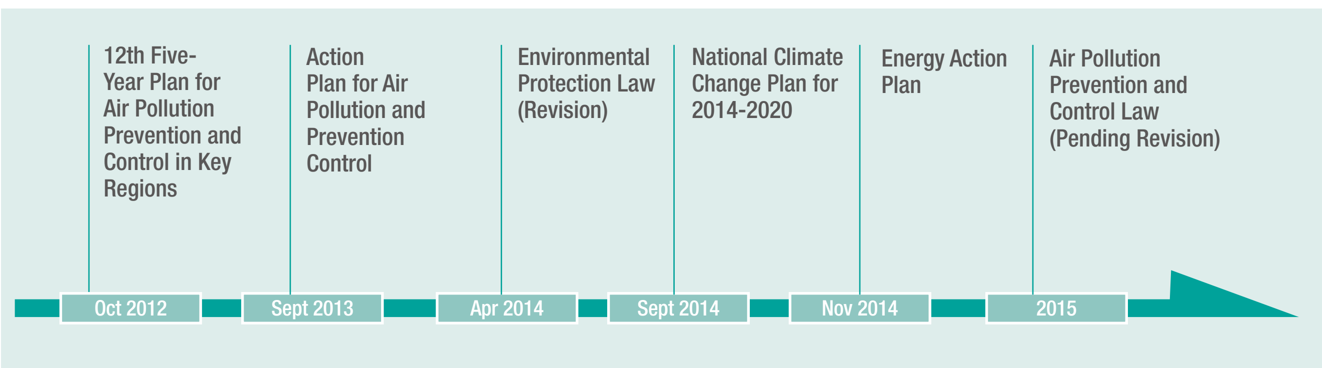
First, resolving ambient air quality issues requires greater regional coordination. Ambient air pollution is complex and often arises from regional sources, implying the need for policies with a larger geographic scope as well as attention to more pollutants. Effective air pollution reduction will require a scientific approach to regional coordination that matches physical transport of pollution across jurisdictional boundaries throughout the North China Plain.

Second, China can benefit from a more comprehensive multi-pollutant policy strategy. The pollution problem arises from multiple sectors, fuels, and pollution precursors. While Beijing and other large cities have achieved reductions in primary PM2.5 emissions from the power, industrial and transport sectors, secondary PM2.5 pollution now represents a larger percentage of the pollution that needs to be addressed.

Third, while China has made dramatic improvement on emissions standards for individual industries and technologies, implementation and enforcement of these laws has lagged. China's environmental regulatory bodies have insufficient staff, independence and authority to strictly enforce standards and penalties, especially for national-level state-owned enterprises (SOEs). Public

While Beijing and other large cities have achieved reductions in primary PM2.5 emissions from the power, industrial and transport sectors, secondary PM2.5 pollution now represents a larger percentage of the pollution that needs to be addressed.

Timeline of Major Air Emissions-related Policy Changes from 2012-2015



Source: Paulson Institute

Major climate change and air pollution control policies have been enacted in China over the past three years.

participation in the governance process is limited due to issues such as a lack of whistleblower protections, institutional and capacity limits of NGOs, and limited data availability.

Fourth, as noted above, China can benefit from much greater coordination between energy, environmental, and economic policy. While China's present energy policies recognize the environmental benefits of energy efficiency and channeling more financial resources toward non-fossil energy, these strategies need still greater attention because of their potential to reduce emissions of both greenhouse gases and air pollutants that cause regional haze. The lack of comprehensive integration of air and energy policies produces results such as investment in environmentally risky coal-to-gas infrastructure, for example. Not only are energy and environmental policy closely related, economic policies are as well. Recent analysis shows that China cannot meet ambient air pollution targets without additional efforts to reduce economic distortions that favor investment in heavy, energy-intensive industry.[54]

China's environmental regulatory bodies have insufficient staff, independence and authority to strictly enforce standards and penalties, especially for national-level state-owned enterprises (SOEs).

Improvement in these areas can help China achieve its desired outcomes for air quality improvement in the Jing-Jin-Ji region, while also cutting greenhouse gas emissions.

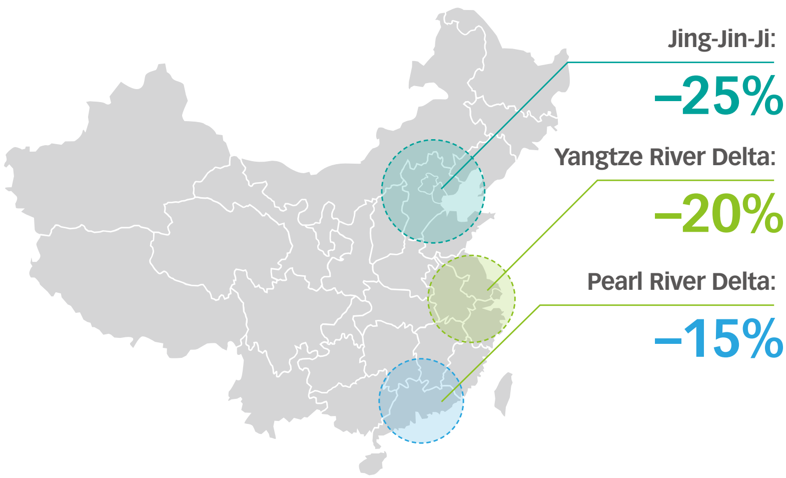
2.2.1 The Action Plan for Air Pollution Prevention and Control can drive performance improvements

The Action Plan for Air Pollution Prevention and Control was a turning point in China's effort to improve air quality. Announced by the State Council, China's highest administrative authority, it sets emissions reduction targets for key regions and calls for a series of adjustments to the national primary energy portfolio.[55] The plan sets ambient PM2.5 reduction targets for the following key regions: 25% for Jing-Jin-Ji, 20% for the Yangtze River Delta, and 15% for the Pearl River Delta, below 2012 levels by 2017. Beijing is required to "control" average annual ambient PM2.5 levels at 60 micrograms per cubic meter[56] and most other large cities are required to achieve at least a 10% reduction in ambient PM10 levels by 2017 below 2012 levels. Other binding ambient PM2.5 reduction targets include a 20% cut for Shanxi and Shandong provinces, and a 10% reduction in Inner Mongolia by 2017 below 2012 levels.[57]

The State Council's Detailed Regulations for Implementation of the Action Plan for Air Pollution Prevention and Control in Jing-Jin-Ji and Surrounding Regions outlines specific actions that should be taken to reduce pollution in the Jing-Jin-Ji region, which includes decommissioning "yellow-label" or high-emission vehicles nationwide, prohibiting construction approval for new heavy polluting industries such as iron, cement and aluminum, and replacing coal with electricity generated by clean energy, including natural gas. According to this target, coal consumption in the Jing-Jin-Ji region should be reduced by 63 million tons.[58]

One potentially helpful aspect of the 2013 Action Plan is that it incorporates ambient PM2.5 targets into key performance indicators (KPIs) for provincial, municipal and district governments. Based on a State Council announcement released in April 2014, in addition to traditional performance measures such as their achievement of ambient PM2.5 targets, officials in the Jing-Jin-

Emissions Reduction Targets for 2017



Beijing, Tianjin and Hebei Announce Emissions Reduction Targets Following State Council's Action Plan

Beijing

Ambient air quality target: 60 micrograms per cubic meter for PM2.5, by 2017, 30% below 2012 levels.

Coal: All four large coal plants to be shut down, and overall coal consumption to be capped at 10 million tons by 2017, versus 22.7 million tons in 2012.[59]

Industry: Cut cement manufacturing capacity by 6 million tons. Forbid construction of small coal-fired boilers while closing all industrial coal boilers under certain efficiency thresholds. Institute energy auditing programs for energy-intensive industry (steel, cement, chemicals, refining) to bring down emissions intensity of production by 30% by 2017 versus 2012 levels.

Transportation: Limit growth in new vehicle ownership, use license plate lottery,[60] eliminate yellow-label vehicles by 2015, EV infrastructure partnerships,[61] and speed up adoption of China 5 vehicle emissions standards.

Enforcement: Local Environmental Protection Bureaus to fine local polluting enterprises that fail to limit or suspend operations during periods of severe haze as much as RMB 500,000, up from RMB 100,000 previously.[62] Repeat offenders could be fined double with no upper limits and could have violations placed on their credit history.[63]

Hebei

Ambient air quality target: 25% cut in ambient PM2.5 between 2013 and 2017 (same as the overall target for JJJ).

Coal: Reduce coal consumption by 40 million tons from 2012 levels (314 million tons).

Industry: Reduce steel production capacity by 60 million tons, cement capacity by 61 million tons, and glass capacity by 36 million tons; decommission thousands of high-polluting facilities.[64]

Transportation: Eliminate heavy-emitting vehicles by 2017.[65]

Tianjin

Ambient air quality target: 25% cut in ambient PM2.5 between 2013 and 2017 (same as the overall target for JJJ).

Coal: Cut coal consumption by 10 million tons from 2012 levels of 53 million tons.

Industry: Cap steel capacity at 20 million tons, cap cement capacity at 5 million tons.

Transportation: Restrict motor vehicle growth, eliminate 290,000 yellow label vehicles by 2015, update requirements to public transport and for new energy vehicles and buses.[66]

Ji region will be evaluated on specific initiatives they have taken to reduce air pollution.[67] There are ten major areas of focus for these initiatives, which include cleaner production, sustainable transportation and green buildings.[66] Several government agencies will play a role in evaluating the officials' performance, including the Ministry of Environmental Protection (MEP), National Development and Reform Commission (NDRC), Ministry of Finance (MOF), Ministry of Housing and Urban-Rural Development (MOHURD), National Energy Administration (NEA) and the Ministry of Industry and Information Technology (MIIT).[69]

Despite the new provincial measures that will contribute to lowering Jing-Jin-Ji ambient PM2.5 concentrations, modeling and analysis by Tsinghua University suggest that under present policies the Jing-Jin-Ji region is unlikely to meet its ambient PM2.5 targets. The analysis shows that actions outlined in the Action Plan would produce only a 25.6%, 18.7%, and 14.7% reduction in ambient PM2.5 levels in Beijing, Tianjin and Hebei, respectively.[70] The study also concluded that successfully achieving these reductions would depend on weather conditions, which can vary significantly year to year. The study found that Jing-Jin-Ji reductions in NO_X and SO_2 over the next three years are also expected to increase ammonia (NH3) emissions, especially in the winter months, potentially compromising air quality. Only under an "enhanced scenario" of stricter control measures, including more aggressive cuts in coal consumption in Hebei from 40 to 60 million tons, and reductions in VOC (volatile organic compound) emissions in Tianjin between 30-40%, could the Jing-Jin-Ji region achieve its 2017 ambient air quality targets.[71]

2.2.2 The National Climate Change Plan calls for stabilization of CO_2 emissions from energy-intensive industries by 2020

According to the U.S.-China Climate Announcement, China anticipates carbon emissions will peak by 2030 and non-fossil fuel sources will represent at least 20% of the national primary energy mix by 2030.

The National Climate Change Plan for 2014-2020 is a good example of China's ability to integrate carbon reduction and energy goals into one policy initiative focused on cleaning up heavily polluting industries. The plan, approved by the State Council in September 2014, outlines the nation's strategy for slowing carbon emissions through 2020.[72] The same goals were echoed in the U.S-China climate accord that followed on the 2014 Asia-Pacific Economic Cooperation (APEC) meetings in Beijing. According to the U.S.-China Climate Announcement, China anticipates carbon emissions will peak by 2030 and non-fossil fuel sources will represent at least 20% of the national primary energy mix by 2030.[73]

The National Climate Change Plan sets binding carbon reduction targets for provincial and municipal level governments, as well as for specific government agencies across China. The Plan is organized around the following key categories: GHG emission control, climate change adaptation, pilot project implementation, regional climate change policy improvement, and the establishment of an effective incentive carbon reduction mechanism.[74] Key targets and program details most relevant to the control of conventional air pollutants and carbon emissions in the Plan include:

- Capping CO_2 emissions from the cement and steel industries by 2020 based on 2015 levels

- Developing greenhouse gas (GHG) emissions standards for the power, metallurgy, iron, petrochemical, chemical, transportation, and construction industries
- Improving GHG monitoring nationwide

The Plan links quantitative targets to a set of specific actions. Each mandate will be translated into detailed targets for governments and industries.

2.2.3 Amendments to the Environmental Protection Law strengthen environmental authorities and raise penalties

The April 2014 revision of China's national Environmental Protection Law represents a major step forward in strengthening environmental governance.[75] The revision broke new enforcement ground by extending to NGOs the right to file public-interest lawsuits and by authorizing regulators to impose daily fines for pollution violations. The first update since the Environmental Protection Law's adoption in 1989, the revision equips environmental protection bureaus (EPBs), courts and the general public with better tools and processes to hold polluters accountable for their actions and encourage environmental compliance.[76] The law achieves these goals as follows:

- First, the updated Environmental Protection Law toughens penalties for pollution violations. While the law does not specify a minimum fine for violations, it authorizes local EPBs to charge violators recurring fines immediately following an offense. Article 59 states that polluters are subject to daily fines until unlawful activities halt. This clause is a major improvement over the country's previous approach to fines, which often were levied on a one-time basis at amounts capped at levels too low to deter non-compliance.[77]
- Second, the law expands data transparency and channels for public participation. According to Article 58, NGOs that are registered with the relevant civil affairs department at the prefecture level and above, and that have at least five consecutive years of experience working on environmental protection issues, with no history of legal violation, can file cases against entities undertaking environmental activities deemed harmful to the public good.[78] The law also raises expectations for data transparency at all levels of government. According to Article 54, EPBs are required to publish all data on air quality, pollution emissions and penalties.[79] This emphasis on data transparency sends a strong signal regarding the importance of data availability and accessibility in improving environmental governance.

The signs of progress on energy and environmental policy have accumulated rapidly over the past two years and are likely to continue. In the following sections, this report discusses additional actions and steps that appear to need further attention from policymakers, including enhanced coordination of emissions and energy policy at national and regional levels, a multi-pollutant strategy, improved enforcement and greater attention to energy efficiency and fuel-switching away from coal.

The April 2014 revision of China's national Environmental Protection Law represents a major step forward in strengthening environmental governance.

* The Ministry of Environmental protection measures air quality based on six major atmospheric pollutants including PM10, PM2.5, SO_2, NO_X, carbon monoxide (CO) and ozone (O_3).

Enforcement challenges: Since the 1990s, inconsistent implementation of laws and poor enforcement have limited China's ability to achieve emissions targets outlined in five-year plans.

2.3 Additional steps: effective enforcement

Lack of compliance with environmental rules is one of the biggest factors hindering China's ability to maximize the impact of its environmental laws and policies. This section summarizes recent evidence of ongoing enforcement challenges and concludes with specific recommendations for improvement. While China's environmental laws and policies are more comprehensive than a decade ago, in many cases implementation and enforcement lag due to weak authority and capacity of local EPBs, under-developed implementation mechanisms, limited data for informed decision-making, and lack of defined roles for government agencies.

2.3.1 Enforcement: historical context in China

As described above, China takes a decentralized approach to implementing and enforcing its environmental laws, with local governments taking the lead on implementing specific strategies to achieve national targets and goals. However, according to one study conducted by the Organization of Economic Cooperation and Development, this decentralized approach can result in inadequate oversight and accountability.[80] In some cases, local EPBs may have wide discretion about enforcement decisions.[81] Environmental policies of the central government are sometimes perceived as less important than local key performance indicators and short-term economic goals.

Since the 1990s, a mixed record of enforcement has limited China's ability to achieve targets outlined in its five-year plans. During the 9th Five-Year Plan (1996-2000) the central government established total emission control (TEC) targets for SO_2 in key regions and sectors. However, enforcement was mixed and in some cases SO_2 levels even increased from previous years.[82] While GDP growth and coal consumption contributed to the increase in SO_2 levels, enforcement issues also played a role. Inadequate enforcement continues into the current decade. According to a professor at Sichuan University, in 2011 as much as 30% of power plant desulfurization equipment did not operate properly or was simply turned off until visits from inspection officials.[83] And in 2014, the China Electricity Council reported that several power companies were still receiving subsidized power prices from the grid even though they were not operating desulfurization and de-NO_X equipment.[84]

2.3.2 Environmental Protection Bureau staffing and authority

Historically, China's national and local level environmental protection agencies have had fewer staff and less authority than comparable agencies in advanced industrial countries. While there are nearly 1,400 staff members that work on air quality issues at the U.S. EPA, there are only a few dozen staff working on air issues at China's Ministry of Environmental Protection.[85] Additionally, U.S. state environmental agencies have an average of 83 staff dedicated to air policy issues.[86] States also have substantial budgets dedicated to all aspects of air quality policy, including monitoring, technical assistance, and enforcement. California alone has thousands of state and local air inspectors that conduct random inspections daily, as over a hundred inspectors at the California Air Resources Board pay unannounced visits to ships, trains, and airplanes to audit fuel quality and emissions.[87] Relatively speaking, the entire Jing-Jin-Ji region has far fewer inspectors, requiring the central government to send out occasional high-profile inspection teams that are necessarily less effective than a permanent, widespread, on-the-ground presence.[88]

Though the obstacle of limited local enforcement capacity may seem daunting, there is precedent in China for rapidly expanding enforcement capacity. In the buildings sector, for example, in a few short years China established more than 5,000 certified inspection companies with more than 100,000 registered inspectors. This surge in staffing capacity helped increase building code compliance across China during the 11th Five-Year Plan period.[89]

Before the revised Environmental Protection Law went into effect in 2015, limited authority of local environmental protection bureaus (EPBs) also hindered effective enforcement of laws. Until recently, China's EPBs have been restricted in their ability to charge violators for their actions and were powerless when it came to ordering necessary firm closures. In some cases, EPBs face conflicts since their salaries are administered by local governments, which are motivated to protect local polluting firms to prevent job losses or maintain the local tax base. Sometimes EPB enforcement officials have even had to put their personal safety at risk to enforce the law.[90]

Local EPBs have faced difficulties enforcing pollution laws on nationally-administered state-owned enterprises (SOEs). SOEs enjoy financial support from regulatory privileges from national and local governments, which makes it difficult to challenge these giants through administrative or judicial processes. Essentially, EPBs are at a lower administrative level than national SOEs.[91] In the past, regulators have sometimes refrained from taking SOEs to court for failure to pay environmental fines because they cannot count on support from government officials. In other cases, SOEs have been able to argue that complying with regulations would be too burdensome.[92] A Greenpeace study of emissions data from 2014 shows that 85% of Hebei and Jiangsu state key-monitored facilities violated emissions standards, often consistently and at levels far beyond legal standards.[93] Many of these facilities are large SOE power companies, steel companies and cement companies. During the international APEC meetings in Beijing, publicly available emissions data from SOEs showed that several SOE coal and steel plants in Shandong continuously operated at emissions levels far above regulatory thresholds.[94]

A study of emissions data from 2014 shows that 85% of Hebei and Jiangsu state key-monitored facilities violated emissions standards, often consistently and at levels far beyond legal standards.

Until recently, even when EPBs were in a position to use their authority to penalize violators, enforcement funding has been limited and fines have been too low to deter non-compliance.[95] There are signs that this may be changing. Jiang Kejun of the National Development and Reform Commission's Energy Research Institute in a recent interview said that coal-reliant firms "haven't realized that environmental performance will determine whether or not a company survives," referring to the government's growing priority to hit power plants with stricter fines.[96]

Building institutional capacity and strengthening authority of EPBs are not the only changes needed. While an agency's degree of effectiveness depends on internal capacity, it is also dependent upon the laws and regulations that govern its authority and influence.

The U.S. EPA Approach to Emissions Penalties

For pollution penalties to effectively deter non-compliance, the U.S. EPA believes in recovering, at a minimum, any economic benefit associated with a violation as well as an additional penalty based on the seriousness or magnitude of the violation (gravity component). To ensure that enforcement programs have a deterrent effect, companies that knowingly violate laws should not gain an economic advantage over those that comply. The additional gravity component is needed to discourage polluters from just "taking their chances" and seeing if they get caught. In addition to the economic gains from non-compliance, factors taken into account when determining the level of penalties include:

- Gravity of the harm from the violation;
- History of non-compliance;
- Ability to pay;
- Extent of deviation from the standards or emission limits; and
- Cooperation of the violator in remedying the environmental harm.

While ability to pay is among the factors that may be considered, it is important that polluters do not view violation of environmental requirements as a way of aiding a financially troubled business.[97]

2.3.3 Data monitoring and reporting

Building the capacity of environmental protection bureaus and companies to monitor and report emissions is critical for air quality management. Consistent reporting of emissions data helps ensure that violators are caught and that enforcement officials have the information needed to determine how populations directly exposed to emissions are affected, as well as the implications for air quality in downwind jurisdictions. Accurate reporting also ensures informed decision making with regards to corrective actions, closures, and future policies. Incentivizing emissions disclosure is easier said than done. Nevertheless, as discussed below, governments and NGOs are coming up with new ways of encouraging transparency.

Improving access to air quality data is one of the most notable achievements China has made to strengthen environmental enforcement. The years 2012 and 2013 saw the most rapid progress. This was triggered by a combination of factors including public attention surrounding one of the most severe pollution days on record (January 2013), availability of hourly PM2.5 readings for Beijing from the U.S. Embassy's Twitter feed, and the Weibo campaign of SOHO China Chairman Pan Shiyi calling for a new clean air act.[98] Ultimately, greater awareness, transparency, and government attention have become self-reinforcing, giving the air quality issue greater policy momentum than ever before.

In response to growing awareness and public demands, in 2012 the MEP began publishing hourly ambient PM2.5 data for 35 locations in Beijing in 2012.[110] As of January 2014, 179 Chinese cities published real-time ambient air quality data, of which 161 made their data available via the MEP's online National Urban Air Quality Real-Time Disclosure Platform.[111] Real-time

Timeline of recent action on air pollution in China

2008	Extraordinary measures taken against pollution during the Summer Olympics in Beijing[99]
	U.S. Embassy in Beijing Twitter Feed begins hourly ambient PM2.5 and AQI readings for U.S. nationals[100]
January 2012	MEP begins publishing hourly ambient PM2.5 data[101]
January 2013	SOHO China Chairman Pan Shiyu Weibo campaign for a new clean air act[102]
	74 Chinese cities begin releasing real-time ambient PM2.5 data[103]
January 2014	179 Chinese cities publish real-time ambient PM2.5 data[104]
June 2014	IPE launches air pollution app, with real-time emissions disclosure for large industrial plants[105]
January 2015	New Environmental Protection Law comes into effect;[106] 367 Chinese cities publish real-time ambient PM2.5 data[107]
March 2015	"Under the Dome" online documentary publicizes health effects of PM2.5, accessed by 200 million Internet users[108]
April 2015	MEP calls out local EPBs for tampering with PM2.5 data and announces two-year campaign to rectify data[109]

Public awareness: Chinese reporter Chai Jing released "Under the Dome" in March 2015, an online documentary that publicized the health effects of PM2.5 and was viewed by more than 200 million Internet users.

disclosure has accelerated enforcement and engaged the public in ways previously unimaginable. Start-ups have developed user-friendly apps that aggregate information on air quality and recommend actions to protect health.[112] As a result of real-time data, local governments have better data to coordinate with neighbors to reduce emissions during severe pollution episodes.[113]

China's public air quality data is now better than that of many developed countries, but more can be done to improve completeness, timeliness and accuracy. In 2008, the Institute of Public and Environmental Affairs (IPE) and the Natural Resources Defense Council (NRDC) developed an environmental data transparency index that highlights the disparity in environmental data reporting methods across the country.[114] In 2013, IPE included real-time emissions disclosure in its criteria for environmental data transparency.[115]

Emissions data from individual facilities and corrective actions are all important aspects of data transparency. IPE's Pollution Map app, available since June 2014, consolidates and publishes real-time air pollution emissions data from over 3,000 high-polluting factories nationwide.[116] The app provides

SCREENSHOT OF MEP AMBIENT AIR QUALITY INDEX READINGS (LEFT) AND LOCALLY-MONITORED STACK EMISSIONS (RIGHT)

Source: MEP air quality index readings and IPE app, accessed December 16, 2014

Air pollution data has become increasingly accessible in China over the past two years. The right picture shows ambient AQI readings from Ministry of Environment (MEP) monitoring stations throughout Jing-Jin-Ji. The left picture shows stack emission sources in the same region from individual factories that are breaking the law, compiled in an app created by the Institute of Public and Environmental Affairs (IPE). The blue coloring indicates companies that have contacted IPE and are actively working to fix the problem.

Real-time disclosure has accelerated enforcement and engaged the public in ways previously unimaginable.

the general public with data that can be shared on social media platforms and tagged to local EPB Weibo accounts to make follow-up with relevant EPB staff about violations and corrective actions easy. The IPE app provides insight into where some of the largest emitters are located and what they are doing—or not doing—to reduce emissions.

China can do more to improve the timeliness, completeness and frequency of emissions data publication, such as through independent third-party auditing. Equally important is requiring companies to publish emissions information. In the U.S., when real-time pollution monitors stop functioning, regulators can impose maximum daily pollution fines. This encourages firms to ensure that equipment is working at all times.[117] China's newly revised Environmental Protection Law (effective as of January 2015) is helping the country move toward a more transparent governance system by forcing key emitters to disclose emission data. Nevertheless, more can be done to build a robust national reporting system that includes pollutant release data from major emissions sources, easily accessible via trusted platforms and closely aligned with national environmental objectives.

In recent years China has made progress developing emissions inventories. A notable milestone was reached in 2012 with the first release of Tsinghua University's Multi-resolution Emission Inventory for China (MEIC), a technology-based inventory of SO_2, NO_X, carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), ammonia (NH3), carbon dioxide (CO_2), PM10, and PM2.5.[118] The MEIC tool includes an emissions grid that scientists, planners and officials can use to model the impacts of policy changes on emissions and regional ambient air quality.

Data monitoring and reporting are critical components of enforcement. Regulators and policymakers alike must have access to consistent, accurate data in order to issue reasonable fines, order appropriate clean-up measures, and make informed policy decisions. The public can serve as an invaluable resource for governments in the enforcement of environmental regulations, and while the new environmental law represents progress, obstacles to participation remain. Only about 700 environmental NGOs of the total 7,000 that are registered meet the requirements to file a public interest case.[119] Funding is also an obstacle. Currently, costs associated with lawsuits are high in comparison to the annual operations budgets of NGOs, making legal action difficult without monetary support from external organizations.[120] A judicial interpretation by the Supreme People's Court in January 2015 suggests that China is taking steps to reduce the cost burden for environmental groups filing public-interest lawsuits.[121] Ensuring that there are laws in place that protect whistleblowers is also critical.

Only about 700 environmental NGOs of the total 7,000 that are registered meet the requirements to file a public interest case.

2.3.4 **Suggestions and conclusions on strengthening enforcement**

Our analysis concludes that while major progress has been made on air quality policy and related areas, policy gaps remain, especially as it relates to inadequate implementation and enforcement. These gaps are linked to several capacity and resource issues discussed above, including inadequate staffing and training, inadequate data (especially on emissions inventories and point-source emissions), and the need for wider public engagement on air quality enforcement. Key suggestions are summarized below.

Enforcement capacity. Strengthening enforcement capacity is one of the most economical investments that China can make to reduce air pollution. For many enterprises, it remains more economical to pay air pollution penalties than comply with air regulations, both because of poor enforcement and low penalties. The following steps can be taken to build the capacity of enforcement agencies and ensure higher compliance rates:

- Boost the number of enforcement officers, permitting staff and scientists in local EPBs;
- Enhance MEP oversight of provincial implementation decisions;
- Increase institutionalization of training programs for EPB officials; and
- Strengthen the authority of local enforcement agencies, particularly with respect to enforcement actions for large SOEs.

Data monitoring and reporting. Air quality data accessibility has improved markedly across China since 2012. By January 2014, real-time ambient air quality data was available in over 160 cities nationwide. Nevertheless, more can be done to ensure that air data are timely and complete, that industrial

Multiple polluters: In the Jing-Jin-Ji region, China's most polluted, the government will need a multi-pronged strategy that simultaneously targets many sectors and fuels to reduce air pollution. Sources range from agricultural fires, transportation, buildings, heavy industry and more.

emissions are consistently monitored and publicized, and that reporting methods are consistent across jurisdictions:

- Expand real-time disclosure of point-source air pollution emissions to more facilities and publicize data via government web sites, while penalizing inaccurate data reporting to deter non-compliance.
- Improve existing emissions inventories and publish annual emissions inventories that include both total emissions as well as emissions by industry to track trends in air quality and to ensure informed policymaking.
- Expand access to legal channels to NGOs and the general public with funding support. China could also consider compensating plaintiffs for legal costs incurred if public-interest lawsuits are successful. A January 2015 judicial interpretation by the Supreme People's Court to reduce the cost of litigation for environmental groups is one sign that China is moving in this direction.[122]
- Establish and implement whistleblower protections to encourage citizens to expose illegal pollution activities.

2.4 Additional steps: Enhanced policy coordination

One of the greatest challenges in environmental policy is its overlap with other policy areas. While the public often conceives of the environment as the concern of a single government department, emissions are deeply related to economic and energy policies, typically controlled by different agencies. Indeed, the complex relationships between industries, energy production and use, and emissions bedevils policymakers in every country, and in various respects China has done a better job acknowledging the need for policy integration than most—in many ways the task is just more challenging than elsewhere.

Policy integration is needed in four main areas:

1. Development of a multi-pollutant strategy across PM2.5 and its precursors;
2. Better regional coordination;
3. Greater integration of policies on climate change, energy, air quality and water;
4. Greater attention to economic policies that distort funding and resources in favor of energy-intensive industries. Understanding the linkages between air quality policies and other policy goals related to energy, water, carbon, and economic development is critical to achieving China's policy objectives at the least total cost to society.

2.4.1 Multi-pollutant strategy

In prior years China has taken a number of steps to address individual air pollutants, including setting standards and targets for NO_X, SO_2 and PM2.5. A look at the sources of ambient PM2.5 in the Jing-Jin-Ji region—China's most polluted region—illustrates why China will need a multi-pollutant strategy that simultaneously targets many sectors and fuels to effectively address its air quality challenges. Air pollution in this region cannot be fully resolved by a strategy focused only on the largest emitting categories or fuels due to the complexity of pollution sources. Factors such as the regional transport of emissions and the changing composition of pollution during periods of intense haze mean that all sources of emissions that contribute to formation of ambient PM2.5 must be controlled together to reach ambient air quality targets of 35 micrograms per cubic meter.

The fastest growth in emissions in Jing-Jin-Ji is taking place in sectors that represent a fairly small percent of China's economy, a trend that is likely to continue as the country moves from a strong manufacturing and agriculture base into a more service-focused economy. Ammonia emissions from agricultural fertilizer, for instance, provide an example of how a relatively small source of PM2.5 impacts air quality, and of the benefits of controlling these kinds of emissions.

Understanding the linkages between air quality policies and other policy goals related to energy, water, carbon and economic development is critical to achieving China's policy objectives at the least total cost to society.

Sources of air pollution are diverse

The first step in understanding air quality is to understand the broad issue of where air pollution comes from. While the question is simple, the science behind what are called *source apportionment* studies can be quite complex, requiring costly instruments, modeling of chemical reactions and air movements, and data on weather conditions. Studies relying on the same data sources can also categorize sources in various ways, leading to seemingly different conclusions. This section uses five major categories: industry (particularly heavy manufacturing sectors such as iron and steel, glass, and cement; not including the power sector), electric power generation, buildings (which includes both residential and commercial), transportation (which includes all motor vehicles and road dust, but excludes oil refining and vehicle manufacturing), and agriculture.

Industry is responsible for the vast majority of ambient air pollution in the Jing-Jin-Ji region. Industry accounts for 54% of primary PM2.5, 43% of nitrogen oxides (NO_X), 63% of sulfur-dioxide (SO_2) and 64% of volatile organic compounds (VOCs), according to a Tsinghua study.[123] A large portion of PM2.5 in Jing-Jin-Ji comes from the residential sector (32%), particularly biomass burning for rural heating.[124] The transport and power sectors are also significant contributors, especially for secondary PM2.5 from NO_X.

What is PM2.5

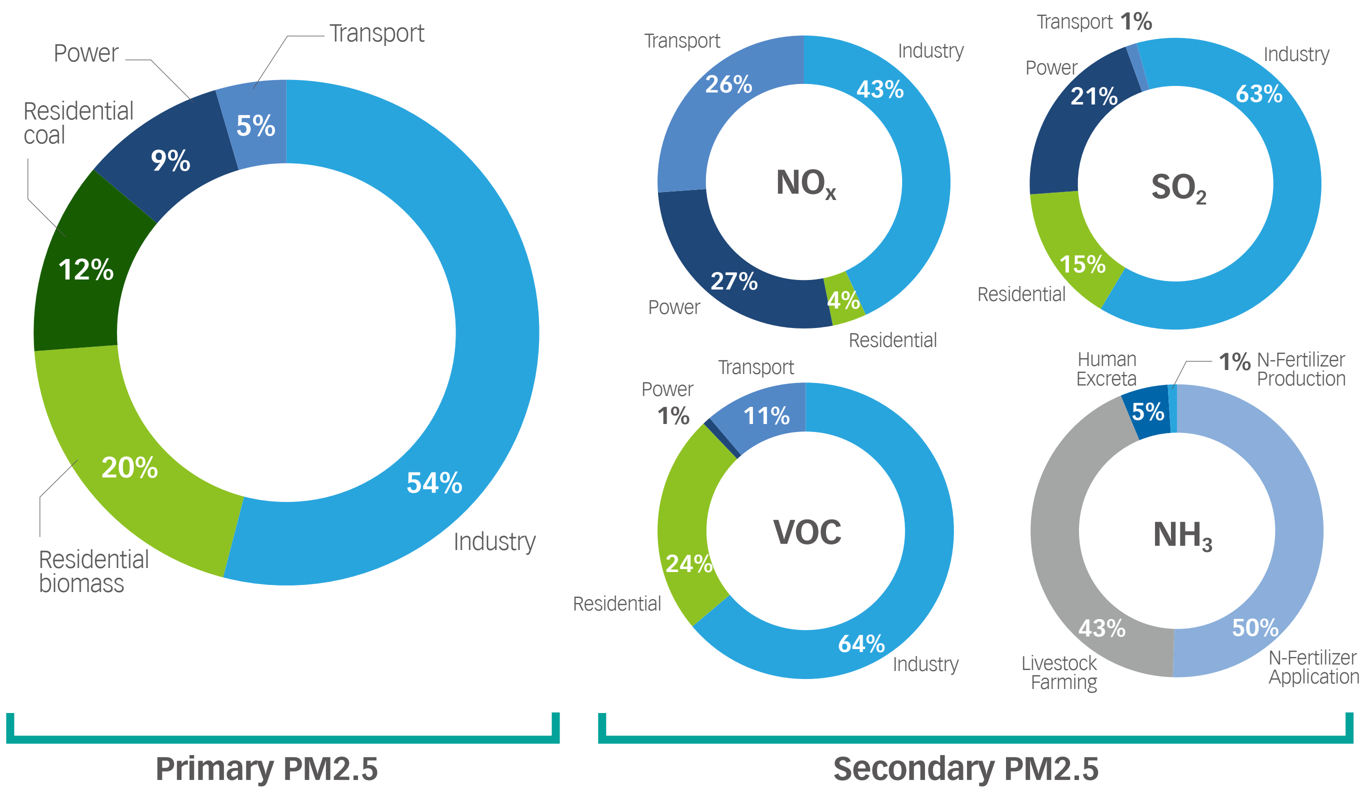
PM2.5 refers to particulate matter less than 2.5 microns in diameter, the most damaging particulate matter to human health.

human hair | Grain of sand | PM10 | **PM2.5**

Primary and Secondary PM2.5

Particulate matter can be categorized into primary and secondary sources. Primary PM2.5 originates directly from a source such as dust or fossil fuel combustion. Secondary PM2.5 describes particles that form through chemical processes in the atmosphere. Typically, secondary PM2.5 derives from a combination of NO_X, SO_2 and ammonia. In Jing-jin-ji, most particulate matter originates from primary emissions, but a significant fraction—roughly a third in Beijing[125]—is secondary PM2.5.

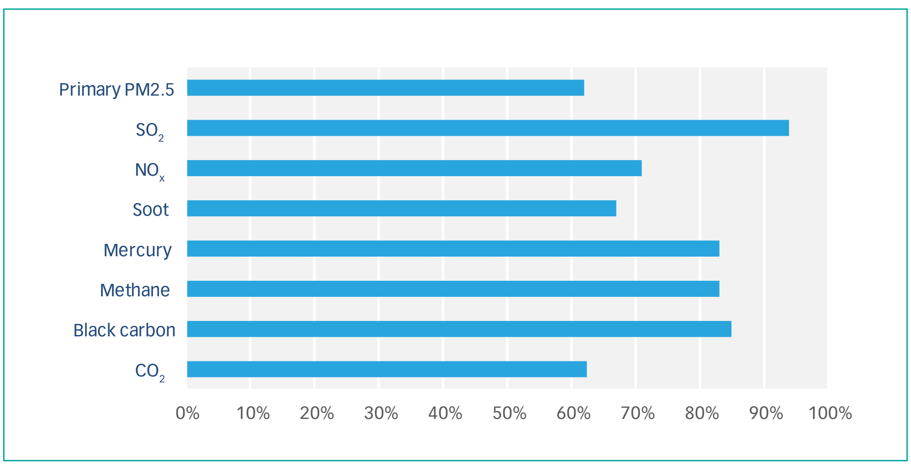
Source of Annual Jing-Jin-Ji PM2.5 and other Pollutants, 2010



Source: He Kebin, Tsinghua, 2013; Shuxiao Wang, 2011.
Note: Ammonia (NH_3) emissions are based on China's national 2005 emissions inventory.

Industry is responsible for the vast majority of ambient air pollution in the Jing-Jin-Ji region, contributing both to primary PM2.5 and secondary PM2.5 sources.

Contribution of Coal to Pollutant Emissions in China, 2012



Source: Yang Fuqiang et al., NRDC, 2014

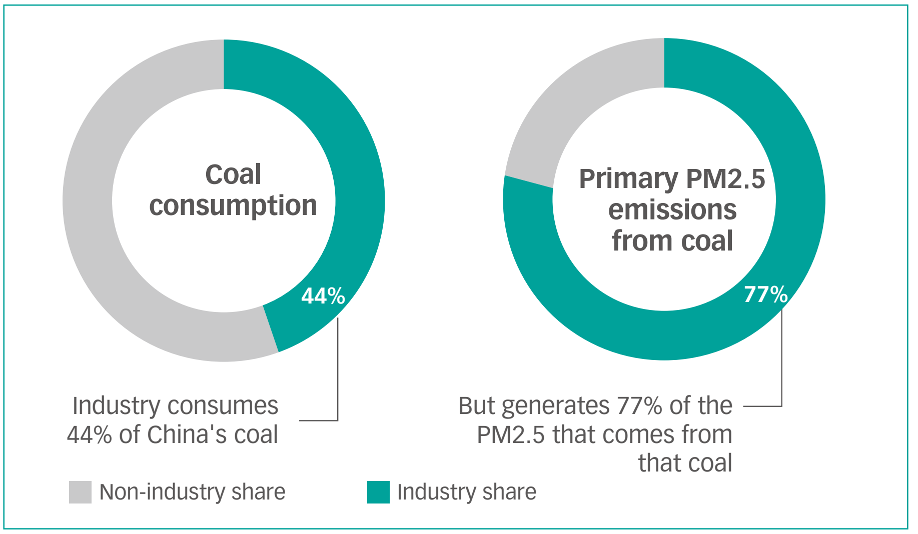
By fuel, coal is the largest contributor nationally to most other air pollutants, including those that also contribute to the formation of secondary PM2.5.

By fuel, coal is the largest contributor to PM2.5 emissions nationally and in Jing-Jin-Ji. This is no surprise given that coal accounted for 68% of China's primary energy supply in 2013,[126] and burning coal generally results in higher emissions compared to other fuels. For this reason, controlling emissions from coal has been and will continue to be a major element of any strategy to improve air quality.

China uses coal for generating electricity, fueling boilers at industrial plants, heating homes and businesses, and even cooking food. Among these, the power sector uses the most coal, at approximately 46% of the country's coal consumption in 2012.[127] In the Jing-Jin-Ji region, coal burning is responsible for 85% of sulfur and 47% of NO_X, both of which contribute to PM2.5 formation.[128] Among coal emissions sources, industry is the largest emitter of SO_2 and NO_X. Industrial processes are also responsible for the largest share of primary PM2.5.[129] Larger industrial facilities and power plants have an outsized effect on regional pollution because of their tall stacks, which emit pollutants at a higher level of the atmosphere, which are then carried longer distances—hundreds or thousands of kilometers—and remain in the atmosphere for longer periods than pollution emitted from smaller sources such as vehicles or cooking stoves.[130]

China's coal power sector has become much more efficient over the years, as the country now relies on relatively efficient supercritical* coal plants for the majority of new coal plant construction while leading development of ultra-supercritical coal plant technology.[131] Coal power plants have also gradually installed flue gas

Industry Share of Coal Use and Emissions in China, 2012



Source: YNRDC, Coal Use Contribution to China Air Pollution, October 2014
Note: Represents the industry share of total industry and power coal use and emissions, not total coal use and emissions.

Industry accounts for a much larger share of emissions from coal consumption than its share of coal use would imply. China's industrial sector (not including the power sector), consumes 44% of the country's coal total consumption, but 77% of the primary PM2.5 emissions from coal arise from industry. This accounts for the government's efforts to increase the electrification of industry to reduce emissions.

* A supercritical or ultra-supercritical power plant is one that operates at higher temperatures resulting in higher efficiencies and lower emissions than traditional power plants

Pollution without borders: Tall industrial smokestacks, such as the one pictured above, lead to longer-distance spread of pollution to downwind cities. A significant portion of ambient air pollution can originate from outside any given area, making regional cooperation important.

desulfurization for sulfur, fabric filters for PM, and de-NO_x equipment for NO_x.[132] For these reasons, power output has increased faster than emissions have grown, and sulfur emissions from the power sector have fallen rapidly, especially in Jing-Jin-Ji.[133] However, outside the power sector, industry has fallen behind in reducing emissions from coal. Industry accounts for a much larger share of emissions from coal consumption than its share of coal use would imply.[134]

While industrial emissions are the leading contributor to ambient PM2.5 in Jing-Jin-Ji,* transportation sources are also important, contributing 5% of primary PM2.5 in the region and over a fourth of NO_X—not counting industrial sources such as oil refining and auto manufacturing that are related to transportation. Transport emissions include tailpipe emissions from both heavy and light-duty vehicles. According to MEP data, the vast majority of vehicle emissions nationally come from heavy vehicles such as trucks, especially diesel trucks.[135] Aside from tailpipe emissions, road dust contributes up to 13% of ambient PM2.5 in Beijing.[136] While large cities such as Beijing have stricter standards for tailpipe emissions and entry of so-called "yellow label" or high emissions vehicles, other nearby regions such as Hebei have lower standards and older vehicles. Transportation emissions are high in NO_X and VOCs, both of which can form secondary PM2.5. On winter days with stagnant air conditions, high relative humidity and air inversions, local NO_X emissions remain trapped near the surface, especially in evening hours, leading to accumulation of local PM2.5.[137]

2.4.2 **Trends in haze composition imply need for more systematic, multi-pollutant control**

China has made immense progress in reducing NO_x, SO_2 and particulates from the power and industrial sectors, achieved through new technology, strengthened emissions standards, and improved enforcement. In cities like Beijing and Tianjin, progress has been even more rapid due to stricter standards and efforts to move polluting industries beyond city boundaries. Shifts away from household coal burning for heating and cooking have also played a major role. The net result is that average annual ambient PM10 has fallen while average annual PM2.5 levels in cities like Beijing have remained fairly flat over the past decade[148] despite rapid economic growth, increasing electricity output, a growth in car ownership, and industrial expansion in the Jing-Jin-Ji region surrounding the capital.

A rising fraction of ambient air pollution in Beijing arises from secondary PM2.5, formed through chemical reactions in the atmosphere.

Overall, many sectors of China's economy, such as electricity and cement, have shown steady output increases with flat or declining total emissions. A 2013 study by the State Key Laboratory of Pollution Control & Resource Reuse showed that during the 11th Five-Year Plan period (2005-2010) most industries made impressive reductions in emissions per unit of production.[149] For the electricity sector, between 2005 and 2010, the proportion of electricity from coal plants with capacity over 300 MW increased from 50% to 80%. Emissions of particulates and SO_2 per kWh generated by coal plants fell by over half.[150] In the power sector, for example, between 1996 and 2011 China tightened standards for NO_x, SO_2 and particulates repeatedly[151]—the standards

* Reports that describe transportation as the largest contributor to ambient PM2.5 in Beijing and other cities often break down emissions categories so that industrial emissions are divided into separate sectors such as iron & steel, cement and so forth, which individually are smaller than transportation as a whole.

COMPLEXITY OF AIR POLLUTION

Policymakers in Jing-Jin-Ji should understand the regional complexity of air pollution when adopting actions to improve air quality. This is because the sources of pollution vary dramatically on a daily and even hourly basis, and because resolving the problem requires not just a reduction in the average level but also strategies to prevent episodes of severe haze.

The following factors all influence air pollution levels in Jing-Jin-Ji:

Wind: Pollution levels in Jing-Jin-Ji cities depend heavily on wind conditions. Generally, wind from the south, southwest and southeast brings in pollution from Hebei, Henan, Shandong and other industrial areas of China. Stagnant air combined with air inversions can also lead to pollution accumulation. A short burst of wind from the north in some seasons can quickly clear the air in Beijing.[138] During a Beijing haze event on November 27, 2014, for example, PM2.5 concentrations fell from over 400 ug/m^3 to 46 ug/m^3 in the span of five hours.

Weather: Temperature, rain, relative humidity and sunshine all impact PM2.5 levels, each contributing in unique ways to the formation and removal of particulates. Higher relative humidity leads to secondary particle growth[139]—often a major factor during severe haze events. Precipitation can help remove pollution.[140] Sunlight promotes reactions of SO_2 and NO_X to form secondary sulfate and nitrate particulate matter.[141]

Season: Historically, winter in Beijing has been the most polluted of the four seasons, in part due to air inversions combined with the winter heating season. The trend in recent years has been toward increased pollution in summer, apparently due to rising emissions from outside of the Beijing area, even as local pollution controls improve conditions during the winter.[142] In addition, the composition and origin of PM2.5 is different by season due to a variety of factors such as wind direction, agricultural burning and chemical processes in the atmosphere.[143]

Time of day: Ground-level ambient pollution levels in Beijing are usually worse in the evenings and nighttime due to continuous local emissions combined with cooler temperatures resulting in less convective mixing.[144]

Topography: The mountain ranges to the north and west of the North China Plain can prevent air flow and encourage the accumulation of stagnant, polluted air.[145] The trapping of pollution in this arc of mountains can often be seen on satellite images.

Agricultural: Agricultural fires can contribute to heavy pollution episodes during the end of June and beginning of October.[146] Smoke from fires can travel long distances, mixing with industrial emissions to form secondary PM2.5. Agricultural burning can lead to intense concentrations of PM2.5, accounting for almost 50% of ambient pollution on some days in affected areas.[147]

The science of air pollution in Jing-Jin-Ji is therefore extremely complex, which makes solving the problem significantly more challenging for policy makers. Resolving air pollution problems in Beijing or Tianjin inherently requires regional and national policies as well as better enforcement. It also requires the government to address pollution stemming from a wide variety of sources—ranging from large power plants to thousands of agricultural fields and construction sites.

for new and existing plants are now as strict or stricter than those in the U.S.[152] Most Chinese coal power plants have already installed desulfurization and electrostatic precipitators,[153] though they may not always be in use.[154] Hundreds of inefficient and polluting plants have already been closed down.[155]

Chinese industry has also made efforts to cut emissions: Between 2005 and 2010, cement plants with precalciner* technology rose from a 40% market share to 80%. SO_2, particulates and CO_2 emissions per unit of cement production fell by over 60%, while NO_X rose by over 30%[156]. In the iron and steel sector, between 2005 and 2010, SO_2 and particulates per unit of production fell by 30-40% while SO_2 per unit fell over 15%.[157] The nonferrous metallurgy sector saw SO_2 and particulate emissions per unit of production fall by roughly 45% between 2005 and 2010.[158] In all of these sectors, production increased substantially during this period, and overall emissions rose.[159]

For transportation as well there has been significant progress on tailpipe emissions standards. The national government and city governments have adopted automobile and truck emissions standards and are gradually ratcheting them up to levels not far behind those in effect in Europe.[160] Beijing and other large cities have also restricted growth in new vehicle ownership.[161] These actions have helped reduce the average emissions per vehicle, while keeping the overall vehicle emissions in large cities fairly stable during a period of rapidly rising vehicle ownership and driving.[162]

These actions in the power, industrial, and vehicle sectors show that the government is already addressing some of the easy wins, especially in large cities such as Beijing and Tianjin. In some respects, however, success to date in reducing emissions through improved standards for these sectors makes next steps more challenging. The composition of ambient air pollution is changing, shifting toward sources that are more complicated for the government to address, especially secondary air pollution sources. A rising fraction of ambient air pollution in Beijing arises from secondary PM2.5, formed through chemical reactions in the atmosphere.[163] Motor vehicles, especially heavy diesel vehicles, are a relatively large contributor to urban NO_X emissions.[164] As heavy industry shifts away from the largest cities, its contribution to urban primary PM2.5 emissions may fall while raising its contribution to secondary PM2.5 from sulfates. Sulfates, in contrast to NO_X, are typically injected into the atmosphere from tall industrial smokestacks upwind, leading to longer regional transport to downwind cities.[165]

The role of ammonia and VOCs in the formation of secondary air pollution points to the benefits of comprehensively controlling air pollutants from all sources. Unlike primary PM2.5, SO_2 and NO_X, ammonia emissions are predominantly from the agricultural sector: 43% from livestock raising and 50% from fertilizer application.[166] Ammonia is the only alkaline chemical in air. It reacts with SO_X and NO_X to formulate ammonium sulfate and ammonium nitrate, which are main contents of secondary particulates that make up a large share of total ambient PM2.5, as discussed above.[167] And ammonia emissions are increasing rapidly—rising an astonishing 271% from 1977 to

* Precalciner technology involves adding another burner to the cement making process, which results in higher heat and significant decarbonation

2005 while crop yields rose 98%.[168] Looking at fertilizer as an example, as of 2005, farmers in the North China Plain use over six times as much nitrogen fertilizer per hectare as those in the U.S.[169] Approximately 40% of ammonia fertilizer is ultimately released into the air in China. Emissions of N_20, a gas with a global warming potential approximately 300 times more potent than CO_2, have been rising rapidly. A 60% cut in nitrogen fertilizer would reduce yields by 2% while reducing N_2O emissions 50%.[170]

Because ammonia can react with either nitrate and sulfate aerosols to form secondary PM2.5, controlling SO_2 and NO_X emissions individually is less effective than jointly controlling SO_2, NO_X and ammonia.[171] In fact, a recent analysis has shown that cutting sulfur emissions without simultaneously addressing ammonia emissions has actually resulted in more formation of secondary PM2.5 than would have otherwise been the case—illustrating the importance of controlling all PM2.5 precursors systematically.[172]

The role of ammonia and VOCs in the formation of secondary air pollution points to the benefits of comprehensively controlling air pollutants from all sources.

While difficult to address, ammonia is an area where other countries have made progress in reducing emissions. In the U.S., many states have implemented complex nitrogen fertilizer management plans, including outreach to farmers and certified crop advisors, monitoring of soil and wells, and monitoring of total fertilizer sales.[173] Animal waste management has been deployed successfully as well, as nitrogen fertilizer contributes to emissions of both ammonia and N_2O.[174] A recent study showed that North China could reduce nitrogen fertilizer application by 60% with no significant decline in wheat crop yields, while N_2O emissions would decline by 50%.[175]

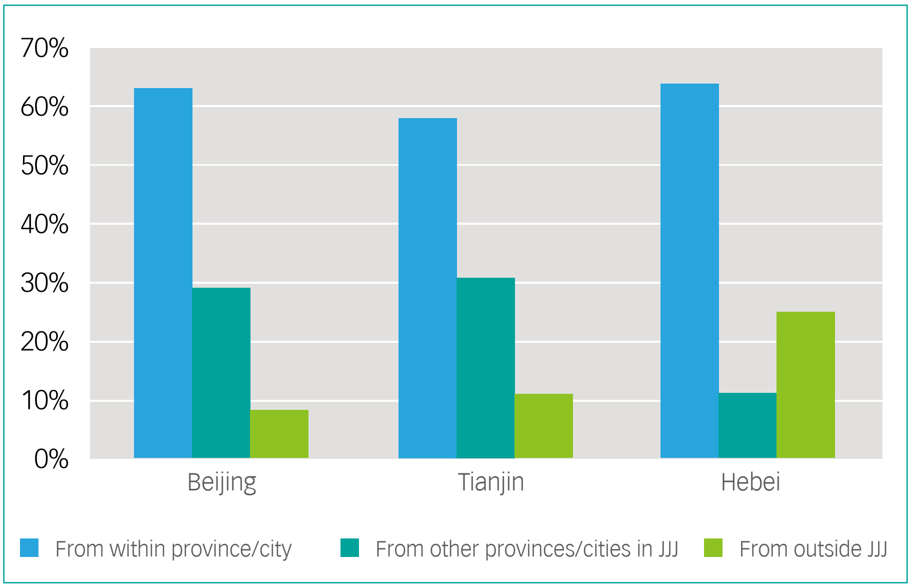
Another area where it makes sense to consider multi-pollutant control is in industries that produce VOCs, which are an important precursor to particulate matter, interacting with SO_2 to form secondary PM2.5.[176] VOC emissions come from the petrochemical industry, paint manufacturing, and emissions from fuel consumption by motor vehicles—with the latter the dominant source in large cities like Beijing.[177] VOCs have only recently attracted regulatory action in China: they were left off a list of air pollutants in 2000 requiring regulation,[178] and the 12th Five-Year Plan (2011-2015) did not set any target for controlling or reducing VOC emissions.[179] Only in the recent Air Action Plans has the government set quantitative targets for their reduction.[180]

As a result of the greater recognition of the role of secondary PM2.5, the government is already examining the issue of strategies and standards for controlling ammonia and VOCs. Various organizations, including the Energy Foundation China, Tsinghua University and China Agriculture University, have recommended a systematic multi-pollutant strategy to address both primary PM2.5 and precursors of secondary PM2.5. A systematic, multi-pollutant strategy is needed here as well.

2.4.3 **Need for greater regional emissions coordination in Jing-Jin-Ji**

China takes a decentralized approach to implementing and enforcing its environmental laws. While laws, policies, and national development plans are drafted at the central level in China, local governments are responsible for implementing strategies to achieve centrally mandated targets.[181] Delegation of implementation authority to local governments allows provinces the

Annual PM2.5 Transport from Within and Outside Jing-Jin-Ji, 2010



Source: Wang Jinnan, MEP, 2014

In Beijing, Tianjin and Hebei, roughly a third of ambient particulates originate from outside the respective province or municipality, underscoring the importance of regional cooperation on emissions control.

freedom to develop plans and adopt measures that best fit local needs.

However, air pollution does not necessarily respect these local government boundaries. Air pollution in Beijing and most other large Chinese cities is a regional problem, meaning that haze accumulates over areas that extend far beyond urban boundaries. Most of Eastern China is affected by high levels of ambient air pollution. China has established the region of Beijing-Tianjin-Hebei as one of three regions for special air quality, emissions and energy targets. Jing-Jin-Ji's target is to reduce ambient PM2.5 concentrations by 25% from 2013-2017, which represents a larger reduction than called for the other two regions (Yangtze River Delta, 15%; Pearl River Delta, 10%). Because of the policy priority attached to Jing-Jin-Ji, which as of 2013 has a population of almost 110 million, the Paulson Institute's Climate Change and Air Quality Program is focused on policies affecting air quality in this region.

In Beijing, Tianjin and Hebei, roughly a third of ambient particulates originate from outside the respective province or municipality. According to one estimate, on an annual basis in 2010, 36% of PM2.5 in Beijing originated in Hebei, 4% from Tianjin, and 8% from outside the Jing-Jin-Ji region. In Hebei, which covers a much larger land area, a total of just 11% of PM2.5 came from Beijing and Tianjin, and 25% from outside the Jing-Jin-Ji region.[182]

While regional transport contributes roughly a third of ambient PM2.5 on an annual basis, during extreme haze events the proportion of pollution transported by wind from neighboring provinces can be much higher. During some Beijing haze events, the majority of pollution can come from beyond the city boundaries. This is especially true during the summer, when winds are frequently from the south: one study showed that during summer haze events in 2010 up to 90% of ambient PM2.5 was transported from regions outside of Beijing.[183] Severe haze events in the fall and winter can also result from pollution transported from outside of Beijing, while at other times result from accumulation of local pollutants during periods of stagnant air and high relative humidity.[184]

Air quality policy is complicated due to the interplay between national and local policies, and between energy and environmental policy. Because of this complexity, even large cities cannot resolve air quality problems on their own.* The case of Los Angeles, California, can provide some insight into how large cities can work within a complex political system to achieve more regional cooperation on air quality control. Los Angeles, which first began efforts to control smog as far back as the 1940s, ultimately created an air quality management district with regulatory authorities over several cities that constituted the Southern California air shed—a term that describes where air pollution typically flows and accumulates. This regional approach was a critical step in resolving the city's smog problem.[185]

Similar to LA, and notwithstanding their ambitious air action plans, Beijing and Tianjin cannot achieve ambient air quality improvement without adequate regional coordination.[186] Individual cities within Hebei face a similar need for coordination, particularly with the upwind areas of Shandong and Henan.[187] Because air pollutants do not respect municipal boundaries, several factors influencing ambient air quality are beyond the control of any single local jurisdiction. This can result in misalignment between policy goals—the desire to reduce overall air pollution—and accountability mechanisms, which are often limited to single cities or jurisdictions. The creation of Key Performance Indicators (KPIs) related to ambient air quality in official evaluations is a case in point.[188] Ambient PM2.5 levels depend upon emissions of PM2.5 precursor chemicals, actions taken in upwind areas, and weather; therefore ambient PM2.5 levels cannot fully represent the progress of local policies in reducing pollution. As a starting point, more emphasis should be placed on specific measures taken to reduce local emissions while ambient PM2.5 concentrations can be used to gauge progress.[189]

Similar to LA, and notwithstanding their ambitious air action plans, Beijing and Tianjin cannot achieve ambient air quality improvement without adequate regional coordination.

Hebei, Tianjin and Beijing have recognized the importance of collaboration in air quality management. The three jurisdictions are already putting systems in place to collaborate on multiple levels ranging from addressing pollution at its source to improving pollution prediction capabilities.[190] Guo Yingchun, and engineer and spokesperson for Hebei's Meteorological Bureau, said in February 2014 that the province is cooperating with Tianjin, Beijing, Hebei, Shanxi, Henan and Shandong on several joint projects, including the development of an air pollution early warning system. This project will begin with combining local data on regional wind and temperature trends with emissions data from the Hebei Environmental Protection Department to better predict pollution trends.[191]

The central government has taken the lead in initiating collaboration in the Jing-Jin-Ji region through the April 2014 establishment of a working group

* That said, local sources of air pollution also matter: riding a bicycle behind a heavy diesel truck, sitting in a smoke-filled bar, or standing over a coal-fired cook-stove all have real health effects. While not discounting the importance of local pollutants to human health, this report focuses primarily on the issue of ambient air quality at the city and regional level and its link with energy consumption and greenhouse gas emissions.

At the national level, China's air quality, climate change and energy objectives align, but implementation is difficult since reduction of carbon and conventional pollutants are managed by different agencies at different levels.

under Zhang Gaoli, Vice Premier of the State Council.[192] An article released by the State Council's Development and Research Center (DRC) describes in further detail the importance of coordination.[193] The DRC notes the importance of empowering local planners to ensure consideration of both negative and positive economic and social impacts of reducing regional emissions. Effective regional coordination also ensures that local planners have a role in designing regional pollution reduction plans that affect them and remain committed to pollution reduction efforts in the long term.

2.4.4 Need for greater collaboration between air quality and climate agencies

Another area where China's decentralized approach to implementing environmental policies can lead to paradoxical results is the intersection of climate and air quality policy. At the national level, China's air quality, climate change and energy objectives align, but implementation is difficult since reduction of carbon and conventional pollutants are managed by different agencies at different levels. For example, local EPBs are tasked with achieving ambient PM2.5 reductions, while energy prices, large-scale energy project approvals, and climate change are under the jurisdiction of the NDRC.[194] These realities, when combined with limited staff, overlapping responsibilities and strained financial resources, exacerbate the governance challenge.

The results of this division of responsibility can be quite stark, and perhaps the most often-cited example is in the area of coal transformation, which includes coal-to-synthetic gas, coal-to-liquids, and coal-to-chemicals. Coal transformation projects have the potential to help cities like Beijing reduce reliance on local coal combustion while providing a source of cleaner-burning gas.

LA Lessons: the experience of Los Angeles, pictured above, can provide some insight into how large cities can work within a complex political system to achieve more regional cooperation on air quality control.

Production of syngas from coal has caused widespread controversy both within and outside of China due to high air emissions and water use requirements. Policies to reduce pollution in Eastern China by establishing coal-to-gas projects in Inner Mongolia, Xinjiang, and elsewhere could result in dangerous increases in pollution and greenhouse gas emissions, along with increased water stress and other environmental impacts.

As of 2014, China had two coal-to-synthetic gas plants in operation, with plans for up to 48 more such plants, mainly in Xinjiang and Inner Mongolia. These plants could produce as much as 225 billion cubic meters of gas if they all proceed,[195] resulting in over 1 billion tons of carbon emissions annually. Greenpeace estimates this is more than the total carbon emissions reductions planned under the coal caps established by the Action Plan for Air Pollution Prevention and Control in September 2013.[196]

The life-cycle energy use for coal-based synthetic gas is between 20% and 108% higher than competitive alternatives *for every application*, including cooking, power generation, and steam for heat and industry, according to a 2013 study by the State Key Laboratory for Control and Simulation of Large Power Systems and Power Stations at Tsinghua University.[197] Coal-to-syngas uses more energy and emits more lifecycle CO_2-equivalents than the most competitive alternatives. Thus, while coal-to-gas may help Beijing Municipality and other regions achieve energy goals, it may set China back on energy and emissions goals.

Water is another major concern. Eighty percent of the potential output from the planned coal-to-gas plants would come from areas of high or extremely high water risk, according to World Resources Institute data.[198] A single coal-to-gas plant in Inner Mongolia could use 24 million tons of water annually.[199] If all of Inner Mongolia's proposed coal-to-gas projects proceed, they could use over 700 million tons of water, compared to a current provincial water deficit of 1 billion tons annually.[200] While all energy from fossil fuels requires considerable water, coal transformation is especially water intensive.[201] On an energy basis, coal-to-gas production consumes far more water than conventional coal, conventional natural gas, or gas from shale.[202]

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Given the large water needs for coal-to-gas and coal-to-chemical processes, water pollution is a major issue. In fall 2014, investigations of Datang's coal-to-gas facility in Inner Mongolia showed that while the company claimed the facility was a "zero wastewater discharge" site, large amounts of heavily polluted water were being deposited in an apparently unlined discharge pond.[203] Thus, it is unclear how coal transformation projects can be reconciled with China's water policy goals at the national and provincial levels.

Given the high capital investment costs, long lead times, and long planned asset life for capital cost recovery, the environmental impacts of coal-to-gas have a large potential "lock in" effect. Plant developers, banks that provide financing to these projects, and policy makers may not be adequately considering the environmental and financial risks of coal-to-gas investments. Future carbon prices, pollution penalties, environmental taxes and changes in prices of alternatives could all render coal-to-gas projects financially untenable, resulting in stranded assets and financial risks to those involved. Perhaps the largest risk is that the coal-to-gas sector as a whole is out of step with the rest of China's energy, water and carbon strategy. This underlines the need to ensure that large, energy-intensive capital investment projects are reconciled with national and local targets and policies across the various aspects of energy, emissions, water and economic transformation.

2.4.5 Need for greater coordination between environmental and economic policy

China's present environmental policies heavily emphasize technical solutions within existing industries and administrative actions such as shutting down outmoded capacity. Yet air pollution and carbon emissions problems arise in large part due to the structure of China's economy, with its heavy weighting toward secondary industry (which includes transformation of raw materials into products and commodities—including manufacturing, refining and power generation), and specifically toward heavy industry. A 2014 study by Ma Jun of the People's Bank of China concluded that China could not achieve its 2030 ambient air quality objectives without addressing issues related to the country's economic structure. Even reducing emissions from secondary industry by 80%—the limit of what appears technically achievable today—and reducing the growth of industry to that of the economy overall, the Jing-Jin-Ji region would still fall short of its air quality goals.[204]

Energy prices that inadequately reflect externalities such as air pollution, water pollution, and greenhouse gas emissions represent a structural economic distortion in favor of energy-intensive industries.

There are several ways in which China's economic policies currently tilt in favor of heavy industry. First and foremost, as already discussed, poor environmental enforcement reduces the cost of doing business for those engaged in energy-intensive and high-emissions activities such as cement and steel manufacturing. In the short term, this gives these heavy industries a competitive advantage in trade, and also reduces the financial and business risks for investment in polluting industries, even when the national government has long-standing policies to discourage overcapacity in steel and cement.

Energy prices that inadequately reflect externalities such as air pollution, water pollution, and greenhouse gas emissions represent a structural economic distortion in favor of energy-intensive industries. Because of this price distortion, manufacturers decide whether to upgrade facilities and pursue energy-efficiency improvements based on returns that do not reflect true energy and emissions costs. Investors and firms evaluate capital allocation decisions based on relative returns from different production methods and different industry sectors that exclude environmental costs. The result is that China's long-term economic balance is excessively tilted in favor of energy-intensive, high-emissions activities. Administrative actions such as closures of high-emitting facilities or outdated surplus production capacity have a short-term impact, but do not change the long-run equilibrium favoring energy-intensive, emissions-intensive production caused by mispricing.

Another distorting factor within China's economy is that heavy industry benefits from favorable tax treatment and land availability compared with the service and consumer sectors. This may result from the performance incentives for officials, which stress short-term economic growth rates that can be influenced most quickly by policies that attract large industrial investments. Other factors distort the relative size of the service sector versus industry, such as relatively higher tax rates in the service sector,[205] financial sector practices that favor large industrial SOEs with lower lending rates and more funding,[206] and service sector monopolies that reduce competition and new entrants.[207]

Local land policies play a large role in reducing costs for heavy industry. The average cost of industrial land in China is 13% of the cost of commercial land and 16% of the cost of residential land, while these ratios range from one-third to one-half in most developed countries.[208] One cause of China's low industrial land price is local competition to sell land quickly and attract jobs and business.[209] A second is the overall high supply of industrial land. In 40 medium and large cities in China, industrial land accounts for 40-50% of land use, while residential land only accounts for around twenty percent.[210]

Another factor that tilts economic activity in favor of large investments in energy-intensive industries is that many of these firms are SOEs, which are perceived as low-risk investments by the state banks. As a result, these firms dominate the lending portfolios of China's major banks. In the future, if SOEs with poor environmental performance face greater regulatory and operational risks due to penalties and plant closures, this in turn will affect both business and lending decisions. As noted earlier, in China poor enforcement and low penalties for non-compliance have meant that many high-emissions, SOE-dominated industries face little regulatory or operational risk.

Requiring companies to disclose emissions to investors and lenders could also tilt investors away from higher-risk industries. Studies of the impact of the U.S. Toxic Releases Inventory have shown that disclosure of emissions has an impact on both investor behavior through reduced asset prices for polluting firms, and on company behavior through decisions to reduce emissions and invest in lower-emissions activities.[211] U.S. publicly-listed company financial statements generally include analysis and discussion of material environmental and regulatory risks, and a number of third-party organizations provide institutional and individual investors with information on company environmental performance. Increasingly, these organizations are also pushing companies to disclose material climate risks, such as investments in areas with high projected sea level rise or extreme heat impacts.

A 2014 study by Ma Jun of the People's Bank of China concluded that China could not achieve its 2030 ambient air quality objectives without addressing issues related to the country's economic structure.

Reducing economic distortions that tilt the economy toward energy-intensive, emissions-intensive production and sectors can help improve allocation of financial resources toward less energy-intensive, lower-emissions sectors, industries, technologies and business models. Increased disclosure of environmental practices, both to the public at large and specifically to investors, can also play a major role in improving allocation of capital to reduce financial risks associated with large environmental impacts.

2.4.6 **Suggestions on improving environmental outcomes through regional coordination and better policy integration**

As the foregoing has shown, greater policy integration and coordination is essential to achieving air quality and climate policy goals. This ranges all the way from coordination at the narrow level of individual air pollutants by developing a multi-pollutant strategy for PM2.5 to the broadest macro-

The buildings and energy dividend: Adoption of energy efficient technology and integrative design alone could cut China's building energy use in 2050 by nearly half relative to the base case, according to a recent study. Greater industrial efficiency will make a huge difference, too: China's iron and steel sector uses some 65% more energy to produce a ton of steel than South Korea.

economic strategies for economic development that have distorted local investment in the Jing-Jin-Ji region in favor of energy-intensive industries. Our suggestions in these areas are extremely broad, and reflect the Climate Change and Air Quality Program's view that policy makers themselves will have to decide the actual modality of achieving greater integration.

- Develop a multi-pollutant control strategy for NO_X, SO_2, VOCs, ammonia and PM2.5. Without systematic control of all pollutants, it will be impossible to resolve the problem of ambient PM2.5 in China's cities.
- Increase regional coordination, especially in the Jing-Jin-Ji and surrounding region that currently suffers the most severe air quality problems. Regional transport of emissions makes it difficult for a single city such as Beijing to resolve air quality problems through control of emissions in the local area.
- Adjust air quality key performance indicators (KPIs) for local officials to include items related to air quality that the officials actually control, with less emphasis on ambient air quality. Given the role of weather and regional transport of air pollutants, several factors influencing ambient air quality on a day-to-day basis are beyond the control of any single local jurisdiction. Therefore ambient PM2.5 levels cannot fully represent the progress of local policies in reducing pollution. As a starting point, more emphasis should be placed on specific measures taken to reduce emissions, such as enforcement rates and total emissions volumes.
- Increase integration of policies on climate change and ambient air quality. Fossil fuel combustion, particularly coal, is responsible for a large share of primary PM2.5 and its precursors, as well as for greenhouse gas emissions. Yet energy, emissions and carbon policies are often not well integrated at the local level, leading to investments that decrease local air emissions while raising carbon emissions elsewhere. Though not discussed in this report, water and agricultural policies are also intertwined in these issues. Local investment in large, energy-intensive industries such as coal plants, steel plants and coal-to-gas should be explicitly reconciled with national and provincial targets on carbon, energy, water and air emissions.
- Increase attention to local economic policies that create distortions favoring coal combustion and energy-intensive industry. These distortions have played a role in the development of Hebei province in particular as a center of steel, cement and glass despite its low environmental carrying capacity. Eliminating distortions in industrial land pricing, availability of cheap financing to energy-intensive SOEs, and promoting greater disclosure of environmental risks can all help resolve air quality issues and encourage the transformation of the local economy toward higher-value, cleaner industry.

2.5 Additional policy steps: Stronger focus on efficiency

The cheapest form of energy is the energy you never use. Studies over many years have shown that energy efficiency remains the lowest cost option for reducing emissions. China is no exception.

Policymakers in China are aggressively pursuing energy efficiency, and the country has made significant gains in the past decade. While China's energy intensity of GDP worsened by 5% in the 10th Five-Year Plan period (2001-2005), it improved by 12% in the 11th Five-Year Plan period (2006-2010) after greater investments in energy efficiency.[212] Some of the largest gains were made in industry, transportation and buildings. With these actions, China saved hundreds of millions of tons of coal consumption in comparison to the amount that would have been consumed under status quo conditions—a savings of around 10%.[213]

Despite this progress, energy efficiency remains challenged in implementation. Consumers pay little attention to energy efficiency when making purchase choices, and building developers and management have little incentive to incorporate energy saving decisions into building design and operation. Furthermore, industry often lacks the technology and know-how to implement energy efficiency or evaluate energy-efficiency investments. The progress already achieved in China and elsewhere provides plenty of reason for hope, as the following sections reflect.

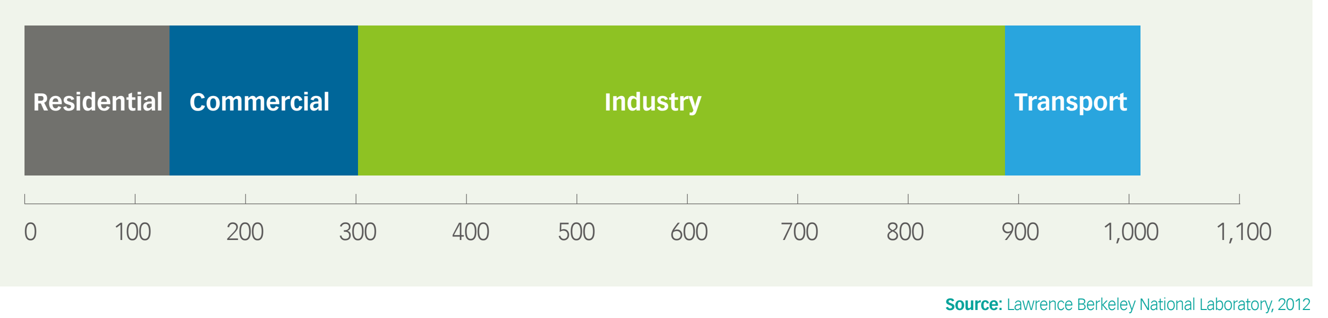
The cheapest form of energy is the energy you never use. Studies over many years have shown that energy efficiency remains the lowest cost option for reducing emissions.

2.5.1 Industrial energy efficiency has improved, but more can be done

Given that industry accounts for most primary energy consumption in China, it has been a major target for energy intensity reductions. These efforts have clearly borne fruit: In the steel sector, for example, the energy needed to produce a ton of steel in China fell by 31% between 2000 and 2008.[214] In the 1990s, China steel production doubled, but the sector's energy use rose only around 30%.[215] These gains came about as a result of process improvements, many promoted by government policy such as those of the 11th Five-Year Plan. Similarly, the Chinese cement sector reduced energy consumption per unit of cement by 30% between 1980 and 2009, reaching levels comparable with those in the U.S. and Europe.[216] And studies suggest that the 13th Five-Year Plan will continue to target efficiency gains in industry.[217]

Despite these gains, there is unquestionably room for improvement. Studies show that many of China's industrial sectors remain far more energy intensive than those in other countries. For example, China's iron and steel sector

2013 Primary Energy Savings by Sector Under LBNL Maximum Technology Case (Mtce)



Source: Lawrence Berkeley National Laboratory, 2012

LBNL's "Maximum Technology" scenario represents a high degree of efficiency improvements with regards to energy intensity per ton of industrial product output, technology mix, and fuel mix. In this scenario, efficiency improvements are maximized to the highest technical potential for end uses in the industrial, commercial, transport and residential sectors through aggressive programs and policies.

uses approximately 65% more energy to produce a ton of steel compared to Korea.[218] A 2012 study by the China Council for International Cooperation on Environment and Development (CCICED) found that 79 options for reducing industrial emissions and energy use—options additional to those currently being pursued—could cut 1.2 billion tons of carbon emissions by 2020 versus a baseline scenario, compared to total emissions around 6.2 billion tons in 2010. The report reveals the gap between energy intensity and Chinese industrial emissions versus best international practices, finding substantial room for industrial upgrades.[219]

A separate 2011 CCICED study identified hundreds of mature technologies that could save China 450-750 million tons carbon equivalent of energy by 2020.[220] Similarly, a 2012 Lawrence Berkeley National Laboratory (LBNL) study suggested major industrial energy efficiency gains are possible versus a baseline scenario using present policy.[221] Under the LBNL's "Max Tech" scenario, the industrial sector could save energy equal to 600 million standard tons of coal versus a base case for 2030 (roughly 13% of baseline national energy use). In the analysis, the residential and commercial sectors have potential savings of 300 million tons standard coal equivalent in energy savings and transport offers savings of 150 million tons standard coal equivalent.

An overall move from an industrially based economy to one more reliant on services could also provide impetus for efficiency gains. Over the past decade, most of China's industrial efficiency improvements have resulted directly from efficiency improvements within existing sectors, as opposed to a larger transition toward lower-intensity industries.[222] During the past two decades, investments in fixed-assets dominated China's economic growth pattern, leading construction-oriented and energy-intensive manufacturing sectors like steel and cement to grow more rapidly than the economy as a whole.[223] As China moves toward increased domestic consumption and less fixed-asset investment, demand for steel, cement and glass may grow more slowly than industries targeting the consumer economy.

Based on China's urbanization plans, energy consumption in buildings is expected to rise 50% by 2040.

2.5.2 **Transportation efficiency is increasingly important as car use and oil consumption rise**

China's transportation sector accounts for a relatively small 10% of primary energy consumption,[224] but this share is rising rapidly due to increased driving and car ownership. China has already surpassed the U.S. as the world's largest oil importing country,[225] and could become the world's largest oil consumer by 2030.[226] China now has more than 240 million vehicles[227] and more than 20 million vehicles were sold in China in 2014,[228] though demand growth is projected to slow.[229] Given that China's per capita vehicle ownership rate is still far lower than that of the U.S. or Japan, some forecasts project China could have as many as 500 million vehicles by 2030.[230] Assuming most or all new vehicles are petroleum-fueled, the implications of increased driving for China's energy use, emissions and energy security are dire.

The government has already taken a number of actions that will help through both local action plans on air pollution as well as through national five-year plans. On the energy efficiency front, China acted in 2004 to address fuel efficiency standards, ratcheting up fuel economy for new passenger cars to 6.92 liters per 100 km (34 miles-per-gallon) as of 2014. Standards will continue to strengthen to 5 liters per 100 km (47 miles-per-gallon) by 2020.[231] To accelerate efficiency gains and retire older, polluting vehicles, the government has implemented vehicle scrapping programs. The government has established incentive programs for fuel-efficient hybrids and other vehicles, plus subsidies for liquefied-petroleum gas (LPG) and compressed natural gas (CNG) vehicles.[232] In addition, the government is promoting the electric vehicle market in various ways.[233]

Livable cities: The Chinese government is promoting the electric vehicle market, and many urban planners believe that new sustainable cities should be "people-centric," using design principles that encourage walking and biking.

LBNL's 2012 study of China 2030 energy scenarios found that energy efficiency has immense potential to reduce energy use and emissions in transportation. The study assumed accelerated efficiency gains in all transport sectors including cars and trucks, plus 25% penetration of electric vehicles (EVs).[234]

The national and local governments also continue to invest heavily in public transport infrastructure, including creating vast new subway networks in most of China's mega-cities, as well as a densely integrated bus network. High-speed rail makes trains more convenient than air travel for many intercity trips. China's 2014 Energy Action Plan calls for increased effort to plan walking and biking routes as alternatives to driving and public transport.[235]

But there still is room for improvement. Many observers have critiqued China's rapid urbanization, noting that newly built cities often rely on vehicle-centric planning principles: wide avenues, super-blocks, and long distances between major employment centers and residential zones.[236] Many urban planners believe that new sustainable cities should be "people-centric" and use design principles that encourage walking and biking and allow for short commute times between different urban clusters.[237] China's most recent urbanization strategy document uses the phrase people-centered urbanization.[238] Today, only a few cities are focusing on pedestrian-oriented development—Shenzhen is one example.

2.5.3 **Building efficiency can be improved significantly throughout China**

In recent years China has constructed 2 billion square meters of floor space every year, or roughly half of the world annual total. Based on China's urbanization plans, energy consumption in buildings is expected to rise 50% by 2040.[239] In comparison with the developed world, while China's buildings are far less energy efficient, with poor insulation and inefficient heating and cooling, they also paradoxically use far less energy. This is likely due to a combination of differences in design practices and usage patterns, and particularly to the minimal usage of air conditioning across China.[240] Nevertheless, expected convergence in energy use patterns in buildings, combined with continued urbanization and increasing building floor area, will likely cause energy use in buildings to rise quickly in the coming decades, confirming the need to address building energy efficiency in China today.

As with other sectors, the government has already taken several actions to boost energy efficiency, including tightening building codes and improving enforcement.[241] China has performed building-energy retrofits on hundreds of millions of square meters of buildings over the past decade, particularly in

Rise of renewables: The Chinese government is supporting the development of renewable energy with low-cost loans for manufacturers and developers, feed-in tariffs for wind and solar and subsidies for distributed energy.

the residential sector.[242] The country has also adopted its own green building standard and is promoting green buildings for government construction.[243] However, green buildings currently account for less than 1% of new construction in China.[244] Furthermore, heating reform for Northern provinces is behind schedule and building retrofits have proceeded at a slow pace.[245] Despite China hiring over 100,000 building code enforcers and increasing the reported building code enforcement rate to nearly 100%, the quality of building energy efficiency enforcement remains low.[246]

In addition, China's newly adopted building codes are less stringent than international standards.[247] And while new technologies such as passive house design—ultra-low energy buildings that require little energy for space heating or cooling—make even larger gains possible, China currently lacks the knowhow and industrial supply chain to adopt such practices.[248]

Energy awareness is also lacking in China, notwithstanding widespread support for energy conservation as both an economic value and personal responsibility. Education of building owners and building managers is especially critical, since they bear an outsized responsibility for ensuring efficient building operation and maintenance related to energy efficiency.

According to the 2014 "Reinventing Fire – China" study by LBNL and the Rocky Mountain Institute (RMI), China's building sector has immense room for energy-efficiency gains over the next few decades. Whereas the LBNL-RMI base case anticipates a steady growth in building energy use through 2050—due to increased floor area and rising energy intensity—the Reinventing Fire case maps a scenario that would lead to a peak in building energy use around 2030. The study shows that adoption of energy efficient technology and integrative design alone can cut building energy use in 2050 in nearly half relative to the base case. Most of these gains result from integrated design,[249] which refers to a collaborative, multi-disciplinary process that results in energy-saving materials and equipment choices being matched to climate, use, building design and systems.

As with other sectors, energy-efficiency investments often pay for themselves, even without considering environmental benefits. According to a McKinsey study, many of the emissions abatement actions with the most attractive payoff are building energy efficiency measures, including efficient LED lighting, better building envelopes, and passive design.[250]

Given that China is in the midst of rapid urbanization, the time is now to adopt strict building codes and practices to prevent the new building stock from locking in high energy consumption for future decades.

2.5.4 Suggestions for improving energy efficiency outcomes across industry, transportation and buildings

Energy efficiency should be a core aspect of China's emissions reduction and energy security strategy. It is one of the most economically effective ways to reduce emissions from both conventional pollutants and greenhouse gas emissions. Steps to increase energy efficiency in many cases have negative net cost, though they may face institutional or market barriers.

By implementing stricter standards for fuel efficiency, buildings and even industrial processes, China has sent a clear signal about its commitment to energy efficiency. While industry is the largest consumer of primary energy, however, there is a need for and great value in implementing efficiency measures across all sectors. The Climate Change and Air Quality Program's suggestions for energy efficiency, many of which are quite broad by design, reflect the view that more can be done to strengthen implementation of standards and achieve goals.

- For industry, continue targeting energy efficiency improvements in iron and steel. Many of China's industrial sectors remain far more energy intensive than those in other countries, particularly in iron and steel.
- Take full advantage of mature technologies to reduce energy consumption in the industrial, commercial, and residential sectors, in part by continuing to work with businesses and energy services companies to identify and reduce financial and policy barriers to such investments.
- Build on current urban transportation networks to reduce reliance on cars and plan cities in a way that ensures high accessibility within and across community clusters.
- Raise awareness among building owners and managers about the benefits of energy efficiency and continue to advocate for energy use disclosure and benchmarking for buildings as a means of accelerating development of stricter standards and targets.

2.6 Additional steps to control air pollution: Moving away from fossil fuels

The most obvious reason for China to control its air pollution and greenhouse gas emissions together is that they both generally result from the same cause: China's high reliance on fossil fuels. The Chinese government largely recognizes that the country's reliance on coal has created both economic and environmental problems. Diversification of fuel supply has been a long-term goal, leading in past decades to investment in alternatives. There are three major strategies the government is already pursuing on the supply side to shift the country away from its reliance on coal: increased reliance on non-fossil energy such as wind, solar, hydro and nuclear; increased production and imports of natural gas, and caps on coal use.

2.6.1 China is increasing renewable electricity production

As a part of its efforts to shift away from coal and diversify fuel supply, China has already become a renewable energy powerhouse. Policies encouraging a shift away from coal include targets for increased non-fossil energy share in the 12th and 13th Five-Year Plans. The country has the world's largest hydropower capacity,[251] has more wind energy capacity than any other country, and is on-track to become the world's largest solar country (China is already the largest manufacturer of solar PV modules).[252] The Chinese government has supported development of renewable energy with policies and subsidies on both the supply and demand sides, including low-cost loans for manufacturers and developers, feed-in tariffs for wind and solar, and

As a part of its efforts to shift away from coal and diversify fuel supply, China has already become a renewable energy powerhouse.

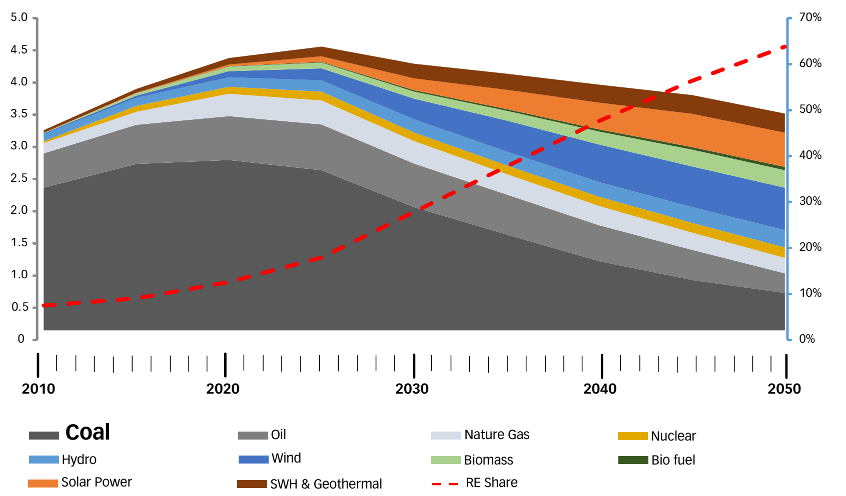
GW OF INSTALLED NON-COAL POWER CAPACITY, BASED ON CURRENT TARGETS

	2013 year-end	2015	2017	2020	2030
Natural Gas	44			85	230
Hydro	257	290	330	350	400
Nuclear	16	40		58	120
Wind (grid connected)	78	100	150	230	560
Solar PV	19	35	70	100	308

Source: NDRC 12th Five-Year Plan, 2013; NEA 2017 targets, 2014; NDRC Energy Action Plan, 2014; IRENA, 2014

Current plans suggest China will add hundreds of GW of solar and wind by 2020 and perhaps over 1,000 GW of these technologies by 2030.

CHINA HAS THE POTENTIAL TO INCREASE RENEWABLE ENERGY TO 60% OF FUEL MIX BY 2050



Source: China National Renewable Energy Center (CNREC) and Energy Research Institute (ERI), April 2015

An April 2015 study led by the China National Renewable Energy Center argued that it is technically and economically feasible for the country to get 85% of its electricity and 60% of total energy from renewables by 2050.

subsidies for distributed energy.[253] But because of the country's voracious growth in energy demand, and the ready supply of cheap coal compared to other fuels, growth in non-coal energy has not yet led to a sustained drop in coal consumption.

Thanks to China's early start, as well as cost declines in renewable energy enabled by China's own manufacturing scale-up in the industry, the country is now able to set more aggressive goals for both absolute capacity of non-fossil energy and share of total energy. Under the 12th Five-Year Plan (2011-2015), wind power is targeted to rise 300% to 100 GW of grid-connected capacity by 2015, solar PV is expected to increase by 3,500% to 35 GW, and hydro is targeted to increase by over 50% to 330 GW.[254] Targets for 2020 call for 200 GW of wind and 100 GW of solar PV—a doubling of wind and tripling of solar over the five-year period.[255] Nevertheless, by 2020 non-fossil energy will still account for just 15% of energy consumption in China,[256] rising to at least 20%

of total energy consumption by 2030.[257] Non-fossil energy includes solar, wind, hydro, nuclear and biomass.

China's targets for hydro, wind, solar and nuclear place the country at the forefront of deployment of these technologies worldwide, and for the most part the government has steadily ramped up the targets at regular intervals. Current plans suggest hundreds of GW of solar and wind by 2020 and perhaps over 1,000 GW of these technologies by 2030.

2.6.2 China is raising natural gas production and imports

If produced and managed responsibly, natural gas offers significantly lower emissions of both conventional pollutants as well as carbon dioxide.[258] The U.S., which reduced emissions by shifting energy use from coal to natural gas over the last decade, demonstrates the many benefits of natural gas, though it also provides a cautionary tale for the potential downsides of unregulated gas production, which can lead to methane leaks, water contamination, and other environmental issues.[259] China began the century from a totally different position—with lower domestic gas production, and few natural gas pipelines or gas-fueled power plants. While China has rich natural gas reserves, including shale gas reserves that may be the world's largest,[260] its resources are likely to be considerably more difficult to develop compared with the U.S.[261]

In particular, natural gas development will depend on China's ability to resolve critical policy issues such as gas prices, pipeline construction and market access. The most important factor holding back gas is domestic production, which is hobbled by a myriad of regulatory and market problems ranging from pipeline access to lack of exploration and production data.[262] Since China's gas demand far exceeds present domestic supply, the country must rely on imports via liquefied natural gas (LNG) and international pipelines.[263] As a result, gas prices are considerably higher in China than in the U.S. Cost of domestic production, imports and associated infrastructure raise the cost of natural gas versus coal. At present, coal is simply too cheap to encourage fuel-switching to gas. A combination of resource taxes, emissions allowance trading and coal caps should be used to rectify this situation.

Another obstacle for natural gas is competition from coal-to-synthetic gas—an expensive alternative to natural gas. Several of the regions currently channeling funding into coal-derived synthetic gas are also home to China's most abundant natural gas reserves. More transparent enforcement of central government policies—including coal caps, emissions control, water management and energy pricing—could help shift funding away from coal-to-gas infrastructure and toward cleaner alternatives such as natural gas, renewable energy and energy efficiency.

Despite these obstacles, China has the ambition to grow natural gas alongside all other coal alternatives. According to government targets, natural gas should account for 7.5% of energy consumption by 2020, up from 5.9% in 2014.[264] The supply will come from a combination of increased liquefied natural gas and pipeline imports—recent deals signed with Russia could help—and more domestic supply from conventional gas, coal bed methane and shale.

Capping coal: while caps on coal consumption currently only exist at the provincial and municipal level, they are expected to be extended to the national level by 2020. In less than two years, a national coal cap has gone from unimaginable to official policy.

Natural gas development will depend on China's ability to resolve critical policy issues such as gas prices, pipeline construction and market access.

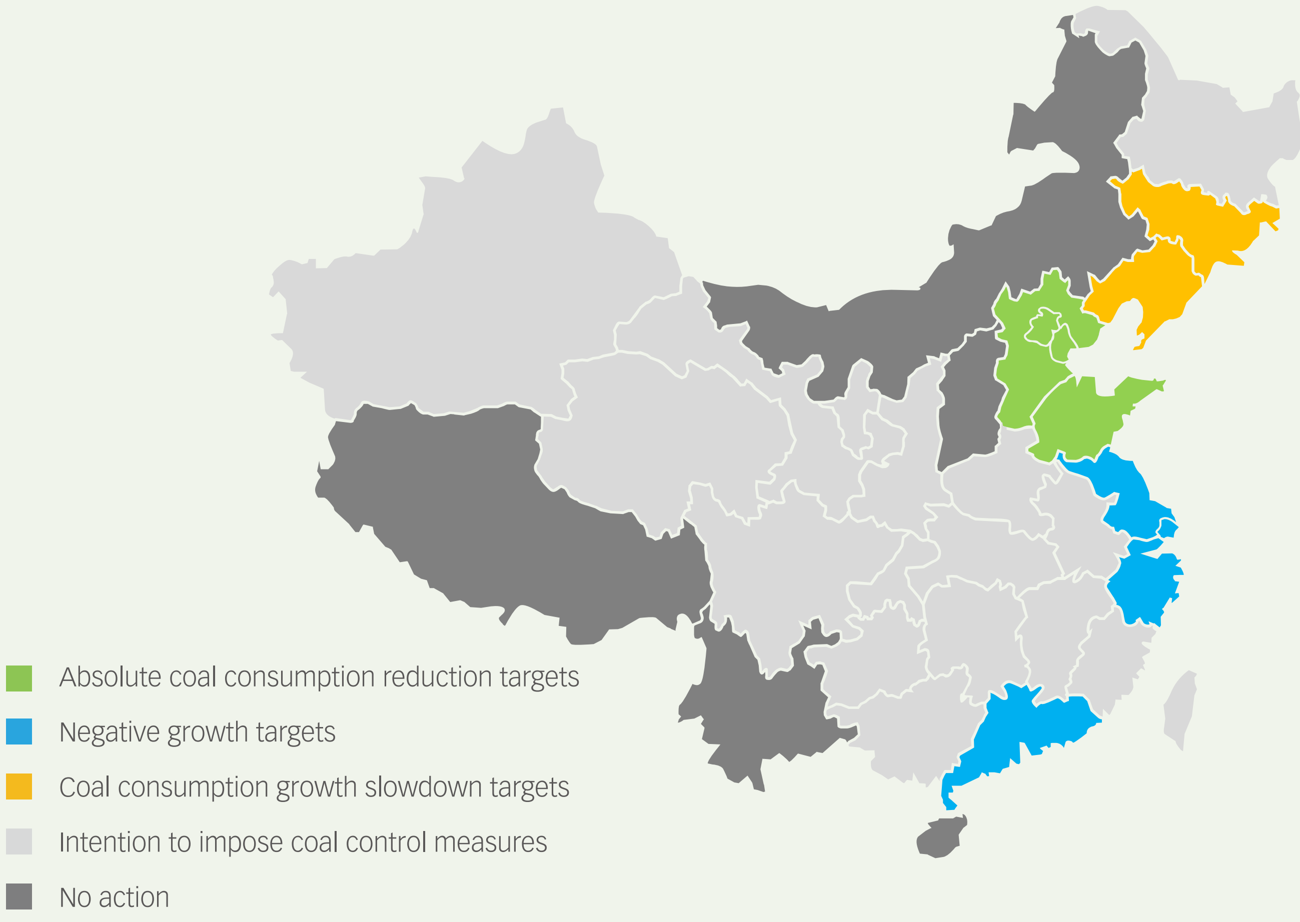
2.6.3 China is capping coal in several provinces

There are now multiple scenarios under which China will reach peak coal before 2030.

Just a few years ago, most experts believed that China's coal use would rise inexorably barring some dramatic policy change. Slowed economic growth combined with more rapid industrial restructuring has shifted this perception. In September 2013, Citibank published research suggesting that China's coal use would peak before 2030, something the authors at that time called "unimaginable." However, they noted factors pushing China in this direction including policies to reduce air pollution, lower GDP growth, development of non-fossil energy, and improved efficiency in coal use.[265]

At the same time, China was already moving toward capping coal use in certain provinces, especially in Northeast China, in part to address air pollution. The September 2013 Action Plan for Air Pollution Prevention and Control – the plan released by the State Council that makes 10 specific policy measures to improve air quality nationwide – specifically called for such caps,

OVERVIEW OF CHINA PROVINCIAL COAL CAP POLICIES AS OF 2014



Source: Greenpeace, 2014

Jilin and Liaoning provinces plan to cap coal consumption at levels not far above current consumption, while Shanghai, Jiangsu, and Zhejiang have targeted "negative growth" in coal consumption. A further four provinces (Heilongjiang, Anhui, Fujian and Jiangxi) have plans to reduce coal consumption growth.

which were subsequently adopted by individual provinces. The State Council also announced that new coal-fired power plants would be banned in the three regions of Jing-Jin-Ji, Yangtze River Delta and the Pearl River Delta.[266]

Four provinces and municipalities in East China, three of which make up the Jing-Jin-Ji region, have adopted plans to cut absolute coal consumption by 2017:

- Beijing: Cut 13 million metric tons by 2017, versus 22.7 million metric tons consumed in 2013 (a 57% cut).
- Tianjin: Cut 10 million metric tons, versus 53 million metric tons consumed in 2013 (a 19% cut).
- Hebei: Cut 40 million metric tons, versus 313.6 million metric tons consumed in 2013 (a 13% cut).
- Shandong: Cut 20 million metric tons, versus 402.3 million metric tons consumed in 2013 (a 5% cut).[267]

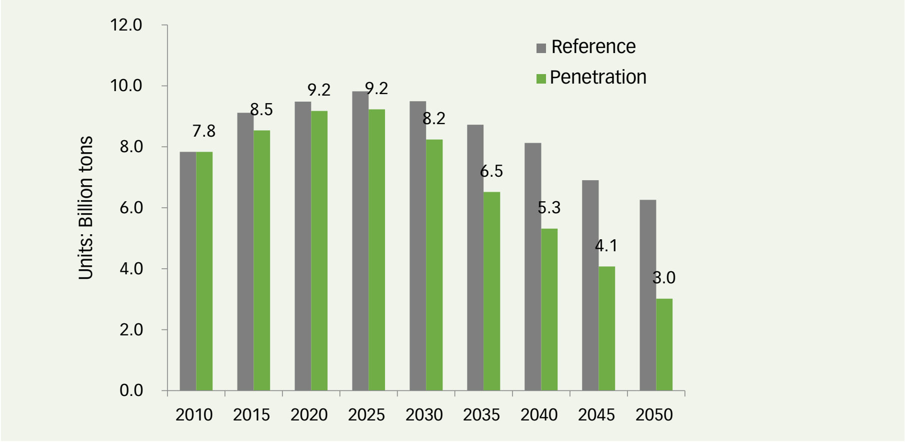
These figures imply a total of 10.5% lower consumption of coal for these four provinces in 2017 versus coal consumed in 2012.[268] Jilin and Liaoning plan to cap coal consumption at levels not far above current consumption, while Shanghai, Jiangsu and Zhejiang have targeted "negative growth" in coal consumption. A further four provinces (Heilongjiang, Anhui, Fujian and Jiangxi) have plans to reduce coal consumption growth.[269]

In an April 2014 analysis of the provincial coal caps announced to date, Greenpeace wrote that these policies could bring China close to the levels of emissions reductions needed to stay in line with the International Energy Agency's 2 degree Celsius global warming path.[270]

While caps on coal consumption currently only exist at the provincial and municipality level,* they are expected to be extended to the national level by 2020. According to the State Council's Energy Action Plan, released in November 2014, the country will cap 2020 coal consumption at 4.2 billion tons

While caps on coal consumption currently only exist at the provincial and municipality level, they are expected to be extended to the national level by 2020.

China Could Peak Coal by Early Next Decade



Source: China National Renewable Energy Center (CNREC) and Energy Research Institute (ERI), April 2015

There are now multiple scenarios under which China will reach peak coal before 2030. This projection from the China National Renewable Energy Center shows China reaching peak coal by 2025.

of standard coal, roughly 8% above the 2014 level.[271] Based on this target, coal should represent 65% of primary energy by 2015,[272] and should fall to 62% by 2020.[273] The proportion could fall to under 50% by 2030.[274] In less than two years' time, the concept of a national coal cap has gone from unimaginable to official policy.

There are now multiple scenarios under which China will reach peak coal before 2030. Research organizations, such as NDRC's Energy Research Institute (ERI) and the China National Renewable Energy Center, have modeled China's energy development pathways, incorporating present policies as well as various plausible updates.[275] Over the course of the last three years, authors of such reports have gradually moved the dates forward for peak coal, peak carbon and peak energy. The change in expectations coincides with China's commitment to peak carbon emissions before 2030 announced in November2014.

Given coal's contribution to air pollution, local and national coal caps represent an important step forward in reducing pollution from the energy and industrial sectors. However, implementation and enforcement remain challenging.[276] The exact mechanism for implementing coal caps and related industrial policy will be an important policy choice. Administrative options to close facilities have proven only partially effective in the past. Market-based systems such as resource taxes and emissions allowance trading could help price in the externalities of fossil fuel production and use and better guide long-term investment decisions.

U.S.-China Energy and Environmental Cooperation

As the two largest energy consuming countries and major contributors to the world's total greenhouse gas emissions, China and the U.S. share many of the same policy priorities regarding energy and the environment. Both countries have prioritized development of low-carbon energy sources such as wind, solar and natural gas, deepened efforts on energy efficiency and demand-side management, and pushed forward the development of advanced technologies in energy storage, electric vehicles and carbon capture and storage. While China has much to learn from the U.S. in some scientific and technical fields, today China is recognized worldwide for its booming R&D sector and ability to take the lead in financing and scaling up new energy technologies. This means that U.S.-China energy cooperation is more of a two-way street, with technology transfer from the U.S. to China happening in some fields (like carbon capture and storage), and China taking the lead in scaling up other technologies where tech transfer has already occurred (like advanced nuclear). In some areas, government-to-government collaboration and scientific collaboration is producing results that both countries can deploy and use, as epitomized by the efforts of the various organizations and companies participating in the U.S.-China Clean Energy Research Center.

U.S.-China cooperation is a core element of the Paulson Institute's mission. Working with officials in both countries, the Paulson Institute is bringing together experts in fields across the energy and environmental disciplines. Future Climate Change and Air Quality Program research will focus on ways that U.S. and Chinese experts, officials and companies can work together to resolve joint problems for mutual benefit.

2.6.4 Suggestions for speeding the transition away from fossil fuels

China has the opportunity to dramatically reduce conventional pollutants and carbon emissions by reducing its reliance on fossil fuels through fuel-switching. Responsible development of natural gas resources and effective integration of renewable energy sources into the national grid and across regional grids will reduce emissions and drive innovation in clean energy development. There are several steps China can take to ensure that net reductions of greenhouse gas and conventional pollutants are achieved when transitioning to cleaner fuels.

- Implement stricter guidelines as domestic natural gas development expands: Require annual methane emissions data reporting to local environmental protection bureaus and MEP, inspect and renovate transmission infrastructure annually to reduce leaks during distribution, and minimize methane leakage during production.
- Ensure that solar and wind resources are fully utilized as installed capacity grows: Improve grid integration of renewable energy resources by boosting transmission and ensuring more effective dispatch of power plants.
- Combine efforts to boost renewable energy capacity with China's growing interest in demand response –for example, push forward with experimentation of vehicle-to-grid programs to improve power grid operation and flexibility, and absorb more renewable energy into the grid.

In summer 2015, the Paulson Institute's Climate Change and Air Quality Program will publish two separate papers on power sector reform and demand response and their role in both reducing emissions and accelerating the transition toward cleaner energy sources.

Greater policy coordination is one of the most important outstanding issues related to solving climate change and air quality problems—and one of the most challenging.

2.7 Summary and conclusions

This report makes the case that both air pollution and climate change are urgent problems that China must address today. Air pollution is a serious challenge for China, with most large Chinese cities experiencing levels of pollution far above levels considered acceptable by international health experts. China also faces enormous short- and long-term risks from climate change, including increased extreme weather events, more frequent and longer droughts affecting the country's food supply and rural economy, and over 50 million people at risk of flooding due to sea level rise, including millions in economic centers such as Shenzhen and Shanghai.

To fully address both climate change and air quality, China must continue to strengthen both policies and enforcement. Strengthening enforcement capacity is one of the most economical investments that China can make to reduce air pollution. For many enterprises, it remains more economical to pay air pollution penalties than comply with air regulations. To meet these challenges, China will need to increase the number of enforcement officials, boost training, and empower officials to enforce laws on SOEs. Accessibility of air quality data has improved markedly across China since 2012, but more can be done to expand real-time disclosure, improve emissions inventories, and expand the role of NGOs in assisting with enforcement activities.

Greater policy coordination is one of the most important outstanding issues related to solving climate change and air quality problems—and one of the most challenging. China will need greater coordination of policies across air pollutants through a multi-pollutant PM2.5 strategy, better regional coordination, improved integration of policies on energy, emissions and water; and greater attention to economic distortions that favor energy-intensive industries in regions with low environmental carrying capacity like Hebei. Ideally, local officials will be evaluated not only on environmental targets such as ambient air quality, but how well they do on integrating across these areas to achieve a comprehensive set of goals beyond pure short-term GDP growth.

In addition to strengthening and better enforcing existing regulations, policymakers can best address climate change and air quality together by developing stronger initiatives in two specific areas: energy efficiency and fuel-switching away from coal. Emissions policy and enforcement have typically focused on implementing industry-specific end-of-pipe solutions, such as NO_X emissions standards for power plants or tailpipe standards for automobiles. These solutions often address only one or a few pollutants at a time, they can lock in existing energy production patterns, and they may even lead to higher emissions of other pollutants. In contrast, policies that promote energy efficiency and fuel-switching away from coal accomplish many policy goals while reducing emissions across all pollutants. Often energy-efficiency investments or operational changes have low cost or actually save money—for example, LED lighting and better building insulation pay for themselves in cost savings, while simply changing the way existing power plants are utilized to favor cleaner, more efficient units could save China billions of RMB annually.[277]

The best path forward is to shift increasingly toward an integrated, systematic allocation of resources to meet government targets for air pollution, climate and water while promoting the rise of cleaner industry as China's economic engine of growth.

Energy policy is always a matter of investing under long-term uncertainty in ways that ideally maximize economic and environmental outcomes. Because energy covers such a broad swath of activities, regulatory and investment policy is divided among many sectors and government actors. In the past, this has produced rapid economic growth that has sometimes come at the expense of clean air and long-term climate stability, particularly in the Jing-Jin-Ji region.

As China looks forward to the next two decades, the country must do more to channel investment toward activities that produce more long-term gains with fewer long-term costs. Doing so will not be easy, but the gradual scaling-up of renewable energy and natural gas over the past decade has reduced the risk considerably and opened up new options for China.

Ultimately, the best path forward is to shift increasingly toward an integrated, systematic allocation of resources to meet government targets for air pollution, climate and water while promoting the rise of cleaner industry as China's economic engine of growth. In Jing-Jin-Ji and China as a whole, this will require the government to pursue economic development strategies that jointly address air pollution and greenhouse gas emission. Though the immediate benefits of controlling air pollution are more obvious than those of reducing greenhouse gas emissions, simultaneously addressing the two is the most economically efficient approach with the best ratio of benefits to costs.[278]

In the last five years, China's energy situation has undergone significant change. The costs of wind, solar and energy storage have fallen,[279] and expected energy consumption growth has also slowed markedly.[280] If these trends continue, the practicality and cost-effectiveness of co-control of air pollution and carbon emissions through fuel-switching and energy efficiency are likely to improve over time. Ultimately, given the urgency of addressing both air pollution and climate change, China cannot afford to wait.

APEC blue: Beijing delivered blue skies like these, above, for part of the APEC government meetings in November, 2014, by shutting down industry in the surrounding region. But short-term fixes like that are not sustainable.

REFERENCES

All references, including links, are available in the online version of the paper, accessible under the Climate Change & Air Quality Program page at www.paulsoninstitute.org

ABOUT THE AUTHORS

Anders Hove

Anders Hove is Associate Director for China Research at the Paulson Institute. He guides the Institute's research work related to China air quality and climate change, developing insights related to policy, market and technology solutions. He also provides research support for other Institute programs. Hove has more than 15 years of public and private sector experience related to energy policy and markets, including nine years on Wall Street and four years in China. He began his career as an energy policy analyst with the Rand Corporation in Washington, D.C., then performed equity research in the electric utilities and oil services sectors with Deutsche Bank AG and Jefferies and Co. Hove has both a Master of Science and a Bachelor of Science in Political Science from MIT, and he is a Chartered Financial Analyst.

Merisha Enoe

Merisha Enoe is Manager of Research at the Paulson Institute's China Office. She develops insights for the Institute's Climate Change and Air Quality Program, producing reports and recommendations for air quality improvement in northern China. Before joining the Paulson Institute, Enoe worked at the China Greentech Initiative, where she led the development and production of *The China Greentech Report* as well as several research projects on topics including shale gas development and the impact of national policies on clean technology adoption. Enoe received her BA in biochemistry and Mandarin Chinese from Middlebury College and her Master's in Environmental Management from Yale University.

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Jeremy Schreifels
Environmental Consultant

Shuxiao Wang (王书肖)
Director, Air Pollution and Control Research Institute, Tsinghua University School of Environment

Yan Wang (王彦)
Project Director, China Environmental Law and Governance, Natural Resources Defense Council

Steve Wolfson
Senior Attorney, International Environmental Law Office, Environmental Protection Agency

Lijian Zhao (赵立建)
Environmental Management Program Director, Energy Foundation

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