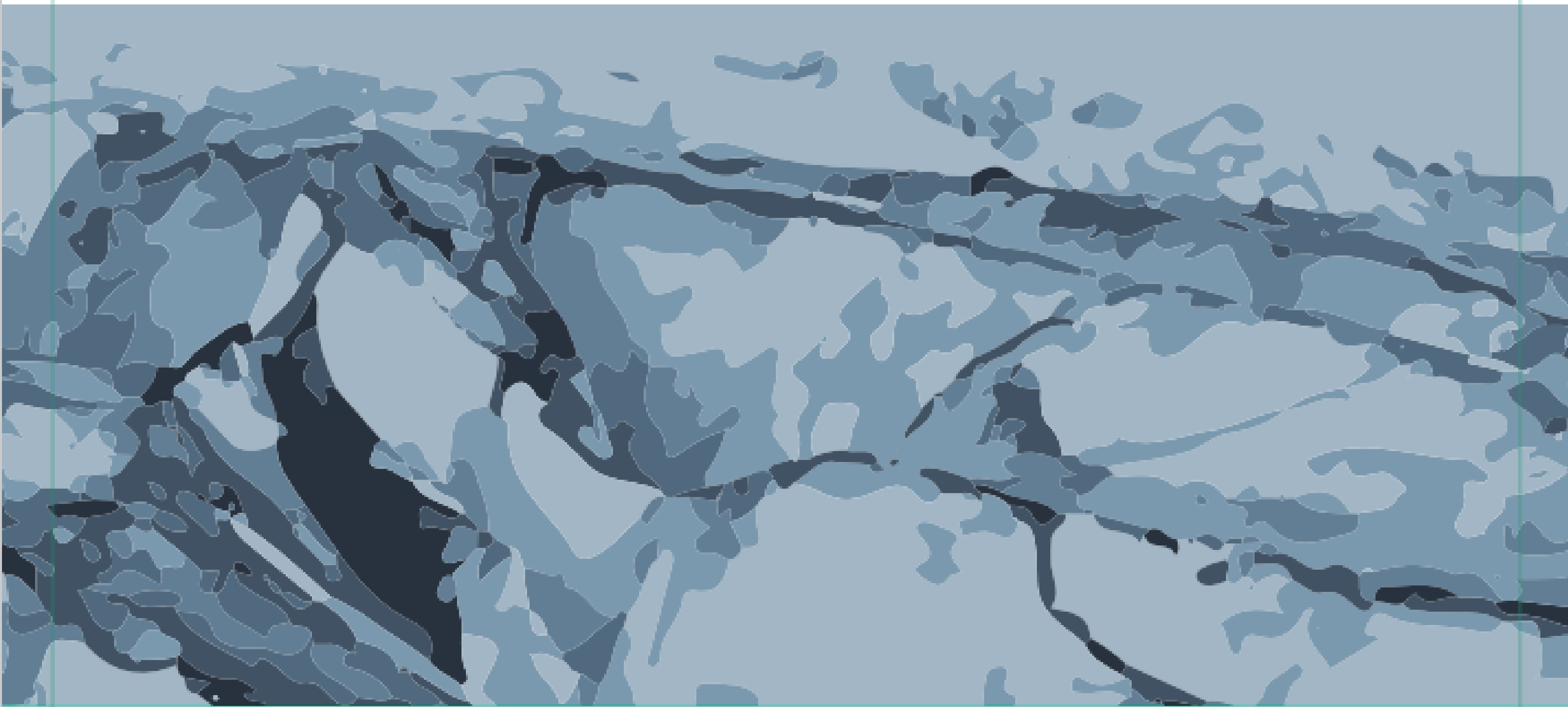
Review report 1

ChiNorBC

REVIEW OF BC/OC EMISSIONS AND CONTROL MEASURES IN CHINA AND NORWAY



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

CAEP

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Norwegian Environment Agency

NIPH

Review of BC/ OC emissions and control measures in China and Norway

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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 maximize the co-benefits.

The project has six outputs. This report is a result of Output 1, Review of BC/OC emissions and control measures in China and Norway. 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

1 Introduction

Since greenhouse gas emissions such as carbon dioxide and air pollutant emissions have many of the same sources, there can be good synergistic effects of emission reductions both for climate and air pollution. In order to maximise the benefits, however, it is important to perform integrated studies and make holistic plans. During the 14th Five-Year Plan period (2021–2025),[1] China will accelerate the transformation and upgrading of industrial structure and strictly control the construction of high energy-consuming and high-emission projects. The fundamental policies are: (1) construction of a clean and low-carbon energy system, development of non-fossil energy, and reduction of fossil energy consumption; (2) increasing optimization and adjustment of transportation structure, and promoting public to rail, public to water, and multimodal transportation; and (3) selection of typical regions and cities to carry out pilot demonstrations of meeting environmental quality standards and carbon emission peaks. At the same time, China will strengthen work coordination and conduct unified policy planning and standard setting, along with unified monitoring and assessment, unified supervision and enforcement, and unified inspection and accountability, in order to provide support and guarantees for achieving the synergistic effect of pollution reduction and carbon reduction.

The Chinese-Norwegian Project on Emission, Impact, and Control Policy for Black Carbon and its co-benefits in northern China will promote the understanding of the negative impacts of BC/OC on air quality, climate change, and health. In addition, implementation and development of an environmental policy system of control strategies for BC/OC in northern China will be improved greatly by disseminating the results of this project. The results will be a significant contribution to the Chinese government's capacity for environmental management. Furthermore, developing a strategy for BC/OC co-control will greatly benefit reductions in regional and national air pollutant emissions and improve air quality.

The purpose of this report is to review the status of BC/OC emissions and control in China and Norway.

[1] Information on the 14th Five-Year Plan period (2021–2025) for China. http://www.gov.cn/xinwen/2021-03/13/content_5592681.htm, last accessed 25 May 2022.

2 Review of China's Status on BC/OC Control

This section provides a review and summary of BC/OC control related policy and regulations carried out in China.

2.1 Strengthening Environmental and Climate Regulation and Institutional Arrangement

2.1.1 Improving Legal Framework for Improving Air Quality

Since 2013, China has made and revised many laws and regulations on prevention and control of air pollution, including the Environmental Protection Law of the People's Republic of China, the Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution, the Law of the People's Republic of China on Environmental Impact Assessment, the Environmental Protection Tax Law of the People's Republic of China, the Law of the People's Republic of China on Prevention and Control of Desertification, and the Law of the People's Republic of China on Energy Preservation. They cover various fields of air pollution control. The Environmental Protection Law of the People's Republic of China and the Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution are described in more detail below.

The Environmental Protection Law of the People's Republic of China is a law enacted to protect and improve the environment, prevent and control pollution and other public hazards, safeguard public health, promote ecological progress, and promote sustainable economic and social development. The term "environment" as used in this Law refers to the totality of all natural and artificially transformed natural factors affecting human existence and development, including the atmosphere, water, oceans, land, mineral deposits, forests, grasslands, wetlands, wildlife, natural and human remains, nature reserves, scenic spots, and urban and rural areas. The Environmental Protection Law of the People's Republic of China was adopted at the 11th Session of the Standing Committee of the Seventh National People's Congress on December 26, 1989, and entered into force as of the date of promulgation. On April 24, 2014, the eighth session of the Standing Committee of the 12th National People's Congress adopted the Revised Environmental Protection Law, which is described as the "strictest in history." The new law went into effect on January 1, 2015.

The Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution is a law enacted to protect and improve the environment, prevent and control air pollution, safeguard public health, promote ecological civilization construction, and promote sustainable economic and social development. The Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution was adopted at the 22nd Session of the Standing Committee of the Sixth National People's Congress on September 5, 1987, and entered into force as of June 1, 1988. The law was revised for the second time at the 16th Session of the Standing Committee of the 12th National People's Congress on

August 29, 2015, and became effective as of January 1, 2016. As revised, “The Law of the People’s Republic of China on the Prevention and Control of Atmospheric Pollution” expanded from the original 66 to 129 articles, focusing on the goal of improving the quality of the air environment, strengthening source management and collaborative control, implementing joint prevention and control of air pollution in key regions, actively responding to heavily polluted weather, effectively implementing local government responsibility, increasing the penalties for air environmental violations, and making specific provisions to strengthen prevention work regarding coal, industry, motor vehicles, dust, agriculture, and other sources of air pollution. According to the Deepening Party and State Institutional Reform Program announced by office of the Central Committee for Institutional Development in March 2018, the former Ministry of Environmental Protection was renamed the Ministry of Ecology and Environment, with significant changes in function configuration, internal structure and staffing, and the full implementation of the Air Pollution Prevention and Control Action Plan is an important part of its new function. In accordance with this change, the new names of the relevant institutions were subsequently revised in the Law of the People's Republic of China on Prevention and Control of Air Pollution, and was adopted and issued for implementation by the Standing Committee of the 13th National People's Congress at its sixth meeting on October 26, 2018.

The early versions of the law mainly controlled emission of SO_2, NOx, dust, and harmful gases from factories, power plants, motor vehicles, and ships. The 2015 and 2018 versions, however, showed a significant change in the country’s strategy for air pollution governance, from individual pollutant emission controls to overall air quality improvement, which highlights the regulation of emission sources rather than just focusing on end-of-pipe emissions. Furthermore, the revised versions highlighted regional joint prevention and control, while the co-governance of greenhouse gases and such air pollutants as PM, SO_2, NOx, ammonia (NH_3), and volatile organic compounds (VOCs), was proposed for the first time. An accountability and performance target evaluation system has been established in China to enforce environmental and climate governance. Major targets have been established at the national level and then disaggregated to provincial and lower levels of government (UNEP, 2019). Thus, local governments of the 31 provinces, municipalities, and autonomous regions in China promulgated or revised supporting regulations on environmental protection and prevention of air pollution. Some regions have even framed special legislation for key tasks. For instance, Zhejiang, Anhui, and Chongqing have released guidelines for the prevention and control of motor vehicle pollution.

2.1.2 Carbon Peak and Carbon Neutrality Action in China

General Secretary Xi Jinping has solemnly proposed China's carbon-control timeline to the world. In 2020, Xi said 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 a comprehensive way. The Paris Agreement on Climate Change represents the general direction of the global green and low-carbon transition, and is the minimum action needed to protect the Earth as a home for life, and countries must take decisive steps. Countries should establish a new development concept of innovation, coordination, greenness, openness, and sharing, seize the historic opportunity of the new round of scientific and technological revolution and industrial change, promote the “green recovery” of the world economy after the Covid19 epidemic, and gather a strong synergy for sustainable development (Xinhua, 2020). As the world's largest carbon emitter, China has clearly proposed a long-term climate goal to control emissions.

Achieving the ambitious goals of carbon emissions and carbon neutrality will not be easy and will require a Herculean effort. In terms of timing, Europe and the United States have a 50–70-year transition period from peak carbon to carbon neutrality, while China only has a 30-year transition period. As the largest developing country, China still has many shortcomings in addressing climate change. China's low-carbon development transition also faces three major challenges: (1) China's manufacturing industry is still in the middle and low end of the international value chain since product energy consumption and material consumption are high, the value-added rate is low, and economic restructuring and industrial upgrading tasks are arduous; (2) the share of coal in Chinese energy consumption is still more than 50% of Chinese energy consumption, the intensity of carbon dioxide emissions per unit of energy is about 30% higher than the world average, and the task of optimizing the energy structure is arduous; and (3) the energy intensity (energy consumption per unit GDP) is very high, 1.5 times the global average and 2 to 3 times that of OECD countries, and the task of establishing a green low-carbon economic system is extremely arduous.

China is actively promoting carbon trading pilot work. In 2011, China launched the carbon market pilot work. Seven provinces and cities—Beijing, Tianjin, Shanghai, Chongqing, Guangdong, Hubei, and Shenzhen—have launched local pilot carbon emissions trading systems (ETSs). The seven local pilot carbon markets have started online trading, one after another, since 2013, covering nearly 3,000 key emission industries in more than 20 sectors such as power plants, steel, and cement. The national carbon ETS launched online trading on July 16 2021. The power generation industry was the first industry to be included, with 2,225 power companies taking the lead. According to the Ministry of Ecology and Environment's calculations, the carbon emissions of the enterprises covered by the first carbon market exceeded 4 billion tonnes of carbon dioxide, meaning that China's carbon emissions trading market will become the world's largest carbon market covering greenhouse gas emissions as soon as it is launched (Xinhua, 2021).

2.1.3 Standards and Action Plans on Air Quality Improvement

Revision of Air Quality Standard. China’s ambient air quality standards were first issued in 1982, and subsequently revised in 1996, 2000, and 2012. On February 29, 2012, China’s current Ambient Air Quality Standard (GB3095-2012) was published, incorporating the monitoring indicators of $PM_{2.5}$, and identifying the six basic components in environmental air pollutants—$PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, and O_3—and four other components—TSP, NOx, Pb, BaP. It also specified the concentration limits and monitoring requirements of various pollutants. This Standard marked the beginning of the transformation of China’s atmospheric environmental management from a target-oriented approach of controlling environmental pollution to a target-oriented approach of improving air quality. The ambient air quality levels, pollution components covered, monitoring methods, etc. were classified in the Standard. The pollutant concentrations are all mass concentrations (see Table 1 for details). The Standard was implemented in stages and by regions:

- In 2012, Beijing-Tianjin-Hebei, the Yangtze River Delta, the Pearl River Delta, and other key regions and municipalities directly under the central government and provincial cities;
- In 2013, 113 key cities and the national environmental protection model city for environmental protection;
- In 2015, all cities at prefectural level and above;
- In 2016, nationwide implementation of the new Standard.

An amendment to the Ambient Air Quality Standard (GB 3095-2012) was released on July 31, 2018 and implemented on September 1, 2018. The modification list is as follows for the contents of Article 3.14: The original said: "Standard state refers to a temperature of 273 K and pressure of 101.325 kPa. The pollutant concentration in this standard is the concentration in the standard state." This was modified to: "Reference state refers to when the atmospheric temperature is 298.15K and the atmospheric pressure is 1013.25HPa. The concentration of gaseous pollutants such as sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone and nitrogen oxide in this standard is the concentration under the reference state. The concentrations of particulate matter PM_{10} (particle size less than or equal to 10 μm), particulate matter $PM_{2.5}$ (particle size less than or equal to 2.5 μm), total suspended particulate matter and its components lead and Benzo [a] pyrene are the concentrations under atmospheric temperature and pressure at the time of monitoring." The AQI values correspond to different pollution levels (Class I to Class VI) and air quality types ("excellent" to "severe pollution") (Shown as Figure 1), which can be used as a general criterion to judge the air quality and its impact on human health (MEE, 2016). A list of Air Pollutant Emissions Standards in China from 2013 to 2020 can be found in Annex I.

Table 1 Basic Particles in Ambient Air Quality Standard (GB3095-2012)

Name of Pollutant	Average Time	Concentration Limits		Unit
		Grade Ⅰ*	Grade Ⅱ*	
SO_2	Annual average	20	60	μg/m³
	24-hour average	50	150	
	1-hour average	150	500	
NO_2	Annual average	40	40	
	24-hour average	80	80	
	1-hour average	200	200	
CO	24-hour average	4	4	mg/m³
	1-hour average	10	10	
O_3	Average in the top consecutive 8-hour period	100	160	μg/m³
	1-hour average	160	200	
PM_{10}	Annual average	40	70	
	24-hour average	50	150	
$PM_{2.5}$	Annual average	15	35	
	24-hour average	35	75	

*NOTES: Some of China's air quality standards Grade I and II are in line with level I and III target values for global air quality guidelines (2005) issued by WHO.

Index	Grade	Category	Health Recommendations
0-50	I	Excellent	Outdoor activities are recommended
51-100	II	Good	Outdoor activities are OK
101-150	III	Mild pollution	Susceptible populations should reduce heavy outdoor activities
151-200	IV	Moderate pollution	Susceptible populations would be significantly affected
201-300	V	Heavy pollution	Everyone should reduce outdoor activities
>300	VI	Serious pollution	Try not to stay outdoors

Figure 1 AQI classification in Technical Regulations for Ambient Air Quality Index (AQI) (Trial Implementation) (HJ633-2012)

2.1.4 Air Pollution Prevention and Control Action Plans

China has delineated a clear path for achieving its clean air goals in a series of national policies and plans in the 13th FYP period, mainly including the Action Plan of Air Pollution Control and Prevention (SCPRC, 2013) and the Three-Year Action Plan to Win the Battle for Blue Skies (SCPRC, 2018). The timelines of individual action plans are given in Table 2.

The Air Pollution Prevention Action Plan (Action Ten, 2013–2017), also known as the Ten Articles of Air Quality, was formally released by the State Council of China in September 2013 against the backdrop of pressing air pollution in China. The plan lays out the roadmap for air pollution control by setting concrete pollutant reduction targets in 2017 and 2020 with a focus on three key regions: The Beijing-Tianjin-Hebei region, the Yangtze River Delta (YRD), and the Pearl River Delta (PRD). The Action Plan is the first plan at national level that sets air quality targets for China. The Chinese government gives considerable attention to the prevention and control of air pollution, taking it as an important measure to improve people’s livelihood, a concrete action to build an ecological civilization, and an effective tool to maintain economic growth, adjust economic structure, and promote reform and upgrading of the Chinese economy.

According to the Action Ten, by 2017 the concentration of inhalable particulate matter, or PM_{10}, in cities at and above the prefecture level should be reduced by more than 10% from 2012 levels. The concentration of fine particulate matter, or $PM_{2.5}$, in the Beijing-Tianjin-Hebei region, the Yangtze River Delta, and the Pearl River Delta should go down by 25%, 20%, and 15%, respectively, compared to 2013 levels, with the average annual $PM_{2.5}$ concentrations in Beijing being kept at about 60 $\mu g/m^3$. To achieve the above goals, ten specific measures were identified:

1. **Intensify comprehensive control measures and reduce pollutant emission.** This will comprehensively improve small coal-fired boilers and accelerate the construction of desulfurization, denitration, and dust removal renovation projects in key industries. There will be comprehensive control of urban dust and cooking fume pollution. Phasing out of yellow-labelled [2] and old vehicles will be accelerated. Public transportation will be vigorously developed, the use of new-energy vehicles[3] promoted, and improvement of fuel quality accelerated
2. **Adjust and optimise industrial structure, promote the transformation and upgrading of the economy.** Strictly control new production capacity in industries with high energy consumption and high emissions. Speed up the elimination of backward production capacity with outdated technology, and resolutely stop construction of illegal projects under construction in industries with severe overcapacity.
3. **Accelerate the technical transformation of enterprises, improve scientific and technological innovation ability**. This will vigorously develop the circular economy, foster and strengthen energy conservation and environmental protection industries, and promote the innovative development and industrialised application of major environmental protection technologies, equipment, and products.
4. **Speed up the adjustment of energy structure, increase the supply of clean energy**. By 2017, coal's share of total energy consumption shall fall below 65%. The Beijing-Tianjin-Hebei region, the Yangtze River Delta, the Pearl River Delta, and other regions will strive to achieve negative growth in total coal consumption.
5. **Investment projects must adhere strictly to principles of energy conservation and environmental protection.** Barriers to beginning projects will be strengthened. Construction industry projects in ecologically fragile or environmentally sensitive areas will be strictly limited.
6. **Give play to the role of market mechanism, improve environmental economic policies**. The central government set up special funds to implement the policy of replacing subsidies with awards. It will adjust and improve policies on prices and taxes, and encourage governmental and non-governmental investments in the prevention and control of air pollution.
7. **Amplify the system of laws and regulations with strict supervision and management in accordance with the law**. The state regularly publishes air quality rankings of key cities, and has established a mandatory disclosure system for environmental information on heavily polluting enterprises. This will improve our ability to monitor the environment and step up enforcement of environmental laws.
8. **Establish regional coordination mechanisms, carrying out overall regional environmental governance**. In the Beijing-Tianjin-Hebei region and the Yangtze River Delta region, a cooperative mechanism for air pollution prevention and control has been established. The State Council has signed target responsibility letters with provincial

[2] "Yellow-Labelled Vehicle" is an alias for high pollution emission vehicles, which are gasoline vehicles that do not meet the National I emission standard, or diesel vehicles that do not meet the National III emission standard. As they are affixed with a yellow environmental label, they are called yellow-labelled vehicles.

[3] New energy vehicles refer to those that use natural gas, electricity, or methanol as fuel, and to hybrid vehicles.

governments, conducted annual assessment, and strictly investigated responsibility.

9. **Establish a monitoring and early warning emergency system**. Establish and launch a perfect emergency response plan in a timely manner to properly deal with heavy pollution conditions.
10. **Clarify the responsibilities of all parties** to mobilise the whole population to participate and to improve air quality.

Effectiveness of Action Ten. In 2017, China successfully achieved the target of the Action Ten: the average concentration of $PM_{2.5}$ in 74 major cities was 48 μg/m^3, down 33.3% from 72 μg/m^3 in 2013.The average $PM_{2.5}$ concentrations in the Beijing-Tianjin-Hebei region, the Yangtze River Delta, and the Pearl River Delta was 64.6, 44.7, and 34.8 μg/m^3, respectively, down 39.2%, 33.3%, and 26.0%, respectively, compared with 2013. The average concentration of $PM_{2.5}$ in Beijing was 57 μg/m^3, down 36.0% from the average annual level in 2013 and meeting the target of 60 μg/m^3 set in the Action Ten.

The Three-Year Action Plan to Win the Blue-Sky Defense War (Three-year Action Plan, 2018–2020). To speed up the improvement of environmental air quality and win the battle for blue skies, a "Three-year Action Plan to Win the Battle for Blue Skies" (hereinafter referred to as the Action Plan) was released by the State Council of China on June 27, 2018. The Action Plan aims to cut total emissions of SO_2 and NOx by more than 15% by 2020 compared to 2015 levels. The concentration of $PM_{2.5}$ in cities at and above the prefectural level should fall by more than 18% compared to 2015, the number of days with good air quality reached 80%, and the number of days with heavy pollution should drop by more than 25% in 2020. Provinces that have completed the 13th Five-Year Plan ahead of schedule should maintain and consolidate their achievements. Further, the plan states that provinces that have not yet reached objectives must ensure that they fully meet the binding targets set for the 13th Five-Year Plan. The goal of improving Beijing's ambient air quality should be further improved on the basis of the 13th Five-Year Plan. The Action Plan sets out six tasks and measures to achieve the above targets of air quality:

1. **Adjust and optimize industrial structure and promote the development of green industry.** The plan will improve the distribution of industries, strictly control the production capacity of industries with "too high levels," strengthen the comprehensive control of enterprises with "disorderly and polluting" industries, deepen the treatment of industrial pollution, and vigorously foster green and environmental protection industries.
2. **Speed up the adjustment of energy structure and build a clean low carbon efficient energy system.** It will effectively promote clean heating in the northern region, continue to control total coal consumption in key regions, comprehensively improve coal-fired boilers, improve energy efficiency, and accelerate the development of clean and new energy sources.
3. **Actively adjust the structure of transportation and develop a green transportation system.** It will substantially increase the proportion of freight carried by railways, upgrade the structure of vehicles and vessels, upgrade the quality of oil products, and strengthen the prevention and control of pollution from mobile sources.
4. **Optimise adjustment of land use structure and promote non-point source pollution control**. It will carry out windbreak, sand-fixation, and afforestation projects, advance the comprehensive improvement of open pit mines, strengthen the comprehensive treatment of dust, and strengthen the comprehensive utilization of straw and the control of ammonia emissions.

5. **Action implementation of major projects, greatly reduce pollutant emission.** It will carry out major campaigns in autumn and winter in key areas, fight a tough battle against pollution caused by diesel trucks, carry out special campaigns to control industrial furnaces and kilns, and carry out special campaigns to control volatile organic compounds.
6. **Strengthen means to prevent spread of pollution zones, effectively cope with heavy pollution weather**. It will establish and improve regional cooperation mechanisms for the prevention and control of air pollution, strengthen the coordination of heavy pollution weather emergencies, and consolidate emergency mitigation measures.

The Action Plan calls for speeding up the improvement of relevant policies to provide a strong guarantee for air pollution control. It will improve the system of laws, regulations, and standards, expand investment and financing channels, and increase economic policy support. It will improve the environmental monitoring and monitoring network, strengthen the foundation of science and technology, step up environmental law enforcement, and carry out in-depth inspections of environmental protection. It will strengthen organizational leadership, clearly implement the responsibilities of all parties, strictly assess and hold people accountable, and make environmental information more public, so as to build a national pattern of action.

Table 2 The timelines of Action Plans and the 13th Five-Year Plan

<table>
<tr><th>2013</th><th>2014</th><th>2015</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th></tr>
<tr><td colspan="5">The Action Plan of Air Pollution Control and Prevention Tier I (Action Ten, 2013–2017)</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="5">The 13th Five-Year Plan</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td colspan="3">The Action Plan of Air Pollution Control and Prevention Tier II (Three-year Action Plan to Win the Battle for Blue Skies, 2018–2020)</td></tr>
</table>

Effectiveness of Action Plan 2018-2020. In 2020, which was the closing year of the 13th Five-Year Plan in China, the Action Plan was completed with remarkable results, with both the concentration of $PM_{2.5}$ and the numbers of good and excellent days exceeding the 13th Five-Year Plan targets and tasks ahead of schedule. In 2020, the average ratio of good and excellent days in China was 87%, increasing 7.7 percentage points between 2018 and 2020. The average concentration of $PM_{2.5}$, PM_{10}, SO_2, NO_2 and CO in China were 33, 56, 24, 10 μg/m^3 and 1.3 mg/m^3, down 15.4%, 21.1%, 28.6%, 17.2% and 13.3% compared with 2018, respectively. The average ratio of good and excellent days in Beijing-Tianjin-Hebei and surrounding areas was 63.5%, up 13 percentage points since 2018; $PM_{2.5}$, PM_{10}, SO_2, NO_2 and CO concentration were 51, 87, 12, 35 μg/m^3 and 1.7 mg/m^3, down 15%, 20.2%, 40%, 18.6% and 22.7% between 2018 and 2020, respectively . The proportion of good and excellent days in Beijing was 75.4%, up 13.2 percentage points compared with 2018; $PM_{2.5}$ concentration was 38 μg/m^3, down 25.5% since 2018. The average number of good and excellent days in 41 cities in the Yangtze River Delta region was 85.2%, up 11.1 percentage points since 2018; $PM_{2.5}$ concentration was 35 μg/m^3, down 20.5% between 2018 and 2020. The average number of good and excellent days in 11 cities in the Fenwei Plain was 70.6%, up 16.3 percentage points since 2018; $PM_{2.5}$ concentration was 48 μg/m^3, down 17.2% from 2018 to 2020.

In January 2020 the World Health Organization (WHO) declared a global health emergency because of the novel coronavirus disease (COVID-19) that has been uncontrollably spreading all over the world (WHO, 2020). The COVID-19 pandemic has put much of the world into lockdown; as one unintended upside to that response, air quality has been widely reported to have improved worldwide (Liu et al., 2021). It is estimated that the change rates of fine particulate matter ($PM_{2.5}$), NO_2, and SO_2 before and during the lockdown in the Chinese megacities ranged from -49.9% to -78.2% (average: -59.3%± 9.4%), -55.4% to -32.3% (average: -43.0% ± 9.7%), and - 21.1% to 11.9% (average: -10.9% ± 15.4%), respectively (Gao et al., 2021).

Causes of Severe Air Pollution and Solutions. In recent years, China has launched key R&D programs, including the Study on Causes and Control Technology of Air Pollution, the Clean Air Research Program, and the Scientific Research Project for Public Welfare, with a focus on research in combined atmospheric pollution and R&D in controlling technology. Established in 2017, the National Center for Air Pollution Prevention and Control organised nearly 2,000 scientists and researchers to find the causes of severe air pollution and provide solutions. Various follow-up research programs in different cities allow fast transformation from research to management practices.

One city, one policy. In 2017, the then Ministry of Environmental Protection sent a team of 28 experts and 500 researchers from universities and institutes to the “2+26” city cluster (Air pollution transmission channel cities, see Table 3) where they carried out research on “One City, One Policy” and provided on-site technical guidance. The team established a working model integrating research, yield, application, feedback, and improvements. They proposed comprehensive solutions targeting the characteristics of local air pollution to serve the local government in air pollution prevention and control.

Table 3 The range of “2+26” city cluster

No.	Provinces	Cities
1	Beijing	Beijing
2	Tianjin	Tianjin
3	Hebei	Shijiazhuang
4		Tangshan
5		Langfang
6		Baoding
7		Cangzhou
8		Hengshui
9		Xingtai
10		Handan
11	Shanxi	Taiyuan
12		Yangquan
13		Changzhi
14		Jincheng
15	Shandong	Jinan
16		Zibo
17		Jining
18		Dezhou
19		Liaocheng
20		Binzhou
21		Heze
22	Henan	Zhengzhou
23		Kaifeng
24		Anyang
25		Hebi
26		Xinxiang
27		Jiaozuo
28		Puyang

2.2 Sector Specific Plans, Policies, and Regulations in China

2.2.1 Upgrading Industrial Standards and Companies

China has been pushing ahead with pollutant emissions control of industrial enterprises. Since 2013, 39 standards for key industries such as cement and petrochemical industries and transportation were released or revised (See Annex Ⅱ for details). Upgrading and renovation programs for pollution control facilities in key industries such as steel, cement, and plate glass were pushed forward. It was estimated that strengthening industrial emission standards led to reductions of 7.01 Tg (43% of total abatements) of SO_2, 4.77 Tg (60%) of NOx, and 1.42 Tg (41%) of primary $PM_{2.5}$ emissions at the national level.

Strengthen industrial emission standards. 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, which resulted in China having the world’s largest clean coal-fired power generation system (Figure 2)[4]. China's coal consumption exceeds 4 billion tonnes, which accounted for more than 50% of the world's coal consumption in 2019 (Energy Research Institute National Development and Reform Commission, 2019), 51.8% of which was burnt in power plants (Department of Energy Statistics, National Bureau of Statistics, 2020).

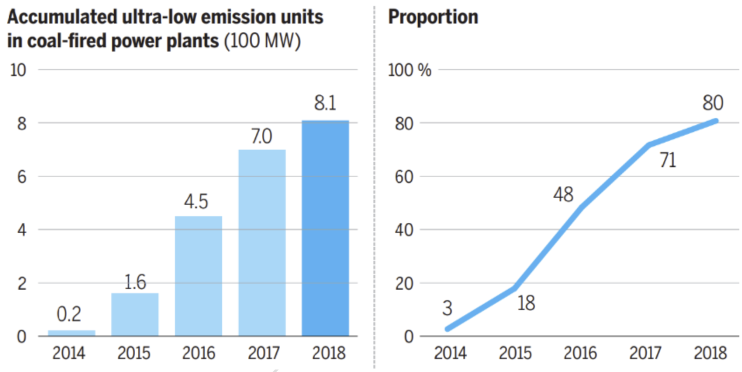


Figure 2 Proportion of ultra-low emission units in coal-fired power plants in China from 2014 to 2018（Source: Chinese Academy of Environmental Planning）

Meanwhile, China has launched VOCs control in the petrochemical industry, starting with the promotion of LDAR technology (leak detection and repair) and oil and gas recovery in gas stations. Online monitoring devices have been installed in more than 8,000 gas-relevant enterprises with critical pollution sources. Based on online data of pollution sources, the Ministry of Ecology and Environment has organized remote supervision of heavy polluters suspected of excessive emissions or discharges, with local environment authorities responsible for follow-up inspections.

2.2.2 Industrial Restructuring

Enterprises are forced to transform, upgrade, and speed up efforts to shut down backward production

[4] In 2014, China introduced an ultra-low emissions (ULE) standards policy for renovating coal-fired power-generating units to limit SO_2, NOx, and particulate matter (PM) emissions to 35, 50, and 10 mg m^{-3}, respectively. The ULE standard policy had ambitious levels (surpassing those of all other countries) and implementation timeline.

facilities, address overcapacity, and improve the industrial structure. The share of the tertiary industry (provision of services) has grown year-on-year. In 2015, the tertiary industry contributed over 50% of the nation's GDP for the first time; in 2018, the figure was 52.2%, up 5.3% from 2013.

Phase out outdated industrial capacity. From 2013 to 2017, China slashed production of steel by 200 million tonnes, cement by 250 million tonnes, plate glass by 110 million weight cases, and coal-fired units by 25 MW, and barred the production of 140 million tonnes of nonconforming steel to upgrade traditional industries and achieve environmental, economic, and social benefits. Consequently, during the period 2013–2017, this structure-focused measure led to the reduction of 2.08 Tg, 1.23 Tg, and 0.69 Tg in SO_2, NOx, and primary $PM_{2.5}$ emissions, respectively.

Upgrades on industrial boilers. Industrial coal boilers are major sources of emissions, especially SO_2, because of their considerable coal consumption. From 2013 to 2017, more than 200,000 small coal boilers (≤7 MW) were shut down and all small coal boilers in urban areas were phased out. Large operating boilers were extensively equipped with SO_2 and particulate control devices after enforcement of the new emission standard (i.e., GB 13271–2014) in 2014. Consequently, considerable emission abatements were obtained: abatements of 5.54 Tg (34% of all abatements) in SO_2 and 0.71 Tg (20% of all abatements) in primary $PM_{2.5}$ emissions..

Phase out small and polluting factories. Small and polluting factories, i.e., those companies that do not comply with industrial policies and plans, do not have government approvals, and fail to reach emission standards, are mostly small scale, widely spread, hidden, and with no pollution control facilities, making supervision extremely difficult. Complaints about these companies were continuously received. Driven by tightened emission standards, this measure aimed to replace small and highly polluting factories with large facilities equipped with clean production technologies and advanced pollution control equipment, with a focus on northern China. In 2017, China launched a campaign to investigate and crack down on such companies, resulting in that 62,000 were investigated and shut down in the "2+26" city cluster in Beijing-Tianjin-Hebei and neighboring areas. This measure yielded 10%, 3%, and 9% of regional abatements in SO_2, NOx, and $PM_{2.5}$ emissions, respectively.

2.2.3 Optimizing Energy Structure

In 2013, China put forward the concept of "total coal consumption control" in the Action Plan of Air Pollution Control and Prevention (2013-2017), and set targets for coal consumption controls in key areas. From 2013 to 2018, the proportion of coal consumption in primary energy dropped from 67% to 59%, curbing the trend of rapid growth of coal consumption as shown in Figure 3.

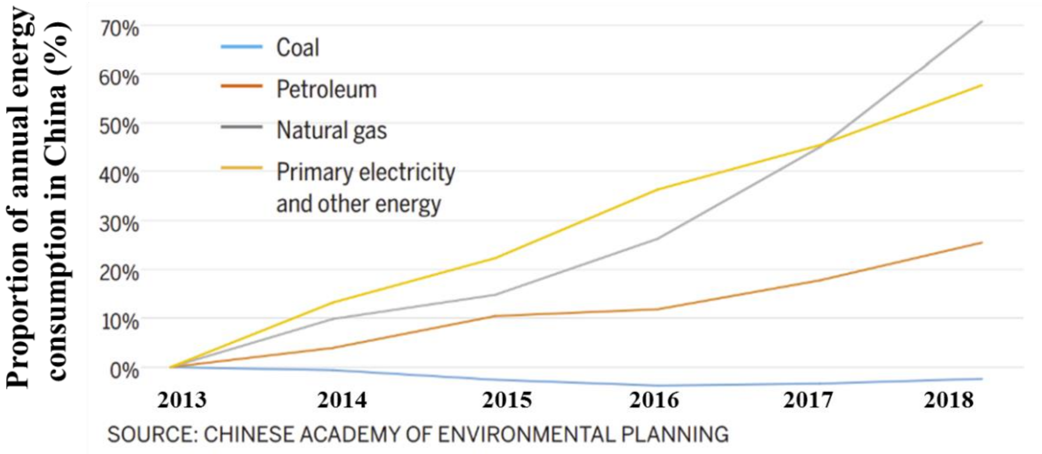


Figure 3 China's annual energy consumption since 2013

Setting Coal Quality Standards. China has exerted tight controls over the distribution and burning of low quality coal with high sulfur and ash content. In 2014, China released the Interim Measures for Quality Control of Commodity Coal, bringing inferior coal with ultra-high ash and sulfur under control. In 2017, standards for bulk coal for household use and briquettes were issued, introducing mandatory requirements for coal quality in production, processing, storage, transportation, sales, and burning (Table 4).

Table 4 Quality standard for bulk coal for household use

Items	anthracite coal No.1	anthracite coal No.2	bituminous coal No.1	bituminous coal No.2
Volatile matter	≤12%	≤12%	≤37%	≤37%
Ash	≤16%	≤30%	≤16%	≤25%
Sulfur	≤0.5%	≤1%	≤0.5%	≤1%
Mercury	≤0.25 μg/g			
Arsenic	≤20 μg/g			
Phosphorus	≤ 0.1%			
Chlorine	≤0.15%			
Fluorine	≤200 μg/g			

Eliminating Small Boilers. In 2013, China launched a campaign to shut down coal-fired boilers with steam capacity of 10 tonnes per hour or below in urban built-up areas. As of 2018, more than 230,000 boilers were removed. Meanwhile, no new boilers under 20 tonnes per hour are allowed in those areas, and no new boilers under 10 tonnes per hour, in principle, can be built in other areas.

Promote clean fuels for heating in the residential sector. The residential sector is a notable contributor to $PM_{2.5}$ pollution in China, especially in northern China during the heating season. To resolve this issue, advanced stoves and clean coal were promoted nationwide from 2013 to 2016 by providing subsidies to individual households. In the winter of 2017, a clean heating program was launched in northern China featuring natural gas, electric energy, solar energy, geothermal energy, and biomass energy replacing coal. The government helped fuel the project with financial support, pricing policy, and energy supply. The central budget devoted more than 20 billion yuan to push through bulk coal control for more than 100 million households. The clean heating area increased by 1550 km^2. The substitution of coal with natural gas and electricity was further promoted, affecting 6 million households nationwide, among which 4.8 million households were located in the BTH (Beijing-Tianjin-Hebei), and surrounding regions. This measure has reduced 0.14 Tg of SO_2 (11% of total abatements) and 0.1 Tg (20%) of primary $PM_{2.5}$ emissions, respectively.

Clean Energy Development. Since 2013, the installed capacity of wind power and photovoltaic power in China has maintained high growth (Figure 4). By the end of 2018, the installed capacity of hydropower, wind power and photovoltaic power was 35,000 megawatts, 18,000 megawatts and 17,000 megawatts, respectively. The non-fossil energy power capacity grew to about 40 % of the total installed capacity. The proportion of clean energy in the primary energy mix increased from 15.5 % to 22.1 % (MEE, 2019).

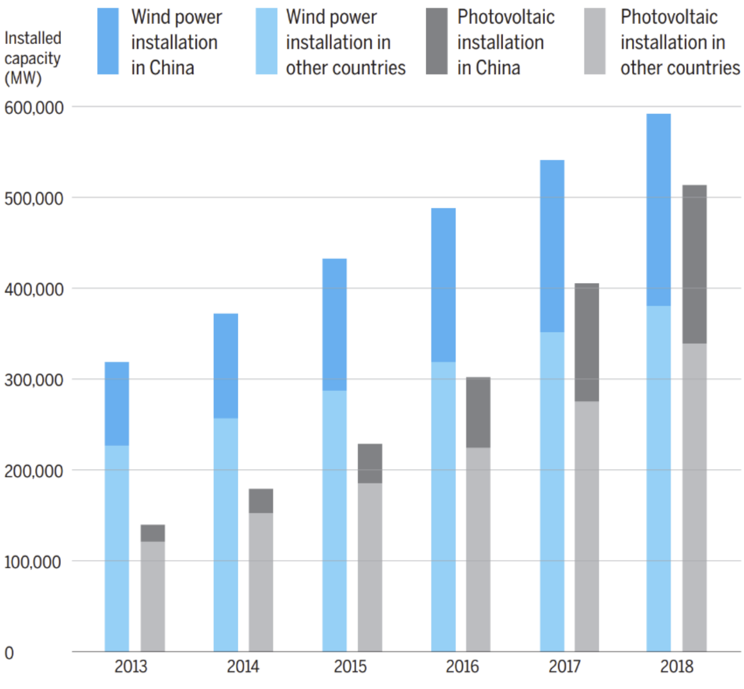
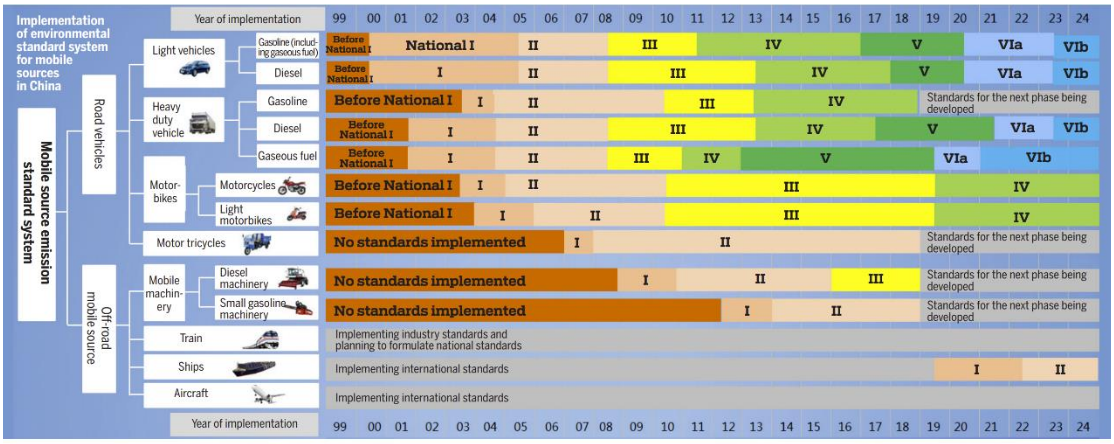


Figure 4 Installed capacity of wind and photovoltaic power generation in China and other countries since 2013

2.2.4 Pollution Control of "Fuel, Road, Vehicle"

Strengthen vehicle emission standards. This measure was a prominent contributor to NOx abatements (1.06 Tg, 13% of all national abatements). This shift was mainly a result of fleet turnover triggered by the strengthened emission standards in the transportation sector (i.e., China 4 and China 5 emission standards implemented from 2013 to 2017) and the forced elimination of old vehicles (Figure 5). In less than two decades, China has raised the standards for vehicle emissions from National I to National V. China implemented the National I Vehicle Emission Standard in 2001; now, the National V standard has been implemented fully. In 2016, China unveiled the Limit Value and Measurement Method of Pollutant Emission from Light Vehicles (the sixth stage in China). Compared with National I, individual car pollutant emission levels were down by more than 90% under the National VI standard, with emissions of particulate matter per 100 km of diesel cars reduced from 293 grams to 1.5 grams.



SOURCE: CHINESE RESEARCH ACADEMY OF ENVIRONMENTAL SCIENCES

Figure 5 Environment standard implementation process for vehicles in China

Push for Low-Sulfur Fuel. When the National V standard was implemented for vehicle fuel in 2017, sulfur content was down to 10 ppm from 150 ppm for gasoline and 350 ppm for diesel in 2013. In 2018, China unified the standards for vehicle diesel, general diesel, and some types of marine diesel. On January 1, 2019, the National VI standard for vehicle gasoline and diesel came into force.

Restructuring Transportation. Compared with more developed countries, China for long had an irrational freight transport structure featuring a high proportion of highway transportation. Chinese highways handle 2.5 times the cargo handled by railways, but per unit pollutant discharge is 13 times that of railways. In September 2018, China issued the Three-Year Action Plan for Promoting Transportation Restructuring (2018–2020), which clarified the targets of adjusting the transport structure and vigorously developing railway transport. On May 1, 2017, Tianjin Port stopped accepting truck-delivered coal or bulk cargo, and all cargo must be transported by train. Consequently, the number of coal trucks entering Yanqing district of Beijing daily is down by half to 3,000–4,000 trips.

New Energy Vehicles. At the end of 2012, only 17,000 new energy vehicles were on the road in China. In 2018, over 1.2 million such vehicles were manufactured and sold in China, accounting for more than half the world’s total, bringing the total number of new energy vehicles on the road to 2.61 million (Figure 6).

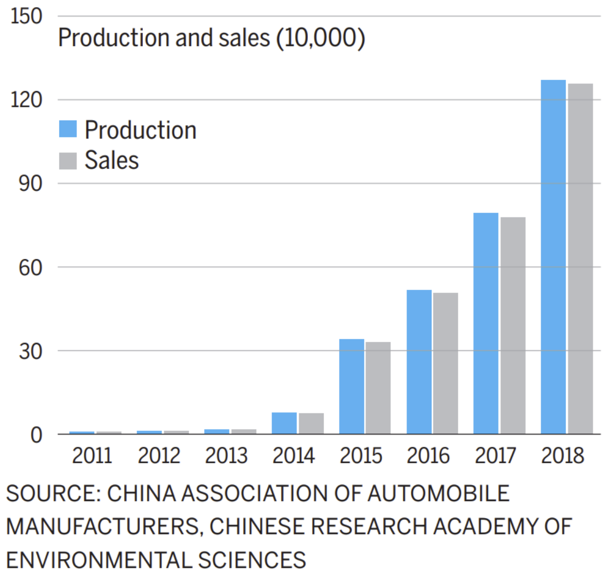


Figure 6 Annual production and sales of new energy vehicles in China 2011-2018

Eliminate "Old" and "Yellow Label" vehicles. "Yellow label" cars are gasoline vehicles that do not meet National I emission standards and diesel vehicles that do not meet National III emission standards. "Old cars" are vehicles that do not meet National IV emission standards. Since 2013, more than 20 million old and "yellow label" vehicles have been phased out of the Chinese market.

In-Use Motor Vehicle Supervision System. Local authorities monitor in-use vehicles across China to precisely locate vehicles with excessive emissions through a combination of remote sensing, regular detection, remote online supervision, road inspection, and big data analysis. China has built 851 remote sensing monitoring sites and 6,140 environmental emission inspection institutions for vehicles. The data at national, provincial, and city levels are connected.

Ship Emission Control Zone. In December 2015, China set up ship emission control zones in the waters of the Pearl River Delta, Yangtze River Delta and Bohai Rim (Beijing-Tianjin-Hebei), the first time the country put forward requirements on pollution discharge for ships. In 2018, the coverage was extended to all sea areas 12 nautical miles off the coast, and the trunk lines of the Yangtze River and the Xijiang River. There are strict rules on sulfur content of marine fuel, NOx control, control of electricity usage for ships going ashore, and VOCs emission.

2.2.5 Treatment of Non-Point Source Pollution

For years, the government has reinforced construction of an ecological security barrier in the sand control zone of northern China, pushing forward forest and grassland protection, wind-proofing, and sand-fixing projects and improvement of the Sanbei shelterbelt (North, Northeast, and Northwest China). As a result, desertification and stony desertification have been effectively curbed and the forest coverage rate has improved, with a marked reduction of dust storms.

China has made great contributions to the world's afforestation effort. A study by Boston University posted on February 11, 2019 on the website of *Nature* said that by reviewing remote sensing data collected from 2000 to 2017 by NASA satellites, researchers made a surprising discovery (Chen et al., 2019): Total global green area was bucking the trend and had increased by 5%, the size of the Amazon rainforest. China is a top contributor, accounting for 10.5% of global afforestation (Figure 7).

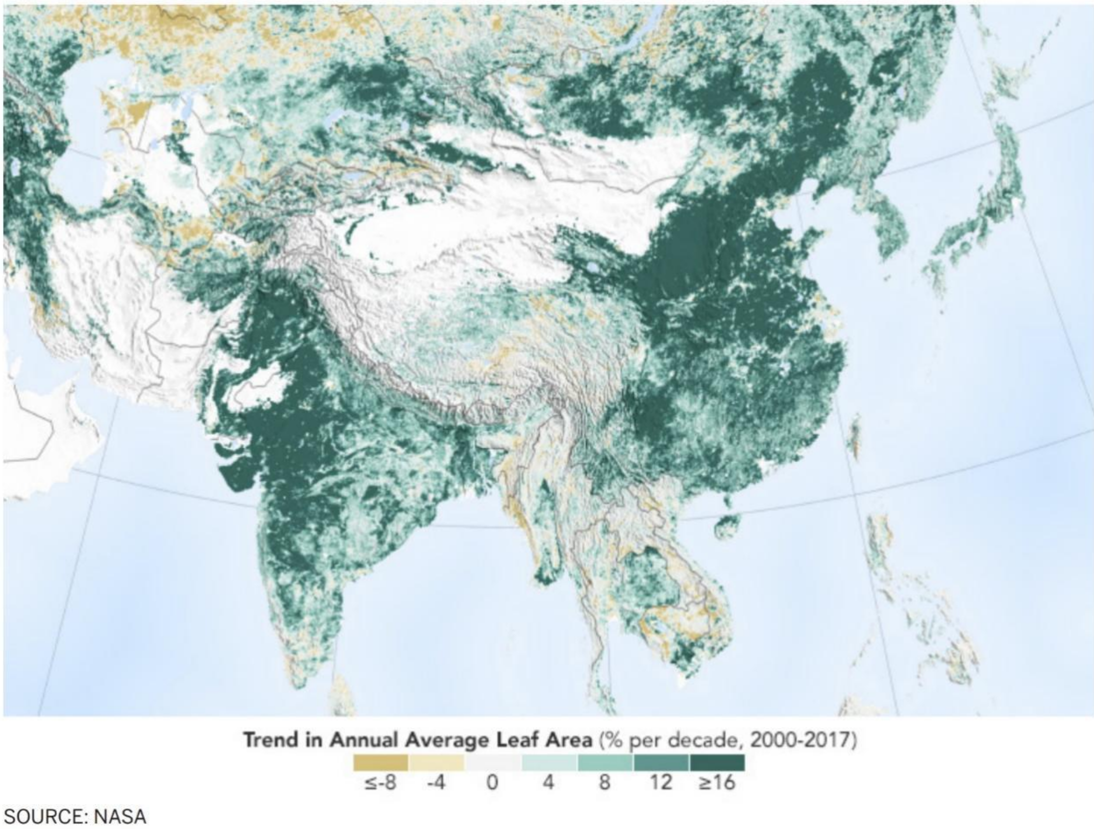


Figure 7 Data analysis of China’s afforestation efforts on NASA’s official website

With large-scale afforestation, the occurrence of dust storms has been reduced markedly. Over the past 60 years in northern China, the average number of days with sand and dust storms has dropped 0.46 days/10 years, and the average number of days with dust-storms in spring (March–May) has dropped 1.67 days/10 years (Figure 8).

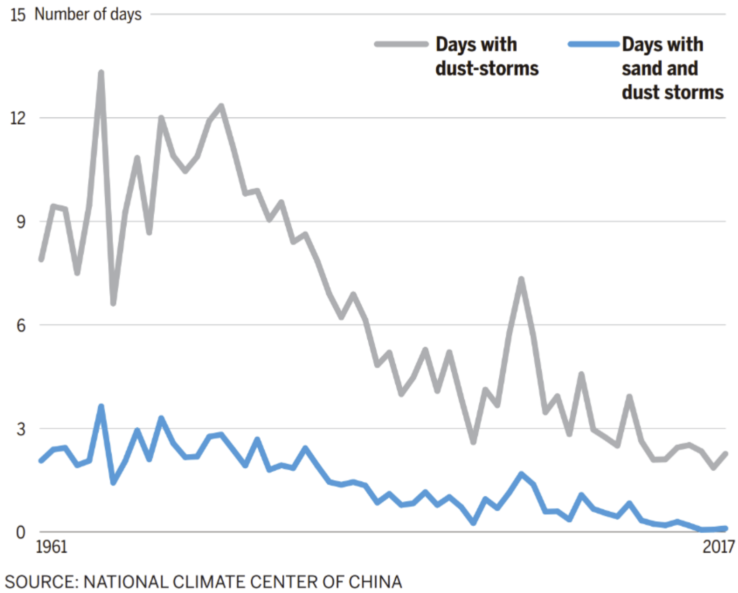


Figure 8 Sand and dust activities from 1961 to 2017

Strengthening comprehensive utilization of straw. In recent years, the comprehensive utilization rate of straw has been greatly improved through feed, fertilizer, and energy, and the control of open burning of straw has been strengthened through grid-based supervision. Since 2013, open burning of straw has been basically controlled in northern and eastern China.

Strengthening comprehensive management of dust. Large construction sites should basically achieve "six hundred percent"[5] with regard to site perimeter fencing, material piling coverage, wet excavation, road hardening, vehicle washing, and enclosing the load of vehicles transporting dirt; vigorously promote mechanised road cleaning and cleaning operations; and gradually increase the rate of mechanised cleaning of driveways in urban built-up areas. In pilot cities (e.g., Tangshan City, Hebei Province), innovative road dust mobile monitoring and control means have been installed in cabs with vehicle-mounted mobile road dust monitoring systems to monitor the amount of dust accumulation in urban streets in real time. The monitoring data are presented on a GIS map, forming a trajectory map of the cleanliness of urban roads, which visually reflects the level of road dust pollution (Figure 9).

[5] "six hundred percent" means 100% fencing around the site, 100% coverage of material stacking, 100% flushing of incoming and outgoing vehicles, 100% hardening of construction site ground, 100% wet work on the demolition site, and 100% sealing of the loads of vehicles transporting dirt

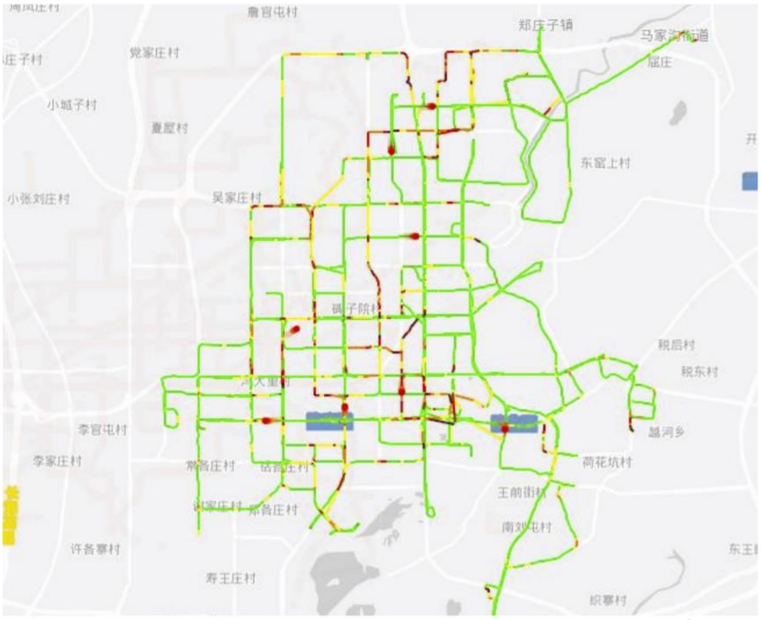


Figure 9 GIS Map of Street Cleanliness in Tangshan City (Source: National Joint Center for Air Pollution Prevention and Control)

2.3 Gaps and Needs to Optimise Policy Making

As relatively new fields, the emissions, impact, and control policy for BC/OC and its co-benefits remain very challenging tasks, especially regarding policy making and planning. The challenges or constraints faced include:

Practical studies are needed: One of the reasons for the difficulties in the BC/OC emission inventory is the lack of practical studies. First, most previous related studies have focused on air pollutant emissions or chemical reactions other than air quality management methods. As a result, the study results are rarely used by any governments for emissions inventories or air quality management activities.. Second, the aim of many related studies is simply to publish findings and report theoretical implications and not to support governments in any form. Therefore, the findings are rarely understood and duplicated by governments. Third, some studies developed indicators and approaches for emission inventories or chemical reactions, but they are too theoretical and complicated to be understood and used by governments.

Narrow the uncertainties of BC/OC emissions: Adequate knowledge of BC emissions is the basis for insight into air quality/climate/health effects and control measures. However, the BC/OC emission inventories in China have been developed by different institutions and are often inconsistent in total amounts or in specific sectors due to the significant differences in emission factors chosen, activity levels recognised, and methodologies applied. These inconsistent emission results often lead to misunderstandings and confusion, and add difficulty when trying to identify major emission sources and formulate pertinent policy. For this reason, a more comprehensive and convincing BC/OC emission inventory for China should be developed to provide scientific data support to formulate and implement policies by incorporating new emission factors derived from new measurements, by investigating activity levels and by improving methodology. In addition, it is also necessary to present an emission inventory of other pollutants (PM, $PM_{2.5}$, NOx, nmVOCs, CO, SO_2, and methane) for air quality and climate modeling purposes. Such inventories could be constructed by integrating and improving the inventories developed by other institutions; however, all inventories need to be consistent. According to available literature, the residential and mobile source sectors are among the largest emission sources and with high uncertainties. These sectors are experiencing rapid changes due to China's economic development, increasing standard of living, and strengthening of specific environmental efforts. Intensive studies are necessary to narrow knowledge gaps in emissions estimates in these sectors.

Links between scientists and governments need to be established: The links between scientists and governments are extremely important to apply BC research in policy making, because the ultimate aim of these studies is to support governments in policy making and planning, which in turn will promote improved regional air quality and decrease the negative effect on climate change and human health. Little communication currently exists between Chinese scientists and governments, and the governments are not involved when a study is designed and conducted. Many options are available to establish such links between scientists who conduct studies in this field and governments. These options include: (1) governmental participation in the studies from beginning to end, which will enable government officials to understand the valuation procedures and approaches and to use the results or methods in their work and policy making process; (2) a communication channel should be set up so that scientists understand the needs and requirements of governments before the design and implementation of their studies, so that scientists will be able to provide results, approaches, and information needed by governments for policy making and planning; and (3) government supported studies, not only studies financially supported by scientific funds or the Ministry of Science and Technology, should be encouraged to ensure the utilization of research results.

Knowledge and awareness of government officials need to be enhanced: Currently, BC is steadily growing and contributing increasingly to urban and regional air pollution and health problems without a restrictive target to control the problem. Serious photochemical smog and haze have emerged in some areas, and air pollution from local and regional sources reacts and contributes to a complex pollution situation. In addition, the international focus on climate change and air quality is increasing, so China, which is a key emitter of pollutants, is under pressure to take measures to reduce BC emissions. However, it is widely recognised that the lack of understanding and awareness on the negative impact of BC on climate change and air quality is one of the main reasons that governments ignore this issue. Undoubtedly, the knowledge and awareness of government officials will play a decisive role in this aspect because the decisions and policies for controlling BC will be made by those officials. The promotion of more stringent BC emission targets in policy making, planning, and actions should be made parallel to efforts to enhance the knowledge and awareness on the roles of BC in air quality and climate change. The targets will include government officials and the public. This can be realised through training and workshops, particularly direct towards participation of government officials in the related workshops or seminars.

This proposed way forward will focus on enhancing knowledge and awareness, with emphasis on the balance of trade-offs between air pollution and economic development.

Lack of experience: We are proposing pioneering work in BC emissions, effect evaluation, and policy making. The lack of adequate knowledge of the negative impacts of BC/OC emissions has become a major bottleneck. At present, China is taking the first step to develop strategies for controlling SO_2 and NOx. Measures to reduce BC/OC emissions have not started. It has become an urgent task for the Chinese government to establish scientifically reasonable policies to reduce BC/OC emissions.

Legislation: In response to the major needs of "scientific, precise and legal pollution control," China urgently needs to build a modern governance system for air pollution prevention and control. Under the leadership of advanced science and technology in air pollution prevention and control, a regional legal and regulatory system for air pollution prevention and control will be formed, and the development and implementation of four major structural adjustment mechanisms for energy, industry, transportation, and land use will be accelerated to give full play to the potential of structural adjustment in air pollutant reduction. At the same time, it will take the opportunity to achieve China's carbon peak and carbon neutrality targets, achieve a "win-win" situation in terms of air quality improvement and climate change response, and promote changes in China's participation in the global governance system. On this basis, through the "double leverage" of air quality improvement and national carbon peak and carbon neutrality, it promotes the exploration and practice of green development model in key regions in China.

2.4 Highlights for Emission, Impact, and Control Policy for BC/OC

China's air pollution control efforts accelerated in 2013 and have incessantly broken new ground since then. The measures contained non-electricity industry treatment, clean heating in rural areas, coal-fired boiler remediation, mobile source emission control and VOC treatment, etc. It is valuable and useful to evaluate the effect of these measures on emission, health, climate change, and air quality, which also can provide a reference for the 14th Five-Year Plan and even medium and long-term Chinese air quality improvement.

- **Updated emission inventory for the change of energy structure**. Taking residential heating as an example, where residential coal consumption continues to decrease and is replaced by natural gas or electricity, emissions from residential combustion sources should be updated based on constantly updated activity data and emission factors.

- **Updated emission inventory for transportation restructuring**. China's emission standards for vehicles continue to tighten, strictly controlling the number of heavy-duty diesel trucks, and significantly increasing production and sales of new energy vehicles since 2013. Emission inventories for the transportation sector need to be updated with the latest transportation restructuring data.

- **Multi-effect evaluation**. With the obvious improvement of air quality in China and further reduction of BC/OC concentrations, there is an urgent need to track and assess its multi-effect on health, air quality, and climate in order to provide guidance for Chinese medium and long-term air environment management.

3 Review of Norway's Status on BC/OC Control

This section provides a review and summary of BC/OC control related policy and regulations carried out in Norway.

3.1 Scope

The scope of this section is primarily Norway, while EU and global climate conventions are also discussed. Norway is not a member of the EU but is a member of the European Economic Area (EEA), and as such Norway has implemented several of the EU Directives relevant to climate and air pollution. We have not covered legislation within Norway or the EU completely but highlighted some aspects that we find most relevant in this context. Relevant EU policy and regulations are also presented in Annex II.

Norway and EU quick facts:
-There are approximately 5.4 million residents in Norway.
-The number of residents in the EU is approximately 447 million.
-Norway is not an EU member but has special agreements though EEA.
-Norway has an area of 385,207 km ²
-The Norwegian coastline is over 2,650 km long.

The pollutants covered here will mainly be particulate matter (BC/OC, PM_{10}, and $PM_{2.5}$).

Particulate matter (including black carbon) is covered, for example, in the following international bodies in which Norway participates:

- Arctic Council
- Climate and Clean Air Coalition (CCAC)
- Convention on Long-range Transboundary Air Pollution (UNECE-CLRTAP)
- Intergovernmental Panel on Climate Change (IPCC)

3.2 Introduction to Norwegian Emissions of Black and Organic Carbon

The Norwegian emissions of BC amounted to 2,841 tonnes in 2019, a total reduction of 41% since 1990 and of 6% since 2018 (Norwegian Environment Agency (NEA), 2021a). Figure10 shows the trends per sector in BC emissions from 1990 to 2019. In 2019, the most important source of emissions was “other combustion,” contributing 37% of total emissions (Figure11). 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.

Emissions of OC in Norway amounted to 9,537 tonnes in 2019 and are primarily from residential wood burning.

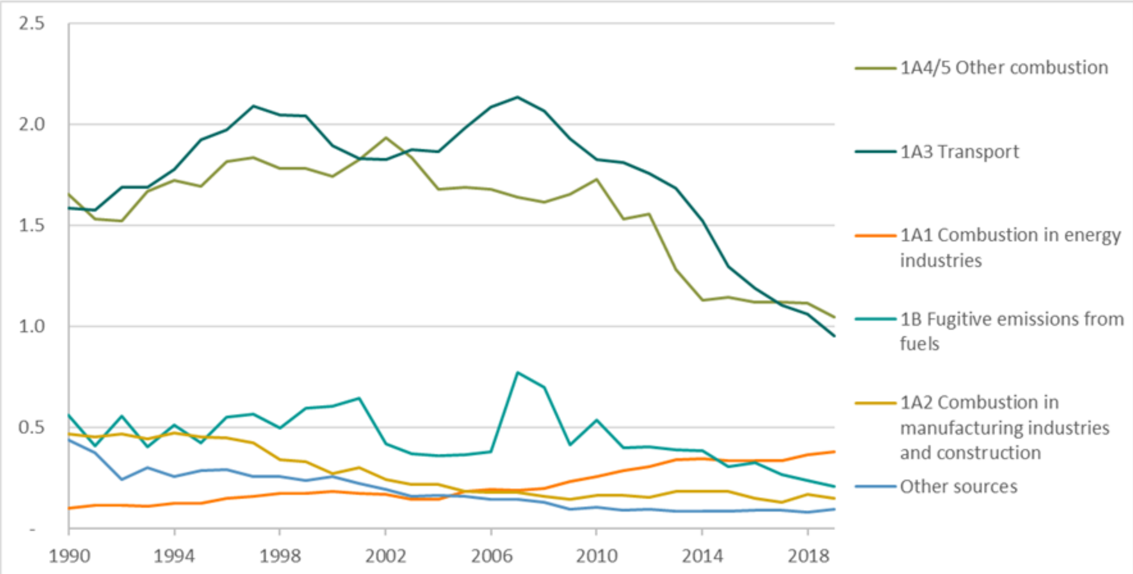


Figure 10: Trends in BC emissions, 1990–2019. 1,000 tonnes (NEA, 2021a)

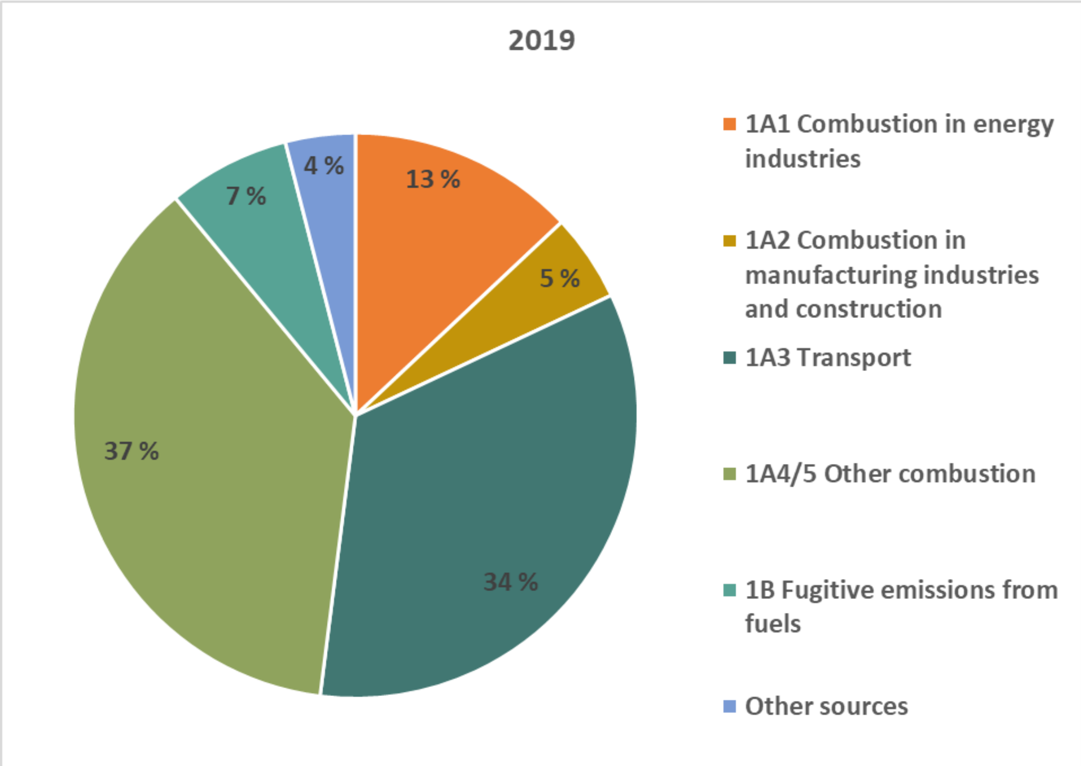


Figure 11: Distribution of BC emissions between emission sources, 2019 (NEA, 2021a)

Nationally reported emissions to UNECE (CLRTAP) were also spatially distributed to the EMEP (The co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe) grid system in 2015 (CEIP, 2020). Downscaling of nationally reported emissions are required every four years for all pollutants in each emissions sector. Figure12 shows an example of downscaled BC emissions for the emissions category for off-road sources from 2015 nationally reported data.

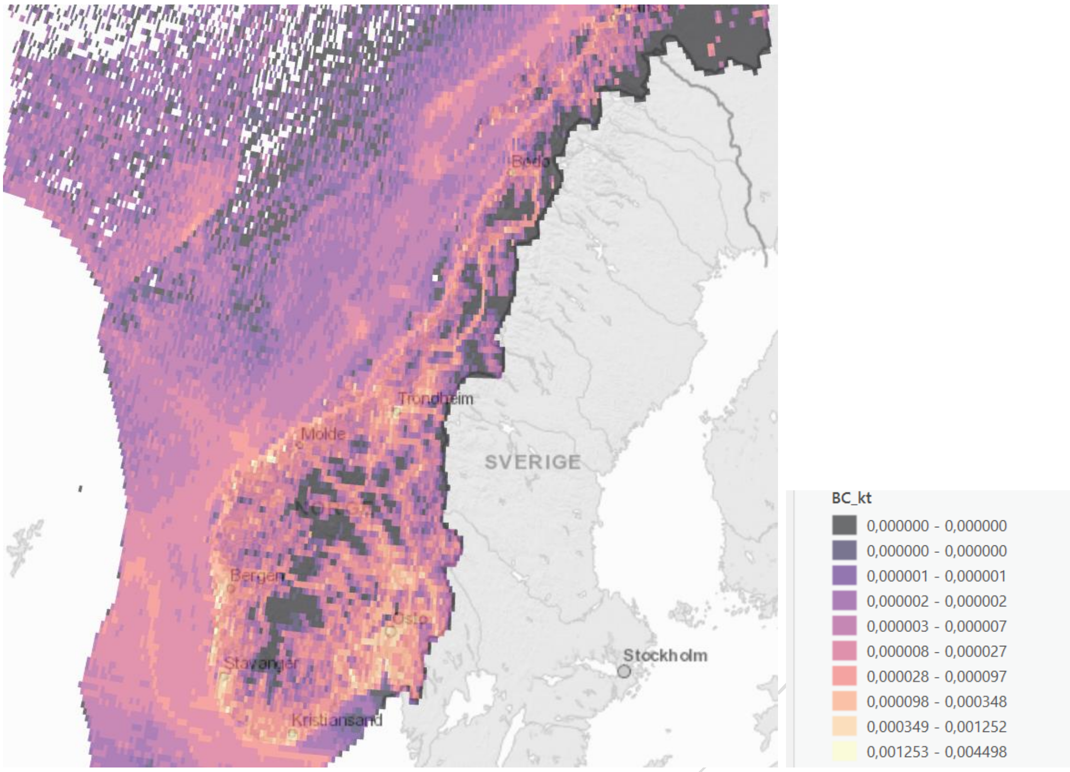


Figure 12 Spatial distribution of BC emissions (kt/year) from off-road sources, 2015. Spatial resolution is at the EMEP grid, approximately 8 x 8km.

Norway has developed many fine scale bottom-up emission models for BC/OC and PM fractions (see Table 5). These models cover all the main emission sources for PM and generate data at very high spatial and temporal resolutions. Data from these models are mainly used in dispersion modeling for local air quality mapping. However, some of the data from these models are also used to present climate and air pollution information for local municipalities and in national reporting (for example to CLRTAP).

A detailed presentation of each specific model is shown in Annex III

Table 5: Overview of fine scale bottom-up emission models for local air pollution in Norway

Emissions Source	Model/tool	Components	Spatial resolution	Temporal resolution
Wood burning	MetVed-2	BC, OC, + all major air pollutants	250m	Hourly (with regional time variations)
Shipping	Havbase/UtAgg	BC, OC, + all major air pollutants	250m, 1,000m, 8km	Hourly
Road traffic, exhaust	NERVE-H	PM, + all major air pollutants	Road links >50m	Hourly (with general time variations)
Industry	Tilde	Soot, + all major air pollutants	Point sources	Hourly (with general time variations)

Road traffic, non-exhaust	NORTRIP	PM	Road links >50m	Annual
Airports*	Flybase	PM, + all major air pollutants	Airport site (~$5km^2$)	Hourly
Construction sites*	EmSite	PM, + all major air pollutants	Construction site ($1km^2$)	Hourly

*Model under development, available at the end of 2021

3.3 Introduction to Norwegian Policies and Regulations

The polluter pays principle is a cornerstone of the Norwegian policy framework for air pollution and climate change. Norway does not have regulations, policies, or national targets 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.

In 2017, the eight member states of the Arctic Council adopted a collective goal to reduce black carbon emissions by 25–33% below 2013 levels by 2025.[6] There are large uncertainties in the emission data, but a 2021 assessment[7], shows that the collective goal probably will be attained. The collective goal does not, however, require each country to have a national target for reductions in black carbon emissions.

Policies and regulations affecting BC/OC are presented below.

3.3.1 Air Quality

Both Norway and the EU have ratified protocols under the Convention on Long-range Transboundary Air Pollution (LRTAP, the Air Convention). The Air Convention was adopted in 1979 and celebrates its 40th anniversary in 2019. Within the Air Convention framework, a number of task forces, centres, and International Cooperative Programmes provide research, scientific assessments, and dialogue on the common knowledge base on air quality issues. The most important program for Norway is the co-operative program for monitoring and evaluation of the long-range transmission of air pollutants in Europe (EMEP).[8] The program includes four task forces and five centres.

The Air Convention has been extended by eight Protocols. Notably, the original Gothenburg protocol was agreed to in November 1999 and formed the basis for the original National Emission reduction Commitments Directive (NEC), Directive 2001/81/EC. The protocol was revised in 2012, and the reduction commitments established for 2020 for the EU and its Member States have been transposed into EU law by a new NEC Directive, Directive 2016/2284/EU. The Directive sets 2020 and 2030 emission

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[6] https://oaarchive.arctic-council.org/handle/11374/1936, last access 25 May, 2022

[7] https://oaarchive.arctic-council.org/handle/11374/2610, last access 25 May, 2022

[8] https://www.emep.int, last access 25, May, 2022

reduction commitments for nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOCs), sulfur dioxide (SO_2), ammonia (NH_3), and fine particulate matter ($PM_{2.5}$).

The revised Gothenburg Protocol recognises the human health and climate co-benefits of reducing black carbon and ground-level ozone (Mark W. Framton et.al., 2006). An objective is that Parties should, in implementing measures to achieve their national targets for particulate matter, give priority, to the extent they consider appropriate, to emission reduction measures that also significantly reduce black carbon.

Norway and the EU continue to work closely with the Air Convention to encourage ratification and implementation of the revised Protocol by the broadest range of parties, and to pursue further work on key areas such as Black Carbon and intercontinental transport of air pollution.

The EU Ambient Air Quality Directives[9] (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. The country-specific guidelines and laws for air quality management in Norway are given in Chapter 7 of the National Pollution Regulations Regarding Ambient Air Quality.[10] Norway has various levels of air quality standards (Table 6):

- **EU Air Quality directive limit values**: legally binding values for the entire EU; if not met, mitigation measures must be performed to hold the values under these limits. Air quality plans should be developed for areas where concentrations of pollutants in ambient air exceed, or are in danger of exceeding, the limit values. These plans are reported back to the EU.
- **National Legal limit values**: legally binding values specific for Norway; if not met, mitigation measures must be performed to hold the values under these limits. Air quality plans should be developed for areas where concentrations of pollutants in ambient air exceed, or are in danger of exceeding, the limit values.
- **National Goals**: the government's long-term goals for local air quality in Norway. These goals are set to the same levels as the air quality criteria.
- **Air Quality Criteria**: health-based goals for air quality that establish safe air quality when levels are under the criteria.

[9] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0050&from=EN, last access 27 May, 2022

[10] https://lovdata.no/dokument/SF/forskrift/2004-06-01-931/KAPITTEL_3#KAPITTEL_3, last access 27 May, 2022

The values for these various standards for PM are shown in Table 6.

Table 6 EU and Norwegian limit values, goals, and criteria for PM

		EU Air Quality Directives limit values	**National legal limit value**	***Proposed national legal limit value****	**National goals**	**Air quality criteria**
PM_{10}	Daily	50 µg/m³ (max 35 exceedances)	50 µg/m³ (max 30 exceedances)	*50 µg/m³ (max 15 exceedances)*	n/a	30 µg/m³
	Annual	40 µg/m³	25 µg/m³	*22 µg/m³*	20 µg/m³	20 µg/m³
$PM_{2.5}$	Daily	n/a	n/a	*n/a*	n/a	15 µg/m³
	Annual	25 µg/m³	15 µg/m³	*12 µg/m³*	8 µg/m³	8 µg/m³

*In addition, there have been proposed changes to the National legal limit values, which took effect January 2022 .

In addition, Norway has air pollution classes that are used in forecasting of air quality; the classes for PM are shown in Table 7.

Table 7 Norwegian pollution classes used in air quality forecasting of PM.

Classes	Level	Health risk	PM_{10} Day(µg/m³)	$PM_{2,5}$ Day (µg/m³)	PM_{10} Hour* (µg/m³)	$PM_{2,5}$ Hour* (µg/m³)
	Low	Low	<30	<15	<60	<30
	Moderate	Moderate	30-50	15-25	60-120	30-50
	High	Considerable	50-150	25-75	120-400	50-150
	Very high	Serious	>150	>75	>400	>150

* The pollution class for fine particulate matter (PM_{10} and $PM_{2.5}$) is primarily given for the daily mean (the mean concentration in a 24-hour period). The equivalent pollution class for hourly mean (the mean concentration in one hour) is a mathematical conversion based on statistics. As an example: When the hourly mean for particulate matter is in the yellow pollution class, it is most likely that the day will also be yellow.

According to Norway's National Pollution Regulations, $PM_{2.5}$ from background stations must be analyzed for OC/EC (Elemental Carbon), and BC measurements have been previously taken for specific research projects.

If a municipality exceeds the legally binding limit values for local air quality, the regulations require production of an Air Quality Plan for the municipality. The plans must show how the proposed mitigation will allow for air quality for the entire municipality to be under the limit values. These plans normally include detailed emission calculations and dispersion modelling to quantify the air quality situation, and are based on the following general parameters:

- Description of meteorology and local variations
- Localization of housing and other planning areas
- Localization of emission sources

These action plans have primarily addressed PM_{10} and NO_2 concentrations, as other pollutants have been less problematic in recent years in Norwegian municipalities. Sources of these PM_{10} concentrations are normally road dust and re-suspension. In addition, the national goals for $PM_{2.5}$ (see Table 6) are listed as national Environmental Indicator number 4.4.2, in which the goal currently has a "good" status with "positive" development.[11]

3.3.2 Climate Change

Climate change policy will in many cases also contribute to the reduction of BC and OC emissions. Climate change and emission of greenhouse gases have been concerns of Norwegian policy since the late 1980s and remedial measures have broad political backing. The polluter pays principle is a cornerstone of the policy framework on climate change. CO_2 taxes on emissions were introduced in 1991 as a cost-effective policy to limit emission of greenhouse gases. The EU emission trading scheme covers around 50% of Norway's greenhouse gas emissions. Together with the Norwegian CO_2 tax, economic measures cover almost 80% of total greenhouse gas emissions.

When developing its climate policy, Norway also addresses drivers of climate change other than reduction of the greenhouse gases included in Annex A to the Kyoto Protocol. Measures covering certain sources of CO_2 emissions may also affect black carbon emissions and other short-lived climate forcers.

In June 2017, the Norwegian Parliament adopted the Climate Change Act. The purpose of the Act is to promote Norway's long-term transformation to become a low-emission society by 2050. Norway's climate targets for 2030 and 2050 are established by law in the Act.

In its White Paper on the 2030 climate strategy[12] from 2017 the government states that it will promote the use of cost-effective mitigation measures to meet the 2030 commitment (see below). If the CO_2 tax is not considered to be an adequate or appropriate instrument, other instruments that provide equally strong incentives to reduce emissions will be considered, including direct regulation under the Pollution

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[11] Norwegian Environmental Indicators: https://www.environment.no/, last access 27 May, 2022

[12] https://www.regjeringen.no/en/dokumenter/meld.-st.-41-20162017/id2557401/, last access 27 May, 2022

Control Act and voluntary agreements.

In February 2020, Norway submitted an enhanced climate target under the Paris Agreement, number 2 in the following list of national mitigation targets:

1. Under the Kyoto Protocol, Norway will reduce global greenhouse gas emissions by the equivalent of 30% of its own 1990 emissions by 2020.
2. Under the Paris Agreement, Norway has undertaken a commitment to reduce emissions by at least 50%, and up to 55%, by 2030 compared to 1990 levels (increased from the previous target of "at least 40%").
3. Norway will be climate neutral by 2030. This means that from 2030, Norway must achieve emission reduction abroad equivalent to remaining Norwegian greenhouse gas emissions. Possible mechanisms are the EU emissions trading system, international cooperation on emissions reductions, emissions trading and project based co-operations.
4. Norway has established by law a target of becoming a low-emission society by 2050. In quantitative terms this means reducing emissions by 90–95% compared to 1990 levels.

Norway and Iceland are cooperating with EU to fulfil their emission reduction targets of an at least 40% reduction of GHG emissions by 2030 compared to 1990 levels. . This cooperation means Norway and Iceland will participate in the three pillars of the EU climate legislation towards 2030: Manufacturing plants and power stations in Norway and Iceland have been part of one of the EU pillars—the EU emissions trading system (EU ETS)—since 2008. The EU ETS entails no national targets. It puts a limit to the overall emissions from covered installations, which is reduced each year, reducing emissions by 43% in 2030 compared to 1990. Within this limit, companies can buy and sell emission allowances as needed. Through the climate cooperation with EU and Iceland, Norway will be part of the other two EU pillars: the Effort Sharing Regulation (ESR) and the Regulation on Land-use, land-use change, and forestry (LULUCF). Through the ESR, Norway will have yearly emissions budgets and a commitment to reduce emissions not covered by the EU emission trading system (so-called non-ETS emissions) by 40% in 2030 compared to 2005. In the government's political platform, it is stated that the government intends to reduce domestic non-ETS emissions by 45% in 2030 compared to 2005 levels.

Norway will therefore be well prepared when the EU strengthens its climate legislation. Norway also intends to cooperate with the EU on the enhanced 2030 climate targets. Norway may have to meet stricter requirements under EU climate legislation as rules are tightened to meet the enhanced 2030 target the EU has adopted.

In 2021, the Norwegian government submitted a white paper with a Climate Action Plan for 2021–2030. The plan shows how Norway can attain its national climate targets by implementing measures and instruments. One of the main instruments proposed is to gradually increase the CO_2 tax from around 590 NOK/tonne CO_2 today to 2000 NOK/tonne CO_2 in 2030. The plan was approved by Parliament with some amendments. The main elements of the climate plan had support from a majority of the parliament. Still, elements of the plan, such as the gradual increase of the CO_2 tax, are expected to be debated in the yearly budgets in the years to come.

3.4 Sector Specific Plans, Policies, and Regulations in Norway

Policies and regulations that affect BC/OC emissions for specific emission sectors in Norway are presented below. This section includes several sectors, but with a focus on transport and residential combustion, because these are the two main emission sectors for BC/OC that are prioritised in this project.

3.4.1 Transport

The EU has adopted stringent emission standards for various vehicle categories, which also apply in Norway (see Figure 13 that shows light-duty vehicles). The Euro 6 emission standards include PM and have been active for nearly 10 years, with even stricter Euro 7 expected to be proposed later in 2022.

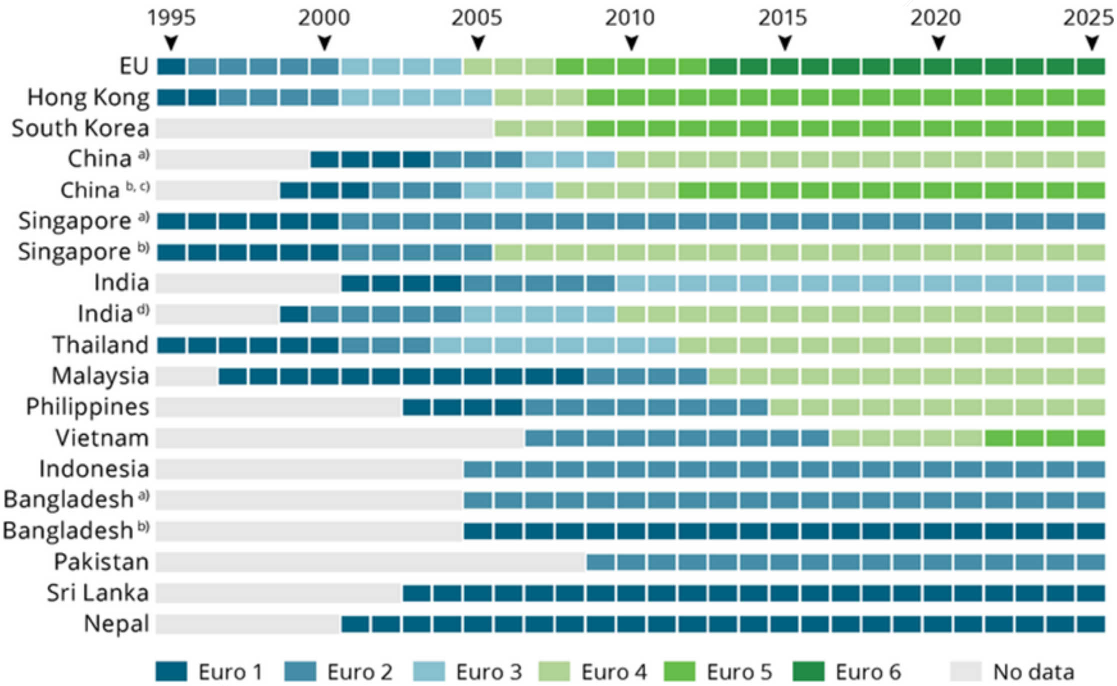

Figure 13 EU vehicle emission standards for light-duty vehicles in comparison to other countries (Source: EEA, 2016). a) gasoline, b) diesel, c) entire country, d) Delhi, Mumbai, Kolkata, Chennai, Hyderabad, Bangalore, Lucknow, Kanpur, Agra, Surat, Ahmedabad, Pune and Sholapur

Norway has set out ambitious national goals for rapid transition to electric mobility through incentives such as tax breaks and reduced toll fares.

From 2018, cash payment was introduced for scrapping motorcycles, mopeds, campers, and caravans. Scrapyards get operational support for receiving these vehicles. Cash payment for scrapping passenger cars has been in place since 1978.

Since the 1990s, electric battery vehicles have been exempted from registration tax, benefitted from free parking, and been exempted from tolls, etc. The sale of electric vehicles has increased considerably over the last six years (Figure 13), emissions have decreased, and air quality has improved (especially NO_2

concentrations). The Norwegian policy for electric battery vehicles is further described below.

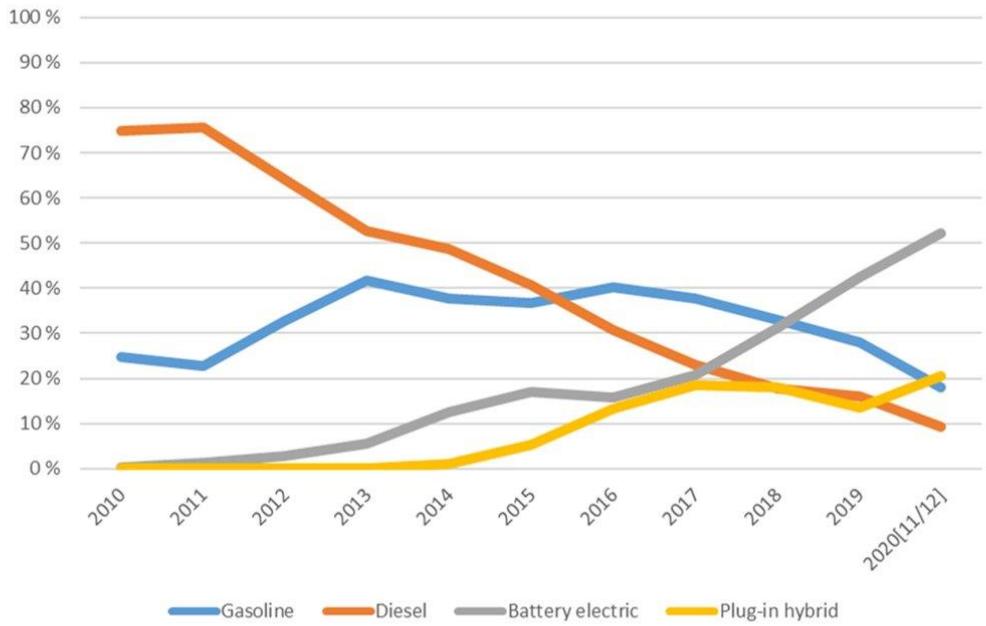

Figure 14: Vehicle sales (%) in Norway from 2010-2020.

To reduce emissions through cleaner diesel fuels and vehicles, Norway aims for a rapid transition to zero and low emission transportation. This will reduce emissions of black carbon in addition to CO_2 emissions. Norway has the highest sales rate of electric vehicles in the world. In 2020, 141,412 new passenger vehicles were sold, of which the share of zero emission cars amounted to 54% (OFV, 2021). This represents an increase of 20% from 2017. Sales have increased considerably because Norway has for several years had in place numerous measures to promote the uptake of zero emission vehicles.

The zero VAT rate for the supply and import of electric vehicles was adopted in 2001. An important element is also the general tax on CO_2 that covers the use of most transportation modes. The use of fossil fuels in vehicles is charged with a CO_2 tax, which favors the use of electric vehicles. Furthermore, fossil fuels for road traffic are charged a road use duty. This duty is intended to cover the externalities from road traffic, apart from CO_2, such as local air pollution, accidents, and noise. Electric vehicles contribute to such effects but do not pay a road use duty. In addition to the reduced taxes, zero emission cars can have benefits related to usage such as free public parking, free charging at public charging stations, access to bus lanes, and reduced fees on ferries. Currently, zero emission vehicles are not charged at all toll roads, and the Norwegian parliament has established a maximum toll of 50% of the toll that fossil fuel vehicles pay. However, local governments can reduce or remove the user benefits if the zero emission cars are causing difficulties and inefficiencies. For instance, if the electric vehicles are filling the bus lanes and causing queues for public transport.

ENOVA SF is owned by the Norwegian Ministry of Climate and Environment. Enova makes financial contributions to individuals and businesses in order to start using the newest and most climate friendly technologies. ENOVA has support schemes for establishment of charging stations and zero emission technologies in the transport sector. In addition to these schemes, a zero-emission fund for commercial transport was established in 2019, with a budget of 1 billion NOK for 2020. The Government has set ambitious targets for emission from new vehicles in 2025 and 2030. In its White paper on the National Transport Plan for 2018–2029,[13] the government established several new targets:

- All new passenger cars and light vans sold in 2025 shall be zero-emission vehicles.
- All new urban buses sold in 2025 shall be zero emitters or use biogas.
- By 2030, all new heavy-duty vehicles, 75% of new long-distance coaches, and 50% of new trucks shall be zero emission vehicles.
- The distribution of freight in the largest urban centres shall have almost zero emissions by 2030.

A regulatory framework for public procurement entered into force in January 2018. Requirements for emission are set out for vehicles, as well an obligation to adopt best practice on environment for overall public procurement policy. An increasing number of local and national authorities and agencies require, through public procurement, that mobile and stationary engines at construction sites do not use fossil fuels. The Norwegian Environment Agency manages a support scheme called *Klimasats*, supporting local initiatives on climate change mitigation, such as fossil free construction sites and more environmentally friendly ferries. ENOVA and Innovation Norway also offer economic support.

The Parliament adopted the White Paper on National Transport Plan 2018–2029 in June 2017. In June 2017, the government also issued a White Paper on climate policies,[14] in which the government set a working target of a cut of 35–40% in greenhouse gas emissions from the transport sector by 2030, compared with 2005. Further, the government said in the White Paper that it would build upon current policy instruments to stimulate use of zero emission vehicles, and by that contribute to reaching the targets for zero emission vehicles in the National Transport Plan 2018–2029. Depending on market development, the government will consider necessary changes in policy measures. The government also stated that it will facilitate making zero emission cars competitive, and that economic measures should support this. A new White Paper with a Climate Action Plan 2020–2033 was submitted to the Parliament in January 2021. The plan states that the government will reduce emissions from the transport sector by half by 2030, using the policy instruments presented in the climate action plan. The targets for zero-emission vehicles set out in the National Transport Plan 2018–2029 are to be maintained, and the government will design the policy instruments described in the climate action plan so that they can be achieved. The government has also recently launched the National Transport Plan for 2022–2033 (NTP, 2021), which has the general goal for the entire transport sector of an effective, environmentally-friendly and safe transport system in 2050.

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[13] https://www.regjeringen.no/en/aktuelt/a-national-transport-plan-for-better-and-safer-daily-travel/id2548623/ , last access 27 May, 2022

[14]https://www.regjeringen.no/en/dokumenter/meld.-st.-41-20162017/id2557401/, last access 27 May, 2027

Norway has an action plan for fossil free public transport by 2025 and an action plan for infrastructure for alternative fuels. Furthermore, an action plan on fossil-free construction sites in the transport sector is being developed.

The Norwegian government launched its action plan for green shipping in 2019, in which a key element is wider use of alternative fuels.[15] The Norwegian government's ambition for its domestic shipping and fishing vessels is to reduce emissions by 50% by 2030 and promote the development of zero- and low-emission solutions for all vessel categories. Norway's action plan for green shipping describes the status of the fleet and how Norway will work to speed up the pace of this transition.

3.4.2 Residential

Norway had 2.3 million households in 2016 according to Statistics Norway (SSB). About half of those, 1.2 million, heated their homes by burning wood; 60% of the households burnt the wood in stoves with new technology.[16] Since 1998, enclosed wood heaters must be approved for sale and use in Norway according to Norwegian standard NS 3058. The stoves and fireplaces must meet the emissions requirements described in NS 3059 (10 g PM/kg dry wood). Eco-design regulation (COMMISSION REGULATION (EU) 2015/1185) entered into force on January 1, 2018, with new emission limits applicable from 2022 (5 g PM/kg dry wood). A side effect of the legislation targeting PM is reduced BC emissions.

The Nordic Swan Ecolabel was established in 1989 by the Nordic Council of Ministers as a voluntary ecolabelling scheme for the Nordic countries Denmark, Finland, Iceland, Norway, and Sweden. It is an effective tool to help companies that want to go ahead with sustainable solutions and thereby enable consumers and professional buyers to choose the environmentally best goods and services. The Nordic Swan Ecolabel scheme is in accordance with the Norwegian standard NS 3058/59, but with a stricter emission limit of 4 g PM/kg dry wood .

Some cities like Oslo and Bergen have exchange programs and give subsidies to residents who exchange their old wood stoves. Burn right campaigns are being organized all over the country in cooperation with the fire brigades. ENOVA SF has programs for energy efficiency, including enhanced home heating efficiency.

A measure that combines accelerated exchange of wood stoves for the best wood stoves on the market and exchange of old wood stoves for electric heating was included in the report *Klimakur 2030* (Klimakur 2030, 2020). With the current design of this measure it is estimated that GHG-emissions can be reduced by 0.51 million CO_2 equivalents primarily due to methane reductions.

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[15] https://www.regjeringen.no/contentassets/2ccd2f4e14d44bc88c93ac4effe78b2f/the-governments-action-plan-for-green-shipping.pdf, last access 27 May, 2027

[16] https://www.ssb.no/natur-og-miljo/artikler-og-publikasjoner/mindre-ved-brennes-i-gamle-ovner, last access 27 May, 2027

Unintended rebound effects are possible when advocating for the use of modern appliances. In Oslo, Norway, a follow-up study that investigated the results of a stove exchange program found that despite relatively rapid change-out of appliances, emission reductions did not follow. Although the new stoves emitted less per unit of wood burned, the study found that users used their stoves more and thereby increased their wood use, thus negating emission reductions. This case emphasises the importance of advocating, when possible, for the adoption of the cleanest technology possible in change-out programs. Similarly, energy efficiency in buildings is a critical element in achieving emission reduction for change-out programs, in order to reduce energy required to heat homes.

The view of wood as a renewable alternative to fossil fuels can present a roadblock for action to reduce black carbon emissions from wood burning appliances. Individuals who are motivated to reduce their own carbon footprints may opt for solid fuel combustion appliances and inadvertently contribute to poor air quality and short-term climate impacts from resulting black carbon and other SLCF emissions. Therefore, educational and awareness-raising campaigns should endeavor to inform the general population on the air quality and climate consequences of solid fuel combustion.

The building code is the main legal instrument for improving energy efficiency. Norway introduced energy requirements for buildings in 1949. They have been revised and made stricter several times, most recently in 2016. The new and stricter requirements (passive house level) entered into force on January 1, 2016. The 2016 requirements were tightened such that dwellings became 26% more energy efficient and office buildings 38% more energy efficient compared to previous requirements. Energy performance certificates are mandatory for buildings that are to be sold or rented out. Among other things, the new energy requirements specify that installation of fossil fuel heating installations are not permitted. For specifications on the building code energy requirements, see Norway's Seventh National Communication under the UNFCCC (2018).[17]

In June 2018, the Norwegian government introduced a prohibition on the use of mineral oil for permanent heating of buildings from January 1, 2020. Schemes to support households to phase out the use of mineral oil for heating of buildings have been in place for several years; the use of mineral oil for heating of buildings has been regulated through different measures such as CO_2-tax, mineral oil tax, standards in the building code, and support schemes from Enova and municipalities.

3.4.3 Industry

The Pollution Control Act sets out a general prohibition against pollution from industrial activities unless a permit from the authorities has been issued. Specific emission limit values are set on a case-by-case basis in the individual permits, based on best available techniques (BAT) as defined nationally or in the

[17] https://www.regjeringen.no/contentassets/52d65a62e2474bafa21f4476380cffda/t-1563e.pdf, last access 27 May, 2022

EU.[18, 19] In addition, local factors are considered when the emission limits are set (Ambient air quality guidelines). Emission limits can be set for soot, total organic carbon, dust, and/or particulate matter emissions, and, more rarely, for BC.

Emissions to air of these components are reported to the Norwegian Environment Agency (NEA) annually, and the figures are published on NEA's website The Norwegian PRTR.[20]

Flaring of natural gas in the oil and gas industry is only permitted when necessary for safety reasons. Implementation of the flare gas recovery system is BAT for new field development projects in the oil and gas industry. For large-scale modification projects on existing installations, flare gas recovery is evaluated as part of the Plan for Development and Operation of petroleum deposits (PDO). Firms/oil companies operating on the Norwegian Continental Shelf are encouraged to engage in forums and programs. Examples of such important programs and forums are the Climate and Clean Air Coalition, the Global Methane Initiative, Global Gas Flaring Reduction Partnership (GGFR), and the Oil and Gas Climate Initiative (OGCI).

3.4.4 Agriculture

Burning of agricultural residues gives emissions of a large range of standard combustion

products. Emissions of NO_X, CO, NH_3, NMVOC, SO_2, particles, and the heavy metals Pb, Cd, Hg, As, Cu, and Cr, and benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and

indeno(1,2,3-cd)pyrene (PAH-4) and dioxins are included in the Norwegian inventory.

Emissions from the burning of crop residues are being calculated in accordance with a Tier 1 approach (EEA 2019):

$E_{Pollutant} = AR_{residue\_burnt} * EF_{Pollutant}$

Where: $E_{Pollutant}$ = emission (E) of pollutant

$AR_{residue\_burnt}$ = activity rate (AR), mass of residue burnt (dry matter)

$EF_{Pollutant}$ = emission factor (EF) for pollutant

The annual amount of crop residue burned on the fields is calculated based on crop production data for cereals and rapeseed from Statistics Norway, and estimates of the fraction burned are made by the Norwegian Crop Research Institute and Statistics Norway. The fraction of crop residue burned on fields was updated in 2012 by the Norwegian Agricultural Authorities.[21] This reduced the fraction for 2011 from 7.5% to 4%. For cereals, a water content of 15% is used (Statistics Norway). The activity data are

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[18] EUR-Lex - 32010L0075 - EN - EUR-Lex (europa.eu), last access 27 May, 2027

[19] EUR-Lex - 32016D0902 - EN - EUR-Lex (europa.eu), last access 27 May, 2027

[20] https://www.norskeutslipp.no/en/Frontpage/ , last access 27 May, 2027

[21] Johan Kollerud, Norwegian Agricultural Agency, unpublished material, 2012

consistent with the data used in the estimations of N_2O from crop residues.

Agricultural waste burning is estimated to occur on about 80 million m^2 annually and almost exclusively during the spring season. This is because it is a condition for grants to alter tillage in the Regional environmental subsidy in agriculture (RMP), i.e., grants to take environmental measures on one's own farm or rental land. It is also prohibited to burn agricultural waste in many municipalities. Therefore, agricultural waste burning is on a clear downward trend in Norway.

Table 8 The emission factors used for particulate matter are shown in the table below

Component	Emission factor	Unit	Data source
TSP	5.8	kg/ tonnes crop residue (d.m.)	EEA (2019)
PM_{10}	5.7	kg/ tonnes crop residue (d.m.)	EEA (2019)
$PM_{2.5}$	5.4	kg/ tonnes crop residue (d.m.)	EEA (2019)
BC	13	% of $PM_{2.5}$	GAINS model (IIASA)

3.4.5 Wildfires

The Norwegian Directorate for Civil Protection (DSB) is the national contact towards the European Union Civil Protection Mechanism, under which countries can ask for bilateral aid, e.g., as Sweden did to fight the great forest fires of 2014 and 2018.

During the hot summer in 2018, DSB devised an ambitious media strategy with educational campaigns to increase awareness on how to help prevent forest fires, such as promoting a prohibition on barbecues (that several municipalities enforced). According to a questionnaire by DSB, 72% of the population took preventive measures as a consequence of the high fire risk that summer. Following the hot and dry summer of 2018, with its high number of forest fire incidents, DSB issued an evaluation report (in Norwegian) [22] with lessons learned and recommendations for the future.

The Norwegian Meteorological Institute has developed a wildfire hazard index for 100 locations in Norway. Monitoring is also done using aircraft, drones, and satellites to detect wildfires at an early stage.

3.5 Methodology for Emission Inventories Development and Reporting

3.5.1 Air pollution

There are currently two international bodies, to which official Norwegian inventory estimates of black carbon are reported: UNECE-CLRTAP and the Arctic Council. In both forums the reporting of national black carbon emissions data is not mandatory, but rather encouraged. Despite the absence of a mandatory reporting obligation, a relatively high level of reporting has been achieved in recent years. As of 2018,

[22] https://www.dsb.no/globalassets/dokumenter/rapporter/skogbrannsesongen_2018.pdf

41 of the 51 CLRTAP Parties, 26 of 28 EU Member States, and all eight Arctic Council Member States (plus 10 of 13 Observer States) had submitted estimates for national total black emissions to some extent during recent reporting cycles (EU, 2019a; EU, 2019b).

Reporting of emissions under CLRTAP should follow the EMEP/EEA air pollutant emission inventory guidebook (EEA, 2019). Norway established a methodology for estimation of BC and OC emissions in 2013 (SSB, 2013), well before guidelines were available under CLRTAP. Emissions are estimated from specific emission factors for different fuels used by different types of machines in different sectors. In general, emissions are estimated by emissions (E) = activity level (A) x emission factor (EF), but different approaches are used to estimate emissions of BC/OC depending on the information available. Activity data are available from Statistics Norway, but emission factors for BC and OC applicable to Norwegian technologies and circumstances are not readily available. Furthermore, to ensure consistency of BC and OC emissions with emissions of $PM_{2.5}$, the emission factors for BC and OC are estimated as shares of the $PM_{2.5}$ emission factors, except for wood burning and flaring.

Wood combustion in the residential sector is the largest source of particulate matter in Norway, and thus it was necessary to have emission factors that adequately reflected the emissions from this source, and measurements were requested. The amount of elemental carbon (EC) and OC and the total amount of particles (TSP) emitted from Norwegian wood stoves were measured (Seljeskog et al. 2013). In a follow up study, the effect of maintenance on particulate emissions from residential woodstoves was measured (SINTEF, 2016).

Flaring of natural gas is only performed for safety reasons in Norway. The emission factors applied are taken from the literature (McEwen and Johnson, 2012). For point sources where emissions of TSP are reported to the Norwegian Environment Agency, emission of BC and OC are estimated based on fractions of the $PM_{2.5}$ emission. For sources where emissions of BC and OC are assumed to occur, and information on BC and OC were not available in the literature, emissions are estimated by using a default method (SSB, 2013).

3.5.2 Climate

Reporting of emissions to the United Nations Framework Convention on Climate Change (UNFCCC) follows the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and the reporting guidelines adopted by the Conference of the Parties [23, 24]. In addition to the Kyotogases, Norway also reports emission of the air pollutants SO_2, NOx, NMVOC, NH_3, and CO.

In 2019, the IPCC authorised its Task Force on National Greenhouse Gas Inventories to produce an IPCC Methodology Report on short-lived climate forcers, including black carbon. Norway was instrumental to this decision. The overall objective is to fill gaps in existing methodologies and to develop and

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[23] http://www.ipcc-nggip.iges.or.jp/public/2006gl/, last accessed 27 May, 2022

[24] Decision 247CP.19, https://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf, last accessed 27 May, 2022

disseminate an internationally approved, globally applicable methodological guidance based on existing methodologies. The work is now well underway, and Norway is contributing with funds and participation in expert meetings. The process creates a platform for paying more attention to black carbon in future IPCC assessments and in climate negotiations under the UNFCCC.

IPCC's sixed assessment report (AR6, IPCC 2021) has a Chapter 6 dedicated to SLCFs. Even though the IPCC has been taking the climate impact of SLCFs into account also on previous assessments, this is the first time that these pollutants have been addressed so thoroughly. Both emissions, comparisons with long-lived climate gases and mitigation options are assessed in an holistic way. The many co-benefits between climate, air quality and health are pointed out, and the opportunities of short-term mitigation options in combination with long-lived greenhouse gases. The summary for policy makers, Figure SPM.2, show the assessed contributions to observed warming in 2010–2019 relative to 1850–1900 for all climate forcers including Black and Organic Carbon aerosols.

Assumed reductions in anthropogenic aerosol emissions lead to a net warming (primarily due to the assumed reduction of sulphur in these scenarios), while reductions in methane and other ozone precursor emissions lead to a net cooling. Because of the short lifetime of both methane and aerosols, these climate effects partially counterbalance each other and reductions in methane emissions also contribute to improved air quality by reducing global surface ozone. Reductions in GHG emissions is shown to lead to air quality improvements. In the near term, however, targeted measures to reduce air pollutants are needed in addition to the GHG measures in many polluted regions in order to achieve air quality guidelines specified by the World Health Organization .

3.5.3 Verification of Emission Inventories

As stated in the background papers on Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories[25], due to the amount of data and the number of institutions involved in the emission inventory compilation, errors and inconsistencies (e.g., across sources or in time) may easily occur. There is also always some uncertainty in the judgement of representativity of emission factors used in the inventory. Therefore, checking and verification procedures are indispensable elements of the Quality Assurance/Quality Control (QA/QC) system of the inventory management.

Checking is part of the validation of the inventory, which involves ensuring that the inventory has been compiled correctly, i.e., calculations have been done correctly and in line with guidelines and reporting instructions. Thus, validation refers to internal checks of the consistency of the inventory. Verification, on the other hand, refers to activities using external data that help to establish reliability for the intended applications of the inventor, for example, external methods to check the truth of the inventory including comparisons with reference calculations, estimates made by other bodies, atmospheric concentrations, or external review.

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[25] https://www.ipcc-nggip.iges.or.jp/public/gp/gpg-bgp.html, last accessed 27 May, 2022

During past years, several quality assurance and quality control procedures for the preparation of the national emission inventory have been established in Norway. Statistics Norway made its first emission inventory for some gases in 1983 for the calculation year 1973. The emission estimation methodologies and the QA/QC procedures have been developed continuously since then. Norway has implemented a formal quality assurance/quality control plan, which covers the reporting of long-range transboundary air pollution as well as greenhouse gases. A detailed description of this is presented in Annex V in the National Inventory Report for Norway (Norwegian Environment Agency et al., 2021b).

In general, the final inventory data provided by Statistics Norway are checked and verified by the Norwegian Environment Agency. Two verification studies, considered particularly relevant for OC/BC emissions, are briefly described below:

1. In 2006, the Nordic Council of Ministers initiated a new project that was finalised in 2010. In this study, the Nordic particulate matter (PM) emission inventories were compared, and for the most important sources—residential wood burning and road transport—a quality analysis was carried out based on PM measurements conducted and models used in the Nordic countries. The objective was to increase the quality of the national PM inventories. The ratio between the reported emissions of PM_{10} and $PM_{2.5}$ was calculated for each country. The completeness of the inventories was assessed and it was found that the PM emission inventories generally were complete and that the sources reported as "Not Estimated" were expected to have only minor contributions to the total PM emissions. The variability of emission factors for residential wood combustion was discussed and it was shown that the emission factors can vary by several orders of magnitude. For residential wood combustion, differences can probably be attributed to whether the emission measurements are carried out in the hot flue gas, either in-stack or out-stack, or if the measurements are carried out after the semi-volatile compounds have condensed.
2. In 2017, a project, financed by the Nordic Council of Ministers, went through the emission factors for Short Lived Climate Pollutants (SLCP) emissions from residential wood combustion in the Nordic countries. The overall objective of this project was to improve the Nordic emission inventories of SLCPs (Kindbom et al. 2018). The project included comparisons of emission factors for elemental carbon (EC), organic carbon (OC), particulate matter ($PM_{2.5}$), methane (CH_4), and non-methane volatile organic compounds (NMVOC). Emission factors were developed for standard combustion conditions, as well as for “bad” combustion conditions. Emission measurements were conducted on residential wood burning appliances, boilers, and stoves representative of the Nordic countries. Generally the older technologies exhibited higher emission levels than more modern types of equipment. Results from measurements showed, e.g., that the modern stoves were sensitive to moist fuel, where emissions of, for example, $PM_{2.5}$ and OC increased in the order of 5–8 times compared to when fired with standard fuel. To improve the national emission inventories of SLCPs, the large sensitivity to operational conditions (moist fuel and part load) needs to be taken into consideration in national emission inventories, where “real life” emissions are estimated. In order for national emission inventory results to be

comparable, a harmonisation of emission factor levels is needed, unless there are real differences between the countries.

Annual review of individual inventories of each Annex I Party to the UNFCCC became mandatory in a 2003 decision 19/CP.8).[26] The UNFCCC Annex I inventory review guidelines, revised in 2014 (decision 13/CP.20), ensure that the Conference of the Parties (COP) is provided with an objective, consistent, transparent, thorough, and comprehensive technical assessment of the quantitative and qualitative inventory information submitted annually by Annex I Parties. Annual review ensures that adequate consideration is given to recalculations and emission trends over time.

The review of greenhouse gas (GHG) inventories comprises two stages. Each stage complements the previous one.

1. Initial assessment by the Secretariat: a standardised set of data comparisons mainly based on the common reporting format (CRF) data, aiming to determine that each Annex I Party has submitted a consistent, complete, and timely annual inventory in the correct format, including the national inventory report (NIR) and the CRF tables, and to identify issues for further consideration during the review of individual inventories. Status reports for each Party are published at this stage while assessment reports are available to Parties and expert review teams (ERTs).
2. Review of individual annual inventories by ERTs: ERTs examine the data, methodologies, and procedures used in preparing the national inventory. ERTs are required to pay particular attention to key categories (categories with significant influences of the country's inventory), areas of the inventory where issues have been identified and recommendations made in previous reviews or stages of the reviews, progress in the implementation of the planned improvements, and where recalculations or other changes have been reported by the Annex I Party. This is the most detailed review stage. Individual review reports are published for each Party.

Three operational approaches may be used during the second stage of the technical review, namely desk reviews, centralised reviews, or in-country reviews. Review reports are prepared and published on the Secretariat web site.[27]

3.5.4 Uncertainties

The Norwegian Research Institute SINTEF performed an expert evaluation of measurement uncertainty of emission factors from Norwegian wood stoves for particles (TSP and PMT), EC, and OC. The PM

[26] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/review-process, last accessed 27. May 2022

[27] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/inventory-review-reports-2020, last accessed 27. May 2022

uncertainty was in general found to be about 7%. The uncertainty for EC was found to be higher for newer stoves (45%) than for older stoves (27%), which could be because the test measurements resulted in larger corrections in EC measurements from newer stoves than from the older ones.

The uncertainty for EC and OC in the SINTEF study may be mainly because the Norwegian measurement standard (NS 3058 and NS 3059) overestimated the amount of carbonaceous particles on the filters analysed. This resulted in the laser instruments, used to measure EC and OC, not giving trustworthy results in most cases. The filters were then analysed with use of thermal-optical methods (NIOSH protocol 5040, 1999), and it was necessary to apply corrections to the results. The resulting emission factors represent an improvement in relation to previously used factors for PM, but there is still a need for more research and improvements to the Norwegian Standard for emission measurements of EC and OC.

3.6 Integrated Analysis of Climate and Air Pollution

In 2013, the Norwegian Environment Agency (NEA), on behalf of the Ministry of the Environment, published an integrated assessment of the short- and long-term climate, health, and environmental impacts of mitigation measures for Norwegian emissions of short-lived climate forcers (SLCFs) (Norwegian Environment Agency, 2013). Emissions of SLCFs might either warm or cool the atmosphere. As the global climate impacts of SLCFs depend on where the emissions take place. NEA modelled the global climate effects of Norwegian emissions. A new climate metric, GTP10-Norway, was adopted to assess the short-term climate impacts of measures and the cost-efficiency (cost per unit of CO_2equivalent) of measures in a short-term perspective. The study found that Norway's BC emissions have approximately 1.5 times higher climate impacts per tonne of emitted BC than the global average, mostly due to Norway's proximity to the Arctic and to BC deposition on snow and ice (Hodnebrog et al., 2013). The results also showed the importance of reducing Norway's BC emissions due to the health impacts of $PM_{2.5}$ in cities, and that the inclusion of the health benefits of the assessed measures substantially reduced their socio-economic cost. Finally, the assessment pointed out that it is important to assess the net climate effect of emission measures. The 2013 study did not assess greenhouse gas measures, but, given the high short-term climate effect of CO_2, hypothesised that such measures could be as efficient in reducing SLCFs as targeted SLCF-measures. Therefore, integrated assessments of both short- and long-lived climate pollutants could be useful in giving a complete picture of the net climate effect, as well as health impacts, of the measures.

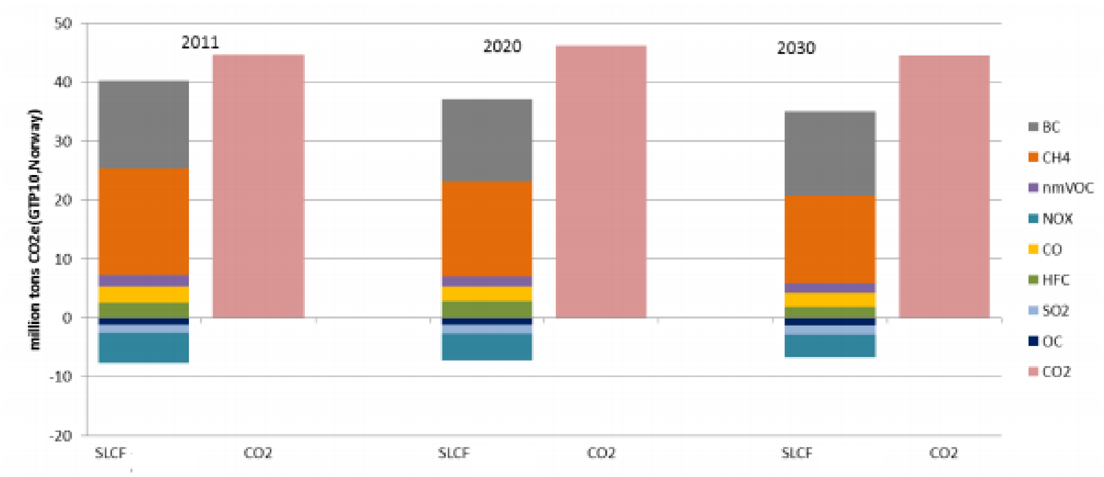

Figure 15 Global climate effect of Norwegian SLCF emissions compared to that of Norwegian CO_2 emissions in 2011, 2020, and 2030. (Source: Norwegian Environment Agency, 2013)

To acknowledge this, the Norwegian Environment Agency has subsequently performed several integrated studies including of both SLCFs and greenhouse gases. In a later study, the Norwegian Environment Agency highlighted that BC could be reduced by 33% and methane by 16% from 2013 to 2025 if the analyzed measures are implemented, compared to respectively 28% and 9% without such measures (Norwegian Environment Agency, 2019). The main measures to reduce BC are *accelerated introduction of new stoves* and *best stoves and pellet burners,* and *electrification of ferries and passenger ships*. Due to methane emission reductions, measures to reduce emissions from wood burning by replacing high emitting stoves with low emitting stoves are now regarded as climate measures as well as health measures. New road transport measures do not result in significant reductions of BC emissions because measures already included in climate and environment policies are expected to reduce BC emissions to almost zero by 2030. This could be different in other countries with a different emission profile.

In 2020, the Norwegian Environment Agency and other agencies published a mitigation analysis of a range of measures that could be used to achieve Norway's 2030 climate target for non-ETS emissions and in the land use, land-use change and forestry (LULUCF) sector (Klimakur 2030, 2020). The Agency subsequently analyzed the short-term climate impacts and the health and environmental co-benefits of these measures. The results show that many of the measures will have substantial climate impacts both in the long term and short term and will also provide health and other co-benefits (Norwegian Environment Agency, 2021c).

Integrated assessments of climate measures are important to highlight measures that have important short-term effects but fail to contribute substantially to long-term climate goals. This type of analysis assists in compiling a portfolio of measures that contribute both to reducing the short-term rate of warming as well as safeguarding the long-term perspectives of the Paris Agreement. In Norway, health benefits have traditionally been included in greenhouse gas analyses. The short-term climate effects of those measures have become increasingly a part of their regular evaluation.

Integrated climate and air quality studies have also had an impact on Norway's international climate policy. For example, Norway included a description of BC and OC in its Seventh National Communication to the United Nations Framework Convention on Climate Change (UNFCCC) (Norwegian Ministry of Climate and Environment, 2018) and Norway's submission to the 2018 UNFCCC Talanoa Dialogue called for the application of a multiple-benefit methodology. Interest in performing integrated analysis of climate and air pollution has been increasing in many countries. Norway has thus played an active role in, e.g., the Climate and Clean Air Coalition (CCAC), and has published results together with, e.g., Tsinghua University (UNEP, 2019).

3.7 Health Effects[28]

The Norwegian Institute of Public Health (NIPH) has found that BC is often used as an indicator in population exposure studies. In general, it is found that short-term exposure has an association with mortality and hospital visits for persons with asthma and heart and lung diseases. For long-term exposure to BC there is a correlation to death and respiratory problems in addition to reduced lung function. The risk estimates for BC in regard to mortality and sickness are higher than for $PM_{2.5}$ and PM_{10}, for both short- and long-term exposure.

Combustion particles are measured with various methods and are described in population exposure studies as black smoke (BS), BC, or EC. It is common in such studies to use the BS to EC conversion of 10 $\mu g/m^3$ BS equals 1.1 $\mu g/m^3$ EC. In such studies, WHO recommends that BC is a better indicator for harmful components, especially for traffic, than the total mass of $PM_{2.5}$ or PM_{10}.

However, there exist few experimental studies on the effect of $PM_{2.5}$ compared to BC/EC or in which the composition of the particles is characterized. The few studies that do exist show that BC/EC does not in itself result in toxicological effects, but that the effects of $PM_{2.5}$ are rather attributed to various organic compounds or metals bound to BC/EC.

Mills et al. (2011) performed a study on the effect of diesel exhaust on the heart and respiratory system, in which the health effects were limited with the use of particle filters. Exposure of healthy volunteers to two hours of ultrafine carbon particles in an ambient concentration (10 $\mu g/m^3$) showed changes in the surface markers on blood cells, something that can represent an early stage of an inflammatory reaction (Framton et al., 2006). Further studies of ultrafine particles (EC 50 $\mu g/m^3$ over two hours) show effects to blood circulation (inhibited vasodilation) in healthy individuals (Shah et al., 2008).

NIPH has compiled a figure that shows the various health impacts from particulate matter (Figure 16).

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[28] Source to this section is NIPH: https://www.fhi.no/nettpub/luftkvalitet/temakapitler/svevestov/, last accessed 27. May 2022

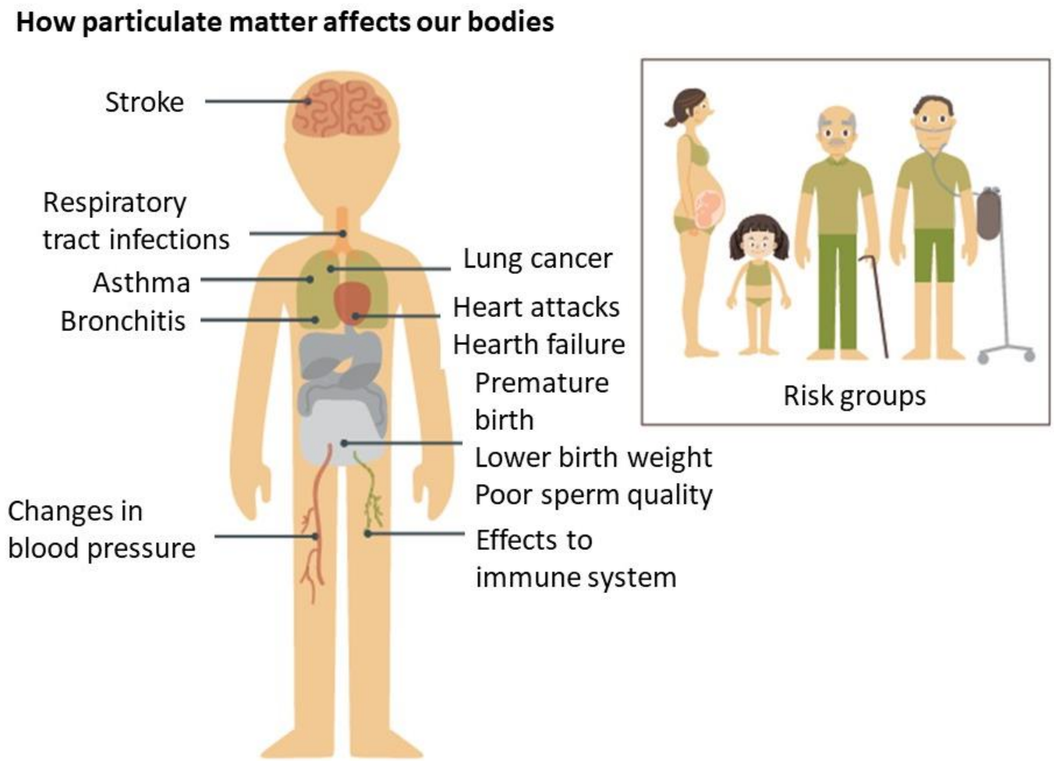

Figure 16 Overview of health effects from PM. (Source: NIPH)

3.8 Effectiveness of Policies

Norway has 24 national environmental goals, several of them dealing with climate and air pollution. The goals are detailed on the Environment Norway web pages.[29] In order to see if the country is on track to attain these goals, Norway has developed environmental indicators. The environmental indicators for climate and air pollution are related to status for and trends in emissions of GHG and concentrations of harmful components.

3.8.1 Emission Trends and Projections

Air pollution and climate policies combined have resulted in large reductions of BC and OC emissions in Norway. The BC emission trends per sector are shown in Figure10. The emissions of BC amounted to 2,841 tonnes in 2019, a total reduction of 41% since 1990 and of 6% since 2018. In 2019, the most important source of emissions was “other combustion” (NFR 1A4 and 1A5), contributing to 37% of the total emissions. From this category, 75% of emissions originated in 2019 from residential stationary plants, primarily due to wood combustion in private households. From 1990 to 2019, emissions from residential stationary plants were reduced by 28%.

[29] www.environment.no

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

Combustion in the energy industries, which in 2019 accounted for 13% of total BC emissions, increased by 269% since 1990 due to increased production. The greatest sources of emissions within this category are public electricity and heat production, and manufacture of solid fuels and other energy industries, which contributed 43% and 56%, respectively, to the sector emissions in 2019. From 1990 to 2019, BC emissions from these sub-sectors increased by 2914% and 134%, respectively (NEA, 2021a).

Flaring is acknowledged as an important source of BC emissions by many researchers, e.g., in the EU-funded Action on Black Carbon in the Arctic (See Annex II). There is little flaring per unit of oil and gas produced in Norway compared to other oil producing countries. The Norwegian Oil and Gas Association estimated that the global average amounts of flare gas per produced unit were 12 times higher than in Norway in 2017. The amounts of flared gas per year decreased by 43% from 1990 to 2019, and BC emissions from flaring decreased by 45% in the same time period. And although amounts of flare gas and emissions have fluctuated, there seems to be a consistent downwards trend in recent years (Figures 17 and 18).

The prohibition of flaring except for safety reasons, together with the CO_2 tax and the EU ETS has resulted in improvements in technology and emission-reducing measures, e.g., flare gas recovery ("closed flare system"). In the late 1990s, several measures were implemented in Norway to reduce continuous flaring through development and use of new technologies (Pederstad et al., 2015). These measures were considered economically profitable for businesses. A large portion of the remaining reduction potential was then associated with limiting flaring at start-up and shutdown of installations/facilities and pressure relief of equipment during maintenance and breakdowns. Low oil prices and limited investment activity resulted in fewer measures implemented during the early 2000s. In recent years, however, there has been renewed attention to flaring and its emissions, both politically and within industry.

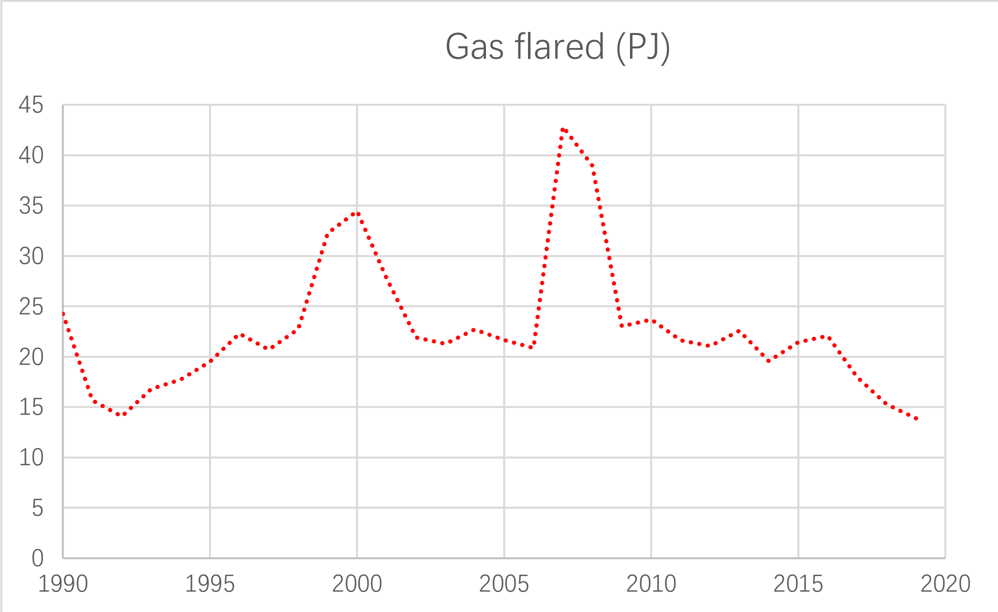

Figure 17 Flare gas amounts (PJ) in Norway 1990–2019 (including Hammerfest LNG). Source: Footprint database with reported data from the operators

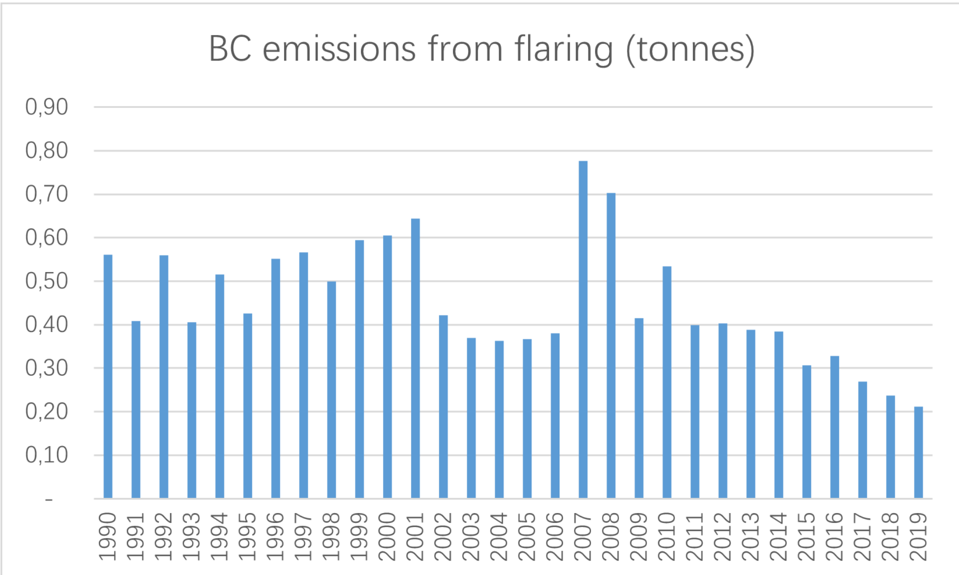

Figure 18 BC emissions from flaring in Norway 1990–2019 (tonnes). Source: Footprint database with reported data form the operators

Norwegian policies and measures are expected to also reduce emissions of BC in the future. According to projections in 2018, when the most important aggregated (GNFR[30]) sector was "Other Stationary Combustion" (mainly residential wood burning) emissions of black carbon are expected to be reduced further towards 2030 (Figure 19).

[30] Gridded Nomenclature for Reporting (GNFR) is the most aggregated format used to report emissions to the Convention on Long-range Transboundary Air Pollution (CLRTAP)

The second and third most important GNFR sectors, “Shipping” and “Road Transport” are also projected to be further reduced towards 2030.

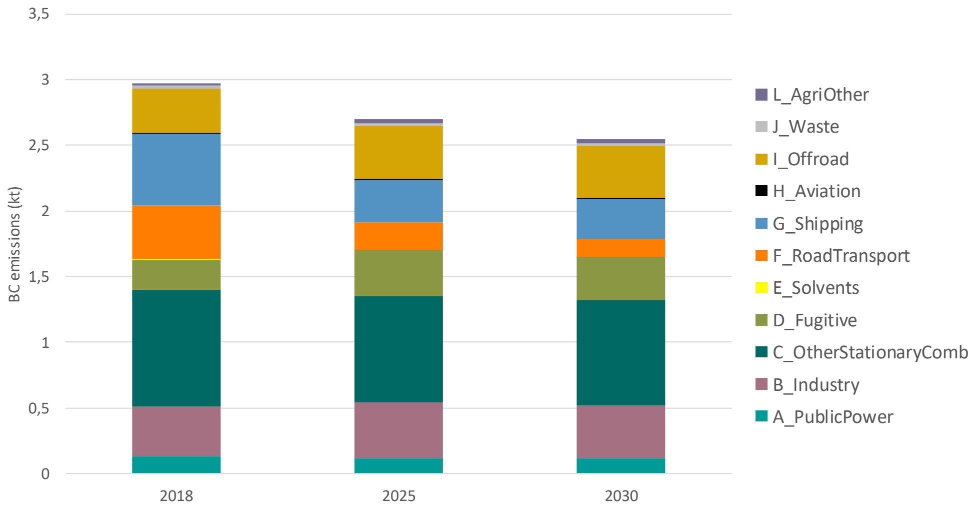

Figure 19 Historical emissions of black carbon in Norway 2018, and projections for 2025 and 2030. (Source: Norwegian Environment Agency and Statistics Norway)

3.8.2 Health Impact Trends

The EEA has estimated that in 2018 there were 1,400 premature deaths in Norway from $PM_{2.5}$ exposure (see Table 9). Premature deaths from $PM_{2.5}$ overall in Europe have been greatly reduced in recent years (Figure 20). In Norway, the relative reduction in premature deaths from $PM_{2.5}$ in 2019 compared to 2009 is between 10% and 20% (Figure 21).

Table 9 Premature deaths from air pollution exposure in Norway compared to the EU, 2018 (Source: EEA, 2018)

Country	Population (x1000)	Annual mean (PM2.5)	Premature Deaths (PM2.5)
Norway	5,296	6.40	1,400
EU-28	507,558	13.20	379,000

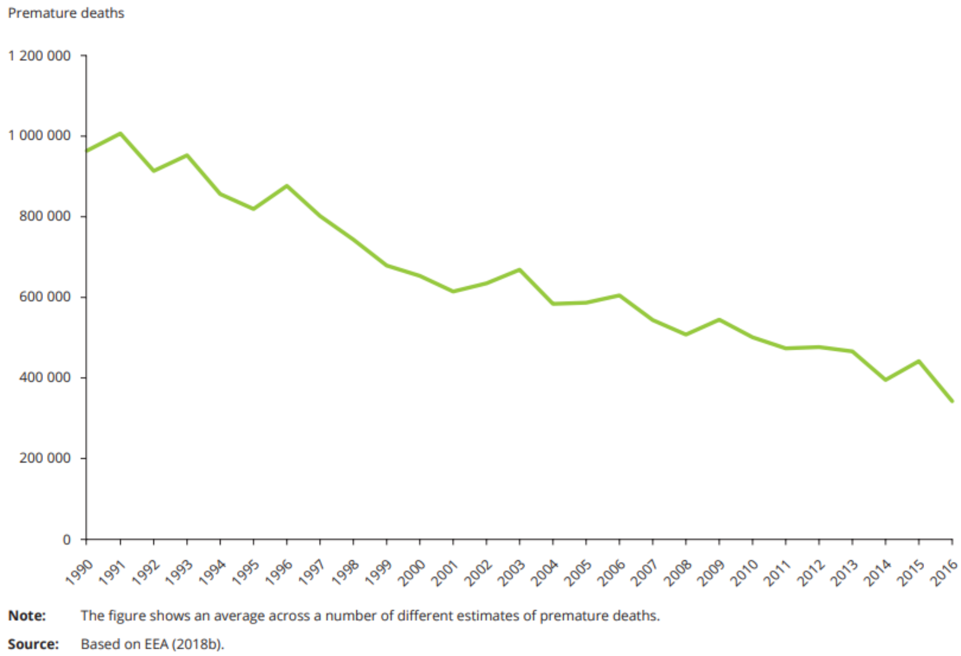

Figure 20 Trends in premature deaths from $PM_{2.5}$ in Europe, 1990–2016 (Source: EEA, 2018)

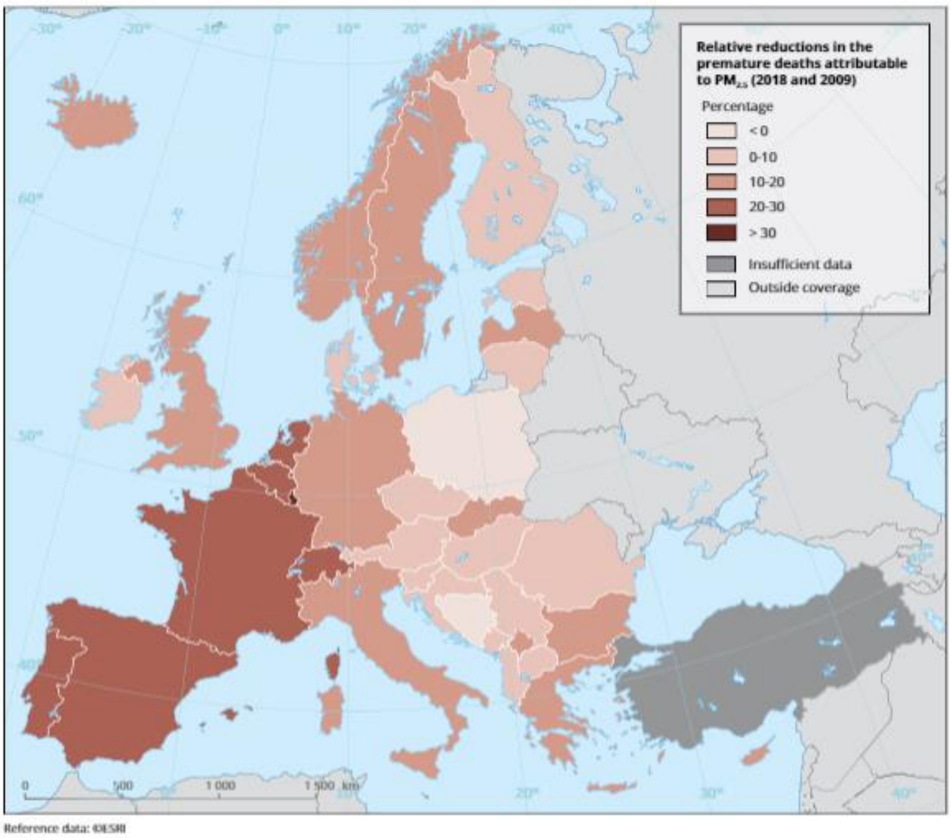

Figure 21 Relative reductions in premature deaths from $PM_{2.5}$ in Europe, 2018 and 2009 (Source: EEA, 2018)

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Annex Ⅰ: List of Air Pollutant Emission Standards from 2013 to 2020

NO.	Name of standard	Code of standard
	Stationary sources	
1	Emission standard for air pollutants for electronic glass industry	GB29495-2013
2	Emission standard for air pollutants for brick and tile industry	GB29620-2013
3	Emission standard for air pollutants for cement industry	GB4915-2013
4	Emission standard for pollutants for battery industry	GB30484-2013
5	Standard for pollution control on co-processing of solid wastes in cement kilns	GB30485-2013
6	Standard for pollution control on the municipal solid waste incineration	GB18485-2014
7	Emission standard for air pollutants for boilers	GB13271-2014
8	Emission standards for pollutants for stannum, antimony, and mercury industries	GB30770-2014
9	Emission standard for pollutants for petroleum refining industry	GB31570-2015
10	Emission standard for pollutants for petroleum chemistry industry	GB31571-2015
11	Emission standard for pollutants for synthetic resin industry	GB31572-2015
12	Emission standard for pollutants for inorganic chemical industry	GB31573-2015
13	Emission standard for pollutants for secondary copper, aluminum, lead, and zinc industry	GB31574-2015
14	Emission standard for air pollutants for crematories	GB13801-2015
15	Emission standard for industrial pollutants for caustic alkali and polyvinyl chloride industry	GB15581-2016
16	Standard for fugitive emission of volatile organic compounds	GB 37822—2019
17	Emission standard for air pollutants for paint, ink, and adhesive industry	GB 37824—2019
18	Emission standard for air pollutants for pharmaceutical industry	GB 37823—2019
19	Emission standard for air pollutants for foundry industry	GB 39726—2020
20	Emission standard for air pollutants for pesticide industry	GB 39727—2020
21	Emission standard for air pollutants for onshore oil and gas exploitation and production industry	GB 39728—2020
22	Emission standard for air pollutants for bulk petroleum terminals	GB 20950—2020
23	Emission standard for air pollutants for gasoline filling stations	GB 20952—2020
24	Technical specification for pollution control of fly-ash from municipal solid waste incineration	HJ 1134—2020
	Transportation	
1	Limits and measurement methods for exhaust pollutants from diesel engines of non-road mobile machinery（CHINA Ⅲ，Ⅳ）	GB 20891—2014
2	Technical requirements and measurement methods for emissions from light-duty hybrid electric vehicles	GB 19755—2016
3	Limits and measurement methods for emissions from motorcycles（CHINA Ⅳ）	GB 14622－2016
4	Limits and measurement methods for exhaust pollutants from marine engines (CHINA Ⅰ，Ⅱ)	GB 15097—2016
5	Limits and measurement methods for emissions of pollutants from mopeds（CHINA Ⅳ）	GB 18176－2016
6	Limits and measurement methods for emissions from light-duty vehicles（CHINA Ⅵ）	GB18352.6-2016

7	Measurement method and specifications for exhaust pollutants from in-use diesel vehicles by remote sensing method	HJ 845—2017
8	Measurement method and technical specifications for PEMS test of exhaust pollutants from heavy-duty diesel and gas fuelled vehicles	HJ 857—2017
9	Limits and measurement methods for emissions from diesel fuelled heavy-duty vehicles (CHINA VI)	GB 17691—2018
10	Limits and measurement methods for emissions from diesel vehicles under free acceleration and lugdown cycle	GB 3847-2018
11	Limits and measurement methods for exhaust smoke from non-road mobile machinery equipped with diesel engine	GB 36886-2018
12	Limits and measurement methods for emissions from gasoline vehicles under two-speed idle conditions and short driving mode conditions	GB 18285-2018
13	Measurement methods for non-regulated emissions from methanol fuelled vehicles	HJ 1137—2020
14	Emission standard for air pollutants for petroleum transport	GB 20951—2020
15	Emissions control technical requirements for non-road diesel mobile machinery	HJ 1014—2020

Annex II: EU Policies and Regulations Relevant for Black Carbon Mitigation

The EU has issued numerous ambitious climate and clean air regulations and policies. Presented here are the most relevant overarching plans and commitments for BC and OC reductions not described elsewhere in this report.

The European Green Deal provides an action plan to boost the efficient use of resources by moving to a clean, circular economy to restore biodiversity and cut pollution. The plan outlines investments needed and financing tools available. It explains how to ensure a just and inclusive transition.

The EU aims to be climate neutral in 2050. A European Climate Law has been adopted to turn this political commitment into a legal obligation. Reaching this target will require action by all sectors of the economy, including investing in environmentally friendly technologies, supporting industry to innovate cleaner, cheaper, and healthier forms of private and public transport, decarbonising the energy sector, ensuring buildings are more energy efficient, and working with international partners to improve global environmental standards.

The EU will also provide financial support and technical assistance to help those most affected by the move towards the green economy. This is called the Just Transition Mechanism. It will help mobilise at least €100 billion over the period 2021–2027 in the most affected regions.

In its Member States, the EU has adopted and implemented numerous regulations that also reduce emissions of BC/OC. Although not necessarily specified for reducing BC, but other pollutants, these implementations also reduce emissions of BC and/or OC.

Norway is also currently considering implementation of the EU's National Ceilings Directive (NEC Directive), and will eventually also have pursuant reporting obligations for NOx, NMVOCs, SO_2, ammonia and $PM_{2.5}$.

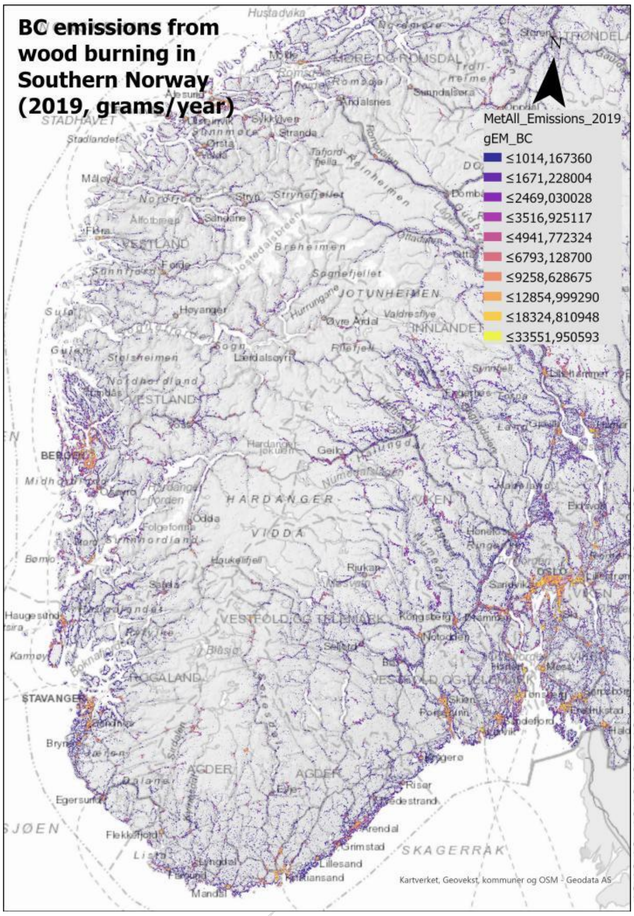
The most relevant EU regulations on emissions of BC are covered in sections 3.3 and 3.4 of this report.

The EU-funded Action on Black Carbon in the Arctic is an initiative sponsored by the European Union to contribute to the development of collective responses to reduce black carbon emissions in the Arctic and to reinforce international cooperation to protect the Arctic environment. It provides and communicates knowledge about sources and emissions of black carbon and supports relevant international policy processes. The EU-funded Action on Black Carbon in the Arctic is implemented through the EU Partnership Instrument providing 1.5 million EUR of funding during 2018–2020.

The initiative supports processes aimed at setting clear commitments and/or targets for reducing black carbon emissions from major BC sources (gas flaring, domestic heating, maritime shipping), and further enhances international cooperation on black carbon policy in the Arctic region—with a special focus on supporting the work of the Arctic Council and Convention on Long-range Transboundary Air Pollution and other national, regional, and international initiatives, and building strong collaboration with EU strategic partners. Thus far the project has published two reviews: *Review of Observation Capacities and Data Availability for Black Carbon in the Arctic Region* (EU, 2019a) and *Review of Reporting Systems for National Black Carbon* Emissions *Inventories* (EU, 2019b). Working recommendations will be explored further during the course of this EU Action on Black Carbon in the Arctic and elaborated in an upcoming *Roadmap for International Cooperation on Black Carbon*.

Annex III: Fine scale emission models for BC and PM in Norway

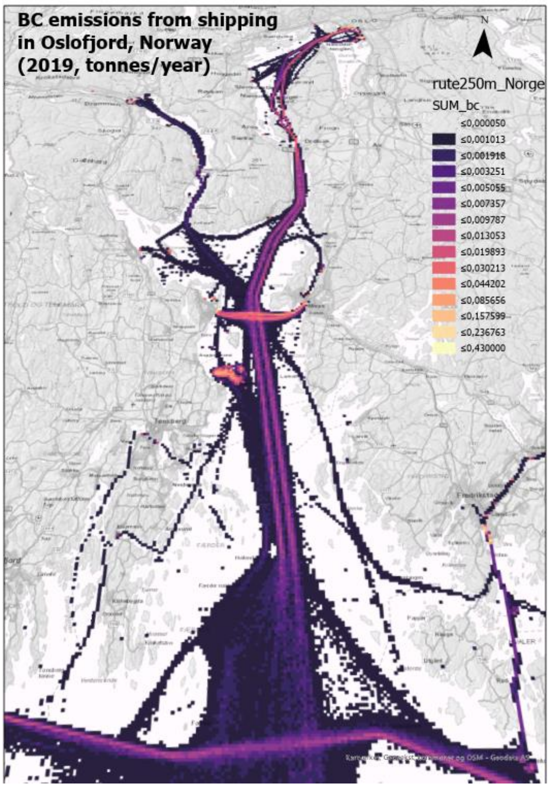
The MetVed-2 model calculates emissions (including BC) from wood burning at a high spatial and temporal resolution for the entire country (NILU, 2019) Wood burning is calculated from residential and recreational housing (see example of emission results for BC in Figure 22).



	Emissions 2019
MetVed-2	Metric tonn/year
SUM_GridConsum	890
SUM_gEM_PM25	11708
SUM_gEM_PM10	12741
SUM_gEM_TSP	13135
SUM_gEM_BC	740
SUM_gEM_OC	7109
SUM_gEM_CH4	7716
SUM_gEM_CO	83107
SUM_gEM_PAH	18
SUM_gEM_PAH_O	3
SUM_gEM_PAH_4	1
SUM_gEM_NOx	873
SUM_gEM_PCB	52
SUM_gEM_Dioxin	0
SUM_gEM_CO2	1426367
SUM_gEM_NMVOC	15747
SUM_gEM_N2O	28
SUM_gEM_SO2	306

Figure 22: Left: BC emissions from wood burning in Southern Norway for 2019 (grams/year, 250m grids). Right: emissions total for various components from the model, 2019 (tonnes/year).

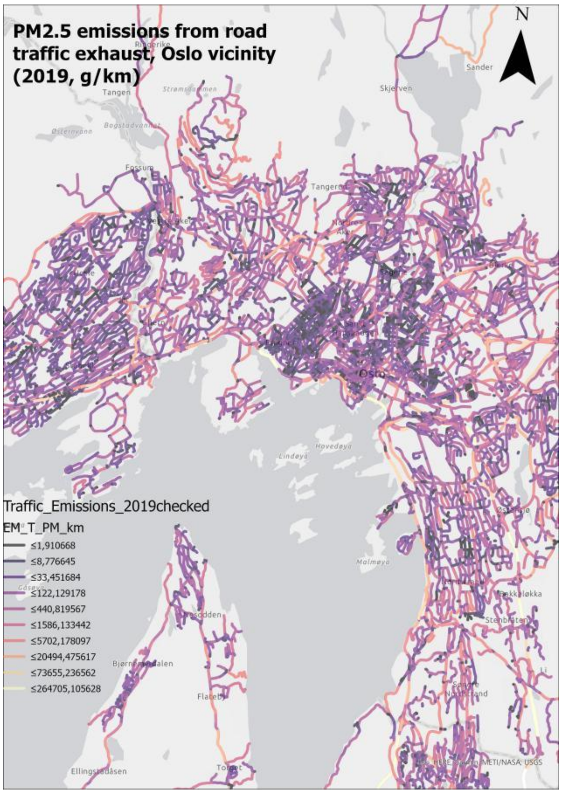
The UtAgg model distributes AIS emission data (including BC) from shipping at a high spatial and temporal resolution (Norwegian Coastal Authority, 2021). These emission data are also available for the main 15 ship categories (see example of BC emissions results from the Oslofjord area in Figure 23).



UtAgg Shipping	Metric tonn 2019
SUM_SUM_fuelco	1547368
SUM_SUM_co2	4913857
SUM_SUM_co	10583
SUM_SUM_so2	8085
SUM_SUM_nox	73950
SUM_SUM_pm	3658
SUM_SUM_nmvoc	3463
SUM_SUM_n2o	146
SUM_SUM_ch4	424
SUM_SUM_bc	279
SUM_SUM_oc	856

Figure 23: Left: BC emissions from shipping in the Oslofjord for 2019 (tonnes/year, 250m grids). Right: emissions totals for various components from the model, 2019 (tonnes/year).

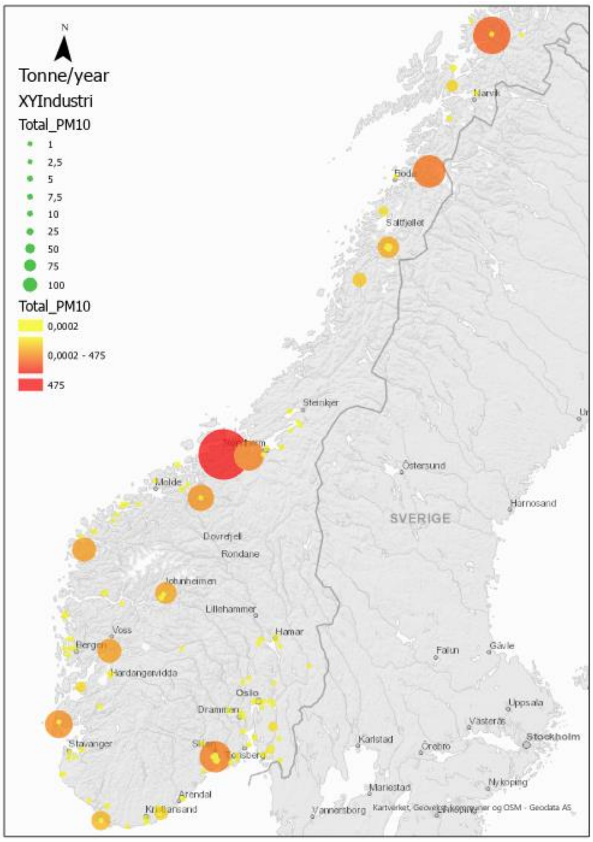
The NERVE model calculates $PM_{2.5}$ emissions from road traffic exhaust at a high spatial and temporal resolution. The emissions data are presented for selected vehicle categories (see example of $PM_{2.5}$ results for the Oslo area in Figure 24).



Emissions exhaust	Metric tonn 2019
NOx cars	17871
NOx trucks	9915
NOx busses	1526
NOx TOTAL	**29313**
PM2.5 cars	385
PM2.5 trucks	1147
PM2.5 busses	29
PM2.5 TOTAL	**629**

Figure 24: Left: $PM_{2.5}$ emissions from road traffic exhaust in the Oslo area for 2019 (g/km). Right: emission totals for various components and vehicle types from the model, 2019 (tonnes/year).

The Tilde database collects emission data reported for industries and includes data for soot and total PM (see Figure 25).



Landbasert industri : Utslipp av Sot (SOT) (i tonn per år) *

År	Til luft	Til vann
2002	26,60	(I.R.)
2003	29,08	(I.R.)
2004	25,72	(I.R.)
2005	15,43	(I.R.)
2006	11,11	(I.R.)
2007	11,15	(I.R.)
2008	9,68	(I.R.)
2009	6,04	(I.R.)
2010	30,55	(I.R.)
2011	22,47	(I.R.)
2012	25,25	(I.R.)
2013	7,98	(I.R.)
2014	20,38	(I.R.)
2015	7,10	(I.R.)
2016	32,37	(I.R.)
2017	32,08	(I.R.)
2018	7,42	(I.R.)
2019	3,67	(I.R.)

Figure 25: Left: PM_{10} emissions from industries in Norway for 2019 (tonnes/year). Right: emissions totals for soot, 2002–2019.