KEY POINTS

- The People's Republic of China (PRC) launched its fight against pollution in 2013. Results show that, within 5 years, the PRC witnessed an unprecedented decline in overall air pollution.
- Despite this, air pollution remains a problem and has even become more complex. Pressing issues have to be addressed, including the lack of comprehensive regulation over motor vehicles and emission reduction policies for volatile organic compounds in key industries, to ensure achievement of air quality recommended standards throughout the PRC.
- The Ecological Civilization principle of the PRC's development strategy will further promote the defense of blue skies, by encouraging greener production and consumption patterns and exploitation of climate co-benefits.

Process and Prospects for Lasting Blue Skies in the People's Republic of China

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ABSTRACT

The People's Republic of China (PRC) launched its fight against air pollution in 2013, with an action plan that is the first of its kind. This paper analyzes the challenges and successes of this fight in defense of the PRC's blue skies. Energy structure adjustment, industrial structure adjustment, and major emission reduction projects conducted in just 5 years, from 2013 to 2017, have led to a remarkable decline in overall air pollution in the PRC. Compared to 2013, the average concentration in 2017 of fine particulate matter in Beijing–Tianjin–Hebei, Yangtze River Delta, and Pearl River Delta decreased by 39.6%, 34.3%, and 27.7%. The average annual concentration of fine particulate matter in Beijing reached 58 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$), exceeding the action plan targets. Yet most of the cities in the PRC cannot meet the prescribed national air quality standards. Furthermore, the fight against pollution has become even more complex due to emerging photochemical air pollution which requires more sophisticated monitoring and modeling tools for its management. The embodiment of the Ecological Civilization principles in the PRC's future economic development strategies will prove a useful ally in the defense of blue skies.

THE PROBLEM

Over the 40 years of reforms and opening up to the world, from 1978 to 2018, the People's Republic of China (PRC) had witnessed rapid socioeconomic development, and with it, rapid urbanization, rapid industrialization, and rapid motorization. While the PRC's urbanization rate was less than 18% in 1978, it exceeded 59% in 2018.¹ Eighty-four percent of the country's energy consumption is concentrated in the cities. Unevenly distributed across the country's 9.6 million square kilometers (km²), the PRC's urbanization is relatively concentrated in the east, in large and small urban agglomerations. A key driving force behind rapid urbanization is industrialization. The biggest difference between urban and rural areas is that urban areas have many buildings formed by reinforced concrete. There are two basic materials to support urban construction: steel and cement. To support rapid urbanization, rapid industrialization is required. The PRC went from having no steel production (before the 1960s and 1970s) to producing nearly 60% of the world's steel in 2018. Another important precondition for urban development is having an energy supply for heat and electricity. Coal provides the largest percentage of the energy supply of the PRC, which has accounted for 50% of total annual coal consumption worldwide since 2011.

Rapid urbanization also drives rapid motorization. In 2009, the PRC became the third country with an annual production of 10 million automobiles, after the United States and Japan. In 2013, the PRC became the first in the world's ranking for automobile production when its annual production exceeded 20 million units.

Rapid urbanization, rapid industrialization, and rapid motorization have resulted in the PRC's swift socioeconomic development and great improvements in the quality of life of its people. However, due to the relatively extensive economic growth model, the three "rapids" have led to three "biases" in the long run: (i) an industrial structure skewed toward heavy chemical industries, (ii) an energy structure skewed toward fossil fuel, and (iii) a transportation structure skewed toward road transport. These three biases have increased pressure on natural resources and contributed to the environmental challenges the PRC is now facing, especially those related to the atmospheric domain. From 1995 to 2015, the total emissions of major air pollutants in the PRC doubled—from about 10 to 20 million tons in the case of nitrogen oxides (NO_x), and their geographic distribution patterns closely follow the urbanization of the PRC, i.e., the emissions are concentrated in the eastern region, especially in the Beijing–Tianjin–Hebei region, where pollutant emission intensity per km² are among the highest levels in the world. In this region, air pollution spans an area of 2.6 million km² nationwide—which is almost one-third of the country's total land area—and affects the health of nearly 600 million people in varying degrees.

GOVERNANCE PROCESS

Since the 1980s, the Government of the PRC has passed a series of governance measures in response to the increasing air pollution problem, including amending the law on air pollution twice and issuing various air emission standards with ever tightening limits. In September 2013, the State Council issued the first Air Pollution Prevention and Control Action Plan, imposing measures to improve the air quality in the country after 5 years, with the goal of decreasing the particulate matter (PM_{2.5}) concentrations in the Beijing–Tianjin–Hebei region by 25%, the Yangtze River Delta by 20%, and the Pearl River Delta by 15%.² The action plan identifies 10 key measures to improve air quality and achieve those targets, as follows:

Accelerate energy structure adjustments by capping total coal use. Coal consumption more than doubled from 1.2 billion tons in 2000 to 3.2 billion tons in 2010. The action plan proposed a cap on total coal consumption in key regions, thereby reducing nationwide coal consumption from 4.2 billion tons in 2013 to about 3.9 billion tons in 2017, with the proportion of coal accounting for primary energy consumption falling from 67.4% to 60.0% within the same period. In addition, more than 200,000 small coal-fired boilers have been eliminated since the action plan was issued.

Promote the adjustment and optimization of industrial structures. In the past 5 years, the country eliminated backward production capacity and cut over 200 million tons of surplus steel, 250 million tons of cement, 110 million weight boxes of sheet glass, and 25 million kilowatts of coal-fired power plants. By 2017, 140 million tons of substandard steel had been cleared; and more than 62,000 enterprises in the Beijing–Tianjin–Hebei region and the "2+26" cities (Beijing, Tianjin, and 26 cities in surrounding areas) had been eliminated or rectified.

Promote national, large-scale emission reduction projects. By 2015, the country's coal-fired installed capacity retrofitted with sulfur dioxide (SO₂) abatement technology accounted for 99% of the total coal-fired installed capacity, and the installed capacity retrofitted with nitrogen dioxides (NO₂) abatement technology accounted for 92% of the total thermal-power installed capacity. More than 20 million yellow-label vehicles were eliminated, and the quality of motor vehicle oil products had been upgraded by two consecutive levels within 5 years of the action plan.

Promote the conversion of large-scale ultralow emission coal-fired power plants. As a result of these more efficient coal burning technologies, the SO₂, NO_x, and smoke dust emission limits of coal-fired power plants had been reduced to below national emission standards by 83%, 50%, and 67%, by 2015, reaching the emission level of natural gas power plants.

¹ World Bank Open Data, United Nations Population Division. World Urbanization Prospects: 2018 Revision. Urban Population (% of total population). <https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?locations=CN> (accessed 1 June 2019).

² On 27 June 2018, the country launched a 3-Year Action Plan, from 2018 to 2020, to gradually eliminate heavy pollution episodes and significantly improve the air quality.

Convert coal-powered heating systems to clean energy systems. The National Development and Reform Commission (NDRC), energy, environmental protection, housing construction, finance, and other national departments jointly promoted clean heating works in the northern region, with the aim of using clean energy “when local conditions allowed.” In 2017, about 6 million households nationwide had shifted from coal to electricity and gas heating. Of these households, more than 4.7 million are in Beijing, Tianjin, Hebei, and surrounding 26 cities. In addition, a “bulk coal-banned area” of about 10,000 km² was established.

Promote a peak shifting production solution across different regions and seasons and adjust the short-term industrial structure. In view of the heavy air pollution that frequently occurs in autumn and winter (or during the entire heating season) in the Beijing–Tianjin–Hebei region and surrounding areas, key industries in this region were subject to peak shifting production control (to stop production or limit production capacity). These regulations applied to the steel, coking, foundry, building materials, nonferrous metals, chemicals, and other industries with overcapacity. The unified implementation across the “2+26” cities not only reflected equal treatment toward cities and industries in the region, but also helped forge and harmonize joint prevention and control mechanisms in different regions.

Establish a comprehensive technical system in response to heavy pollution phenomena. A sophisticated air quality management system was established and now includes forecasting, decision upon consultation, early warning release, emergency response, follow-up assessment, and pre-arranged planning revisions. The system has effectively reduced the peak concentration of pollution in autumn and winter, and protected human health.

Set up a regional air pollution prevention coordination and supervision mechanism. Eight ministries and commissions, including the Ministry of Environmental Protection, the NDRC, the Ministry of Industry and Information Technology, the Ministry of Finance, the Ministry of Housing and Urban–Rural Development, the Ministry of Communications, China Meteorological Administration, the National Energy Administration, as well as other relevant provincial and municipal governments have formed a collaborative working group. A rare example of horizontal coordination in the PRC, this working group held regular meetings to carry out coordinated air pollution prevention and control works in the Beijing–Tianjin–Hebei region, its surrounding areas, as well as the Yangtze River Delta region. A responsibility distribution and investigation mechanism was designed, combining the characteristics of the PRC’s administrative management system, and tasks were assigned at the national, provincial, city, and county levels.

Leverage economic policy to drive pollution control measures. Since the implementation of the action plan, the Government of the PRC has allocated nearly CNY60 billion of special funds for

clean heating in Beijing, Tianjin, and Hebei (from CNY0.5 billion/city to CNY1 billion/city); has provided an on-grid power tariff subsidy of CNY0.027 per degree of desulfurization, denitrification, or dedusting, and CNY0.01 per degree of ultralow emission; has provided subsidies for the phase out of yellow-label vehicles and old vehicles and for the cleaning of residential heating (furnace + electricity price or gas price); has increased the collection standards for emission charges; has levied emission charges for volatile organic compounds (VOCs) for the first time; and has imposed environmental taxes on emission charges.

Adoption of science and technology measures for air pollution prevention and control. Through the comprehensive integration of atmospheric research and other related research projects, the Ministry of Science and Technology and the China Energy Fund Committee have established an effective link between scientific research and application of results, and have rapidly advanced scientific and technological achievements.

The implementation of the action plan has led to a significant decline in the total amount of air pollutants emitted in the PRC. During 2013–2017, the nationwide emissions decreased—SO₂ by 59%, NO_x by 20%, and primary PM_{2.5} by 29%—which marks the fastest decline in world history. Concurrently, the overall improvement of urban air quality in the country has been remarkable. Compared to 2013, the average concentration of PM_{2.5} in Beijing–Tianjin–Hebei, Yangtze River Delta, and Pearl River Delta in 2017 decreased by 39.6%, 34.3% and 27.7%. The average annual concentration of PM_{2.5} in Beijing reached 58 µg/m³, exceeding the Action Plan target (Figure).

Energy structure adjustment, industrial structure adjustment, and major emission reduction projects were at the core of this successful outcome. As suggested by an analysis performed by the Tsinghua University School of Environment on the contribution of various measures to emission reductions, emission reduction projects in particular were responsible for the tremendous SO₂ emission reduction. Coal-fired boiler retrofits, ultralow emission conversion of power plants, and backward production capacity elimination reduced SO₂ by 5.54 million tons, 4.95 million tons, and 2.08 million tons from 2013 to 2017 (resulting in 33%, 29%, and 12% of emission reductions). Significant measures to reduce NO_x emissions led to emission reduction, including ultralow emission conversion of power plants (by 3.45 million tons or 47% of emission reductions), elimination of backward production capacity (by 1.23 million tons or 15% of emission reductions), and emission control of mobile sources (by 1.06 million or 13% of emission reductions). For primary PM_{2.5}, the measures taken reduced emissions significantly. Industrial upgrading reduced emissions by 1.1 million tons or 24% of total emission reductions, dust comprehensive treatment by 1.03 million tons or 22% of total emission reductions, coal-fired boiler remediation by 710,000 tons or 15% of total emission reductions, and backward production capacity elimination by 690,000 tons or 15% of total emission reductions.

Figure: Nationwide PM_{2.5} and PM₁₀ Concentration Improvement

BTH = Beijing-Tianjin-Hebei, m³ = cubic meter, PM = particulate matter, PRC = People's Republic of China, PRD = Pearl River Delta, µg = micrograms, YRD = Yangtze River Delta

Source: Tsinghua University, School of Environment.

The emission reduction contribution of mobile source emission control is more obvious in urban areas. For example, during 2013–2017, a total of 2.167 million old vehicles were scrapped and transferred out of Beijing. All nonroad machinery were equipped with diesel engines that met the emission standards. The total emission reduction of NO_x were 43,000 tons, contributing 46% of total NO_x emission reduction. The results show that the action plan has been effective in controlling mobile source pollution. As the total number of motor vehicles in the PRC's cities is still growing, further control over urban motor vehicle emissions will be necessary.³

FUTURE PROSPECTS

Despite the success achieved so far, the air quality in the PRC still has a long way to go to reach the prescribed national emission standards. The average annual concentration of PM_{2.5} attains the national emission standard only in 64% of the 338 cities in the PRC. Although the air quality in Beijing had significantly improved in 2017, it still exceeded 1.6 times the desired limit. The implementation of the first action plan was just the first step in the PM_{2.5} pollution prevention measures of the PRC. A further decline in PM_{2.5} levels nationwide will be much more difficult to achieve. It is also worth noting that during 2013–2017, the atmospheric ozone concentration in 74 cities nationwide increased significantly, associated with the increase of VOCs' emission and emissions of NO_x from vehicles.

The next generations of strategies to tackle air pollution will have to address the remaining weak links in the air pollution management system. Some prominent issues include the lack of comprehensive management of (non-electricity producing) industries; the lack of comprehensive regulation over motor vehicles, especially diesel engines; the lack of emission reduction policies for VOCs in key industries; and the need to control agricultural ammonia emissions.

According to the requirements of the action plan, alongside the national urban air quality compliance timetable proposed by the Ministry of Environmental Protection in 2013, all provinces and cities across the country need to formulate medium- and long-term compliance planning, and strive to reach national air quality standards in all key cities in the PRC until around 2030.

In an energy industry optimization study conducted by the Tsinghua University School of Environment, a scenario with (i) further optimization of the energy industry structure and (ii) deep energy structure adjustment based on the enhanced emission control could result in the annual average PM_{2.5} concentration of 74 cities nationwide, meeting the national emissions standard in 2030 (which is also the transitional level I standard set by the World Health Organization [WHO], with an annual average rate of 35µg/m³). Not only can all cities meet the standard, but the carbon emission peak could be achieved before 2030.

³ In 2016, measures were intensified and refined in order to ensure the full compliance with the action plan targets by 2017.

Energy conservation and deep energy structure adjustment scenarios can ensure that the PRC's carbon dioxide (CO₂) emissions will decrease by 2030 compared to the levels reached in 2015. In the deep energy structure adjustment scenario, the PRC could reduce CO₂ emissions by approximately 17% in 2030 in comparison to the levels reached in 2015. After the implementing energy structure emission reduction measures (including the campaign to shift from coal to gas, development of nonfossil energy, etc.) and industrial emission reduction measures (including the reduction of steel, cement, and coking capacity, etc.), the PRC could achieve peak carbon emissions targets before 2030.

Multi-scenario analysis conducted by the Tsinghua University School of Environment shows that relying solely on intensified end-policy governance does not guarantee that the air quality of key cities in the PRC will reach the standard by 2030. To achieve full compliance, the industrial structure and energy structure must be significantly adjusted. The PRC must strengthen the strategic adjustment of the proportion of fossil fuels and accelerate the development and utilization of renewable energy. In 2030, the proportion of coal consumption in the country will be limited below 35%, which will not only enable all cities in the PRC to reach a PM_{2.5} standard of 35µg/m³ by 2030, but also will enable nearly 60% of cities in the PRC to reach the interim level II PM_{2.5} standard set by WHO (with an annual average rate of 25µg/m³).

Therefore, the future economic development pattern of the PRC needs to undergo a medium- and long-term adjustment phase. The high-energy industry will need to adjust its decline ratio accordingly. The heavy industry-led model will need to adjust its industrial structure by 2030. The heavy industry products will need to decrease by 25% in output and 20% in energy consumption per unit product by 2030 in comparison to the levels reached in 2015. To this end, it is necessary to control the annual output of key industries such as steel, cement, and glass.

The control of ammonia emissions should be effectively strengthened. By 2030, the proportion of slow-release (organic) fertilization in the country will need to be increased to 30%, and increased further to 80% by 2050.

By 2030, the upgrade of gasoline and diesel fuels will need to be fully completed, so that the "National VI" or more stringent emission standards can be applied to the vehicle industry. The number of motor vehicles in key megacities and provinces will need to be effectively controlled. The urban public transport rate in Beijing and other places will need to reach 41%, the proportion of energy-saving cars more than 50%, and the proportion of electric vehicles over 40%.

Ecological Civilization. Structural adjustments to increase energy efficiency in the energy, industry, and transportation sectors can be further strengthened, and will likely gradually become the core driving force for air quality improvement. Here is where the Ecological Civilization principles, which entered the PRC Constitution in 2012, may prove critical in achieving better air quality, as there is an urgent need to accelerate the exploration and transformation of air quality improvement mode from pollution control to the green development advocated by the Ecological Civilization.

With its call for revitalizing rural areas, including the protection of their natural resources from pollution, the Ecological Civilization also advocates for the reduced use of chemical fertilizers that emit ammonia, which results in a buildup of particulate matter.

By promoting the shift toward industrial modernization, Ecological Civilization is driving future sustained efforts to ease one of the most severe environmental risks, which is health impact from air pollution. Moreover, at least three additional Ecological Civilization drives will positively contribute to air pollution reduction: (i) in addressing the alignment of objectives, cohesion in approach, and synergies needed to optimize benefits, co-benefits between air pollution reduction and climate change mitigation strategies will have to be maximized to their full potential; (ii) in its application of the Ecological Civilization, the "Made in China 2025" strategy is pushing the PRC to the forefront of new vehicle technology development such as, for example, electrical vehicles and battery development, which will concurrently help control emissions from the transport sector, a key area for future air pollution abatement; and (iii) the ecological restoration of the PRC's countryside also happens through the optimized use of better, and thereby less emitting, fertilizers, a silent contributor to air pollution.

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