Chinese implementing Agencies

Chinese Research Academy of Environmental Sciences (CRAES)

Chinese Academy of Environmental Planning (CAEP)

Norwegian implementing Agencies

Norwegian Environment Agency(NEA)

Center for International Climate and Environmental Research-Oslo (CICERO)

Norwegian Institute on Public health (NIPH)

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/.

The co-benefits on air quality and climate change of Black Carbon emissions reduction

How much do you know about emissions, impacts and policies?

Chinese Research Academy of Environmental Sciences
June 2023

Contents

一、ChiNorBC project introduction

According to the memorandum of understanding (MOU) regarding Economic and Technical Cooperation signed by the Government of the people's Republic of China (China) and the Government of the Kingdom of Norway (Norway), as well as the memorandum of understanding signed by the Ministry of Ecology and Environment of the People's Republic of China (MEE) and the Norwegian Ministry of Climate and Environment (MCE). The Ministry of Commerce of the People's Republic of China (MOFCOM) and the Norwegian Ministry of Foreign Affair (MFA) have entered into the Agreement (Chinese-Norwegian Project on Emission, Impact and Control Policy for Black Carbon and it's Co-benefits in Northern China) dated 29 November 2019.

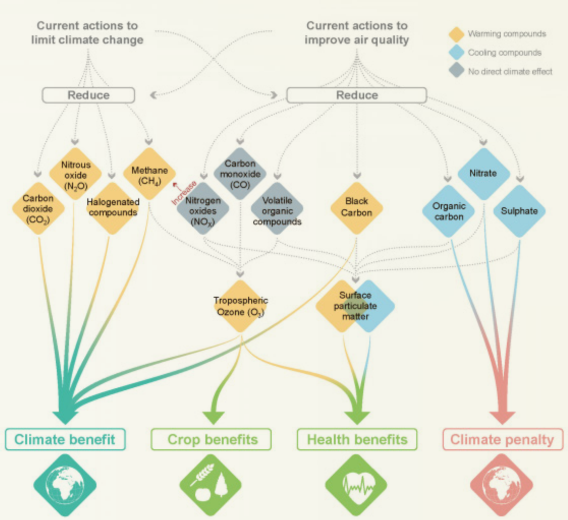
The implementation period of the project is 3.5 years (from October 2019 to June 2023), and the project fund is NOK 24.16 million. This project will first develop a baseline by analyzing the current emission and concentration levels in northern China, as well as existing strategies to reduce the impacts of BC/OC. The study area contains 17 provinces in northern China. Current practices in Norway and other countries will be assessed to gain experience. With this background, the project will develop or update relevant emission inventories and model air quality and climate effects. Effects on health will also be studied and quantified. Finally, the project will develop and propose policy scenarios towards 2035 for reducing the emissions and impacts of BC/OC.

二、Highlights of the ChiNorBC project

1 What is BC / OC ?

Black carbon (BC) is particulate matter formed by incomplete combustion of carbon containing substances such as fossil fuels, biofuels and biomass. As the most important absorbent component of atmospheric aerosol, BC aerosol only accounts for 5% - 15% of aerosol mass fraction, but its radiation characteristics will significantly affect the global radiation balance and the evolution and development of atmospheric boundary layer. BC can strongly absorb solar short wave radiation, release infrared radiation and heat the surrounding atmosphere, thus generating regional warming effect.

Organic carbon (OC) refers to the part of carbon containing aerosol containing organic compounds (compounds containing hydrocarbon bonds and other elements).



The impact of BC on Climate, Environment and Health (IPCC, 2021, FAQ 6.2)

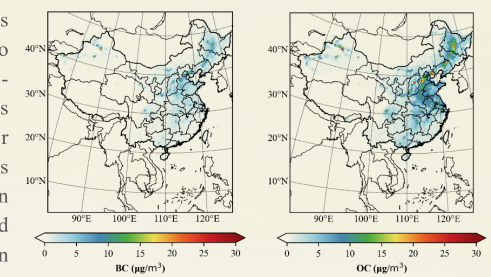
As an important component of atmospheric aerosols, BC/OC aerosols have a significant impact on regional and global climate change, radiation forcing, visibility, environmental quality and human health.

2 The Impact of BC/OC on Air Quality, Climate Change and Health

2.1 Impact of BC / OC on Air Quality

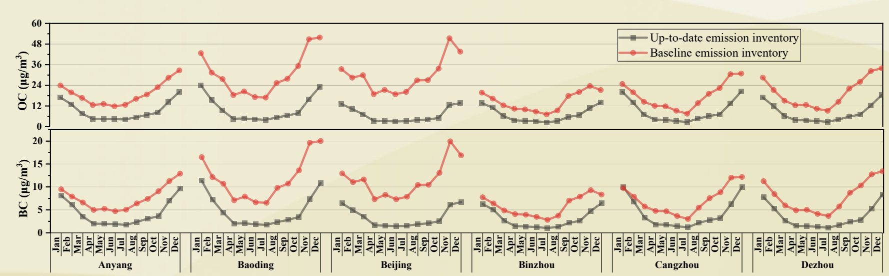
BC is an important particulate pollutant, with BC contributing about 5-15% to the total aerosol mass concentration in urban air, leading to regional air pollution and reduced visibility. The incidence of extreme haze pollution events in China's megacities is enhanced by the heating effect BC aerosols can cause on the boundary layer. It is therefore crucial to provide society and policy makers with accurate modelling of current BC/OC atmospheric component concentrations and possible future developments.

Regional air pollutant concentrations in China from January 2018 to December 2018, based on the up-to-date emission inventory simulations from this project, show that higher annual average concentrations of BC/OC are concentrated in the Beijing-Tianjin-Hebei and surrounding areas, the three eastern provinces, and some cities in northwest China. The areas with high BC/OC pollutant concentrations were more widely distributed in the Beijing-Tianjin-Hebei region, with annual average BC/OC concentrations up to 25 μg/m^3 and 45 μg/m^3.



The spatial distribution of simulated annual BC/OC concentration

The modelled monthly average BC/OC concentrations in key cities in northern China show a trend of high in autumn and winter and low in spring and summer. The ChiNorBC-2018 inventories (up-to-date emission inventories) can simulate BC/OC concentrations in Northern China well, and the overestimation of baseline emission inventories and the simulated pollutant concentration overestimation can be improved significantly.



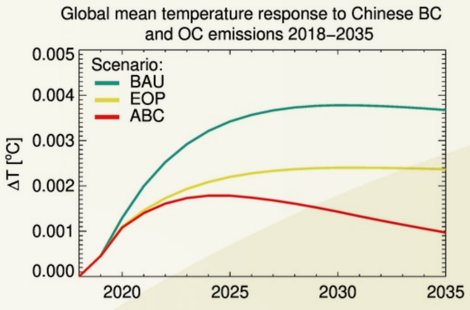
Simulated monthly mean concentration of BC/OC in key cities of northern China

2.2 Impact of BC / OC on Climate Change

BC, OC and other aerosols play a key role in anthropogenic climate change. Aerosols alter the amount of solar radiation reaching the surface and can heat the atmosphere and change the amount and properties of clouds. Most aerosol types, including OC, cause more solar radiation to be scattered back to space and hence give a cooling effect on climate. BC, along with brown carbon (BrC), however, stand out as they absorb solar radiation and hence give a warming climate effect. While there are large uncertainties in the exact magnitude of the aerosol impact on climate, reducing BC emissions are consider an important measure to limit global warming in the near-term while improving air quality. Additionally, aerosols can play an important role in shaping the regional climate and weather, such as precipitation patterns, haze events, and extreme weather.

Quantifying the climate impact of BC and OC require robust and up-to-date estimates of the emissions. We have used the emission inventory developed in the ChiNorBC to model the amounts of aerosols over China. We find the highest concentrations of BC and organic aerosol over the Eastern parts of mainland China, peaking around the Beijing-Tianjin-Hebei region. On average, BC and organic aerosol make up 5% and 14%, respectively, of the total aerosol abundance over China. When compared to one of the most recent global inventories, the Community Emission Data System version 2021, the Chinese emissions of BC are lower in the updated ChiNorBC inventory, while OC emissions are higher. The result is an on average 6-7% lower and higher amount of BC and organic aerosol, respectively. Locally, differences can be significantly higher.

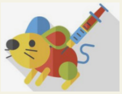
The reduced warming effect from reducing BC emissions can be seen in the scenarios produced in the ChiNorBC project (see section 6 below for description). Comparing the impact on global mean surface temperature, we find that implementing the most stringent set of measures and policies reduces the net impact of BC and OC emissions in China on global mean temperature by 70% in 2035 relative to the business-as-usual case.



The global mean surface temperature effect resulting from Chinese emissions of BC and OC under the three scenarios developed in the project, calculated using a simple, analytical climate model.

2.3 Impact of BC / OC on Health

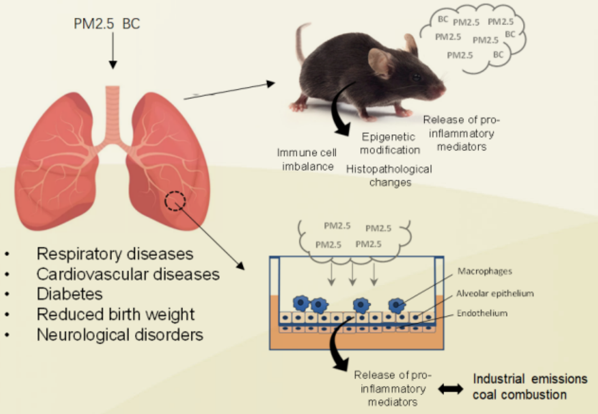
BC is the product of incomplete combustion and the vital fraction of fine particles (<2.5 μm) and ultrafine particles (0.05–0.12 μm). The porous structure of BC allows for easier adsorption of organic compounds which, combined with the small size, might lead to a great impact on human health. Research shows people exposed to BC in the short or long term can experience various adverse effects, particularly on the respiratory system. The results of the meta-analysis conducted in this project show a significant positive association between BC and both all-cause and respiratory system diseases mortality in short-term exposure and a significant positive association between BC and lung cancer mortality in long-term exposure.



Results of experimental studies:

(1)Studies in animals and advanced cell culture models show that exposure to $PM_{2.5}$ can cause inflammation, immune cell imbalance, and changes in gene expression of signaling pathways.

(2)$PM_{2.5}$ sampled in specific cities with representative pollution sources exhibited different inflammatory effects in cell culture models through the release of inflammatory mediators.

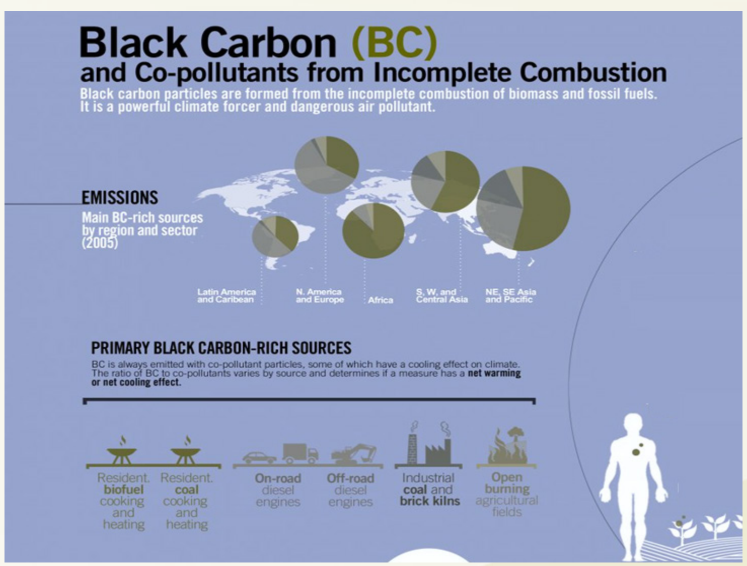


Schematic diagram of health damage caused by $PM_{2.5}$ /BC exposure

3 BC / OC Emissions Sources

The sources of BC / OC in the atmosphere include natural sources and anthropogenic sources. Natural sources include natural emissions such as forest fires, volcanic eruptions and other geological phenomena. Anthropogenic sources include diesel engines for transportation and industrial use, residential fuels such as biomass and coal for cooking and heating, human initiated open burning of forest and savanna (including burning of agricultural wastes), and industrial facilities such as small boilers and brick kilns.

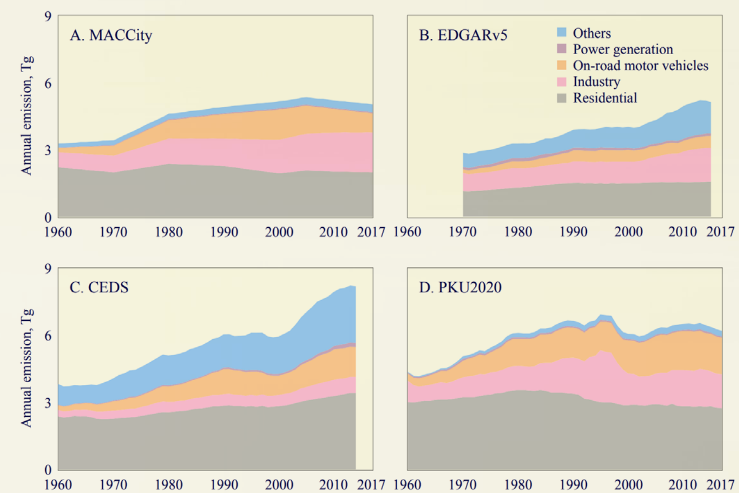
In China, black carbon is emitted from all known anthropogenic sources albeit in varying amounts. Black carbon mainly comes from five major industries: residential (rural and urban residence using biomass, coal as fuel for cooking and heating), industry (using biomass, coal or oil for industrial processes and in industrial boilers), transport (including off-road vehicles and on-road vehicles using diesel fuel), power generation (using coal and oil as fuel) and open burning of biomass (including burning of agricultural waste and residues and using fire for land clearing).



Schematic diagram of main sources of black carbon (CCAC, 2018.)

3.1 Global Emissions of BC / OC

The global BC annual emissions and emission sources time trends from 1960 to 2017 are shown in the following figure. The global BC emissions increased first and then decreased. The global BC emissions increased steadily from 1960 to 2015 and decreased slightly in recent years. The main drivers for the increased emissions are population growth, per capita energy consumption increase, and increased vehicle fleet. The emissions decrease due to residential energy switching, stove upgrading, phasing out of beehive coke ovens, and reduced emission intensity for vehicles and industrial processes. Urbanization caused an important increase in urban emissions as well as a significant decline in overall rural emissions.

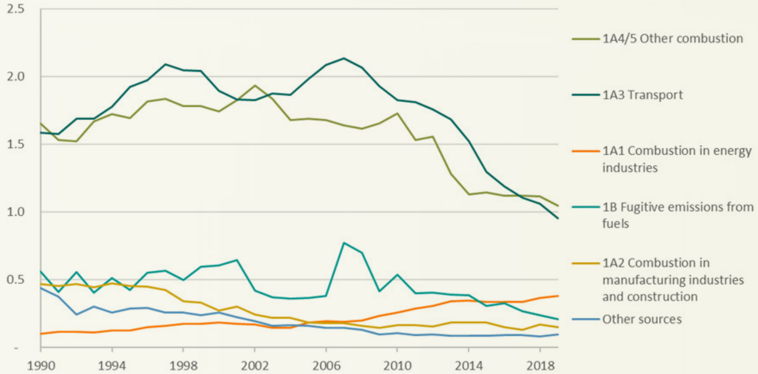


BC emissions in the four emission inventories. (A) MACCity, (B) 19 Emissions Database for Global Atmospheric Research (EDGAR, v5), (C) Community Emission Data System (CEDS), (D) Peking University emission inventories, 2020 version (PKU-2020) (Xu et al., 2021)

3.2 Norwegian Emissions of BC/OC

The Norwegian emissions of BC amounted to 2,841 tonnes in 2019, a total reduction of 41% since 1990. In 2019, the most important source of emissions was “other combustion,” contributing 37% of total emissions. From this category, 75% of emissions in 2019 originated from residential stationary plants, primarily due to wood combustion in private households. From 1990 to 2019, emissions from residential stationary plants have been reduced by 28%.

In 2019, the second most important source of emissions was transport. It contributed 34% of total BC emissions. The greatest share of emissions within the transport sector, 57%, stems from coastal navigation. That is followed by light-duty vehicles, passenger cars, and heavy-duty vehicles and buses, contributing 11%, 12%, and 10%, respectively. From 1990 to 2019, emissions from navigation increased by 15%, while emissions from passenger cars increased by 28%. However, emissions from light- and heavy-duty vehicles have been reduced by 51% and 86%, respectively, from 1990 to 2019, leading to an overall reduction of about 30% from the transport sector.

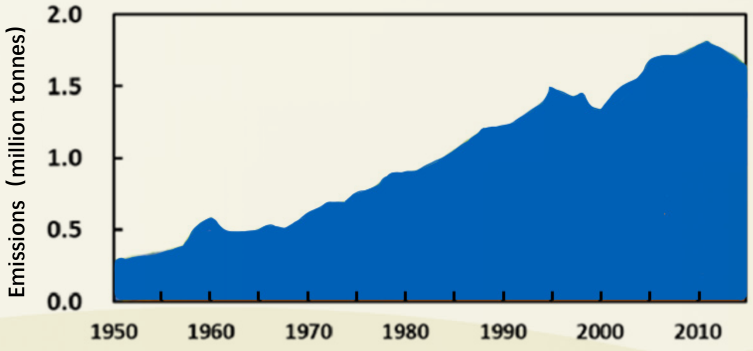


Trends in BC emissions, 1990–2019. 1,000 tonnes

3.3 Chinese Emissions of BC/OC

(1) Total China Emissions

The estimated BC emissions, source attribution, and changing trend in China differ greatly among different scholars due to the differences in the basic data used. Generally speaking, China's total BC emissions have been on the rise in recent decades, mainly due to the rising energy use and more active activities caused by China's sustained and rapid development. However, in the past decade, while production and living activities and energy consumption have risen, China's energy structure, industrial structure and transportation structure have been continuously adjusted and optimized, and various pollution control measures have also been strengthened. Black carbon emissions are basically hovering around 1.5 million tonnes, and show a momentum of decline. According to the relevant scholars, in 2012, in the Chinese mainland area, residential sector contributed the largest part of BC emissions (43.3%), followed by industrial sector, accounting for 42.9% of the national total; transportation and open biomass burning accounted for 9.4% and 3.5%, respectively, while thermal power and heating industry emitted a very small share (0.8%).

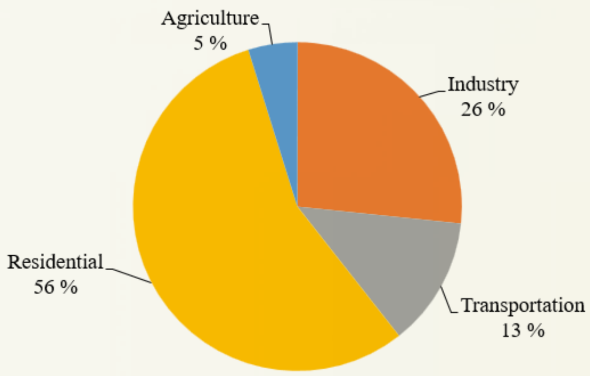


The changing trend of China's black carbon emissions

(2) Northern China Emissions

The China-Norway cooperation project (ChiNorBC) focuses on studying black carbon emissions in northern China. The results show that in 2018, among the 17 provincial regions of northern China that involve winter heating, black carbon emissions reached 827,000 tons, of which the residential sector contributed the most, accounting for more than half, followed by industrial sector, accounting for about a quarter. The mobile (including on-road and off-road mobile sources) and agricultural sectors represented about 13% and 5%, respectively, and power generation sector had a negligible proportion.

The characteristics of the emission structure in northern China show that the heavy use of fossil fuels and biomass fuels in winter heating is the key reason for the prominent emissions in the residential sector, reflecting the importance of promoting clean heating. As the power industry has basically completed the ultra-low emission transformation, black carbon emissions therefrom are extremely low; industrial and mobile sources still have the potential to reduce black carbon emissions.



Sources of BC emissions in northern China

4 BC / OC Emission Reductions Effect of Air Pollution Control in China Since 2013

In recent years, with the implementation of the series of released air pollution prevention and control policies, China has achieved positive results in air pollution prevention and control, with the overall ambient air quality seeing substantial improvement.

4.1 Constructing a Legal Framework for Air Quality Improvement

(1)ctively build a legal framework for air pollution prevention and control

(2)Since 2013,laws and regulations covering all areas of air pollution control has been revised and implemented. Including《Environmental Protection Law》,《Law on the Prevention and Control of Atmospheric Pollution》,《Law on Environmental Impact Assessment》,《Environmental Protection Tax Law》,《Law on Prevention and Control of Desertification》,《Law on Energy Preservation》.

(3)Enforcement of environmental laws were strengthened: Since 2015, the amount of administrative penalty fines imposed has increased year by year.

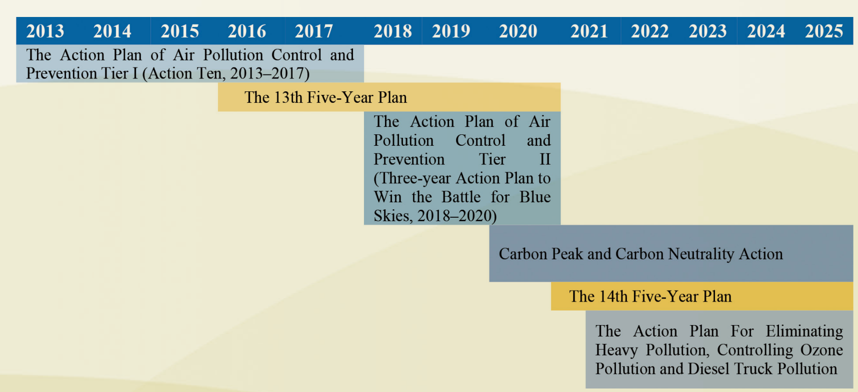
4.2 Implementing Air Pollution Prevention and Control Plans

Since 2013, the Chinese government has promulgated and implemented national action plans as shown below, which have significantly improved the national air quality.

4.3 Carbon Peak and Carbon Neutrality Action in China

China has included carbon peaking before 2030 and carbon neutrality before 2060 in its overall plan for ecological conservation, and promoted the development of a green and low-carbon circular economy in an all-round way in 2020

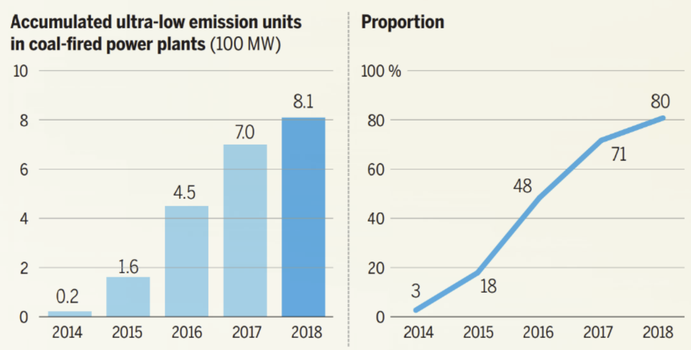
The timelines of Air Pollution Control and Prevention



4.4 Specific Industry Control Plans, Policies and Regulations

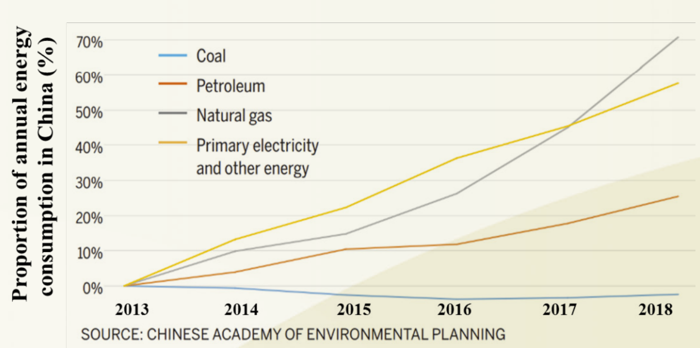
The control plans, policies and regulations of specific industries contained upgrading industrial standards and companies, restructuring industrial, optimizing energy structure, prevention and control of mobile source pollution and treatment of non-point source pollution.

Taking industrial emission standards as an example, ultra-low emission and energy-saving transformation of coal-fired power plants was launched in 2014. By the end of 2018, the capacity of China's coal-powered generators with ultra-low-emissions reached more than 810 million kilowatts, accounting for over 80 percent of the country's total installed capacity of coal-power generating units.



Proportion of ultra-low emission units in coal-fired power plants in China from 2014 to 2018

Taking the energy structure as an example, between 2013 and 2018, the proportion of coal consumption in primary energy had dropped from 67% to 59%, curbing the trend of rapid growth of coal consumption.



China's annual energy consumption since 2013

5 BC /OC Emission Reductions Road and Experience in Norway

5.1 The Polluter Pays Principle

The polluter pays principle is a cornerstone of the Norwegian policy framework for air pollution and climate change. Norway does not have regulations directed specifically to reduce BC and OC emissions, but air pollution and climate change legislation targeting other components has contributed to large reductions in BC and OC emissions since 1990.

5.2 Norwegian Limit Values, Goals and Criteria

The EU Ambient Air Quality Directives (2004/107/EC and 2008/50/EC) set the guidelines, regulations, and laws for managing air quality in Europe. In addition to the limit values set out in the directive, Norway has established its own more ambitious guidelines and laws, while still adhering to the EU regulations. Norway has various levels of air quality standards, including national legal limit values, national goals and air quality criteria. These standards were recently sharpened in Norway January 1st 2023. The EU directives are proposed sharpened, and are currently under review.

EU and Norwegian limit values, goals and criteria for PM

PM		EU	Norway		
		Air Quality Directives limit values	National legal limit value*	National goals*	Air quality criteria*
PM_{10}	**Daily**	50 µg/m^3 (max 35 exceedances)	50 µg/m^3 (max 25 exceedances)	n/a	30 µg/m^3
	Annual	40 µg/m^3	20 µg/m^3	20 µg/m^3	15 µg/m^3
$PM_{2.5}$	**Daily**	n/a	n/a	n/a	15 µg/m^3
	Annual	25 µg/m^3	10 µg/m^3	8 µg/m^3	5 µg/m^3

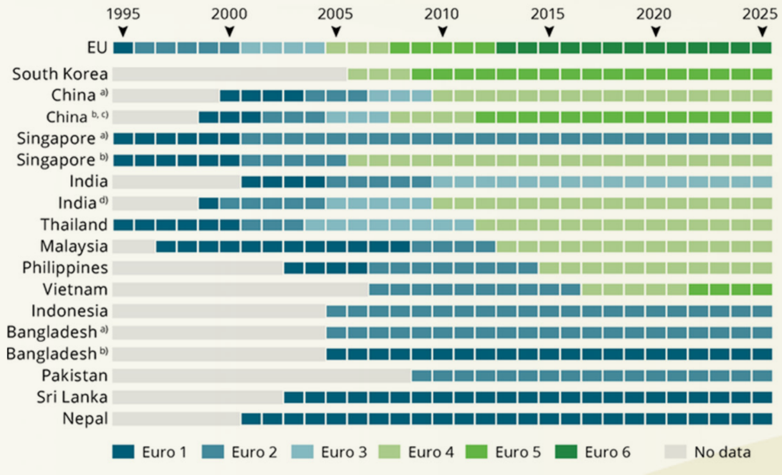
*National legal limit value: legally binding values specific for Norway.
National goals: the government's long-term goals for local air quality in Norway.
Air Quality Criteria: health-based goals for air quality.
n/a means not applicable

5.3 Sector Specific Plans, Policies and Regulations in Norway

Since the end of the 1980s, climate change and greenhouse gas emissions have been the focus of Norwegian policy, and have broad political support, which also helps to reduce BC / OC emissions. Norway has successively introduced sector specific plans, policies, and regulations on all major sectors, such as transportation, residential, industry, and agriculture.

Taking the transportation sector as an example, The EU has adopted stringent emission standards for various vehicle categories, which also apply in Norway. The Euro 6 emission standards include PM and have been active for nearly 10 years, with even stricter Euro 7 standards that were proposed by the EU in 2022, and currently under review.

Norway has implemented aggressive electric vehicle (EV) policies that has resulted in 79% of all new personal vehicles sold in 2022 were EV. It is estimated that by the end of 2023 that this will be closer to 90%, making Norway one of the most successful countries in the world in regards to EV conversion. While this policy has mitigated small fraction exhaust particles from the road transport sector, Norway still has a challenge with large fraction non-exhaust particles from road transport originating from road dust.



EU vehicle emission standards for light-duty vehicles in comparison to other countries (Source: EEA, 2016).
a) gasoline, b) diesel, c) entire country, d) Delhi, Mumbai, Kolkata, Chennai, Hyderabad, Bangalore, Lucknow, Kanpur, Agra, Surat, Ahmedabad, Pune and Sholapur

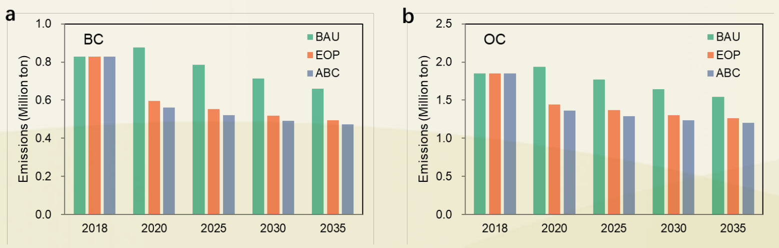
6 The Future Path for BC / OC Emission Reductions in China

6.1 Scenario Design

This study projects future air pollutant emissions in northern China based on an integrated modeling framework that integrates an energy projection model, a database of emission control measures, scenarios projection, and an emission projection model. The analysis projects air pollution emission levels in varying policy strictness based on three scenarios that are designed based on China's strategic target of carbon peaking and carbon neutrality, as well as the construction of a "Beautiful China". These scenarios include the business as usual (BAU), strengthened end-of-pipe control (EOP), and ambitious control by strengthening both end of pipe control and structural and activity adjustment (ABC).

6.2 Emission Projection

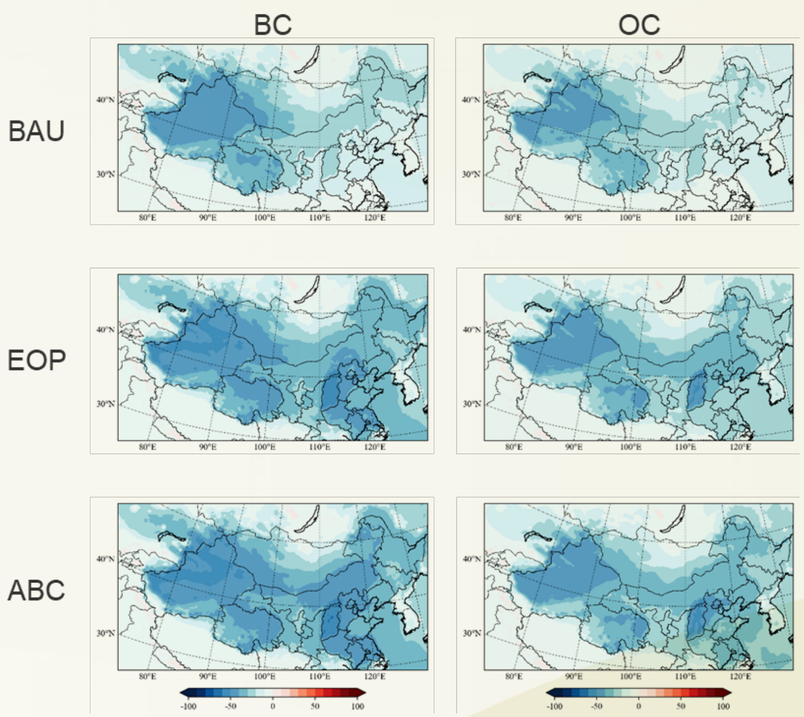
All scenarios show that BC and OC emissions in 2035 would be lower than the 2018 baseline levels. In BAU, emissions of BC and OC will rise in 2020 and then decrease afterward, following the trends of projected activity levels. In EOP and ABC, all emissions will keep decreasing from 2018 to 2035. For both BC and OC emissions, the reduction rates in ABC in all prospective years are greater than those in EOP, and those in EOP are also greater than in BAU. By 2035, emissions of BC will decline by 20-43% in the three scenarios. A twenty percent higher reduction rate could be expected in EOP compared with BAU, indicating that strengthened end-of-pipe control measures will have remarkable emission reduction effects.



Projected BC and OC emissions in northern China.

6.3 Air Quality Improvements

Reductions in emissions would bring substantial air quality improvements. In 2035, concentrations of BC and OC are projected to decreased over the whole northern China in all the three scenarios. In the BAU scenario, the regions with high reductions in simulated concentrations of BC and OC are mainly concentrated in the north-western regions. In the EOP scenario, the largest percentage decreases in annual average BC and OC concentrations were observed in Shanxi, with largest values of 58% and 52%, respectively. The ABC scenario shows the largest decrease in pollutant concentrations among the three reduction scenarios. The largest decrease in the modelled concentrations of BC and OC are also in Shanxi.



Projected reduction rates of BC and OC concentrations in northern China in 2035 compared with the 2018 baseline levels.

7 The Vision for Future BC/OC Emission Reductions

To accelerate the formation of green lifestyle:

Green lifestyle is a modern civilized lifestyle pursuing resource conservation and environmental friendliness.

Low carbon life, be a green citizen! Let's act together!

To expand the consumption of green and low-carbon products:
Purchasing the green products, green food, etc

To Promote the green packaging:
Purchasing the simple packaged goods, etc

To guide green travel:
more bicycles, more buses, etc

To advocate electricity conservation:
using energy-saving electrical appliances, and completely turning off the power after using the appliances; moderate use of air conditioners, etc

To advocate to reduce garbage and garbage classification:
using less disposable products (wooden chopsticks, paper cup, paper towel), etc.