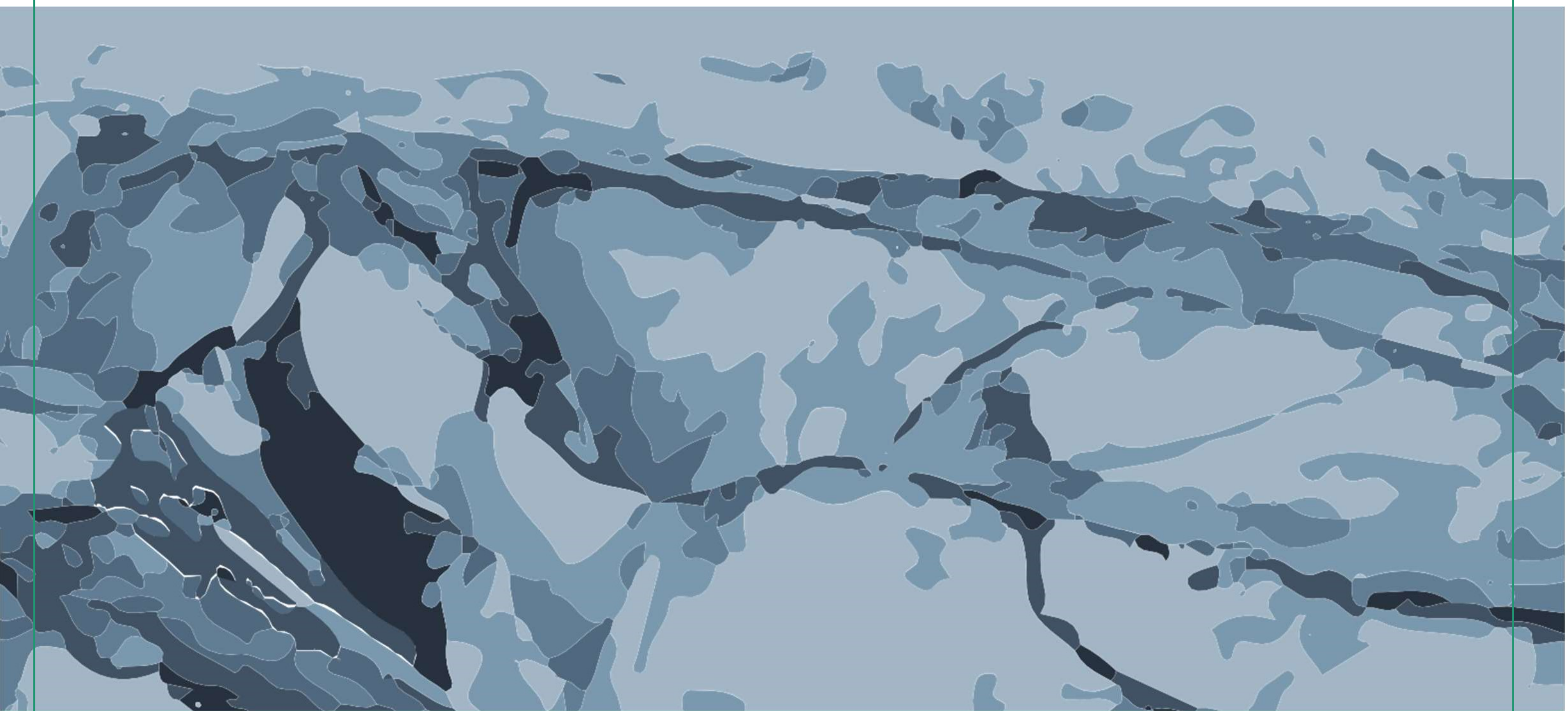
Review report 5 ChiNorBC

Review of Policies of China for the Control of Black and Organic Carbon



Chinese-Norwegian Project on Emission, Impact, and Control Policy for Black Carbon and its Co-benefits in Northern China

CAEP °CICERO CRAES Norwegian Environment Agency NIPH

Review of Policies of China for the Control of Black and Organic Carbon

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About this report

This report is part of a series of outputs produced under the Chinese-Norwegian Project on Emission, Impact, and Control Policy for Black Carbon and its Co-benefits in Northern China (ChiNorBC). The project is jointly implemented by the Chinese Research Academy of Environmental Sciences (CRAES) and the Norwegian Environment Agency (NEA), in partnership with the Chinese Academy of Environmental Planning (CAEP), the Norwegian Institute of Public Health (NIPH) and CICERO Center for International Climate Research, with financial support from the Norwegian Ministry of Foreign Affairs.

There is no internationally agreed definition of black carbon (BC) and organic carbon (OC). BC is the light-absorbing component of fine particles and is produced by incomplete combustion of fossil fuel, biofuel and biomass. BC is always co-emitted with OC. Emissions of BC and OC affects the climate and have adverse health effects. Reductions of BC and OC will have co-benefits for climate, air quality and health.

ChiNorBC will develop improved emission inventories for BC- and OC- emissions in China using the most recent, best available national statistics and measurements obtained in the project. Based on this, new estimates of effects of BC/OC on climate, air quality, and health will be provided. The project will further raise scientific, governmental, and public awareness and enhance the understanding of the positive impacts of BC/OC emissions reductions. Ultimately the ChiNorBC will provide Chinese policy makers with policy solutions for reducing BC/OC emissions in China which maximizes the co-benefits.

The project has six outputs. This report is a result of Output 5, Review of Policies of China for the Control of Black and Organic Carbon. For a more comprehensive description of the project, and to get access to all the project reports, please visit the project web site http://chinorbc.net/.

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The cover design is non-figurative and created by Eilif Ursin Reed, Communication Advisor, Cicero, and is inspired by melting glaciers and polluted snow.

About the partner institutions in the ChiNorBC project

Chinese Research Academy of Environmental Sciences

The Chinese Research Academy of Environmental Sciences (CRAES), founded in 1978, is a leading institute in environment-related studies in China, including studies on short-lived climate pollutants and their impacts. There are more than 1000 employees whose backgrounds cover all important areas of environmental sciences, including atmospheric science. One of the main responsibilities of CRAES is to provide technical and scientific support for decision making to the Ministry of Ecology and Environment (MEE).

Norwegian Environment Agency

The Norwegian Environment Agency (NEA) is an advisory and executive body under the Ministry of Climate and Environment (MCE), fully funded by the Norwegian Government. It has about 700 employees in Trondheim and Oslo as well as in local offices throughout the country. NEA was established 1st July 2013 after a merger of the former Directorate for Nature Management (est. 1965) and the Climate and Pollution Directorate (est. 1974). The Norwegian Nature Inspectorate (SNO) is organized as a department within NEA. The primary tasks of NEA are to reduce greenhouse gas emissions, manage Norwegian nature, and prevent pollution.

The Chinese Academy of Environmental Planning

The Chinese Academy of Environmental Planning (CAEP) is a public institution with independent legal status founded in 2001. Its missions are: Carrying out strategic research on national ecological civilization, green development and beautifying China, and undertaking technical support for the preparation and implementation of national medium and long-term ecological environment planning, key river basins and regions planning, and environmental planning in key fields, so as to meet the major needs of the country.

The Norwegian Institute of Public Health

The Norwegian Institute of Public Health (NIPH) is a Norwegian government agency and research institute and is Norway's national public health institute. NIPH acts as a national competence institution placed directly under the Ministry of Health and Care Services, with approximately 1400 employees in Oslo and Bergen. It is responsible for knowledge production and systematic reviews for the health sector and provides knowledge about the health status in the population, influencing factors, and how it can be improved.

The Center for International Climate Research

The Center for International Climate Research (CICERO) is a private foundation that for over 30 years has delivered interdisciplinary research of high scientific quality on climate science, economics, and policy. CICERO's mission is to conduct research and provide reports, information and expert advice about issues related to global climate change and international climate policy with the aim of acquiring knowledge that can help mitigate the climate problem and enhance international climate cooperation. CICERO has approximately 80 employees situated in the Oslo Science Park.

Content

Acronyms and Abbreviations

CAEP	Chinese Academy for Environmental Planning, China
CICERO	Center for International Climate and Environmental Research-Oslo, Norway
CRAES	Chinese Research Academy of Environmental Sciences
MEE	Ministry of Ecology and Environment of China
MFA	Ministry of Foreign Affairs, Norway
MOFCOM	Ministry of Commerce of China
NEA	Norwegian Environment Agency
NIPH	Norwegian Institute on Public Health, Norway
UN Environment	The United Nations Environment
WMO	World Meteorological Organization

Definition of Concepts

AQI	Air quality index
BC	Black carbon
CO	Carbon monoxide
CO_2	Carbon dioxide
NO_2	Nitrogen dioxide
NO_X	Nitrogen oxides
O_3	Ozone
OC	Organic carbon
$PM_{2.5}$	Fine particles with a diameter of 2.5 micrometers or less
PM_{10}	Inhalable particles with a diameter of 10 micrometers or less
SLCFs	Short-lived climate forcers
SO_2	Sulfur dioxides
THC	Total hydrocarbon
VOCs	Volatile organic compounds

Summary

Since 2013, with the implementation of the Action Plan on Prevention and Control of Air Pollution and the Three-Year Action Plan to Fight Air Pollution, China has achieved positive results in air pollution prevention and control, with the overall ambient air quality seeing substantial improvement. A series of supporting policies involving the industrial, residential, transportation, and many other sectors, including elimination of outdated production capacity, in-depth control of pollution in key industrial sectors (e.g. thermal power, iron and steel, cement), control of coal-fired boilers, clean heating, and prevention and control of mobile source pollution have been implemented in China in recent years. In order to identify the shortcomings of existing measures for BC/OC control, thus to provide inspiration and basis for the design of BC/OC control scenarios in the next step and the research on BC/OC control strategies, this report summarizes China's air pollution control policies and measures for key BC/OC emitting sectors such as coal-fired boilers, residential bulk coal, and motor vehicles.

1 Introduction

Currently, China focuses its air pollution control efforts on fine particulate matter ($PM_{2.5}$) and ozone (O_3) pollution and is yet to formulate specific emission control policy targeting BC/OC emissions. Since 2013, the Chinese government has issued a series of policies including the Action Plan on Prevention and Control of Air Pollution (2013-2017) (SC, 2013) and the Three-Year Action Plan to Fight Air Pollution (2018-2020) (SC, 2018) for the purpose of improving ambient air quality, especially reducing the concentration of $PM_{2.5}$, and implemented a number of measures including elimination of outdated production capacity, energy transformation for clean heating, in-depth control of pollution in key industrial sectors, and prevention and control of mobile source pollution. Though not specifically designed for BC/OC emission reduction, these measures still have a positive effect on the reduction of BC/OC emissions as important $PM_{2.5}$ precursors. To review China's policies on air pollution prevention and control, identify measures that have a positive effect on reduction of primary $PM_{2.5}$, especially on reduction of BC/OC emissions, and identify the shortcomings of existing measures in BC/OC control, can provide inspiration and basis for the design of BC/OC control scenarios in the next step and the research on BC/OC control strategies. This study summarizes China's air pollution control policies and measures for key BC/OC emitting sectors such as coal-fired boilers, residential bulk coal, and motor vehicles. To be noted, we've reviewed the latest policy implementation progress till 2020 in this report though, the base year of our scenario analysis of Output 5 is 2018 considering the project target assignment and the availability of relevant historical emissions and other basic data.

2 Air pollution in northern China

2.1 Overall air quality sees improvement

2.1.1 National air quality

Since 2013, with the implementation of the Action Plan on Prevention and Control of Air Pollution and the Three-Year Action Plan to Fight Air Pollution, China has achieved positive results in air pollution prevention and control, with the overall ambient air quality seeing substantial improvement. Several studies (Hammer et al., 2021; Shi et al., 2021; He et al., 2020; Le et al., 2020) suggested that the decrease in anthropogenic activity level had led to positive effects in improving air quality of China during the Covid-19 lockdown period in 2020. The annual average measured $PM_{2.5}$ concentration of 337 cities at or above prefecture level (hereinafter referred to as the "337 cities") in 2020 was 33 $\mu g/m^3$, down by 29.1% from 2015; at the same time, the annual average measured concentrations of sulfur dioxide (SO_2), carbon monoxide (CO), inhalable particulate matter (PM_{10}) and nitrogen dioxide (NO_2) dropped by 10~56%; compared with the same meteorological conditions in previous years, the peak concentration, pollution intensity, duration, and scale of impact on days of heavy pollution were substantially reduced; the number of cities meeting air quality standards in 2020 was nearly three times that of 2015. Unlike the other five criteria air pollutants, O_3 concentration increased. The national average measured 90th percentile of the maximum daily 8-hour average O_3 concentration (the official metric for evaluating annual O_3 pollution status in China) increased by 12.2% from 2015 to 2020. Non-optimized reduction rate between NO_X (nitrogen oxides) and VOC (volatile organic compound) emissions, as well as the weakened aerosol uptake of hydroperoxy radicals due to $PM_{2.5}$ reduction have been proposed as reasons for the increment in O_3 concentrations.

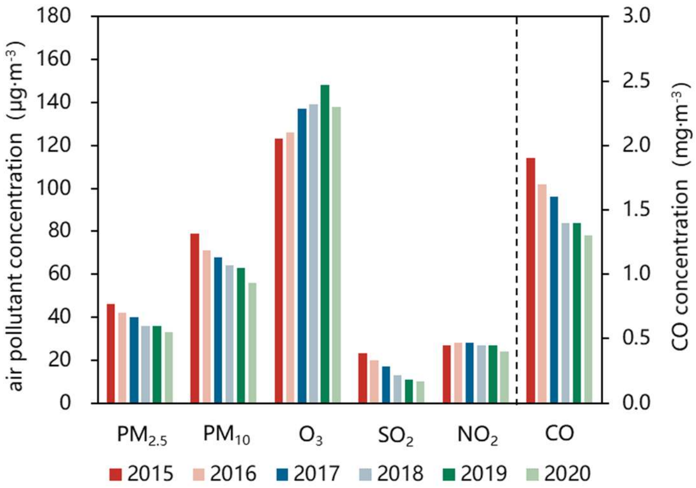

Figure 1 Changes in national annual average measured concentrations of major air pollutants from 2015-2020 in the 337 cities

2.1.2 Air quality in the northern part of China

In the northern part of China, the industrial structure is dominated by heavy industry, energy structure is based on coal, and transportation mainly relies on highways, hence one of the most severely polluted areas in China. In recent years, with the intensified implementation of the Action Plan on Prevention and Control of Air Pollution and the Three-Year Action Plan to Fight Air Pollution, this part of the country has experienced industrial structure transformation and upgrading as well as continuous adjustment and optimization of its energy structure, transportation structure, and land use structure, with the overall air quality improved. From 2015 to 2020, in Beijing-Tianjin-Hebei and the surrounding areas (hereinafter referred to as the "2+26 cities" region), the annual average measured concentrations of various pollutants, except O_3, showed a downward trend (see Figure 2). In 2020, the concentrations of SO_2, PM_{10}, $PM_{2.5}$ and CO dropped by 35-70% compared to 2015, and the concentration of $PM_{2.5}$ was down by 35%. The annual average measured concentration of $PM_{2.5}$ in Beijing dropped by more than 50%, a remarkable progress. Starting from 2016, all of the 2+26 cities met the national annual standards for SO_2 and CO concentration (that is, 60 μg/m^3 for SO_2, and 4 mg/m^3 for CO; national air quality standard issued by the Ministry of Ecology and Environment (MEE), GB3095-2012).

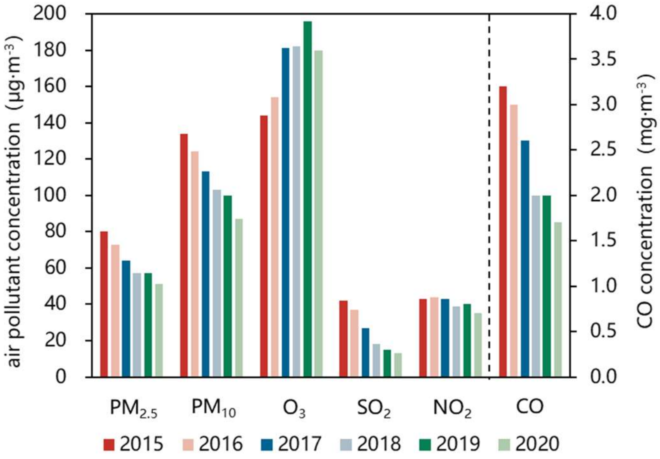

Figure 2 Changes in measured concentrations of major air pollutants in the “2+26 cities” region in 2015-2020

The number of days with measured good air quality (air quality index (AQI) less or equal to 100) in the “2+26 cities” region shows a slight increasing trend (see Figure 3). The ratio of clean days increased from 53.6% in 2015 to 63.5% in 2020. Based on observation-based statistics, the number of days with heavy pollution (AQI >200) shows a decreasing trend. The ratio of days of heavy pollution or above (see Table 1 for the definition) was down from 8.9% in 2015 to 3.5% in 2020.

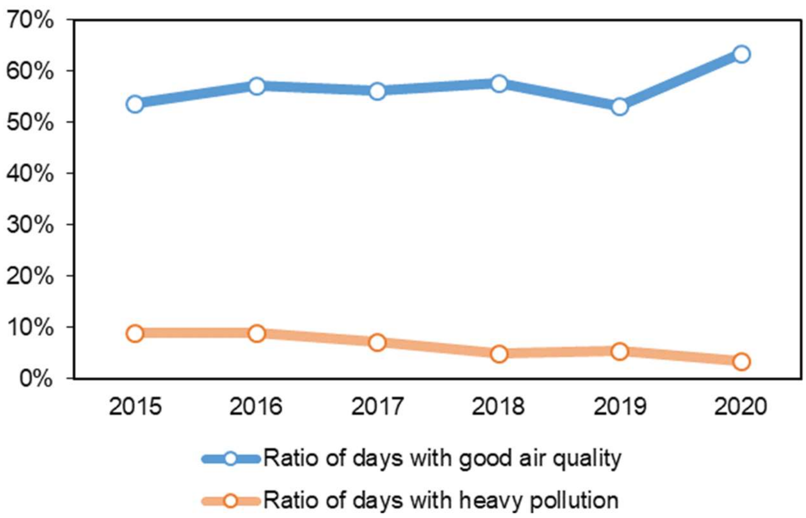

Figure 3 Changes in ratio of clean days and in ratio of days with heavy pollution or above in the “2+26 cities” region in 2015-2020. Days with good air quality refers to days with air quality index (AQI) lower or equal to 100; days with heavy pollution refers to days with AQI greater than 200.

2.2 Air pollution remains challenging

With the successive implementation of a series of measures, the compound air pollution characterized by high concentration of $PM_{2.5}$ in North China has been substantially improved, but the region is still facing huge air pollution challenges. In 2020, the average annual $PM_{2.5}$ concentration in the “2+26 cities” region was 51μg/m^3, which was still at a high level, equivalent to 1.46 times the national air quality standard (GB3095-2012, 35μg/m^3) and 1.57 times the national average annual $PM_{2.5}$ concentration in the 337 cities across the country (see Figure 4), keeping this area the most severely polluted area by particulates in China. In addition, this area is still one of the regions in China with frequent occurrence of heavy-pollution episodes. The problem of heavy pollution characterized by high concentrations of particulates in autumn and winter is still prominent. The $PM_{2.5}$ concentration in autumn and winter is about twice that in spring and summer. At the same time, due to the large consumption of fossil energy in the area, the control of greenhouse gas emissions is facing tremendous pressure. It will be an important challenge for the northern part of China to coordinate the improvement of air quality and the control of greenhouse gases in the management of the atmospheric environment.

Table 1 Annual limits for major air pollutant in the national air quality standard (GB 3095-2012)

Air pollutants		Limit requirements	
		For Class I area	For Class II area
SO_2	Annual average	20	60
NO_2	Annual average	40	40
$PM_{2.5}$	Annual average	15	35
PM_{10}	Annual average	40	70
O_3	90 percentile of daily maximum 8-hour average	100	160
CO	95 percentile of daily average	4	4

Note: Class I area refers to nature reserves, scenic spots and other areas that need special protection; Class II area refers to residential areas, mixed commercial and residential areas, cultural areas, industrial areas and rural areas.

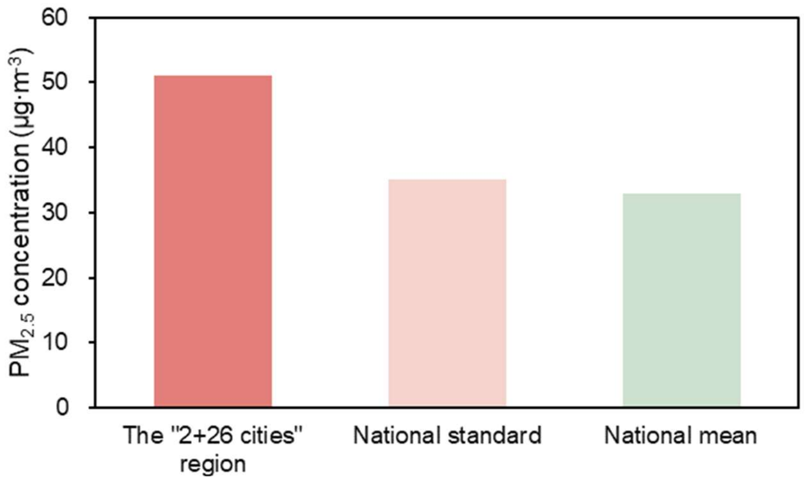

Figure 4 Average annual $PM_{2.5}$ concentration in the “2+26 cities” region in 2020

3 Review of major relevant polices on prevention and control of air pollution

In order to improve the ambient air quality, the Chinese government has successively promulgated and implemented two important policies, the Action Plan on Prevention and Control of Air Pollution and the Three-Year Action Plan to Fight Air Pollution since 2013, and implemented supporting policies including elimination of outdated production capacity, in-depth control of pollution in key industrial sectors (e.g. thermal power, iron and steel, cement) , control of coal-fired boilers, clean heating, and prevention and control of mobile source pollution. The policies involve the industrial, residential, transportation, and many other sectors. This series of measures directly promoted the continuous transformation of China's energy structure, with the proportion of coal in primary energy consumption steadily declining from 67.4% in 2010 to 56.8% in 2020, while primary electricity and energy other than coal, oil and natural gas increasing from 9.4% in 2010 to 15.9% in 2020 (NBS data) (see Figure 5).

Table 2 Summary of major air pollution control measures implemented since 2013

Air pollution control measures	Description
Elimination of outdated production capacity	Include overcapacity industry capacity control, elimination of backward capacity and other measures
Scattered pollution enterprise governance	Refer to the rectification of "scattered pollution" enterprises with incomplete licenses, illegal construction, illegal operation, environmental pollution and non-compliance with local industrial layout planning;
Ultra low emission transformation of coal-fired power plant	Refer to the ultra-low emission transformation of coal-fired power plants to meet the new emission limit standards
Upgrading of industrial source end of pipe control	Refer to the upgrading and transformation of end of pipe control measures such as desulfurization, denitration and dust removal in key industries such as steel, cement and glass.
Renovation of coal-fired and gas-fired boilers	Include the elimination of small coal-fired boilers, efficient desulfurization of coal-fired boilers, upgrading and transformation of dust collectors, and low nitrogen combustion transformation of gas-fired boilers
Civil fuel cleaning	Include coal washing and processing, clean treatment of bulk coal, coal to gas, coal to electricity and other measures
Traffic structure optimization and emission control	Include measures to control the total number of motor vehicles, eliminate yellow-label vehicles and old vehicles, and renovate non road machinery
Comprehensive control of dust sources	Include construction site dust pollution control, road dust pollution control, port and wharf dust pollution control and other measures
VOCs control	Refer to VOCs control work in industries involving VOCs emissions
Comprehensive management of agricultural resources	Include the management of livestock and poultry breeding industry and the improvement of comprehensive utilization rate of chemical fertilizer

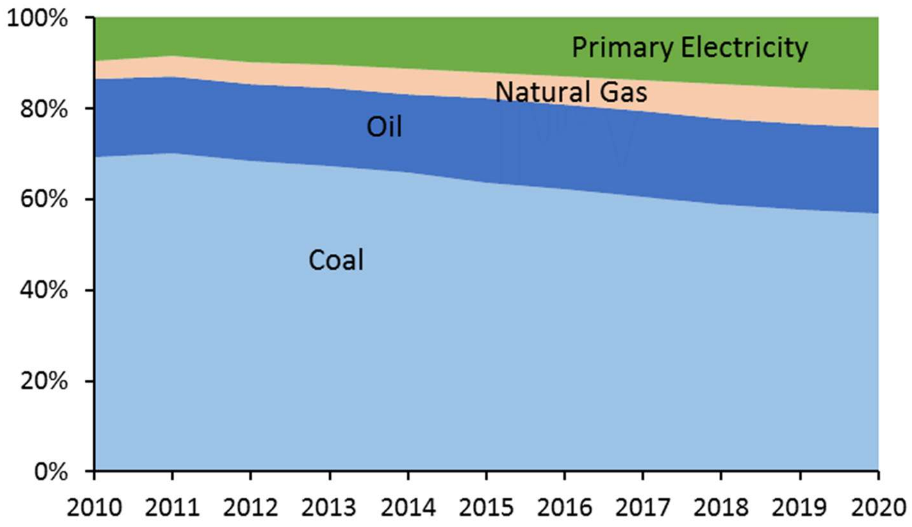

Figure 5 Changes in proportion of energy sources in energy consumption in China 2013-2020

As shown in the following, to better understand the implementation progress of BC control related policies in northern China, we've reviewed the air pollution control policies targeting boilers, residential coal, and vehicles, which are closely connected to BC emission control at the same time.

3.1 Elimination of small coal-fired boilers

3.1.1 Policy implementation progress

In 2013, China fully initiated the elimination of small coal-fired boilers with a capacity at or below 10 ton/hour in built-up areas of cities at or above prefecture level. By 2018, a total of more than 230,000 small coal-fired boilers (widely used across the country to provide heat steam to various small industrial and residential facilities) had been shut down nationwide. At the same time, the Chinese government banned the construction of new coal-fired boilers with a capacity at or below 20t/h in built-up areas of cities at or above prefecture level. In other areas, no new coal-fired boilers at or below 10t/h shall be built in principle. In the "2+26 cities" region, more than 50,000 small coal-fired boilers were eliminated. The elimination of small coal-fired boilers effectively improved the overall efficiency of boilers, because newly-built larger boilers generally have higher combustion efficiency and because advanced end-of-pipe control measures could be applied to larger boilers. The elimination of small coal-fired boilers thus helped reducing BC and OC emissions as well as CO_2 emissions, thereby helping to cope with climate change.

3.1.2 Case introduction of typical provinces

Shandong is an important energy consuming province in China, where the energy consumption structure is dominated by coal and the proportion of high pollution and high consumption industries is relatively high. In order to control the air pollutant emissions from boilers, Shandong promulgated a series of local programs, primarily including the “Implementation scheme of comprehensive improvement project for energy conservation and environmental protection of coal-fired boilers in Shandong Province” in 2015 and the “Guidance on strictly controlling total coal consumption and promoting clean and efficient utilization” in 2019.

Objectives:

Based on the “Implementation scheme of comprehensive improvement project for energy conservation and environmental protection of coal-fired boilers in Shandong Province” in 2015, the objectives of the program mainly included:

“By 2018, promote high-efficiency boilers with the scale of 30000 t/h, and increase the market share of high-efficiency coal-fired boilers to 40%. Complete the task of eliminating backward coal-fired boilers assigned by the state council. Complete the energy-saving transformation of coal-fired boilers with the scale of 20000 t/h. Accelerate the research and development of high-efficiency boilers, cultivate a number of backbone enterprises, increase the average operation efficiency of coal-fired industrial boilers by 5 percentage points on the basis of 2013, and form an annual energy-saving capacity of 4.5 million tons of standard coal. By implementing all the control measures, reduce 112500 tons of soot, 144000 tons of sulfur dioxide and 27000 tons of nitrogen oxides.”

Based on the “Guidance on strictly controlling total coal consumption and promoting clean and efficient utilization” in 2019, the objectives of the program relevant to boiler governance mainly were:

“In about five years, the province's coal consumption will strive for a reduction of 50 million tons. The seven cities involved in “2+26” cities strive to basically eliminate coal-fired boilers with a steam capacity of less than 35 t / h by the end of 2019, and achieve total elimination by the end of 2020.”

Main measures:

Based on the “Implementation scheme of comprehensive improvement project for energy conservation and environmental protection of coal-fired boilers in Shandong Province” in 2015, the main measures implemented in Shandong for boiler pollution control during 2015-2018 mainly included:

a) Promote the application of high efficiency boilers. Vigorously promote the high-efficiency boiler products that have entered the national announcement catalogue and the promotion catalogue of key energy-saving technologies, products and equipment in Shandong Province. For new reconstruction and expansion of fixed asset investment projects and government procurement projects, priority shall be given to products listed in the promotion catalogue of high-efficiency boilers or with energy efficiency grade of grade 1.

b) Eliminate outdated coal-fired boilers. Outdated old boilers that fail to pass the energy efficiency test and have no transformation value shall be eliminated according to law. Except for those necessary to be reserved, all coal-fired boilers of 10 t/ h and below will be eliminated in urban built-up areas. Strictly control obsolete boilers to re-enter the market and prevent outdated boilers from being moved to rural or remote areas for continued use.

c) Transform inefficient coal-fired boilers. Strengthen the energy-saving transformation of boiler combustion equipment, auxiliary equipment and supporting facilities, focusing on the transformation of coal-fired boilers with more than 10 t/h in urban built-up areas and within the coverage of thermal pipe network, and the cogeneration or central heating in industrial parks and industrial concentrated areas. Briquette or clean coal transformation shall be carried out in other areas not covered by the heating and gas supply network. Implement the industrial green power plan, promote the application of solar industrial boilers, and actively use new energy to auxiliary heat the boiler feed water. Clean coal, biomass and natural gas are used to replace raw coal to reduce pollutant emission.

d) Strengthen boiler operation management. Strengthen the energy efficiency test of boilers. Promote the standardized management of safety, energy conservation and environmental protection of boiler system, carry out standard pilot demonstration, and promote the construction of 50 benchmark boiler rooms. Encourage online energy-saving monitoring and diagnosis of boilers. Strengthen the management of water treatment and fuel in boiler installation and operation, and improve boiler efficiency. Improve the level of boiler operators, and organize the training of boiler energy-saving operation skills in process operation procedures and post operation procedures.

e) Improve boiler pollution control level. According to the requirements of comprehensively renovating small coal-fired boilers, in principle, no new coal-fired boilers shall be built in the built-up areas of cities above the prefecture level. Newly produced and installed coal-fired boilers shall be equipped with efficient pollution control facilities. Improve the pollution control level of in-service coal-fired boilers to achieve fully up to standard emission. Coal fired boilers of 20 t/h and above shall be equipped with on-line monitoring devices and networked with local environmental protection departments.

f) Promote the industrialization of high-efficiency boilers. Strengthen the research and development of basic, cutting-edge and common key technologies for boiler energy conservation and environmental protection, overcome key technologies such as efficient combustion, efficient waste heat utilization, automatic control and pollution control, and increase support for the promotion and application of scientific and technological achievements.

g) Promote the optimization and adjustment of fuel structure. Strengthen the quality management of coal, realize the utilization of coal by quality and classification, and promote clean coal combustion. Promote the use of washed coal. Coal-fired boilers shall not directly burn raw coal with high sulfur and high ash. Domestic coal and other small coal-fired facilities shall give priority to the use of briquette with low sulfur and low ash and added sulfur fixing agent. Build coal storage and distribution base, carry out pilot demonstration of centralized coal blending and logistics supply, and improve coal washing and processing capacity.

Based on the “Guidance on strictly controlling total coal consumption and promoting clean and efficient utilization” in 2019, the main measures implemented in Shandong for boiler pollution control during 2019-2020 mainly included:

a) Improve the calorific value of coal, and gradually increase the calorific value standard of coal from 3700-4300 kcal to about 5000 kcal in 3-5 years.

b) Strengthen the transformation of old equipment, promote new coal water slurry and pulverized coal boilers, and improve energy efficiency.

c) The seven cities in Shandong involved in "2+26" cities strive to basically eliminate coal-fired boilers with a steam capacity of less than 35 t/h by the end of 2019, and achieve total elimination by the end of 2020.

3.2 Residential clean heating

3.2.1 Policy implementation progress

In 2017, China launched the clean heating program for the northern part of the country in winter, replacing the coal used by residents for heating with natural gas, electricity, solar energy, geothermal energy, and other energy sources, accompanied by safeguarding measures in finance, price and energy supply. By the end of 2020, the project had completed the bulk coal substitution in 25 million households, and the pilot cities had achieved full coverage of the Beijing-Tianjin-Hebei and its surrounding areas and the Fenwei Plain (Chinanews, 2021). Residential sources, especially rural residential sources, are one of the most important sources of BC and OC emissions. The residential clean heating policies and measures substantially reduced BC and OC emissions in northern China. During the 14th Five-Year Plan period, the Chinese government will continue to promote clean heating in the northern part of the country so as to improve people's living standards and regional air quality.

3.2.2 Case introduction of typical provinces

In order to implement the national plan for clean heating in winter in northern China published in 2017, as one of most air-polluted northern provinces in China, Hebei province released the "Implementation Scheme of Clean Heating Project in Winter for Hebei Province" with many solid measures in the requirement in 2018.

Objectives:

Base on the "Implementation Scheme of Clean Heating Project in Winter for Hebei Province" (https://www.sohu.com/a/243282930_760848), the objectives of clean heating campaign in Hebei province in 2018 were as follow.

a) For build-up area in key cities and counties: focus on promoting clean heating in the main urban areas of Xingtai, Handan and Hengshui, as well as the urban-rural junction and plain counties of Shijiazhuang, Baoding and Hengshui.

b) For rural area: increase central heating capacity and eliminate a number of coal-fired heating boilers.

Main measures:

a) Promote the development of central heating. Promote the commissioning and commencement of cogeneration projects. Improve the heating capacity of industrial waste heat. Accelerate the development and utilization of geothermal energy. Accelerate the construction of biomass (waste) thermal power. Transform and upgrade coal-fired central heating stations, and accelerate the construction of heating pipe network.

b) Optimize the overall layout of clean heating. Orderly carry out the work of replacing coal with gas to ensure sufficient gas source. Strictly control all kinds of new coal to gas projects, and in principle, no new rural gas to replace coal and urban coal-fired boiler to gas projects will be arranged. Pay close attention to the comprehensive "look back" work, comprehensively "look back" on project construction, operation management and gas source implementation, find project loopholes, rectify the problems found, eliminate potential safety hazards and improve management services.

c) Strive to promote the implementation of electricity instead of coal. In combination with the basic conditions of power security and power grid, it is planned to arrange the implementation of Hebei South Power Grid in Shijiazhuang, Baoding, Handan, Xingtai, Cangzhou and Hengshui, and Hebei North Power Grid in Tangshan, Qinhuangdao and Chengde. All cities shall promptly organize relevant counties (cities and districts) to implement tasks, put forward work plans such as village identification, household identification and equipment selection, and connect with the power grid company in advance. Accelerate the construction and transformation of supporting power grids and strengthen overall guarantee in the stable operation of power grids.

d) Carry out renewable energy pilot projects. Select areas with good conditions, pilot promote, demonstrate and drive, and promote renewable energy heating according to local conditions.

e) Promote clean coal in a transitional way. In rural areas where clean heating has not been implemented for the time being, continue to promote the use of clean briquette, blue charcoal and high-quality coal.

3.3 Prevention and control of mobile source pollution

3.3.1 Policy implementation progress

In the past decades, China have been upgrading emission standard of on-road vehicles from National I to National V. In 2001, China implemented the National I emission standard for motor vehicles, and has now fully switched to National V emission standard. In December 2016, China issued the Limits and Measurement Methods for Emissions from Light-Duty Vehicles (China VI). At present in northern China, Beijing Municipality, Tianjin Municipality, Hebei Province, Shandong Province, Shanxi Province, and Henan Province have taken the lead in implementing the National VI standard (for new cars only). Compared with the previous National I emission standard, the National VI standard has reduced the emissions of pollutants per vehicle by more than 90%. Among them, the emissions of particulates from diesel vehicles per 100km have been reduced from 293g to 1.5g

In China, "yellow-label vehicles" refer to gasoline vehicles that do not meet the National I emission standard and diesel vehicles that do not meet the National III emission standard. "Old vehicles" are vehicles that fail to meet the National IV emission standard. Since 2013, China has eliminated more than 20 million yellow-label vehicles and old vehicles. The proportion of vehicles meeting National III and higher emission standards increased from 68.4% in 2013 to 92.1% in 2018.

While phasing out yellow-label vehicles and old vehicles, China vigorously promoted new energy vehicles (that is, battery electric vehicle, plug-in hybrid electric vehicle, and fuel cell electric vehicle) and promoted the optimization of vehicle types. By the end of 2012, China had only 17,000 new energy vehicles. In 2019, China produced and sold 1.2 million new energy vehicles, with both production and sales accounting for more than 50% of the world's totals; the new-energy vehicle ownership reached 3.81 million, of which 81% are battery electric vehicles (see Figure 6).

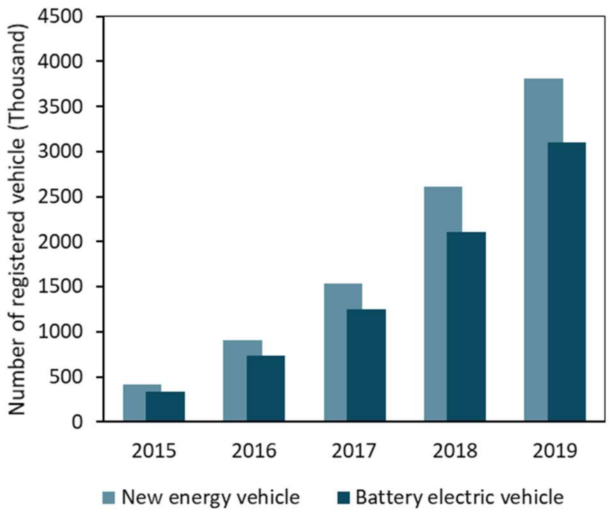

Figure 6 Number of registered new energy vehicles and battery electric vehicles in China by years 2015-2019

Mobile sources, especially diesel vehicles, have a greater contribution to BC emissions than gasoline vehicles. Among them, old vehicles significantly surpass new vehicles in terms of emission factor, and have become a source of BC pollution that has attracted international attention. The Chinese government's measures to tighten motor vehicle emission standard and phase out old and yellow-label vehicles are expected to directly reduce related BC emissions. At the same time, by vigorously promoting new energy vehicles and supplemented with clean electricity (e.g., renewable electricity), the country can also achieve synergistic effect in pollution reduction and carbon reduction.

3.3.2 Case introduction of typical provinces

The pollution prevention and control of vehicles have long been a critical task in Beijing's air pollution control. Focusing on new vehicles, in-use vehicles and fuel quality, Beijing has implemented a series of local emission standards and comprehensive control measures; as well as strengthened traffic management and economic incentives continuously.

a) Stricter emission standards and in-use vehicle retrofitting

Beijing's motor vehicle emission standards have always led the country. In 1999, Beijing became the first city in China to implement the national I emission standard for light gasoline vehicles. In 2004, 2005 and 2008, Beijing took the lead in implementing the "National II", "National III" and "National IV" standards for motor vehicle emissions respectively. In 2013, Beijing continued to take the lead in implementing the "Beijing V" emission standard equivalent to the European phase V standard, further narrowing the gap with the motor vehicle emission control level of developed countries. In 2019, Beijing has officially issued the notice on Beijing's early implementation of National VI emission standards, which required to implement National VI emission standards in stages for difference vehicle types. In the past decade, Beijing has achieved leapfrog development in new vehicle emission control and led the technological progress of energy conservation and environmental protection in automobile industry through standards.

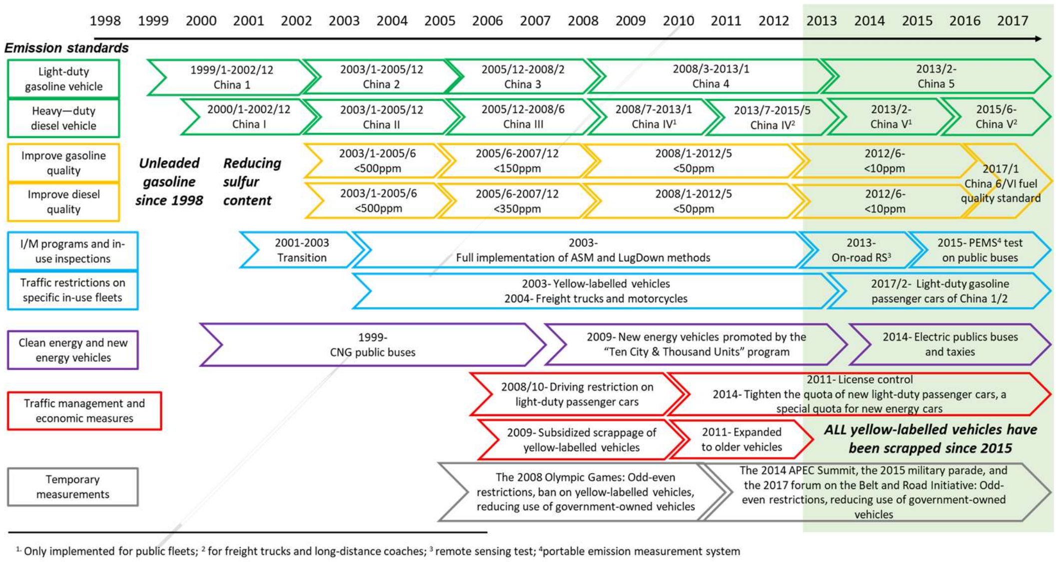

Figure 7 Review of main emissions control measures for motor vehicles in Beijing, 1998–2017 (source: Former Beijing Municipal Environmental Protection Bureau, Tsinghua University, UNEP, 2019)

b) Phasing out old and high-polluting vehicles

In Beijing, yellow-labeled vehicles were first restricted within the Second Ring Road in 2003. During the 2008 Olympic Games period, they were banned in the whole city. In 2010, the scope of the restricted area for yellow-labeled vehicles was extended to within the Sixth Ring Road and then to the whole city in December 2015. For light-duty gasoline vehicles, starting from 2017, those of China National I and National II emission standards have been restricted within the Fifth Ring Road of Beijing; for heavy-duty diesel trucks, those of China National III emission standard or less have been restricted within the

Sixth Ring Road starting from 2017 (UNEP, 2019).

c) Upgrading fuel quality

The quality of oil products is also improved simultaneously in Beijing. In 1997, Beijing took the lead in using unleaded gasoline throughout the country. In 2004, it formulated and implemented the local standard for the stage II of vehicle fuel that was stricter than the national standard. Since then, Beijing's oil standard has continued to lead the country by one or two stages. At present, Beijing has implemented the "Beijing VI" oil standard, and some indicators have been stricter than European standards (Beijingdaily, 2019).

d) Developing new energy vehicles

In 1999, Beijing introduced compressed natural gas (CNG) to the bus fleet and gradually promoted clean fuels and new energy buses. Among the 2,306 buses that were updated in 2016, 1,368 were electric vehicles, accounting for 59% (UNEP, 2019).

e) Integrating a comprehensive "vehicle, oil and road" treatment framework

Over the past 20 years, by formulating and implementing a series of strict local standards for the emission management of new and in-service vehicles and the quality of oil products, adopting comprehensive treatment measures, and continuously strengthening traffic control and economic incentives, Beijing has gradually developed and formed an integrated vehicle emission control framework including "vehicle, oil and road". More important, a large-scale public transport system has been built to allow gradual formation of a green and low-carbon in-city travel habit by the people.

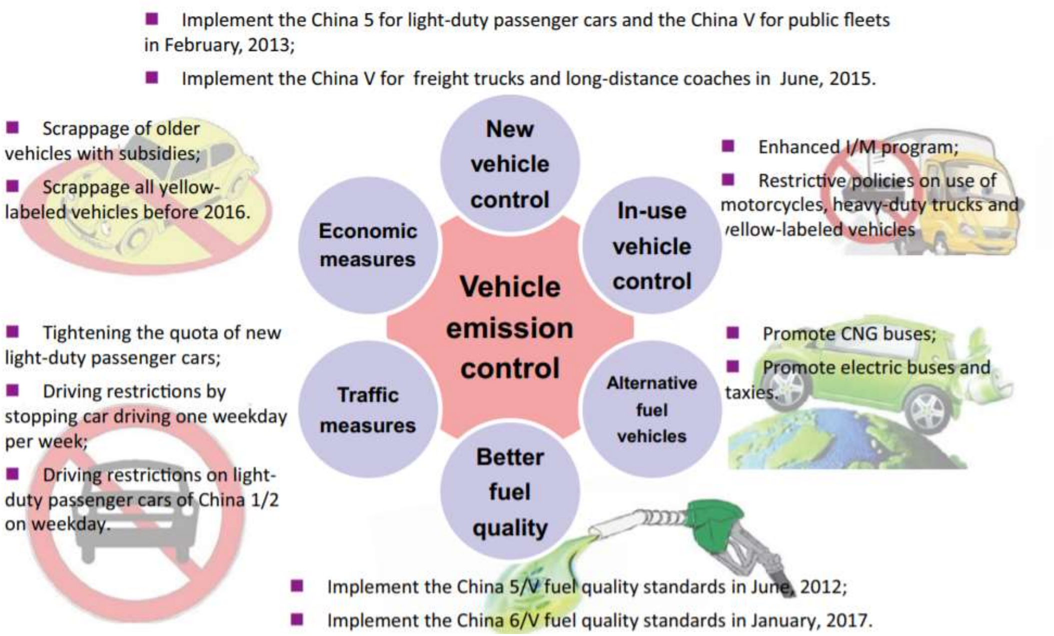

Figure 8 Vehicle-fuel-road integrated control system (source: Former Beijing Municipal Environmental Protection Bureau, Tsinghua University, UNEP, 2019)

Although the number of vehicles increased three-folds in Beijing during the last two decades, the total pollutants emissions decreased remarkably. Based on the study report of UNEP (2019), compared with 1998, CO, THC(total hydrocarbon), NOx and $PM_{2.5}$ emissions from the transportation sector in 2017 were reduced by nearly 89%, 64%, 55% and 81% respectively.

References

The State Council of the People's Republic of China (SC). 2013. Action Plan on Prevention and Control of Air Pollution. http://www.gov.cn/zhengce/content/2013-09/13/content_4561.htm

The State Council of the People's Republic of China (SC). 2018. Three-Year Action Plan to Fight Air Pollution. http://www.gov.cn/zhengce/content/2018-07/03/content_5303158.htm

Hammer, Melanie S. , et al. 2021. Effects of COVID-19 lockdowns on fine particulate matter concentrations. Science Advances 7.

Shi Z , Song C , Liu B , et al. 2021. Abrupt but smaller than expected changes in surface air quality attributable to COVID-19 lockdowns. Science Advances, 2021, 7(3):eabd6696.

He G , Y Pan, Tanaka T. 2020. The short-term impacts of COVID-19 lockdown on urban air pollution in China. Nature Sustainability.

Le T , Wang Y , Liu L , et al. 2020. Unexpected air pollution with marked emission reductions during the COVID-19 outbreak in China. Science, 369(6504):eabb7431.

National Bureau of Statistics of China (NBS). 2021.https://data.stats.gov.cn/easyquery.htm?cn=C01
Chinanews. "MEE: Winning the Blue Sky Battle", https://www.sohu.com/a/452745029_270669

United Nations Environment Programme (UNEP). 2019. A Review of 20 Years' Air Pollution Control in Beijing. Nairobi, Kenya.

Beijingdaily. 2019. The United Nations recommended the experience of Beijing in atmospheric Governance: 'this is not accidental.' https://baijiahao.baidu.com/s?id=1629853516063598794&wfr=spider&for=pc