Paulson Papers On Energy and Environment

Double Impact:

Why China Needs Coordinated Air Quality and Climate Strategies

Valerie J. Karplus

February 2015

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About the Author

Valerie J. Karplus

Valerie J. Karplus is an Assistant Professor in the Global Economics and Management Group at the MIT Sloan School of Management. She leads the MIT-Tsinghua China Energy and Climate Project, an international collaborative team of researchers based at MIT and Tsinghua University, focused on China's role in global energy markets and climate change mitigation. Dr. Karplus has previously worked in the development policy section of the German Federal Foreign Office in Berlin, Germany, as a Robert Bosch Foundation Fellow, and in the biotechnology industry in Beijing, China, both as a Luce Scholar and as an employee of the National Institute of Biological Sciences, Beijing. Her research focuses on resource and environmental management in firms operating in diverse national and industry contexts, with an emphasis on emerging markets and the role of policy. Dr. Karplus is an expert on China's energy system, including technology trends, energy system governance, and the sustainability impact of business decisions. She holds a BS in biochemistry and political science from Yale University and a PhD in engineering systems from MIT.

The author gratefully acknowledges team members at Tsinghua University and MIT who contributed to the research that motivated this policy memorandum and provided helpful comments on earlier drafts: Zhang Xiliang, Li Chiao-Ting, Li Mingwei, Noelle Selin, Kyung-Min Nam, Zhang Da, Paul Kishimoto, and Tiger Luo.

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Introduction

Despite the Chinese government's redoubled efforts to curb air pollution, the air quality index in Beijing continues to spike above 300, well into the hazardous range. Cleaning up the air has climbed to near the top of the government's policy priorities, especially since record air pollution levels in January 2013 in Beijing triggered unprecedented public outrage. This and other episodes prompted pledges to take swift and significant action at the highest levels of the Chinese government, which went so far as to declare a "war on pollution."[1]

The urgency with which Beijing is tackling air pollution is certainly positive, and these efforts will also have concomitant benefits in curtailing carbon dioxide (CO2) emissions—to a certain extent. But it would be a mistake to view the current initiatives on air pollution, which are primarily aimed at scrubbing coal-related pollutants or reducing coal use, as perfectly aligned with carbon reduction.

Air pollution control efforts, while essential, will only take China part of the way toward its stated carbon reduction goals.

This is, in fact, not the case. Air pollution reduction is only partly aligned with CO2 reduction, and vice versa. In addition to air pollution efforts, effective co-control requires a more significant step: a meaningful price on carbon. This is especially so if Beijing is to realize its pledge to reach "peak carbon" by 2030. In other words, air pollution control efforts, while essential, will only take China part of the way toward its stated carbon reduction goals.

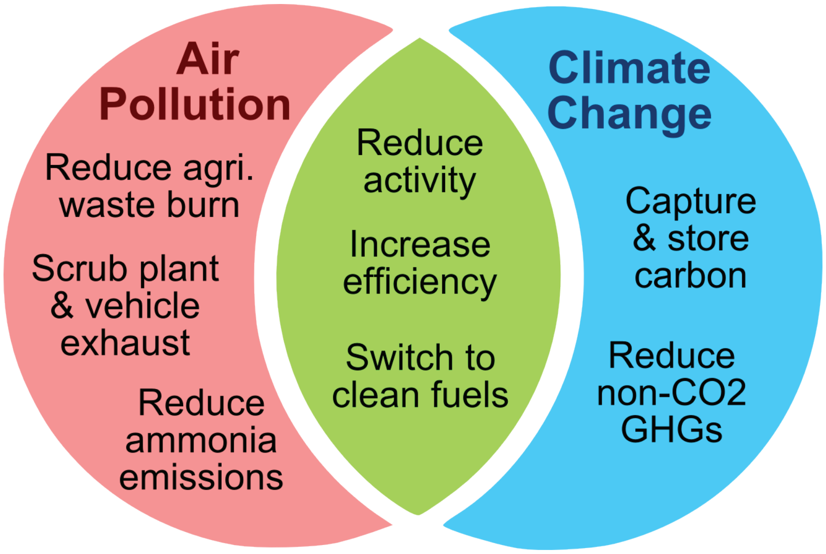
First, let us be clear why countries need a dual approach that explicitly considers both air pollution and carbon. While low-cost solutions for air pollution and carbon reduction can overlap, the reality is that co-benefits run out after low-cost opportunities to reduce or displace the fuel(s) responsible for both CO2 and air pollution emissions—in China's case, mainly coal—are exhausted.[2] Work from our team at MIT and Tsinghua University has found that air pollution control efforts can help China reach its near-term CO2 reduction goals, and vice versa, but co-benefits diminish over time as ever-greater reductions are required.[3]

In China, immediate and deep reductions in coal use would address both problems initially. However, the marginal cost of displacing coal rises as coal is squeezed out of the energy system. Because coal is the cheapest and most domestically abundant source of energy available, reducing its use and replacing it with other fuels will inevitably increase direct costs to the economy, even as it offers health and environmental benefits. Beyond this point, the strategies that make the most economic sense for carbon and air pollution control diverge (see Figure 1 for an overview of how strategies for addressing carbon and air pollution overlap).

Various options for reducing coal use—such as reducing coal-intensive activities, increasing efficiency, and promoting fuel switching—will have different associated costs. In general, curtailing coal-intensive activities altogether is costly to economic growth (but may be economically viable in industries with overcapacity). Some efficiency improvements—via equipment upgrading or improved process management—offer economic benefits for adopters and are therefore considered relatively low cost, while other strategies are trickier to exploit. In fact, efficiency improvements have driven much of China's reductions in energy intensity achieved since the beginning of economic reforms in 1978.[4] As for fuel switching, costs differ by fuel—nuclear is estimated to be less expensive than natural gas as a source of electricity, for example—and will be limited by the substitutability of alternative fuels in different end uses.[5]

Once low-cost opportunities to reduce coal are exhausted, if the focus continues to remain narrowly on air quality, other options—such

Figure 1. Overlapping and Divergent Strategies for Addressing Air Pollution and Climate



Source: Dr. Li Chiao-Ting, MIT-Tsinghua China Energy and Climate Project.

as scrubbing pollutants from the exhaust stream of coal power plants—will either already be more cost-effective or will quickly become so as the marginal cost of displacing coal surpasses that of installing and operating pollution treatment systems. Because these latter options are relatively inexpensive, policymakers and industry will be more predisposed to stick with such end-of-pipe solutions. But here is the rub: simply scrubbing end-of-pipe emissions does next to nothing to reduce CO2.

Moreover, to the extent that cleanup equipment is applied to (and is powered by) carbon-intensive energy, it could actually increase CO2 emissions even as air quality improves. These dynamics make climate change—which lacks the immediate social and environmental burden that poor air quality imposes—the tougher and more costly challenge. Indeed, carbon capture and storage would be the only viable way to "scrub" CO2, but it ranks among the most costly options for CO2 reduction.

This paper begins by examining how China's policymakers have hitherto approached air pollution and climate change management. It discusses potential actions required under goals set for each challenge, and their implications for energy, CO2 emissions, pollutant emissions, and air quality. The paper then details the shortcomings of China's current combined approach, which places more emphasis on near-term air quality improvement than CO2 emissions reduction, although nascent efforts to address CO2 through emissions trading are very promising.

Specifically, the paper makes the case for establishing a national CO2 price in China as soon as possible. End-of-pipe pollution control technologies—a core component of China's Air Pollution Action Plan (APAP)—can address local air pollution but not CO2 emissions. It concludes by emphasizing how the introduction of a CO2 price could ensure air pollution control does not come at the expense of sound, long-term climate change management. By putting early pressure on carbon-intensive energy sources also responsible for air pollution, a CO2 price would reduce the extent of end-of-pipe air pollution controls needed to achieve air quality goals, thereby preventing carbon lock-in.

China's Current Coal-Centric Approach

Beijing's current policy approach to air quality and climate change involves a patchwork of national and local regulations, many of which require cutting energy (or CO2 emissions) intensity as well as installing pollution control equipment. Targets for energy intensity—energy use indexed to economic output—have historically been achieved primarily by reducing incremental energy demand through efficiency measures and shutting down outdated, inefficient production capacity. Directives on air pollution have required the installation of sulfur dioxide (SO2) and nitrogen oxide (NOX) removal equipment.

> *China's pollution reduction effort has mainly centered on reducing, displacing, relocating, or scrubbing emissions from coal-based electric power.*

Pressure to tighten enforcement of the targets has increased as air quality problems have worsened in recent decades. This section reviews current approaches to air quality and climate change management in China.

Cleaning the Air

Take air quality first: China's pollution reduction effort has mainly centered on reducing, displacing, relocating, or scrubbing emissions from coal-based electric power, given that it is a major contributor to poor air quality nationwide. In September 2013, China set targets for 2017 (relative to 2012) in the APAP. It called for a 10 percent reduction in China's inhalable particulate matter (PM10) levels and corresponding reductions in PM2.5 in three major urban regions along the coast: Beijing-Tianjin-Hebei (25 percent) (also known as the "JJJ" region), the Yangtze River Delta (20 percent), and the Pearl River Delta (15 percent).[6]

The plan targets reductions in coal use as central to achieving air quality goals, including a 20 percent reduction in energy intensity between 2012 and 2017 [consistent with the 12th Five-Year Plan (FYP, 2011-2015) goal of reducing energy intensity by 16 percent]. It calls for limiting coal to 65 percent of primary energy mix and prohibiting any increase in coal use in the three major urban regions listed above.

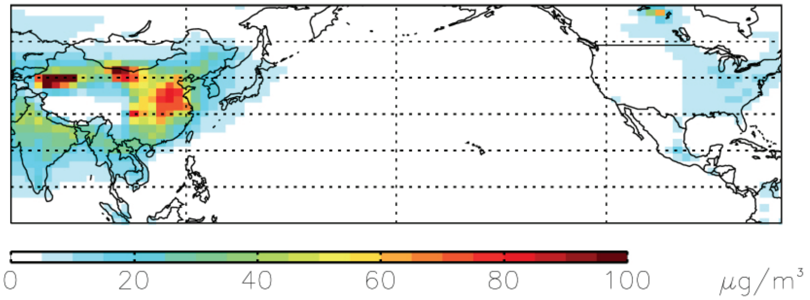
In addition to these targets focused on coal displacement, a core element of the ten-point action plan includes specific measures for limiting emissions by mandating a shift to larger scale facilities and installing pollution control equipment. District heating systems are targeted for retrofits to use electricity or cleaner fuels (e.g. natural gas). Installation and operation of desulfurization, denitrification, and dust removal equipment is required for industrial boilers and furnaces, especially those in close proximity to cities.

The last category includes precisely the end-of-pipe measures—listed in the action plan before optimizing industrial structure, accelerating energy structure adjustment, and increasing clean energy supplies—that will make progress on cleaning up the air but do little to bring down CO2 emissions. In fact, to the extent that the equipment requires coal-based energy to run, it could actually make CO2 emissions worse at the margin.

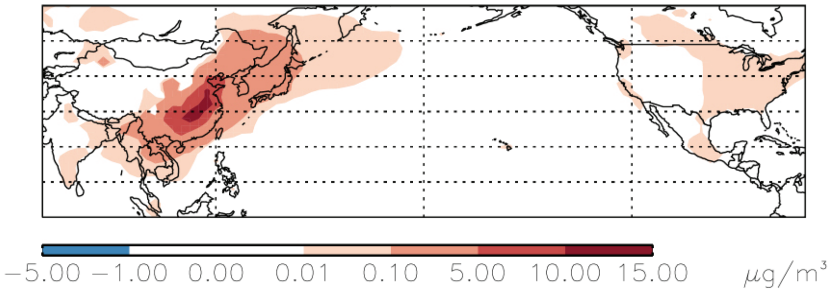
Moreover, addressing China's smoggy skies is not as easy as simply identifying the major contributing sources and

Figure 2. Effect of Ammonia Emissions on Simulated Future Air Quality

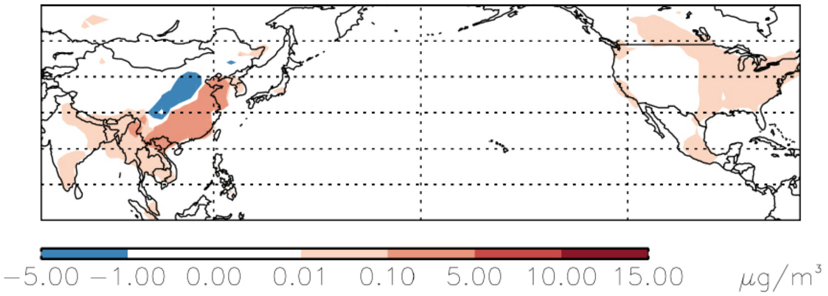
2a. Simulated spatial distribution of annual PM2.5 concentrations in 2010.



2b. Change in PM2.5 concentrations in 2030 compared to 2010.



2c. Change in PM2.5 concentrations in 2030 compared to 2010 if ammonia is held at 2010 level.



Source: Li, M., Selin, N. E., Karplus, V. J., Li, C.-T., Zhang, D., Luo, X., and Zhang, X. (2014).

focusing on reducing them. The problem is complicated by the fact that various air pollutants combine in non-linear ways to affect observed air quality or come from hard-to-control sources unrelated to the energy system specifically, such as agriculture. This means that the relative amount of multiple air pollutants must be regulated simultaneously.

Indeed, this complex chemistry means that reducing the emissions of one or more pollutants will not necessarily lead to air quality improvements, and may perversely make air quality worse. For example, under certain conditions, if NOX emissions are reduced without simultaneously curtailing emissions of volatile organics, the concentrations of ozone—a hazardous form of urban pollution that causes adverse cardiorespiratory effects—may actually rise. Similarly, according to our research, if PM2.5 precursors such as SO2 and NOX (largely byproducts of coal combustion) are reduced but ammonia (emitted from hard-to-control agricultural sources) is not, levels of PM2.5 will fall far less than if ammonia had been controlled at the same time (see Figures 2a, 2b and 2c).

Carbon Cleanup

At the Copenhagen climate talks in 2009, China made the commitment to reduce its carbon intensity by 40-45 percent per unit of GDP in 2020 relative to 2005 levels. To meet this target, China introduced an explicit and politically binding carbon-intensity reduction target during the 12th FYP, supplementing its energy-intensity reduction target (a longstanding feature of China's energy policy that was strengthened during the 11th FYP).

More recently, during the Asia-Pacific Economic Cooperation (APEC) summit in Beijing in November 2014, China's leaders announced their post-2020 climate goal jointly with the United States.

The core components of China's climate plan are to reach peak carbon and to increase the share of non-fossil fuels in its primary energy mix to 20 percent (a significant jump compared to the 2015 goal of 11.4 percent), both by 2030. More significant policies targeting carbon are likely to be part of the 13th FYP (2016-2020). For instance, China has been experimenting with carbon pricing in seven pilot areas (five cities and two provinces), which are to form the basis of a national carbon pricing system, expected to be launched during the 13th FYP period.

Our team's research has investigated how the combination of future climate and energy policies (including additional measures mandated by the APAP) could affect China's energy system through 2050. We find that a carbon price will be needed to achieve continued reductions in carbon intensity and reach the 2030 "peak carbon" goal. In an Accelerated Policy scenario, we model a carbon emissions trajectory consistent with a reduction in carbon intensity of around 4 percent per year, which is implemented via an emissions trading system (ETS) that results in a carbon price rising to $38/ton by 2030.[7]

Given expectations of continued economic growth over the same period, this Accelerated Policy scenario is at the aggressive end of potentially feasible CO2 trajectories under discussion in China. Projections in this scenario anticipate that coal use will peak as early as 2020, while CO2 emissions will peak in the 2025 to 2035 timeframe. (This time lag between the coal and CO2 peaks occurs because fossil fuel consumption continues to increase even as coal use levels off.) While this would be consistent with China's climate pledge, additional measures will be needed to improve air quality in the near term to meet the APAP targets.

Benefits of a Co-Control Strategy

So how should China's policymakers approach the coordinated regulation of both air pollution and greenhouse gas (GHGs) emissions? Economics would suggest that pollution and carbon targets should be set separately and supported by emissions pricing to encourage reduction of both air pollution and CO2 simultaneously and in the most cost effective way.

Climate Co-Benefits of Addressing Air Quality

Setting up a pricing system is more challenging for air pollution than for CO2, given the complex localized chemistry that contributes to air quality (measured in terms of ozone and PM 2.5 concentrations). In fact, since this complex chemistry means that increased pollutant emissions can in some cases translate into decreases in ambient pollutant concentrations, a price instrument targeting air quality that reflects these spatial and temporal effects would be difficult—although not impossible—to design. Moreover, the emissions contributing to local air quality by fuel and by sector vary depending on the time-of-day, season, local environment, and other factors that require additional research to more fully understand and address.

Air pollution measures, as they are currently being pursued in China, will quickly discrouage further reduction in the absolute level of coal consumption.

Given the difficulty of pricing air pollution emissions in a coordinated fashion, targeting coal reduction is often seen as a viable alternative. Reducing coal throughout China's energy system means lower emissions of SO2, NOX, and other particulates. However, as mentioned, impacts can be limited if other pollutants, such as ammonia, rise unabated.

Once low-cost opportunities to reduce coal are exhausted, the continued displacement of coal from China's energy mix becomes expensive. It would be especially so if coal becomes cheaper relative to the fuels displacing it, which is likely to happen if coal demand drops significantly, providing an incentive to continue using it in the long run.

This scenario will quickly lead to a situation where it becomes less expensive at the margin to use and scrub coal than to reduce its use, displace it with another fuel, or capture carbon. For example, installing a selective catalytic reduction (SCR) NOX removal system on a coal-fired power plant in China is relatively inexpensive—about 150 yuan ($25) per kilowatt[8]—which means operating a coal plant is still cheaper than displacing it with a wind or natural gas power plant.

At this point, the co-benefits of air pollution control for climate mitigation end abruptly, as air pollution mitigation measures lock in continued reliance on a carbon-intensive fuel. By contrast, adding carbon capture and storage (CCS), an end-of-pipe solution to scrub CO2, is estimated to increase the levelized cost of generating power from coal in China by at least 50 percent, making it prohibitively expensive for large-scale use at present.[9]

Other opportunities for cleaning up the air besides reducing coal will be extremely important and necessary, but are often overlooked. One is the reduction of biomass burning to clear agricultural land, which contributes significantly to total emissions and poor air quality. Recently, real-time monitoring of land clearing has been critical to reducing the scope of biomass burning. Controlling particulate emissions from diesel trucks and other vehicles also offers an effective and relatively low-cost step to improving air quality in urban clusters and industrial corridors. Yet again, while these are economical ways to improve air quality, they hold little to no potential to meaningfully mitigate climate change.

To summarize, air pollution measures, as they are currently being pursued in China, will quickly discourage further reduction in the absolute level of coal consumption, thereby stalling progress on carbon reduction. This alone makes a strong case for pricing CO2 emissions.

Air Quality Co-Benefits of Addressing Climate Change

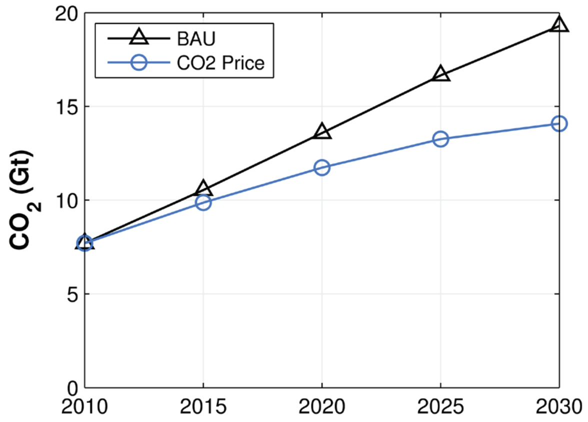
The effect of climate change, by contrast, depends on the total cumulative GHG emissions, regardless of where and when they originated. This feature makes controlling CO2 and other GHG emissions by pricing them much more straightforward, because the marginal cost of emissions is neither spatially nor temporally differentiated, nor is it mutually dependent on other species emitted.

In terms of co-benefits, a price on CO2 emissions will result in direct reductions of some, but not all, air pollutant emissions (see Figure 3). Panel A shows the CO2 emissions trajectory under the same CO2 price as was used in the Accelerated Policy scenario mentioned above (it is compared to the No Policy business-as-usual scenario). Panels B through E show the impact on the various precursors of PM2.5, the tiny particulate matter that contributes to degraded air quality and some of its worst health effects. In fact, CO2 reduction will primarily affect SO2 and NOX by reducing emissions from combustion, but do little to affect volatile organic compounds (VOCs) or ammonia, limiting the total air quality improvement.

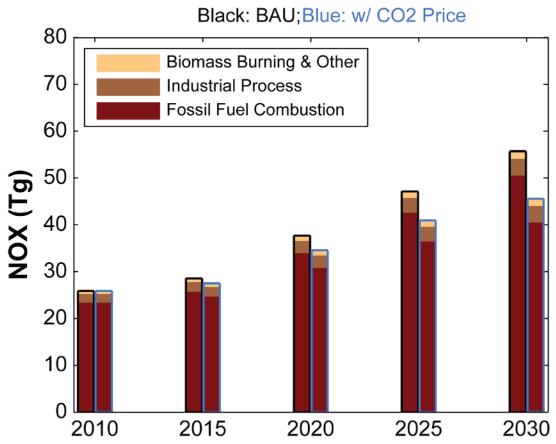
While a plausible CO2 emissions price is not sufficient to improve air quality, present air quality measures in China are insufficient to address CO2 emissions. Neither China's APAP, nor

Figure 3. Impacts of a CO2 Price on Emissions of PM2.5 Precursors, 2010-2030

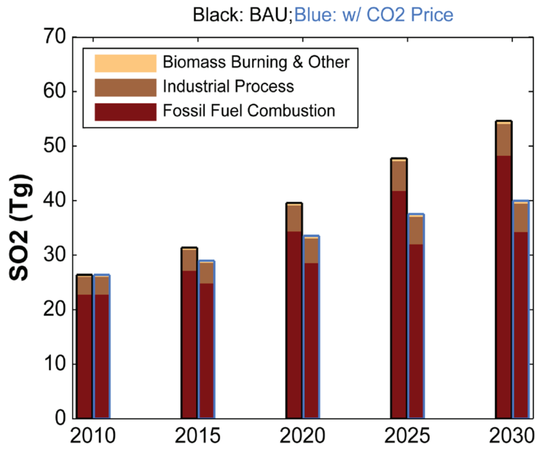
3a. Simulated CO2 Emissions Based on Carbon Price Compared to BAU Scenario.



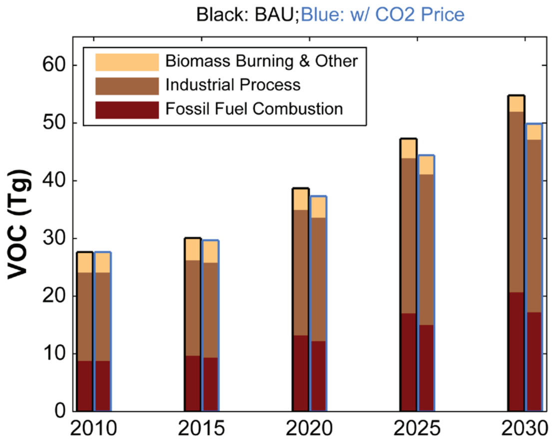
3b. Emissions of NOX, a PM 2.5 Precursor.



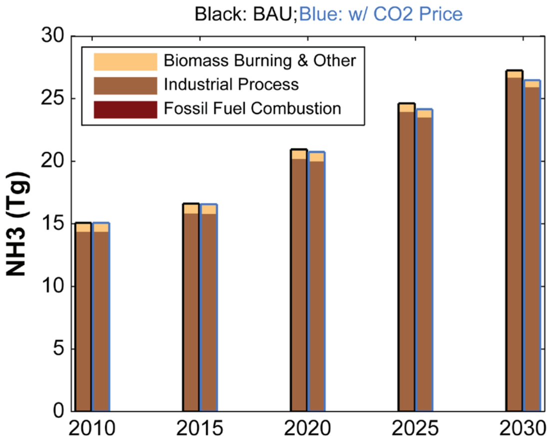
3c. Emissions of SO2, a PM2.5 Precursor.



3d. Emissions of Volatile Organic Compounds (VOCs), a PM2.5 Precursor.



3e. Emissions of Ammonia (NH3), a PM2.5 Precursor.



Source: Li, C.-T., Karplus, V. J., Selin, N. E., and Li, M. (2014).

any of its existing climate or energy policy pledges, would reverse the upward trajectory of aggregate coal use nationwide before 2020. This means that addressing air quality will need to rely extensively on end-of-pipe solutions in the near term.

For instance, assuming the recently introduced, more aggressive policies under the APAP are implemented, along with a modest CO2 price, coal use in China is expected to peak around 2020.[10] Even if coal use in the three large urban regions remains flat through 2017, coal use in the surrounding areas is expected to increase without additional policy constraints because the APAP limits the share, not the absolute amount, of coal use nationally.[11]

Still, achieving and sustaining reduction in coal demand prior to 2020 would deliver both air pollution and carbon reduction. Over the long term, addressing climate change requires displacing ever more coal, especially if end-of-pipe solutions like CCS remain relatively costly. A price on carbon is needed to continue to incentivize coal use reduction, and if designed well, could be complementary to China's air pollution control efforts. In short, a well-designed policy could allow China to achieve what most developed countries have not—air quality improvement *and* significant CO2 reduction at the same time.

The bottom line is this: if China's leaders are willing to take aggressive steps to address climate change specifically by pricing CO2 emissions, they could make meaningful progress on air quality too. Such a prioritization can also help the government avoid part of an otherwise substantial investment in technology to scrub pollutants and emissions from coal-fired power that will, over time, end up locking in a high-carbon energy system.

Conclusion

A serious commitment to reducing carbon across the energy system requires the right incentives to encourage a shift from fossil fuels to low or zero carbon energy sources. Energy and carbon intensity targets, as well as the 65 percent target of coal as a share of primary energy, will help curtail energy-related carbon emissions. But additional incentives will be needed if China wants to meet the peak carbon goal it announced at the APEC summit.

Climate Change Needs Its Own Policy

Putting a price on CO2 emissions, either through an ETS or tax, is the best way to translate China's climate pledge into clear, price-based incentives to decarbonize the economy through 2030 and beyond. It will limit the expansion of coal and other fossil fuels in favor of low-carbon alternatives and demand reduction. And it is also a robust way to ensure that carbon management goals remain binding amid the broad range of environmental priorities, including air quality improvement, which will shape China's energy and economic policy agenda in the coming years.

> *Additional incentives will be needed if China wants to meet the peak carbon goal it announced at the APEC summit.*

Introducing a price on carbon both within and across regions will be an important tool to ensure that reductions are undertaken in the most cost effective way. Beijing is currently in the early stages of building a national ETS for CO2, a critical step in galvanizing the energy system's evolution toward a low-carbon path. Choices made in the design of the system will determine its cost effectiveness.

For instance, will electricity prices—currently managed by the government—be allowed to adjust to fully reflect CO2 emissions charges? What share of CO2 emissions sources will be covered? And if China sticks with targeting CO2 intensity, rather than absolute CO2 emissions, can the system be designed to keep CO2 emissions within an "acceptable band" while acknowledging uncertainties?

Once policymakers have settled on an acceptable band for CO2 emissions consistent with China's recent climate pledge, it will be critical to let the price signal that emerges from the ETS serve as the primary incentive driving CO2 emissions reductions. A market-based approach to emissions control follows the spirit of commitments made at China's Third Plenum in November 2013 to deepen market reforms and establish markets for environmental protection.

A carbon price will adjust automatically to policy changes (such as pollution control measures or energy price reforms), some of which will inadvertently reinforce or accelerate the reduction of CO2 and air pollution emissions through changes in the country's energy system. Moreover, if technology mandates to install pollution control equipment raise the cost of electricity and industrial activity, the carbon price would reflect any ancillary reduction in CO2 that resulted from the decrease in pollution-intensive activities (due to higher costs).

In this way, a CO2 price becomes a "backstop" that ensures that broader future transition in the energy system will be consistent with CO2 reduction goals. Its implementation requires monitoring energy use and CO2 emissions at the company level alongside conventional air pollution. For the CO2 price to work effectively, any national ETS should cover as many CO2-generating activities as possible. Otherwise, any reductions could be offset by increases in the use of fossil fuels in exempt sectors, where their use becomes less costly due to a drop in total energy demand resulting from the imposition of a CO2 price.

In addition to establishing a price on CO2 emissions through an ETS, the approval process for large, energy-intensive projects needs to be consistent in how it applies environmental impact assessments and should include CO2 alongside broader measures of pollution reduction.

Given the vast extent of new construction slated for the coming decades, setting aggressive environmental targets and monitoring energy-intensive investment activity offer a substantial opportunity to accelerate a low-carbon transition. Moreover, the project approval process can be one way to gauge whether investment decisions are responding to incentives such as a carbon price, pollution control costs, and energy price reforms.

Co-Control More Effective in Achieving China's Goals

Effective co-control of CO2 and air pollution first and foremost requires acceptable limits for each. Next, policymakers and others involved should recognize the sources of opportunity to address each problem individually, with attention to the relative cost of the various options and their outcomes.

To tackle air quality, end-of-pipe solutions on existing facilities are inexpensive, but need to be effectively coordinated with reduction of other pollutants in order to ensure an overall improvement in air quality. Depending on how high the CO2 price is, some amount of end-of-pipe controls may be needed to bring air pollutant emissions down faster than CO2 to meet the ambient air quality goals stated in the APAP. Achieving these targets will require attention to hard-to-control air pollutants such as ammonia, which significantly contribute to PM 2.5 formation.

It will also require controlling emissions associated with biomass burning in rural areas, which are not directly connected to energy use and CO2 emissions. Finally, and perhaps most challenging, will be determining how much coal-linked emissions of NOX and SO2 to scrub and how much to reduce through fuel switching, since the latter could have direct climate benefits.

Establishing a CO2 emissions price through a national ETS sooner rather than later will help to ensure that cleaning the air does not come at the expense of prolonging a carbon-intensive energy system. Furthermore, coordinated action led by the National Development and Reform Commission—the government agency responsible for developing the nation's carbon ETS—and the Ministry of Environmental Protection—in charge of air pollution control—will be critical to ensuring that China's energy/carbon and environmental policies do not work at cross purposes.

Ultimately, a price on carbon is needed to reinforce and guide the strong initial steps being taken to address China's air pollution and realize CO2 reductions over the longer term. Separate but coordinated policies for air pollution and carbon reduction are expected to lead to earlier and more enduring long-term reduction in coal use than might have been achieved otherwise. An immediate start down this path will ensure that China's 2030 peak carbon goal is achieved at least cost, while delivering significant benefits for air quality improvement.

Endnotes

[1] "Xinhua Insight: China Declares War Against Pollution," *Xinhua*, March 5, 2014, (http://news.xinhuanet.com/english/special/2014-03/05/c_133163557.htm).

[2] Thompson, T. M., S. Rausch, R. K. Saari, and N. E. Selin (2014), "A Systems Approach to Evaluating the Air Quality Co-Benefits of US Carbon Policies," *Nature Climate Change*, 4, 917-923.

[3] Nam, K.-M., C. J. Waugh, S. Paltsev, J. M. Reilly and V. J. Karplus. (2013), "Climate Co-benefits of Tighter SO2 and NOx Regulations in China," *Global Environmental Change*, 23(6), 1648-1661.

[4] Sinton, J. E., M. D. Levine, and Q. Wang (1998), "Energy Efficiency in China: Accomplishments and Challenges," *Energy Policy*, 26(11), 813-29.

[5] Nam et al. (2013).

[6] "State Council Issues Action Plan on Prevention and Control of Air Pollution Introducing Ten Measures to Improve Air Quality," Ministry of Environmental Protection," 2013, (http://english.mep.gov.cn/News_service/infocus/201309/t20130924_260707.htm). Full text of the Action Plan (in Chinese) accessed from http://www.gov.cn/zwgk/2013-09/12/content_2486773.htm#.

[7] Zhang, X., V. J. Karplus, T. Qi, D. Zhang, and J. He (2014), "Carbon Emissions in China: How Far Can New Efforts Bend The Curve?," Report 267, (http://globalchange.mit.edu/CECP/files/document/MITJPSPGC_Rpt267.pdf).

[8] Xu, Qiang, D. Shen, and H. Cao, (2013), "Longjing Environmental Protection Company Wins Bid on Waste Gas Treatment Project," (http://www.p5w.net/stock/news/gsxw/201308/t20130814_267195.htm).

[9] Zhang et al. (2014).

[10] Zhang et al. (2014).

[11] Li, M., Selin, N. E., Karplus, V. J., Li, C.-T., Zhang, D., Luo, X., and Zhang, X. (2014), "Effects of China's Energy Policy on Future Air Quality in China and the US," Presentation at the American Geophysical Union 2014 Conference, San Francisco, CA.

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