SYNERGIZING ACTION ON THE ENVIRONMENT AND CLIMATE

GOOD PRACTICE IN CHINA AND AROUND THE GLOBE

UN environment programme

清華大學 Tsinghua University

CLIMATE & CLEAN AIR COALITION TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

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Foreword

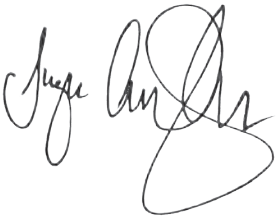
The impacts of the global climate crisis are being felt every day and in every country around the world. At the same time, poor air quality is threatening the lives of millions of city dwellers, villagers, farmers and pastoralists. So many of us have no choice but to breathe dirty air, even as we may be forced to struggle with mounting water and land pollution, biodiversity loss, and the rapidly increasing impacts of climate change. These are not independent problems: they are inexorably linked, and so too are their solutions.

As one of the founding partners of the Climate and Clean Air Coalition, the UN Environment Programme has helped to lead the global effort to deploy whole-of-government approaches to interconnected environmental problems. These approaches provide multiple benefits across all levels of society and ecosystems. We know, for example, that reducing short-lived climate pollutants – like methane, black carbon, and hydrofluorocarbons – can rapidly deliver extraordinary and tangible benefits for public health, food security, biodiversity, sustainable development and near-term climate protection, while complementing efforts to achieve other climate and development goals.

As this report shows, a growing number of countries are beginning to address their environmental problems using holistic approaches that can deliver a rich array of benefits. And it's not just a few rich countries that are doing so, but a wide range of countries at different stages of economic development, and with different regulatory and legal structures. What these pioneering countries are seeing is that, by integrating their climate policies with their clean air policies, they can achieve results that are both more impressive and comprehensive; they can also avoid duplication, refine their decision-making, and build confidence among their policymakers.

The case studies from China and around the world in this report, demonstrate how integrated assessments and co-governance approaches help develop cost-effective and coherent policy decisions that lower costs, increase the chances of success, and identify win-win or win-lose solutions. The multiple benefits provided by such approaches help to justify the allocation of financial, technical and human resources. To that extent, the case studies in this report can help to convince political leaders of the need to move decisively and rapidly. Taken together, these inspiring examples represent a growing body of good practice that can be used to help tackle the many urgent environmental challenges that confront humanity today.

I strongly encourage those working at all levels of governance – international, regional, national, and local – to consider these case studies, and then to find their own ways to support comprehensive and coherent environmental governance. As this report shows, there are so many win-win opportunities that are ready for us to seize: wins for the climate, wins for the Earth, and wins for all of us who call this planet home.



Inger Andersen

Executive Director, UN Environment Programme

Foreword

Four years ago, the Heads of State of China and the United States of America issued a joint presidential statement on climate change, laying the groundwork for the Paris Agreement and rallying the world's support to address the greatest challenge to humanity. Today, the Secretary General of the United Nations calls on the world's leaders to join hands and voices to build new momentum to forge ahead with current climate initiatives and achieve targets set in the Paris Agreement. National experience has shown that climate change action is the most effective and successful when it brings co-benefits that address other domestic challenges such as economic, developmental and environmental issues at the same time. This has led to a new approach to climate change, namely co-governance of climate change and sustainable development challenges, particularly environmental ones.

Air pollution is one such challenge. In most cases, air pollution results from fossil fuel combustion that also emits greenhouse gases. Hence, reducing fossil fuel use cuts emissions of both carbon dioxide and other air pollutants, bringing co-benefits to both climate and the environment.

Like climate change, air pollution is a worldwide challenge, especially in developing countries. The World Health Organization points out that more than 90 per cent of the world's population breath polluted air every day. Air pollution is responsible for 7 million deaths annually, or one in every thousand people in the world. Half a million of these may well be from China according to researchers from the Ministry of Ecology and Environment.

The Chinese government has designed policies to address both air pollution and climate change. These aim to limit the use of fossil fuel by promoting an optimized energy structure, clean energy and energy efficiency. The amount of electric power generated from renewable sources has tripled and wind and solar power capacity grew 25 times in the decade from 2008 to 2018. Currently, 30 per cent of all electricity comes from non-fossil fuels. Substitution of fossil fuels with clean energy, together with improvements in energy efficiency, cut carbon intensity by 45.8 per cent between 2005 and 2018. Meanwhile, air quality has improved dramatically. Within four years between 2013 and 2017, concentrations of particulate matter with an aerodynamic diameter equal to or less than 2.5 micrometres, $PM_{2.5}$, in the Beijing-Tianjin-Hebei region has been cut by 40 per cent and carbon intensity by 18-27 per cent.

In recent years, China's central government launched a coal-cap policy, setting strict limits on coal use, initially in the most polluted regions, then over a much greater geographical area, and eventually across the whole country. Clearly, the co-benefits of climate action go way beyond improvements in air quality. A reduction in the number of deaths from air pollution, reduced medical costs, improvements in public health, and enhanced livability and competitiveness of cities are all important co-benefits. Indeed, action on climate change brings a better environment, a better economy and a better life.

Many governments have increasingly recognized that co-governance is an effective approach to rallying national, local and societal support for and developing a consensus on a low-carbon climate strategy of which the immediate benefits are hard to see. But most people can see and feel the benefits of air pollution control, urban infrastructure retrofits and clean energy development. Besides, by killing multiple birds with one stone, co-governance of the climate, environment and development is cost effective and achieves greater economic, social, environmental and climate benefits. It works in China, and I am sure it will work in other countries.

The Institute of Climate Change and Sustainable Development (ICCSD) at Tsinghua University was established in Beijing, China in December 2017. I serve as the Inaugural President. The ICCSD focusses on strategic research, international dialogue and exchange, and education and training to provide science-based solutions to China's national low-carbon transition and to keep the momentum of advancing the multilateral process on climate change. This report is the first product of the ICCSD in collaboration with other institutions. I hope it will be of help to all countries sharing the common, linked climate, environmental and development challenges that require co-governance solutions.

Xie Zhenhua

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August 28, 2019, Beijing

SYNERGIZING ACTION ON THE ENVIRONMENT AND CLIMATE: GOOD PRACTICE IN CHINA AND AROUND THE GLOBE

1. From Co-Benefits to Co-governance of the Environment and Climate

While climate change is the greatest challenge to humanity, other environmental problems are also threatening the health and quality of our lives, and the ecosystems that all lives rely on. These challenges are addressed globally in the framework of the climate and sustainability, specifically, the Paris Agreement and the 2030 Sustainable Development Goals, under the leadership of the United Nations. At the national level, governments are addressing climate change in the context of their domestic priorities. In nearly all countries, the most important driving force for national climate policy is not just avoiding long-term impacts but also achieving near-term sustainable development objectives, including, most prominently, eradicating poverty and curbing domestic air pollution (IPCC, 2014). Since the sources and impacts of air pollution and climate change are closely linked, focusing on solutions that deliver multiple benefits for air pollution and other development goals allows countries to take ambitious actions that align with both their near-term sustainable development objectives and long-term global climate mitigation. Good practice from many nations has proven that concerted policy and action, or co-governance, is an smart approach because the co-benefits, i.e. the positive effects that a policy or measure aimed at one objective might have on other objectives, can amplify benefits, increase the acceptance and sustainability of action, and catalyze even greater mitigation ambition (IPCC, 2018).

Despite the advantages of co-governance many countries address air pollution, climate and developmental issues separately, which often leads to missed opportunities and poorly integrated policies. Policies that fail to recognize the connections between air quality, climate and public health can bring unforeseen negative consequences which may slow or inhibit ambitious action to combat these threats.

The Special Report on Global Warming of 1.5° C highlights that climate change, air pollution and sustainable development are closely linked (IPCC, 2018). It has been well established that the climate-forcing air pollutants are often co-emitted and well mixed with greenhouse gases, such as carbon dioxide (CO_2) and methane (CH_4), from major sources including fossil-fuel combustion and exploitation, industrial production, agriculture and animal husbandry, waste disposal and land-use change. Once emitted, these pollutants interact with one another in complex ways, affecting climate and polluting the air. For example, CH_4 contributes to the formation of tropospheric ozone (O_3), a powerful air pollutant and greenhouse gas. These pollutants not only have near- and long-term impacts on the climate, but also have immediate impacts on human health.

The interconnected nature of air pollution and climate change means that many of the measures taken to address climate change or to reduce air pollution are likely to result in significant near-term multiple benefits for sustainable development and climate change mitigation. Poorly designed policies and measures that do not account for these connections may unwittingly multiply the costs arising from our current, risky pathway. Understanding the interactions between these factors is key to the selection of mitigation and adaptation options and the coordination of policies that maximize synergies and minimize trade-offs between climate and sustainable development.

Many studies show that extensive co-benefits can be achieved through actions on climate change and the environment. For example, Shindell et al. (2018) showed that stricter climate near-term mitigation consistent with a 1.5° C pathway could lead to 110-190 million fewer premature deaths from reduced air pollution, compared to 2° C pathways. Another study found that implementing 25 measures to improve air quality could simultaneously reduce co-emitted CO_2 by nearly 20 per cent by 2050, in recent integrated air pollution and climate change mitigation assessment for Asia and the Pacific (UNEP and CCAC, 2018). UNECE (2016) estimated that the average financial value of health benefits per reduced tonne of CO_2 is between US$ 58 and US$ 380 globally and the benefits are greater in developing countries than in developed countries. The health benefits in East Asia will be about 10–70 times the marginal cost of abatement. In 2011 UNEP and the World Meteorological Organization (WMO) showed short-lived climate pollutant (SLCP) control measures could slow the global rate of warming by half, while saving roughly US$ 4–32 billion annually from the avoided crop-yield losses and US$ 2–10 trillion each year from the avoided health damage (UNEP and WMO, 2011). Climate change mitigation also has synergies with improvements in energy efficiency and renewable energy development, the benefits of which could equal about 50–350 per cent of the project investment (Ürge-Vorsatz et al., 2014).

2. Practices in China

Over the past decade China has substantial progress addressing its national environmental and climate challenges. The annual average population-weighted $PM_{2.5}$ concentration decreased from 66 micrograms per cubic meter (μg/m³) in 2005 to 53 μg/m³ in 2017 (Health Effects Institute, 2019). Meanwhile, carbon intensity of the economy as measured by CO_2 emissions per unit of GDP was cut by 45.8 per cent from 2005 to 2018, exceeding the target set under the Copenhagen Accord (Ministry of Ecology and Environment, 2019). A suite of measures were taken to achieve the target, and the environmental and climate co-governance was the key at all levels of government policy from national to local, and through initiatives targeting major sectors of intensive energy use.

The Chinese experience can be summarized in four elements: setting and delivering national targets, tightening legal frameworks and standards, establishing national pilots for policy learning and innovation, and emphasizing integrated action in key regions and sectors.

China's national targets on environment and climate actions are set in the Five-Year Plans (FYP's) through a systematic procedure including evidence-based research and policy debate and consensus building. Since 2005, more targets have been explicitly set in the 11th, 12th and 13th Five years plans (See table1). The target setting reflects the national commitments made in the international climate negotiations. The environmental and climate targets are categorized as required or obligatory to emphasize their importance, as compared to other anticipatory targets. Along with target setting are a series of rules and procedures which guide implementation, evaluation and accountability. Failure to deliver the target by local governments or state-owned enterprises may cause consequences in career promotion of the responsible leaders.

The legal framework on climate and environmental protection has been strengthened. The Air Pollution Prevention and Control Law of 1987 was amended in 1995, 2000, 2015 and 2018. In the most recent amendment, the law emphasizes reducing pollutant emissions from key sources by restructuring the country's industrial composition and the energy mix. The 2018 version of the law also added a provision for co-governance of emissions of greenhouse gases and the conventional environmental pollutants. The Energy Conservation Law of 1997 was also amended in 2007, 2016 and 2018 to reflect the need for broader coverage higher standard for energy efficiency. The Renewable Energy Law, which first took effect in 2006, was also amended to promote low carbon transition of the energy system and thus reduce pollution from fossil fuel sources.

Local pilots are often conducted by the central government as key approach to policy innovation, to identify good practices which can be dispersed to other municipalities and provinces. Three pilot programs are of particular relevance to addressing the environmental and climate challenges in China, national pilots for low-carbon development, renewable energy pilots and the sponge city pilots. The low-carbon pilots program was first initiated in 2010 and then augmented in 2012 and 2017. A total of 78 cities of various sizes are included in the three batches of the pilot program. 72 of them declared to peak their CO_2 emissions 5-10 years earlier than the national commitment under the Paris Agreement. All pilot cities achieved reductions in both CO_2 and $PM_{2.5}$ emissions between 2010 and 2015 (Chen and Zhuang, 2018).

China's approach to co-governance focuses on key regions and cities of special significance. The Beijing, Tianjin and Hebei area is politically significant due to its location of nation's capital and is a region with the most polluted air among all metropolitan areas in the country. Limiting overall use of coal and reducing the share of energy intensive industries is proved to be the most effective for cutting carbon emissions and improving air quality. The annual average concentration of atmospheric $PM_{2.5}$ in Beijing decreased from 89.5 μg/m³ in 2013 to 51 μg/m³ in 2018, a drop of 43% in five years. Meanwhile, synergetic actions help Beijing to achieve the peak carbon emissions by 2020, which is 10 years earlier than the national target. The city of Shenzhen leads the change in the Pearl River Delta region. This most rapidly growing city experienced some of the worst period of air pollution and carbon emissions in the 1990's and early 2000's. The environmental monitoring data showed that the city was choked by smoggy air during half of the year in 2004, but the annual $PM_{2.5}$ concentration was down to 26 μg/m³ in 2018, lower than the national standard of 35 μg/m³. In 2013, Shenzhen announced a plan to end coal-fired power generation. Today, over 90% of the electric power is from renewable energy or gas-fired power plants. Almost all vehicles for public transportation, including taxies and buses, are electric. Fossil fuel use is strictly limited for industry, transportation and buildings. The city also announced to peak its overall carbon emissions by 2022.

The power sector has been a focus of co-governance in China due to its sheer size and contribution to the emissions of carbon and other air pollutants. China's power sector produces one quarter of all electricity worldwide and consumes half of the coal produced in the country. Co-control actions brought down the contribution of the power sector to the overall emissions of SO_2 from 51% in 2006 to 9.7% in 2016. Meanwhile, the share of NO_X emissions decreased from 54.9% to 8.7%. The technological improvement helped to save roughly 1 billion tons of carbon dioxide emission per year for the period from 2006 to 2018 (China Electricity Council 2017 and 2018). China has started a nationwide carbon market to be applied first to the power sector since 2017. It is expected that this comprehensive measure will further cut the emissions of carbon and other pollutants from the power sector.

3. Future Targets and Actions in China

China' s medium- and long-term targets for clean air are divided into two phases (Tsinghua University, 2017). The first phase target is to reach the $PM_{2.5}$ standard of 35 µg/m³ by 2030 in the major cities and areas, and the second phase target is to reach 15 µg/m³ by 2050. Under the 2015 Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC), China pledged to reduce CO_2 intensity by 60–65 per cent compared to 2005 levels by 2030, increase the share of non-fossil energy in the national primary energy consumption to 20 per cent, and to reach peak CO_2 emissions around 2030 or earlier.

With the emissions reduction of SO_2 and NO_X by 8 and 10 per cent every five years during the 2015–2050, respectively, the policies will achieve synergistic CO_2 emissions reductions of up to 20 billion tonnes by 2050 (Nam et al., 2013). If China achieves its full range of NDCs by 2030, SO_2, NO_X and $PM_{2.5}$ emissions will also be reduced by 78.85, 77.56 and 83.32 per cent, respectively (Yang et al., 2017). If the decreasing rate of China's carbon intensity is reduced by 4 per cent per year in the 2015–2030 period under a carbon tax, it will result in a 25 per cent reduction in SO_2 and 19 per cent reduction in NO_X emissions compared to a carbon-tax-free scenario. The national population-weighted average $PM_{2.5}$ concentrations will also fall by 12 per cent, avoiding about 94,000 premature deaths (Li et al., 2018). In summary, the co-governance of climate and the environment in the medium- to long-term is to make the environmental target drive climate targets in the near term before 2030, and then reverse the priority on climate afterward.

Immediately after the Paris Conference, China published the National Strategy on Energy Production and Consumption (2016-2030). Under the strategy, the total energy consumption is capped below 6 billion tons of coal equivalent, and the non-fossil shares of power generation and energy mix should reach 50% and 20%, respectively. Such a strategic plan would help to deliver the national environmental targets and meet the international commitments. By 2030, CO_2 and SO_2 emission per unit of electricity will have fallen by a third compared to 2015 levels. If the capacity of solar photovoltaic power generation reaches 400 GW in 2030, CO_2 emissions will fall by 4.2 per cent, and premature deaths from air pollution will fall by 1.2 per cent compared to the baseline scenario (Yang et al., 2018).

With a demand for 640 million tonnes of steel in 2030, 190 million tonnes of steel scrap could be recycled if the recycling rate of steel scrap increases by 50 per cent. This could potentially reduce CO_2 emissions by 67.7 million tonnes compared to the baseline scenario of continuing the existing trends in China's steel sector without imposing any energy-saving or emission–reduction targets. In addition, emissions of SO_2, NO_2 and PM10 would fall by about 110,000, 20,000 and 30,000 tonnes, respectively. Air pollution control could prevent about 28,500-71,000 premature deaths, equivalent to an avoided economic loss of US$ 386–854 million (Ma et al., 2016). In the transport sector, by 2050, improving energy efficiency and optimizing transport structure could reduce CO_2 emissions from the transport sector by 38 per cent and 35 per cent, respectively, and avoid about 120,000 and 102,000 premature deaths caused by air pollution, respectively (Liu et al., 2018). Substitutions of fuel in residential buildings could benefit both air quality and human. If these fuel substitutions were adopted between 2010 and 2030, premature deaths related to air quality would fall by 4 per cent, and premature deaths due to indoor air pollution by 31 per cent (Liu et al., 2018).

4. International Cases

The case studies show that a growing number of countries consider integrated co-governance of climate, air pollution and development as a key strategy for achieving their domestic development agendas while simultaneously meeting international commitments to sustainable development and the mitigation of climate change. The countries highlighted have different levels of economic development and different internal objectives. While they have taken different paths to integrated co-governance, there are similarities in their experience and good practices that can be drawn on.

Each of the countries carried out integrated assessments of policies or measures, using a variety of tools and methodologies, to help them assess the co-benefits for climate change mitigation, health, socio-economic development and delivering the SDGs. To ensure that coordinated action will deliver the maximum benefit and reduce the risk of policy failure, integrated assessments of all air pollutant and greenhouse gas emissions are needed. The integrated assessment of short-lived climate pollutants (SLCPs) and greenhouse gases enabled Ghana and Mexico to identify opportunities to reduce co-emissions, while Norway emphasized the usefulness of integrated assessments in identifying the synergy or lack of it. All countries found that integrated assessments aided robust decision making and monitoring those decisions once they had been implemented.

The local benefits and immediate results of action, both for air quality and climate change mitigation, are important development concerns in many countries and are a key ingredient for developing greater ambitions for emissions reductions. Quantifying impacts on public health are a key driver for action in all cases, even in countries such as Finland which have relatively good air quality. Highlighting the distributional impacts of action, particularly the burden on socio-economically vulnerable populations, was a key conclusion in the UK. Norway's study highlights the importance of assessing the impact of policies over multiple time scales. It found that measures addressing NO_x emissions cause short-term warming but provide health and environmental benefits. It shows that although near-term public health benefits are substantial incentives for action, the implications for climate change could help policy makers balance objectives to achieve a better mix of positive results.

Specific local or regional vulnerabilities to emissions can play an important role in policy making and can be a driver for integrated action. The vulnerability of the Arctic region to BC and other emissions is a crucial driver of coordinated climate mitigation and air pollution action for both Finland and Norway.

A number of cases highlight the importance of a cross-government approach to achieve efficient and sustainable co-governance. The formation of a multi-sectoral working group in Ghana was key to delivering harmonized data and scenarios for an integrated assessment, and for the quick acceptance and uptake of the results across the government. Similar working groups were developed in Mexico and Norway. Chile's case highlights the importance of the multi-stakeholder and multiple-benefits approach for ensuring the broad acceptability and sustainability of policies.

These case studies also show that integrated assessments and co-governance approaches are powerful tools for developing cost effective and coherent policy decisions. These examples demonstrate that coordinated actions increase the chance of success and help justify the allocation of financial, technical and human resources, convincing politicians of the need to move decisively and rapidly.

5. Conclusions

Decades of scientific evidence has established a strong case that climate change and environmental pollution are inexorably connected. Many air pollutants have impacts on the climate, and they are often emitted from the same sources as greenhouse gases, such as CO_2. This link provides an opportunity to design policies and actions that mitigate climate change and reduce air pollution simultaneously, which increases benefits and minimizes costs. The efficiencies achieved through co-governance can increase policy acceptability, policy coherence, sustainability, and spur greater mitigation ambition.

Despite the clear benefits of co-governance, governments have historically managed environmental pollution and climate change separately. The case studies presented in this report, however, show that a growing number of countries see integrated co-governance of climate, air pollution and development as a key strategy to achieve their domestic agendas while simultaneously meeting international sustainable development and climate commitments. While examples like these are increasing in frequency, they are still not an international norm. Succeeding at meeting our common goals for the climate, environment and sustainable development requires that we continue to build on these examples to unlock greater ambition for mitigation in all sectors.

6. Policy recommendations for China

A. Embed a medium- to long-term co-governance strategy in the 14th Five-Year Plan;

B. Expand the coal cap programme, achieve early peaking of carbon emissions in coastal provinces and cities and encourage deep decarbonization in energy intensive sectors;

C. Accelerate development of China's national carbon market and expand coverage to all major emitting sectors;

D. Strengthen the Ministry of Ecology and Environment's capacity to support co-governance;

E. Promote co-governance in the Green Belt and Road Initiative.

7. Recommendations for the world

A. Governments should continue to explore and implement co-governance approaches to harmonize climate and environmental policy;

B. International and regional organizations and agencies should share good practice and tools among nations and regions;

C. Integrated assessments of climate and air quality strategies should become common practice to support robust and harmonized policymaking.

Chapter 1 Introduction

In 2015, 196 countries signed the Paris Agreement, aiming to limit global warming to well under 2° C above pre-industrial levels by transforming their individual development trajectories and setting the world on a path towards sustainable development. In this context, the world established a common objective of co-governance of climate, environment and social development, and recognized that the path that humanity takes to reach its climate target is crucial.

Similarly, the United Nations (UN) 2030 Agenda for Sustainable Development, adopted in 2015, emphasizes the linked and indivisible nature of social, economic and environmental harms. Targets related to air quality, for example, are linked to such priorities as health, sustainable cities, production patterns and climate change mitigation. In addition, climate action and climate recovery are at the core of the transformation of the sustainable development system and are present throughout the entire sustainable development agenda.

National governments are addressing climate change in the context of their domestic priorities. In nearly all countries, the most important driving force for national climate policy is not just avoiding long-term impacts but also achieving near-term sustainable development objectives, including, most prominently, curbing domestic air pollution (IPCC, 2014). Since the sources and impacts of air pollution and climate change are closely linked, focusing on solutions that deliver multiple benefits for air pollution and other development goals will allow countries to take ambitious action that aligns with both their near-term sustainable development objectives and long-term global climate mitigation.

Despite their connected nature, many countries address air pollution, climate and developmental issues separately, which often leads to missed opportunities and poorly integrated policies. Policies that fail to recognize the connections between air quality, climate and public health can bring unforeseen negative consequences as well as slowing or inhibiting action that combats these threats. Integrated policies on climate change and air pollution, on the other hand, can amplify benefits, increase the acceptance and sustainability of action, and catalyze even greater mitigation ambition.

1.1 Connected threats call for integrated solutions

The *Special Report on Global Warming of 1.5° C* highlights that climate change, air pollution and sustainable development are closely linked (IPCC, 2018). Even in the Intergovernmental Panel on Climate Change's (IPCC) *First Assessment Report* published in 1990, air pollutants, such as particulate matter (PM), carbon monoxide (CO) and sulphur dioxide (SO_2) were recognized for their direct and indirect impacts on the climate (IPCC, 1990a) (Figure 1.1). These climate-forcing air pollutants are often co-emitted and well mixed with greenhouse gases, such as carbon dioxide (CO_2) and methane (CH_4), from major sources including fossil-fuel combustion and exploitation, industrial production, agriculture and animal husbandry, waste disposal and land-use change. Once emitted, these pollutants interact with one another in complex ways, affecting climate and polluting the air. For example, CH_4 contributes to the formation of tropospheric ozone (O_3), a

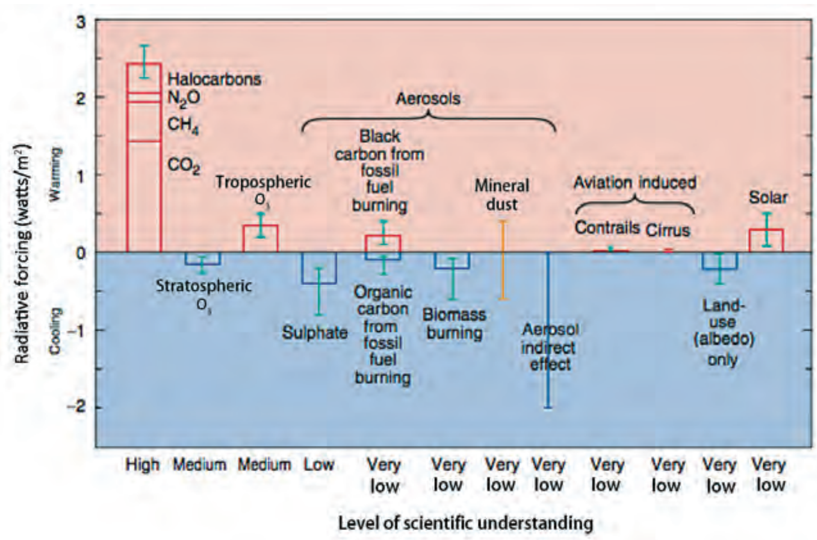

Figure 1.1 Global mean radiative forcing of the climate system, 2000 relative to 1750
Source: IPCC

powerful air pollutant and greenhouse gas.

These pollutants not only have near- and long-term impacts on the climate, but also have immediate impacts on human health. According to the World Health Organization (WHO), nearly 7 million people die prematurely each year from exposure to particulate matter with an aerodynamic diameter equal to or less than 2.5 micrometers ($PM_{2.5}$) both inside and outside the house (WHO, 2016). Exposure to $PM_{2.5}$ is proven to contribute to several adverse health effects, including asthma, other respiratory illnesses and heart disease, and has been linked to cancers, diabetes, increased risk of dementia, impaired cognitive development and lower intelligence levels (UNICEF, 2017). Tropospheric O_3, which forms in the atmosphere when other pollutants such as SO_2, CO and CH_4 interact in the presence of sunlight, is particularly dangerous to children, older adults and people with lung or cardiovascular disease and can worsen bronchitis, emphysema and asthma, and may permanently scar lung tissue.

The interconnected nature of air pollution and climate change means that many of the measures taken to address climate change or reduce air pollution are likely to result in significant near-term multiple benefits for sustainable development and climate change mitigation. Some measures may, however, negatively impact other sustainable development goals by incidentally increasing one type of emissions while reducing another. Poorly designed policies and measures that do not account for these connections may unwittingly multiply the costs arising from our current, risky pathway. Understanding the interactions between these factors is key to the selection of mitigation and adaptation options and the coordination of policies that maximize synergies and minimize trade-offs between climate and sustainable development.

1.2 Major co-benefits of climate change action

Numerous recent studies show that action to mitigate climate-forcing emissions can rapidly generate positive impacts on economies and social welfare through significant benefits for public health and ecosystem sustainability. A recent model analysis found, for example, that stricter climate near-term mitigation consistent with a 1.5° C pathway could lead to 110–190 million fewer premature deaths from reduced air pollution, compared to 2° C pathways (Shindell et al., 2018). Similarly, a recent integrated air pollution and climate change mitigation assessment for Asia and the Pacific found that implementing 25 measures to improve air quality could simultaneously reduce co-emitted CO_2 by nearly 20 per cent by 2050 (UNEP and CCAC, 2018).

Since public health impacts of increased air pollution, damage to staple crops and climate impacts are external costs not reflected in market prices, policy makers often underestimate or even ignore them when formulating or implementing policies. Analyzing the external costs associated with emissions, however, has great implications for policy making. According to a United Nations Economic Commission for Europe (UNECE) study, the average financial value of health benefits per reduced tonne of CO_2 is between US$ 58 and US$ 380 globally. Such benefits are greater in developing countries than in developed ones. In 2030 the health benefits in East Asia will be about 10–70 times the marginal cost of abatement (UNECE, 2016). In 2011 UNEP and the World Meteorological Organization (WMO) conducted an integrated assessment of short-lived climate pollutants (SLCPs) control measures which could slow the global rate of warming by half, while saving roughly US$ 4–32 billion annually from the avoided crop-yield losses (using world market prices) and US$ 2–10 trillion each year from the avoided health damage (UNEP and WMO, 2011) (Box 1.1).

Low-carbon policies usually have positive impacts on the fiscal and taxation system. An International Monetary Fund (IMF) report proposes that the top 20 greenhouse-gas-emitting countries impose a domestic carbon tax of around US$ 57 per tonne of emitted CO_2 to address the challenge of policy distortions caused by currently prevalent fossil-energy subsidies and low energy prices. Such a measure could generate a tax income equivalent to about 2 per cent of the 20 countries' gross domestic product (GDP). In that case, these countries can afford to reduce other taxes, such as income tax, to improve the overall fiscal structure by reducing distortions without affecting their total tax revenue. Such benefits, combined with reduced health damage associated with fossil-fuel emissions, would bring synergistic benefits often larger than the cost of abatement caused by carbon pricing (Parry *et al.*, 2014).

Some case studies show that climate change mitigation also brings about synergies in improvements in energy efficiency and renewable energy development. Synergistic benefits in this area could equal about 50–350 per cent of the project investment. Research also shows that certain forest projects may achieve non-climate

Box 1.1 Short-lived climate pollutants

The UNEP and WMO *Integrated Assessment of Black Carbon and Tropospheric Ozone* was based on the understanding that "*although changes in air quality and climate typically occur at different temporal and spatial scales, many aspects of these issues are closely linked*" (UNEP and WMO, 2011). From approximately 2,000 potential measures, the assessment selected a package of 400 that produce net near-term multiple benefits for climate and air quality, and a smaller group of 16 SLCP measures that collectively achieve nearly 90 per cent of the overall climate impact and reduce air pollution. These measures focused on major sources of CH_4 and black carbon (BC), which along with hydrofluorocarbons (HFCs), are known as SLCPs.

Full global deployment of the 16 SLCP measures could cut the current rate of warming by half, avoiding 0.5° C of additional warming by 2050, 2.5 million premature deaths per year from reduced outdoor $PM_{2.5}$ exposure and the loss of more than 52 million tonnes of crops currently destroyed by outdoor O_3 air pollution. Similarly, a subsequent report on HFCs found that their phase-out could avoid another 0.1° C of warming by 2050 (Xu *et al,* 2013).

synergies equivalent to 53–92 per cent of their total revenue (Ürge-Vorsatz *et al.*, 2014). In addition, synergies are reflected in the macro economy. For example, increasing climate-related capital and labour inputs will affect economic growth and the labour market. In terms of distribution, climate policies can have different welfare effects on different income groups, reducing income inequality and increasing human capital investment.

It is worth noting that because some benefits are hard to monetize, such as improvements in ecosystems, water resources and natural environment resilience, most studies currently include only synergies that can be easily calculated, such as public health, in their assessment of the synergetic effects between climate policy and the social cost of carbon. For example, the economic benefits of avoiding passing climate tipping points, such as the collapse of Arctic summer sea-ice, or avoiding the increase in climate-driven disasters and extreme weather events are not well captured in models. As a result, the real economic value of the synergistic benefits is likely higher than those estimated by these studies.

1.3 From co-benefits to co-governance

Although the term co-benefits has been used in both academia and official documents since the 1990s, it was not until 2001 that the IPCC's *Third Assessment Report* formally defined it in the climate context as "*the non-climate benefits of greenhouse gas mitigation policies.*" Since then, the concept of co-benefits has evolved to be more inclusive and balanced. In addition to the frequently discussed environmental, health and economic co-benefits, climate mitigation policies can, for example, have co-benefits for food production (Chuwah, 2015). In 2018 the IPCC expanded the concept of co-benefits to "*the positive effects that a policy or measure aimed at one objective might have on other objectives, thereby increasing the total benefits for society or the environment*" (IPCC, 2018). This report follows that IPCC definition and focuses on the multiple benefits of integrated policy solutions.

The evolved definition of co- or multiple benefits has strong implications for co-governance of climate and environment issues. First, it emphasizes win-win or multi-win strategies that achieve more than one goal through the implementation of a policy. Second, it underlines the joint implementation of policies which impact climate and air pollutants. From an economic point of view, this integration can reduce policy implementation costs, thus contributing to the formation of cost-optimized policies (Tan *et al.*, 2018). By focusing on both the immediate and long-term benefits of action, policymakers and planners can quantify and communicate the importance of taking action that not only controls global temperature rise but also improves local air quality, livelihoods and the economy.

Co-governance of climate and the environment can frame local/national circumstances and policy priorities within global targets to reduce greenhouse gases, achieve sustainable development and enable urgent air pollution control action consistent with climate change responses. Co-governance should be based on sufficient understanding of the characteristics of both issues. Air pollution and climate change have different temporal and spatial scopes. While air pollution has impacts on human health and ecosystems at local and regional scales in the short term, climate change impacts are global and cumulative in the medium to long term. In the early stages of decision making, both short- and long-term action should be considered in an integrated manner. For countries with heavy air pollution, control measures have significant co-benefits for greenhouse gas emissions mitigation in the near term. In the long term, however, air pollution control measures alone are unlikely to meet the target of achieving net zero global CO_2 emissions; other measures such as carbon capture and storage technologies will also be needed.

Thanks in large part to the growing number of integrated assessments, tools and good examples, international interest in applying integrated co-governance approaches to solve connected climate, environmental and development problems have grown substantially since the early 1990s. Many countries are now assessing the benefits of integrating their climate and air pollution strategies and measures. In 2017, for example, Canada released its first national strategy on SLCPs that addresses climate and air quality concerns concurrently (Government of Canada, 2019). Another example is China's integrated air pollution control policies, discussed in Chapters 2 and 3, which have become one of the most important driving forces for China's response to climate change, promoting the transition towards a cleaner energy and greener economic structure as well as achieving other Sustainable Development Goals (SDGs).

This report presents local and national examples from China and other countries, which demonstrate the growing interest in and application of integrated co-governance approaches around the world. The report consists of five chapters. Chapter 1 introduces the background for co-governance of climate change, the environment and sustainable development. Chapter 2 synthesizes China's climate and environment co-governance practices using national, regional, municipal and industrial case studies. Chapter 3 examines the future impacts of China's co-governance of climate change and the environment. Chapter 4 analyses good practices from six other countries, Chile, Finland, Ghana, Mexico, Norway and the United Kingdom (UK). Chapter 5 concludes the report and provides policy recommendations for China and the world as a whole.

References:

Chuwah, C., Noije, T. V., Vuuren, D. P. V., Stehfest, E., and Hazeleger, W. 2015. Global impacts of surface ozone changes on crop yields and land use. *Atmospheric Environment* 106(161), pp. 11-23.

Government of Canada. 2019. *Short-lived climate pollutants*. https://www.canada.ca/en/services/environment/weather/climatechange/climate-action/short-lived-climate-pollutants.html (accessed 2 August 2019).

IPCC. 1990a. *First Assessment Report*. Intergovernmental Panel on Climate Change.

IPCC. 1990b. *First Assessment Report (AR1) Working Group I, Summary for Policy Makers*. Intergovernmental Panel on Climate Change.

IPCC. 2014. *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

IPCC. 2018. *Global Warming of 1.5° C. An IPCC Special Report on the impacts of global warming of 1.5° C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Intergovernmental Panel on Climate Change.

Parry, I., Veung, C. and Heine, D. 2014. *How much carbon pricing is in countries' own interests? The critical role of co-benefits*. International Monetary Fund. https://www.imf.org/external/pubs/ft/wp/2014/wp14174.pdf (accessed 28 August 2019).

Shindell, D.T., Faluvegi, G., Seltzer, K., and C. Shindell 2018. Quantified, localized health benefits of accelerated carbon dioxide emissions reductions. *Nature Clim. Change* 8, pp. 291–295, doi:10.1038/s41558-018-0108-y.

Tan, Q., Wen, Z. and Yang, H. 2018. Review and Recommendations on the Co-benefits of Controlling Greenhouse Gases and Atmospheric Pollutants. *Environment Protection* 46(24), pp. 53-59. [Chinese].

UNECE Programmes. 2016. *The Co-benefits of Climate Change Mitigation*. United Nations Economic Commission for Europe. http://www.unece.org/fileadmin/DAM/Sustainable_Development_No._2__Final__Draft_OK_2.pdf (accessed 28 August 2019).

UNEP and WMO. 2011. *Integrated Assessment of Black Carbon and Tropospheric Ozone*, United Nations Environment Programme and the World Meteorological Organization.

UNEP and CCAC. 2018. *Air Pollution in Asia and the Pacific: Science-based Solutions*. United Nations Environment Programme and Climate & Clean Air Coalition.

UNICEF. 2017. *Danger in the air: How air pollution can affect brain development in young children*, United Nations Children's Fund.

Ürge-Vorsatz, D., Herrero, S.T., Dubash, N.K. and Lecocq, F. 2014. Measuring the co-benefits of climate change mitigation. *Annual Review of Environment and Resources* 39, pp. 549-582.

WHO. 2016. *Burden of disease from the joint effects of Household and Ambient Air Pollution for 2012 – V2 Updated for 2016*. World Health Organization. https://www.who.int/phe/health_topics/outdoorair/databases/AP_jointeffect_BoD_results_Nov2016.pdf?ua=1 (accessed 18 July 2019).

Xu Y., Zaelke D., Velders G.J.M. and Ramanathan, V. 2013. The role of HFCs in mitigating 21st century climate change. *Atmospheric Chemistry and Physics 13,* pp. 6083–6089. https://doi.org/10.5194/acp-13-6083-2013 (accessed 28 August 2019).

Chapter 2 China's practice

China has experienced rapid social and economic growth over the past four decades. Between 1979 and 2018, gross domestic product (GDP) grew at an average annual rate of 9.4 per cent, which was much higher than the world's average of 2.9 per cent (National Bureau of Statistics, 2019). Over the same period, China's population grew from around 0.98 billion to about 1.4 billion, while civil vehicle ownership increased sharply from 1.6 million to 232.3 million. This growth, however, has also led to significant environmental pollution and greenhouse gas emissions. Since these are largely generated by the same sources, co-benefits from their reduction have strong policy implications for China's response to both climate change and the control of atmospheric pollutants.

Spurred by urgent demands for the alleviation of air pollution and its international climate pledge[1] , China has made tremendous efforts to strengthen policies to address environmental and climate challenges. The annual average population-weighted $PM_{2.5}$ concentration has fallen from around 66 micrograms per cubic metre (μg/m³) in 2005 to around 53 μg/m³ in 2017 (Health Effects Institute, 2019). CO_2 emissions per unit of GDP in China have fallen by 45.8 per cent in 2018 compared to 2005 (Ministry of Ecology and Environment, 2019). Comprehensive action has been taken to foster co-governance of the environment and climate through integrated action at a national level, sub-national and regional cooperation, action at the municipal level, and through initiatives targeting major emitting sectors.

2.1 China's policies on co-governance since the 10th Five-Year Plan

2.1.1 National strategic planning for co-governance

China's most important national strategic plan is the *National Five-Year Plan for Economic and Social Development (FYP).* This sets goals, main tasks and major initiatives for the country's economic and social development for the following five years. Since the 10th FYP (2001–2005), an increasing number of targets have been set in support of co-governance of the environment and climate.

The 10th FYP attached great importance to the environment and highlighted its protection as an important part of economic development and improving people's quality of life. Despite explicitly raising the general goal, only a few specific indicators related to the environment and climate were established – for the reduction of total emissions of major pollutants, mainly SO_2, and forest cover (Table 2.1). At the end of the period, the target of forest cover had been achieved, while, rather than decreasing, total SO_2 emissions had gone up, causing the Chinese government to implement more stringent energy conservation and emissions reduction regulations for the future (Wang et al., 2018).

In the 11th FYP (2006–2010), the reduction of an energy intensity, defined as energy consumption

1. China committed to CO_2 emissions peaking by 2030 or earlier in its Nationally Determined Contribution (NDC) submitted in 2015.

per unit of GDP, was added as a new target. For the first time, the FYP set anticipatory targets and obligatory targets for the country's economic and social development. While anticipatory targets, based on voluntary actions of market entities, reflect what the government want to achieve, obligatory targets are governmental obligations, which are strongly enforced by relevant agencies. Most environmental and climate targets introduced since the 11th FYP were obligatory.

China put forward its first pledge on CO_2 emissions reduction in 2009, committing to lower its carbon intensity, defined as CO_2 emissions per unit of GDP, by 40– 45 per cent below 2005 levels by 2020. To honor this, China introduced two new indicators in its 12th FYP (2011-2015): the reduction of carbon intensity and the share of non-fossil energy in primary energy consumption.

The scope of air pollutant emissions control was also expanded by the inclusion of a new target for the reduction of total emissions of nitrogen oxides (NO_x). As a result of these measures, the 12th FYP includes targets for both environmental pollutants and greenhouse gas emissions.

Considering the urgent demand for improvements in air quality, two more indicators have been added in the 13th FYP (2016-2020): days with good or excellent air quality in cities at the prefecture level and above, and the reduction of $PM_{2.5}$ concentrations in non-attainment cities at the prefecture level and above. This reflects a transition in the core strategy for air quality management–from controlling amounts of pollutant emissions to improving air quality (Xie, 2019). Overall, the gradual improvement of target-setting in FYPs reflects China's overarching objective of strengthening co-governance of air

Table 2.1 Targets listed in China's National Five-Year Plans for co-governance of the environment and climate

Indicator	Target				Actual performance		
	10th FYP (2001~2005)	11th FYP (2006~2010)	12th FYP (2011~2015)	13th FYP (2016~2020)	10th FYP (2001~2005)	11th FYP (2006~2010)	12th FYP (2011~2015)
Energy consumption reduction per unit of GDP (%)		20.0①	16.0①	15.0①		19.1①	18.2①
Share of non-fossil energy in primary energy consumption (%)			11.4②	15.0②			12.0②
CO_2 emissions reduction per unit of GDP (%)			17.0①	18.0①			20.0①
Reduction of SO_2 emissions (%)	10.0①	10.0①	8.0①	15.0①	-27.8①	14.3①	18.0①
Reduction of NO_x emissions (%)			10.0①	15.0①			18.6①
Days of good or excellent air quality③ in cities at the prefecture level and above④ (% of the year)				>80②			
Reduction in $PM_{2.5}$ concentration in non-attainment cities at the prefecture level and above (%)				18.0①			
Forest cover(%)	18.2②	20.0②	21.66②	23.04②	18.2②	20.36②	21.66②
Forest growing stock (100 million m^3)			143②	165②			151②

Notes: ① 5-year cumulative total; ② by the end year of the FYP period; ③ days of good or excellent air quality refers to the days with an Air Quality Index of 0–100; ④cities at or above prefecture level include municipalities, cities or regions at prefecture level, autonomous prefectures and leagues in China.

pollution and climate at the national level.

2.1.2 Strengthening environmental and climate regulation and institutional arrangement

To implement and manage the strategy and targets articulated in the FYPs, China has established and modified a comprehensive system of environmental regulations and institutions. The legal requirements for improving air quality, controlling greenhouse gas emissions, increasing the use of energy from renewable sources and enhancing energy efficiency are mainly contained in the *Air Pollution Prevention and Control Law*, the *Renewable Energy Law* and the *Energy Conservation Law*.

The *Air Pollution Prevention and Control Law*, first formulated in 1987 and amended in 1995, 2000, 2015, and 2018, aims to prevent air pollution, protect public health and promote the sustainable economic and social development in China. The early versions of the law mainly control emission of SO_2, NO_x, dust and harmful gases by stipulating emission standards for factories, power plants, motor vehicles and ships. The 2015 and 2018 versions, however, show a significant change in the country's strategy for air pollution governance from individual pollutant emissions controls to overall air quality improvement, which highlights the regulation of emissions sources rather than just focusing on the end-of-pipe emissions. The new versions clarify the role of source control and planning in air pollution prevention, including optimizing the industrial structure and upgrading the energy mix. Furthermore, they highlight regional joint prevention and control, while, the co-governance of greenhouse gases and such air pollutants as PM, SO_2, NO_x, ammonia (NH_3) and volatile organic compounds (VOCs) is 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 are established at the national level and then disaggregated to provincial and lower levels of government. The targets are also broken into explicit objectives and measures at different levels of government. The *Energy Conservation Law* acts as support to the accountability and performance target evaluation system on energy conservation in China. It mandates the inclusion of energy conservation performance parameters in the evaluation criteria for local-level government and officials. Local governments and officials who fail to meet energy conservation targets face numerous penalties, such as the denial of eligibility to receive any honours or awards for that year. Additionally, any new energy-intensive projects planned for construction in the corresponding regions can be suspended until targets are met. The accountability and performance target evaluation systems, which are clarified in the *Air Pollution Prevention and Control Law*, are also used to control total air pollutant emissions and improve air quality. Total discharge quotas of key pollutants are allocated to provincial-level governments for implementation. For regions that fail to meet their targets, environmental impact assessment approval for new construction projects that may cause an increase in total key pollutants emissions in the region can be suspended. Inclusion of energy conservation and pollutant mitigation performance as part of the performance evaluation criteria is notable because, until recently, the evaluation system for government officials was dominated by criteria tied to local GDP growth. During the 11th FYP period, the target on energy intensity and SO_2 emissions were disaggregated to the provincial level and in the 12th FYP period, the targets for carbon intensity and NO_x emissions were also disaggregated. In the 13th FYP period, total energy consumption was proposed as a new indicator in the *Comprehensive Work Plan of Energy Conservation and Emission Reduction in the 13th Five-Year Plan Period* and then disaggregated to the provincial level.

Apart from the stringent command-and-control measures, market-based instruments for enforcing and incentivizing co-governance have gradually evolved. Carbon trading pilots in two provinces and five cities were operated in 2013, incorporating nearly 3,000 key emission entities in its framework. In 2017, the National Development Reform Commission (NDRC) issued the *Scheme of Building a National Carbon Emissions Trading Market for the Electric Power Industry*, which marks the official start of a national carbon cap-and-trade system (Section 2.4). The *Interim Regulations on the Administration of Carbon Emissions Trading* have been drafted to solicit comments in 2019.

Along with legislative improvement, there has also been progress in institutional arrangement in China. Before 2018, two different ministries are tasked with separately regulating CO_2 and air pollutants. The Ministry of Environmental Protection (MEP) was responsible for setting up policies and regulations for environmental protections except for climate change, and the Department of Climate Change of the NDRC developed and enforced climate policies. In 2018, the State Council restructured the MEP into the Ministry of Ecology and Environment (MEE) and transferred the Department of Climate Change in NDRC into the new MEE. It is anticipated that the merging of climate and environment functions will reduce the cost of coordination among different agencies, improve administrative efficiency and promote the treatment of environmental and climate issues (Wang et al., 2019).

As a result of these changes, China successfully fulfilled all the targets listed in the 12th FYP. Energy intensity, carbon intensity and total pollutant emissions have been significantly reduced, while the share of non-fossil fuels in the national energy mix, forest cover and forest growing stock have all risen quickly (Table 2.1). Predictably, almost all the targets in the 13th FYP will be met or exceeded. The share of non-fossil fuel in primary energy consumption, for example, had increased to 14.3 per cent by the end of 2018, which is very close to the target set for the end of 2020. Emissions of CO_2 per unit of GDP in China have fallen by 45.8 per cent in 2018 compared to 2005, which means the target for reducing CO_2 emissions per unit of GDP by 40–45 per cent in 2020 compared to 2005 has been achieved ahead of schedule. The average percent of attainment days on air quality of the 338 cities was 79.3 per cent in 2018, up by 2.6 per cent compared with that of 2015. (Ministry of Ecology and Environment, 2019; Ministry of Environmental Protection, 2016).

2.2 Exploring coordinated measures in the Beijing-Tianjin-Hebei region

In addition to national action discussed above, China is supporting subnational and regional cooperation for effective co-governance. The Beijing-Tianjin-Hebei (BTH) region provides a case in point. In 2017, the region, which covers approximately 2 per cent of the country's land area, was home to 8 per cent of China's population, produced 9.5 per cent of its GDP, and accounted for 10 per cent of its energy consumption and 7 per cent of its total coal consumption. (Energy Statistics Division of National Bureau of Statistics, 2018; National Bureau of Statistics, 2018). Due to its high population density, high energy intensity and heavy reliance on coal, BTH is one of the most polluted regions in China, with a high incidence of serious air pollution (MEP et al., 2013). In 2013, the annual average $PM_{2.5}$ concentration in the region was about 106 μg/m^3, three times China's National Air Quality Standard of 35 μg/m^3. The BTH region has been designated as one of the key areas for air pollution prevention and control. In 2013, the State Council set the target for the BTH region to reduce its annual average $PM_{2.5}$ concentrations by 25 per cent in 2017 compared to the 2012 level in the *Air Pollution Prevention and Control Action Plan*, which is known as the most stringent air pollution plan to date in China.

Due to the fluidity, diffusivity and inter-regional dynamics of air pollution, Beijing, Tianjin and Hebei Province have to work together to

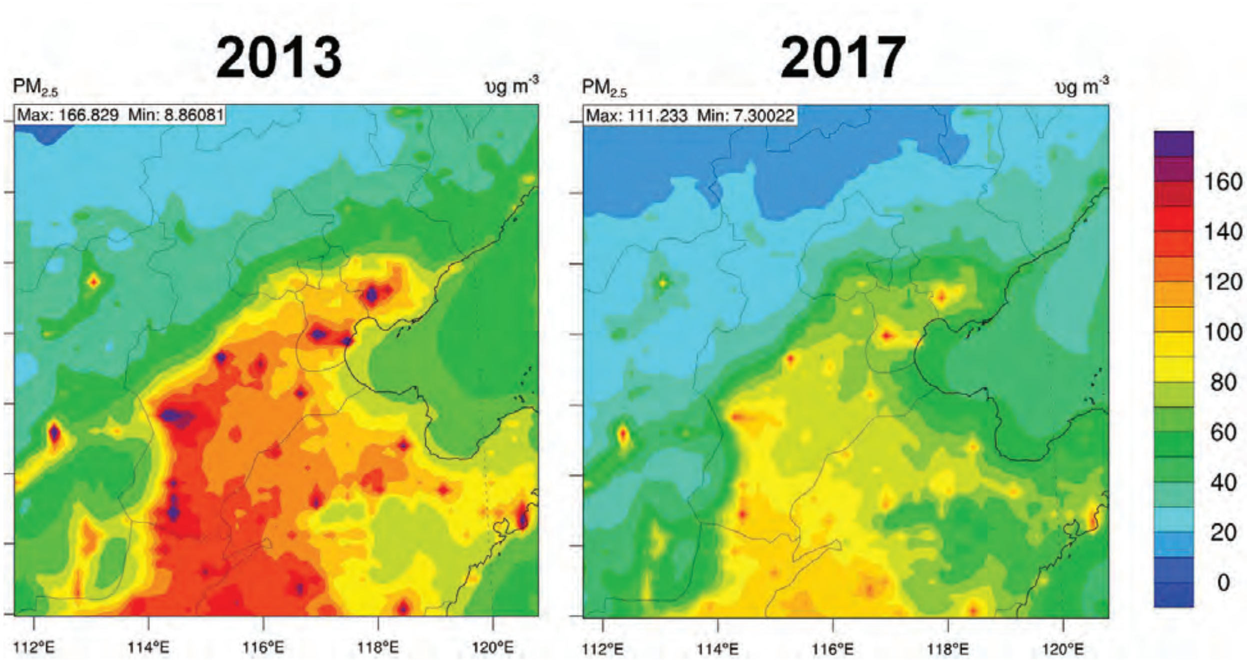

Figure 2.1 Spatial distribution of annual average $PM_{2.5}$ concentration in the Beijing-Tianjin-Hebei region, 2013 and 2017
Source: UN Environment (2019)

solve their serious air pollution problem. In 2013, six ministries, including the MEP, NDRC, the Ministry of Industry and Information Technology (MIIT), the Ministry of Finance (MOF), the Ministry of Housing and Urban-Rural Development (MOHURD) and the National Energy Administration (NEA), jointly issued the *Implementation Details for the Action Plan of the Prevention and Control of Air Pollution in Beijing, Tianjin, Hebei and the Surrounding Areas* (Implementation Details) (MEP, et al., 2013) and launched programmes for the joint prevention and control of air pollution in the area. Regional planning has been unified and a number of measures have been enforced, including but not limited to controlling of coal consumption, the readjustment of industrial structure and the reduction of vehicle fuel use. By 2017, the BTH region had achieved a 39.6 per cent reduction from 2013 in the annual average $PM_{2.5}$ concentration to 64μg/m^3. (Figure 2-1). The percentage of days attaining air quality standards increased by 49.3 per cent (Ministry of Ecology and Environment, 2019) and the number of days with heavy pollution decreased from 75 in 2013 to 28 in 2017 (Clean Air Asia. 2018a). Meanwhile, annual carbon intensity in Beijing, Tianjin, and Hebei Province dropped by 27, 21, and 18 per cent, respectively, between 2013 and 2017.

2.2.1 Control of coal consumption

Coal combustion is a major source of air pollution, CO_2 emissions and consequent environmental degradation in the BTH region and China in general. *The Implementation Details* required Beijing, Tianjin, and Hebei Province to reduce their total coal consumption by 63 million tonnes in 2017 compared to 2012 levels, but by 2017, the BTH region exceeded the target by reducing its coal consumption by 71 million tonnes. Central government has set a further coal consumption reduction target of a 10 per cent by 2020 in the *13th Five-Year Plan for Ecology and Environment Protection*; the coal consumption of Beijing, Tianjin and Hebei Province in 2020 should be no more than 10 million, 41 million and 260 million tonnes, respectively. Beijing has set more stringent target to no more than 5 million tonnes by 2020 in its domestic plan.

The regulations on the phase-out of small-sized, coal-fired boilers were strictly enforced in the BTH region after 2013. Those with a steam-production capacity of 10 tonnes per hour or less were basically phased out in the region, and those with a capacity of 35 tonnes per hour or less were required to be basically closed down by 2020. In 2017, Beijing eliminated more than 27,000 coal-fired boilers, Tianjin retired or retrofitted 10,900 coal-fired boilers and Hebei Province eliminated 39,000 and retrofitted 311 others (Clean Air Asia, 2018b). Provincial and municipal governments have implemented specific policies to support the phase-out of small-scale coal boilers. Hebei Province, for example, provides a subsidy of RMB 30,000 per tonne of steam capacity for the phase out of coal-fired boilers and a subsidy of RMB 80,000 per tonne of steam for the replacement of coal-fired boilers with boilers powered by new energy sources.

The BTH region has also implemented the coal-with-electricity and coal-with-gas replacement programmes to phase out coal use in the residential sector. About 4.74 million households completed the replacement in 2016 and 2017, eliminating a total of 12 million tonnes of domestic coal consumption (Clean Air Asia. 2018a). A city/district variable subsidy of 50 -100 per cent of the total equipment cost and a subsidy of around RMB 0.15–0.3 per kilowatt hour (kWh) of electricity or RMB 0.5–1.5/m^3 of natural gas are provided for the programmes. Every household in Beijing, for example, qualifies for a subsidy of up to RMB 12,000 from the municipal government for switching from coal-powered to electric heating. The households also enjoy an electricity subsidy of RMB 0.2 /kWh for space heating (Research Group of Dispersed Coal Governance in China Coal Consumption Cap Plan and Policy Research Project, 2018).

2.2.2 Readjustment of industrial structure

The BTH region is highly industry-intensive. The production of crude steel and flat glass in the region accounted respectively for 26 per cent and 23 per cent of the China's total production in 2015. As the biggest iron and steel producing province in China, Hebei Province alone produced 190 million tonnes of crude steel in 2017, which was greater than the total production of crude steel in the European Union (EU). To reduce its air pollution burden, the BTH region is required to enforce the phase-out of excessive capacity of major energy-intensive industries. Hebei Province set targets to control its production capacity of iron and steel, cement and flat glass to no more than 200 million tonnes, 200 million tonnes and 200 million weight boxes, respectively, by 2020, resulting in steelmaking capacity dropping to 238.72 million tonnes in 2017 from 320 in 2011, and ironmaking capacity falling from 317 million tonnes in 2011 to 244.01 in 2017 (The People's Government of Hebei Province,2018). Specific policy measures have been implemented to facilitate phaseing out overcapacity, including banning investment in capacity expansion for sectors with over-capacity, enforced retirement of out-dated capacity that does not meet current mandatory energy efficiency and pollutant emissions standards, and providing special incentive and compensation funds to support enterprises in staff resettlement and industrial transformation (Clean Air Asia, 2018a).

At the same time, the BTH region has taken steps to foster strategic new industries, including but not limited to information technology, high-end equipment and new materials, bioindustry, new energy vehicles, new energy, energy saving and environmental protection industries. The proportions of strategic new industries in its GDP are planned to be 30, 20 and 12 per cent respectively in Beijing, Tianjin and Hebei by 2020.

2.2.3 Reduction of vehicle fuel use

Many measures have been taken to phase out outdated low-efficiency and heavily-polluting vehicles. All gasoline vehicles with emission levels below the China 1 emissions standards[2] and diesel vehicles with emission levels below the China 3 emissions standards were phased out in Beijing and Tianjin by 2015, and in Hebei by 2017. Government subsidies have been introduced to facilitate the scrapping of these vehicles.

The deployment of new energy vehicles, including battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) and fuel- cell vehicles, are promoted. Increasing the stock of new energy vehicles is listed as a government target. Beijing and Hebei plan to increase the stock of new energy vehicles to about 400,000 and 300,000 respectively by 2020. Tianjin has established a target to add 20,000 new energy vehicles every year from 2018 to 2020. Priority is given to public buses and sanitation, postal and logistics vehicles. Subsidies are also provided to consumers to encourage the purchase of private electric vehicles and favorable policies for the registration of electric vehicles have been implemented.

In an effort to alleviate traffic congestion and air pollution, Beijing has also restricted private vehicles to driving on no more than six days per week based their number plates – the restrictions have also been applied in Tianjin.

2.2.4 Other action in the Beijing-Tianjin-Hebei region

Aside from the coordinated measures described above, strengthening end-of-pipe control of air pollutant emissions in the power, industriral, and transport sectors is also critical for air quality improvement. End-of-pipe emissions control for coal-fired boilers and natural gas boilers has been tightened in the BTH region. At present, all coal-fired power plants in the BTH region have completed the upgrading of ultra-low emissions with concentrations of PM, SO_2 and NO_x limited to 10, 35 and 50 milligrams per cubic metre (mg/m^3), respectively. Some large-scale coal-fired boilers were required to be retrofitted to match the performance of coal-fired power plants with ultra-low emissions. Natural gas boilers were required, through retrofitting, to achieve NO_x emission concentrations of 30~80mg/m^3. Efforts have been taken to tighten end-of-pipe emissions control for the iron and steel industry too – the BTH region has launched several demonstrations of ultra-low emissions in the iron and steel industry with hourly average emissions concentrations of PM, SO_2 and NO_x limited to 10, 35, and 50mg/m^3, respectively, in the sintering nose flue gas and pellets roasted flue gas. The tightening and enforcement of vehicle emissions standards have effectively curbed vehicle emissions. The China 6 emissions standards have been implemented in the Beijing, Tianjin and Hebei Province since July 2019.

2.3 Municipal action

China's municipalities are also working hard to achieve multiple benefits through co-governance. Municipalities including Beijing and Shenzhen have made major strides, and the national government is supporting innovation and action at the city level through a comprehensive and cross-cutting programme of pilot cities.

2.3.1 Beijing's experience in co-governance

As the capital of China, Beijing has experienced rapid economic development in the past decades. The GDP, population, and vehicle stock in 2017 were, respectively, 11.78, 1.74 and 4.35 times their equivalents in 1998 (UN Environment, 2019). The GDP per capita was more than US$ 20,000 in 2017. The permanent resident population is now 21.7 million and there are 5.99 million registered vehicles. Rapid economic and urban growth has resulted in the deterioration of urban air quality. The annual average concentration of $PM_{2.5}$ was 89.5 $\mu g/m^3$ in 2013, far exceeding the National Air Quality Standard of 35 $\mu g/m^3$, let alone the WHO guideline of 10 $\mu g/m^3$. Thanks to

2. China's vehicle emissions standards 1–5 are consistent EU ones. Limits in China's standard 6a are roughly consistent with Euro 6, but limits in China's standard 6b are stringent than Euro 6.

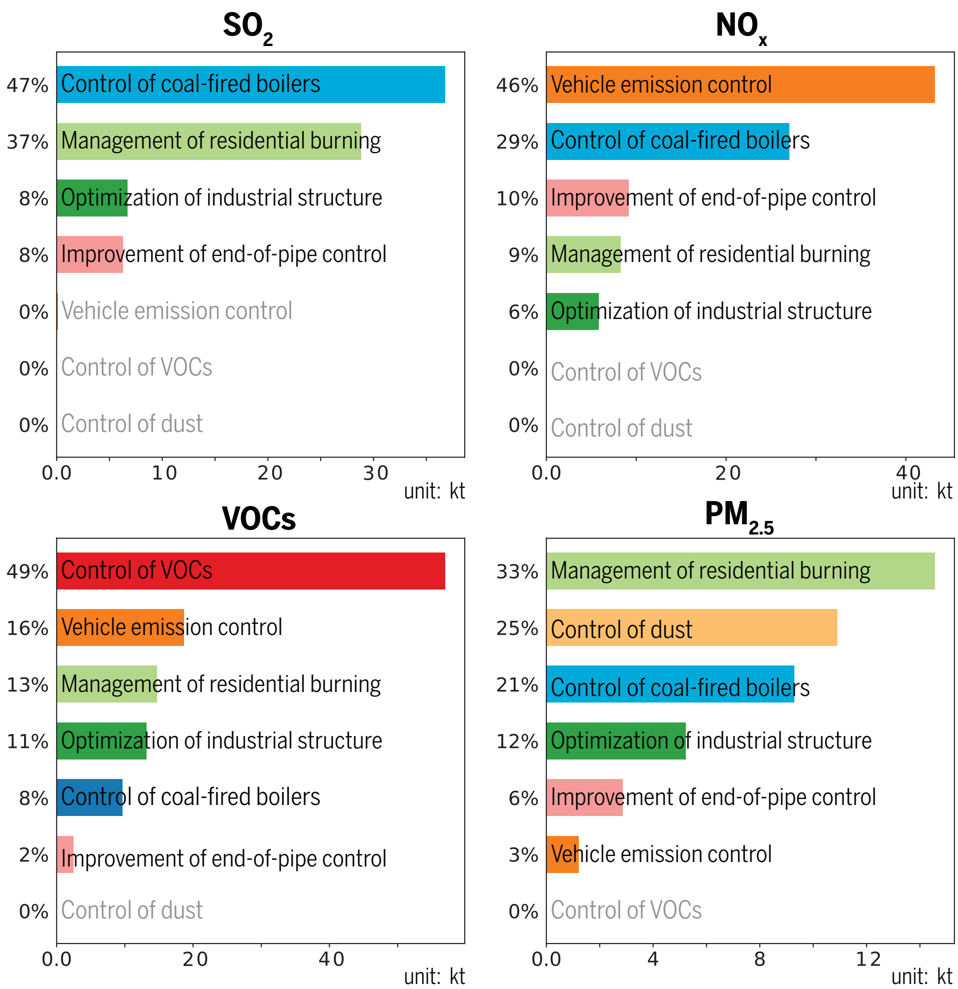

Figure 2.2 Contribution of measures to the reduction of major pollutant emissions in Beijing, 2013–2017
Source: UN Environment (2019)

intensive pollution control, the annual average $PM_{2.5}$ concentration in Beijing reduced sharply to 51 μg/m³ in 2018, 43 per cent lower than the 2013 level. Beijing also places great importance on CO_2 emission mitigation and has set the target of achieving peak CO_2 emissions by 2020.

The policy measures taken in Beijing are very comprehensive. An assessment to quantify the contributions of key policy measures to air quality improvement between 2013 and 2017 selected a total of 32 measures and classified them into seven categories – coal-fired boiler control, clean fuels in the residential sector, optimization of the industrial structure, improvements in end-of-pipe control, vehicle emissions control, fugitive dust control, and the integrated treatment of VOCs (UN Environment, 2019). The contributions these measures made to the reduction of major pollutants are shown in Figure 2.2. The renovation of coal-fired boilers is the foremost contributor to SO_2 reductions and a major contributor to the reduction in NO_x and $PM_{2.5}$ emissions. The management of residential fuel use contributes to the majority of $PM_{2.5}$ emissions reductions as well as being a major contributor to reductions in SO_2 emissions. Vehicle emissions control is the foremost contributor to NO_x emissions reduction and a major contributor to VOC emissions reduction.

Coal combustion has been a major source of air pollution in Beijing. According to a $PM_{2.5}$ source apportionment study of Beijing released in 2014, coal combustion contributed 22.4 per cent of the

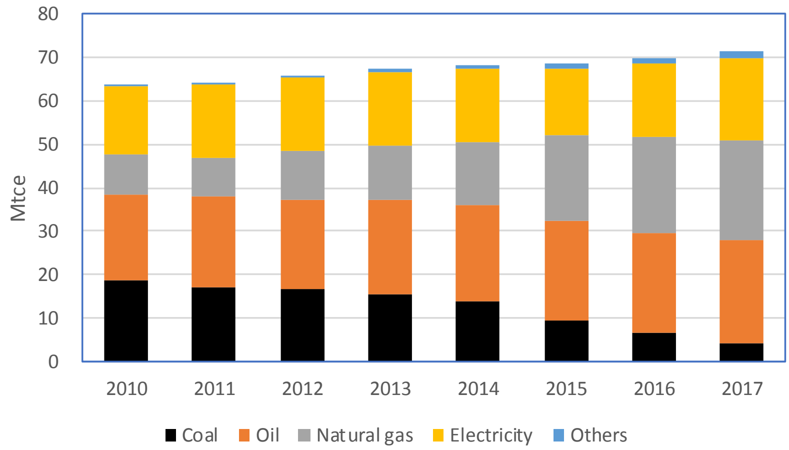

Figure 2.3 Energy consumption by source in Beijing, 2010–2017
Source: Beijing Municipal Commission of Development and Reform (2018)
Notes: Electricity here refers to the sum of net imported electricity and domestic non-fossil fuel power generation.

local sources in 2012-2013 (Beijing Environmental Protection Bureau, 2014). Beijing has taken strong measures to reduce its coal consumption by closing coal-fired power plants and boilers and implementing the coal-with-electricity and coal-with-gas replacement programmes to limit domestic coal consumption. By 2017, all major coal-fired power plants had been closed and coal-fired boilers with a capacity of less than 10 tonnes had been eliminated together with coal-fired boilers in urban areas with a capacity of less than 35 tonnes. As a result, coal consumption has fallen sharply from more than 18.8 in 2010 to 4 million tonnes of coal equivalent (Mtce) in 2017, when it accounted for less than 6 per cent of total energy consumption in Beijing (Figure 2.3). In a new $PM_{2.5}$ source apportionment study published in 2018, the contribution of coal consumption has fallen to about 3 per cent of the local sources in 2017, which implies that coal combustion is no longer a major contributor to $PM_{2.5}$ pollution in Beijing (Beijing Municipal Ecological Environment Bureau,2018).

2.3.2 Shenzhen's experience in co-governance

Shenzhen, located in the Guangdong-Hong Kong-Macao Greater Bay Area on the east bank of the Pearl River estuary, is one of China's four first-tier cities[3] with high population density and intense economic and social activity. Shenzhen's GDP nearly tripled in the 2008-2018 period and reached about RMB 2,400 billion, surpassing its counterpart Hong Kong for the first time (Shenzhen Municipal Bureau of Statistics, 2018).

In the past decade, Shenzhen employed a quality-oriented, innovation-driven, green and low-carbon development strategy that emphasizes economic transition and upgrading. GDP of Shenzhen grew at an average speed of more than 10% in the 2010-2013 period and more than 8% in the 2014-2017 period. Industrial output of strategic emerging industries in Shenzhen grew twice as fast as the GDP of the municipality. In the 12th FYP period, Shenzhen phased out or transformed over 17,000 businesses at the lower end of the industrial chain, in the midst of fast development of high-end, smart, service-related and green manufacturing. Energy intensity of Shenzhen decreased by 26.3% from 0.51 tce/RMB 10,000 in 2010 to 0.38 tce/RMB 10,000 in 2017. Carbon intensity decreased by more than 26% from 0.87 tCO_{2eq} /RMB 10,000 to 0.64 tCO_{2eq} /RMB 10,000. Shenzhen proposed in 2015 that it would achieve its carbon emissions peak around 2022, well ahead of the national target of 2030. Meanwhile, air quality of Shenzhen has improved significantly. Shenzhen has already

3. The first-tier cities of China are Beijing, Shanghai, Guangzhou and Shenzhen.

Table 2.2 The primary sources of CO_2 and $PM_{2.5}$ emissions in Shenzhen, 2018

Sector	CO_2 emissions (%)	$PM_{2.5}$ emissions (%)
Road traffic	49	41
Non-road traffic	12	11
Electric power and thermal power	23	8
Non-energy industries	3	15
Other	13	25

Source: Xu, 2019

met the National Air Quality Standard (35 μg/m^3). Its average annual $PM_{2.5}$ concentrations in 2018 was 26 μg/m^3, ranking sixth out of 169 cities in the monitoring by the MEE, with 94.5 per cent of days having high-quality air.

The Shenzhen municipal government has long recognized the importance of co-governance of the environment and climate change mitigation. Specifically, Shenzhen identified the transport and power generation sectors as the two major contributors of both CO_2 and $PM_{2.5}$ emissions (Table 2.2) and implemented policies that target both sectors.

In August 2013, Shenzhen announced a plan to end coal-fired power generation. Today, only one coal-fired power plant remains in the city, and its power generation is rapidly shrinking. Shenzhen has replaced coal-fired power with power generated from natural gas and renewable sources, which now make up nearly 90 per cent of the city's total power generation capacity. Shenzhen has built 6 landfill gas power plants and is one of the leading cities in terms of power generation from landfill gas. The rapid development of distributed energy has also contributed to the realization of a low-carbon power future for Shenzhen. Shenzhen has actively promoted the use of new-energy vehicles, public transport and rapid bus transport, all aimed at a green, low-carbon transformation. While reducing greenhouse gas emissions, these measures also effectively curbed emissions of air pollutants and improve air quality. Shenzhen is the first mega-city[4] in China and the world to achieve 100 per cent electrification of its buses, with 16,359 electric buses, 510 bus charging stations and 5,000 charging points in operation in 2017 (Shenzhen Transportation Bureau. 2018). In 2019, Shenzhen went one step further by achieving 100 per cent electrification of the city's taxis.

Shenzhen was one of the seven carbon trading pilots in China and created the first carbon trading market in China. Its carbon trading system covered 40% of total emissions of the city. Cumulative trading volume for allowances amounted to 18.07 Mtce, equivalent to RMB 596 million. 635 enterprises were selected as the first batch of trading entities in the carbon trading program in 2013. The coverage of the program was further expanded to 881 enterprises in 2016. The carbon trading market in Shenzhen has by far the widest business coverage, the most dynamic trading activities and the most significant emissions reduction among all trading markets in China.

The carbon market facilitated the greening and decarbonization of electric power supply in Shenzhen. Power supply structure continued to optimize in the 2013-2017 period: the share of coal-fired power generation in Shenzhen

4. cities with a population of more than 10 million people.

decreased from 46.5% to 39.1%, and the share of natural gas-fired power generation increased from 53.7% to 60.9%; total carbon emissions from coal-fired power generation decreased by 0.5 Mtce. Carbon intensity of coal-fired power generation in Shenzhen, which was already leading the nation among power generators of the same type, further dropped by 2.5%, and carbon intensity of natural gas-fired power generation dropped significantly by 8.9%, as a result of which the overall carbon intensity of the power generation sector went down by approximately 10%. Meanwhile, the average carbon intensity for manufacturing enterprises covered by the carbon trading system decreased by 34.8% from 0.43 tCO_2/RMB 10,000 to 0.29 tCO_2/RMB 10,000. Within the manufacturing industry covered by the carbon trading system, the share of industrial value-added for the five sub-industries with the lowest carbon intensities (e.g., computer communication and electronics manufacturing, pharmaceutical manufacturing and machinery manufacturing) grew from 88.8% in 2013 to 92.1% in 2017; its counterpart for the five sub-industries with the highest carbon intensities (e.g., metal surface treatment and electroplating, circuit board, rubber and plastic manufacturing) decreased significantly. Regulation for carbon emissions and stricter environmental standards accelerated the phase-out or upgrade of backward, lower-end production capacity. In the 2013-2017 period, more than 20 enterprises covered by the carbon emissions trading program were shut down or switched to production of other products due to their low value-added, high energy consumption and high pollution.

Box 2.1 Industrial waste heat recycling in Yinchuan City

Using recycled waste heat in urban housing can reduce carbon emissions and improve air quality concurrently. The Ningxia Hui Autonomous Region plans to take advantage of its large Eastern Ningxia Energy Chemical Industry Base and transfer waste heat through its *East Heat for the West* central heating pipe network, which is currently under construction. After the completion of the first and second phases of the project, more than 80 million square metres of housing serving a population of about 1.5 million in Yinchuan City will benefit from the recycled heat from power plants in eastern Ningxia. It is estimated that the project will help reduce the city's annual coal consumption by 1.3 Mtce, reduce energy costs by RMB 500 million and CO_2 emissions by approximately 2 million tonnes (DRC of Yinchuan, 2019).

Guided by the principle of green development, Shenzhen fulfilled the goals of substantial decrease in carbon intensity and significant improvement of air quality, while achieving economic growth of higher quality and higher competitiveness. Shenzhen has made a successful attempt to take on a sustainable path with harmonious, balanced development of the economy, society and the environment.

2.3.3 National pilot-city projects

China's central government has launched a large number of pilot projects aimed at promoting city-level low-carbon development, increasing the share of energy from renewable sources and increasing cities' resilience to flooding and other impacts of climate change. These pilot projects have been used to test new tools and instruments for climate change mitigation and adaptation, which also contribute to a higher environmental quality.

2.3.3.1 Low-carbon cities

One major initiative is the low-carbon-city pilot project run by the NDRC, which launched three batches of pilot low-carbon cities in 2010, 2012 and 2017 involving a total of 78 cities (NDRC, 2017; 2012; 2010). The 10 key tasks of the low-carbon-city pilot project are:

1. developing and improving low-carbon development mechanisms;
2. promoting energy use optimization;
3. building a low-carbon industrial system;
4. promoting urban and rural low-carbon construction and management;
5. accelerating the development and application of low-carbon technologies;
6. forming green and low-carbon lifestyles and consumption models;
7. promoting innovation in development models, institutional design and technology;
8. strengthening capacity building;
9. providing institutional support for low-carbon pilots; and last but not least,
10. setting models for the low-carbon development for other cities.

In selecting the three batches of pilot cities, the state considered different types of cities in central, eastern and western China and paid particular attention to a variety of local low-carbon initiatives (Wang et al., 2013). Dunhuang City in Gansu Province, for example, developed carbon neutral projects; Qinghai Province's Xining City explored a carbon credit system for its residents; Ankang City in Shaanxi Province explored carbon-credit ecological compensation and low-carbon industry poverty alleviation mechanisms; and Yinchuan City in Ningxia Hui Autonomous Region plans to take advantage of its large energy-chemical industry to recycle waste heat for rural housing (Box 2.1). Seventy-two out of the 78 low-carbon pilot cities announced that their CO_2 emissions would peak by around 2020 or 2025. All three batches of low-carbon pilot cities achieved reductions in both CO_2 and $PM_{2.5}$ emissions between 2010 and 2015 (Chen and Zhuang, 2018).

2.3.3.2 Renewable energy pilot cities

China needs to increase its share of power generation from renewable sources and nuclear power to more than 40 per cent of the total power generation by 2030 (Cai *et al.*, 2018). Use of energy from renewable sources is not only crucial for climate change mitigation, but also plays a key role in pollution control and health protection (Cai *et al.*, 2018). In order to increase the penetration of energy from renewable sources and improve its consumption, the NEA launched the first batch of 89 renewable energy pilot cities and industrial parks (NEA, 2014) as well as a number of high-proportion renewable energy pilot counties (BJX Power, 2016, 2018).The pilot cities and industrial parks aim to explore innovative business models for renewable energy development, emphasizing the decisive role of the market and providing incentives for various investors and buyers. Every pilot project has set its own target and development pathway. Datong City in Shanxi Province, for example, replaced more than 1 Mtce of coal supply with renewable energy in 2015, building distributed solar photovoltaics, large-scale photovoltaic power stations and distributed wind power and biomass power stations (NEA, 2014). The aim of establishing high-proportion renewable energy pilot counties is to explore production and consumption mechanisms for high small-scale renewable penetration, providing local experience for achieving high national-scale renewable energy penetration in the future. The NEA also plans to launch pilot projects to seek systematic solutions to complex, low-carbon, safe, efficient energy production and consumption (China Business News, 2019).

2.3.3.3 Sponge and adaptation pilot cities

To improve cities' resilience to water inundation, flooding and climate change, the State Council issued the *Guidelines on Promoting the Construction of Sponge Cities* and launched 30 sponge city pilots in 2015 (State Council Office, 2015). Two years later, the NDRC and the MOHURD issued the *Notice on the Pilot Project of Climate-Adaptive Urban Construction* and launched 28 city pilots (NDRC and MOHURD, 2017). The purpose of the Sponge City Pilot Project is to enhance cities' resilience to urban waterlogging through integrated approaches, considering the full urban water cycle as well as the anthropogenic and ecological demand

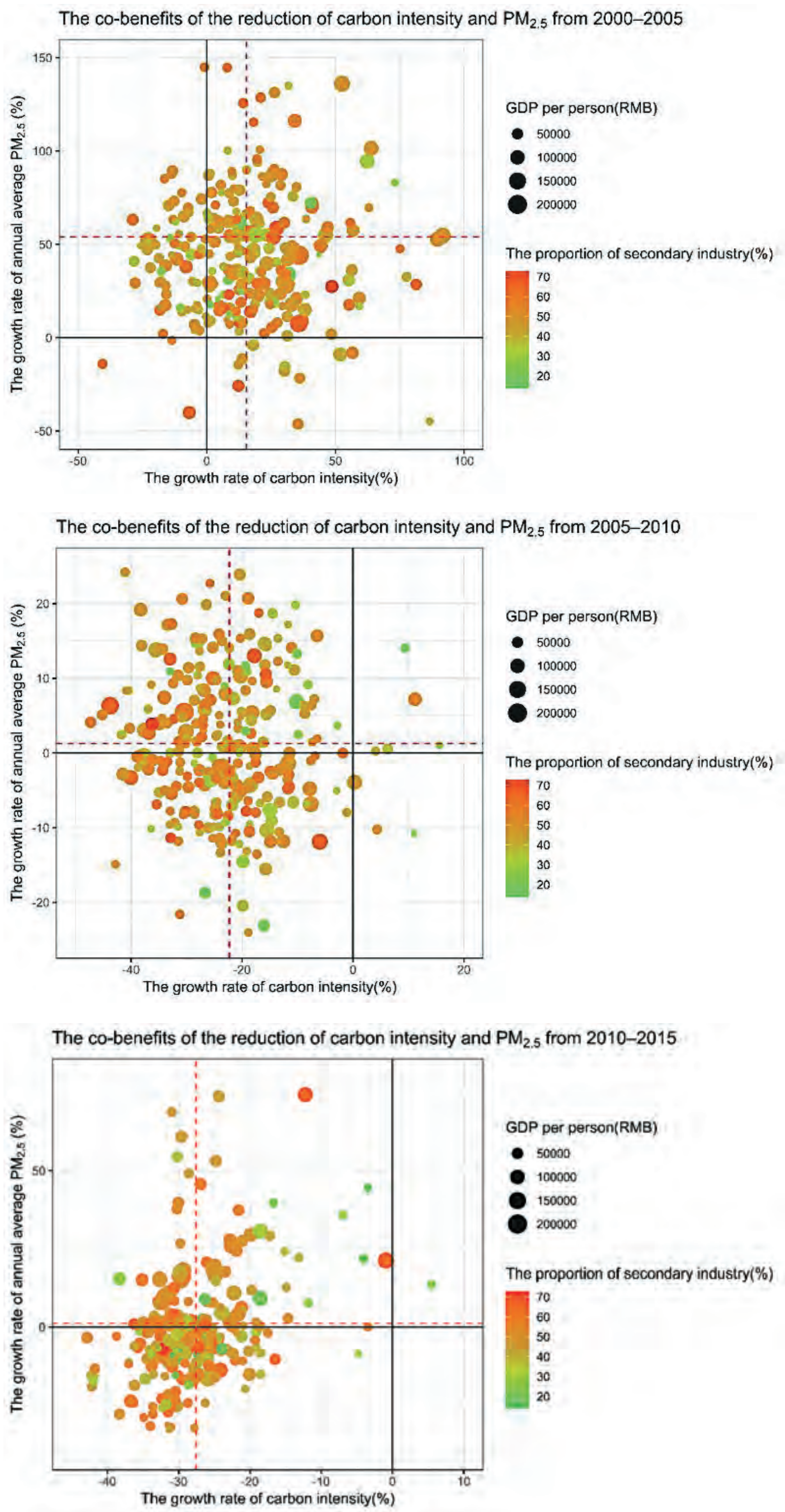

Figure 2.4 Carbon intensity and $PM_{2.5}$ concentrations in China's 286 Cities, 2000–2015[5]

for water in the cities (Wang *et al.*, 2018). The construction of sponge cities in recent years has had positive results. The Chuanzi River in the urban area of Changde City, for example, was previously a black, odorous river channel, eliciting many complaints from local residents. Since the city became a pilot sponge city, the municipal government has taken comprehensive measures including river regulation and storage capacity improvement, flow management and water purification, greatly improving the ecology and environment of the river and increasing real-estate values in neighbouring areas (State Council Office, 2015).

Learning from the experience of the Sponge City Pilot Project, the climate change adaptation city pilots focus on not only water management, but also urban infrastructure design and construction standards to cope with extreme weather and climate events such as extremely high temperatures in summer, freezing storms in winter, droughts and urban flooding. In addition, climate change adaptation city pilots attempt to strengthen the construction of monitoring and alarm platforms for climate change and meteorological disasters, data collection and big data applications. Moreover, the cities aim to strengthen climate disaster management, improve urban emergency response capacity and develop a climate-resilient regime

5. Secondary industry, sometimes known as the production sector includes all branches of human activities that transform raw materials into products or goods. Compared to primary industry and tertiary industry, secondary industry consumed more energy and emits more CO_2 and air pollution.

Table 2.3 Overview of the seven carbon-trading pilots in China

	Launch date	Accumulated transaction amount, 31 July 2019 (mt)	Accumulated transaction turnover, 31 July 2019 (RMB million)
Guangdong Province	December 2013	112.30	1,588.80
Hubei Province	April 2014	322.19	7,452.12
Beijing	November 2013	29.69	642.02
Chongqing	June 2014	8.91	32.99
Shanghai	November 2013	36.76	443.21
Shenzhen	June 2013	62.50	1,795.60
Tianjin	December 2013	6.83	89.90

Note: Excluding first-class market transactions (quota auctions).

involving multiple stakeholders including the government, enterprises, communities and residents. Hefei City in Anhui Province, for example, built a comprehensive monitoring and alarm system for climate change and meteorological disasters consisting of 256 new monitoring stations with an average inter-station distance of 6.7 kilometers. The three-dimensional integrated meteorological-disaster monitoring network covers 100 per cent of streets and townships within its jurisdiction. The Meteorological Bureau of Shihezi City in Xinjiang Uygur Autonomous Region provided technical support and meteorological data services to improve the city's urban planning and experimented with real-life monitoring of cotton growth and peach quality, collecting necessary data to support the decision making for climate adaptation during its urban development (NDRC and MOHURD, 2017).

2.3.4 Results from pilot cities

Through regional co-governance, national pilot projects and local co-governance policy innovation, progress has been made in China's environmental and climate co-governance. An analysis of China's 286 cities in the 2000–2015 period reveals an increasing trend of joint reductions of carbon intensity and $PM_{2.5}$ concentration (Figure 2.4) (Center for Climate Change and Environmental Policy , 2018; van Donkelaar et al., 2018). Between 2000 and 2005, 72 per cent of these cities witnessed coupled increases in carbon intensity and $PM_{2.5}$ concentration, and only three, Heze, Tongchuan and Yulin, had joint decreases. From 2005 to 2010, 45 per cent of the cities achieved coupled decreases in carbon intensity and $PM_{2.5}$ concentrations, while 48 per cent experienced a decrease in carbon intensity but an increase in $PM_{2.5}$ concentrations. From 2010 to 2015, 58 per cent of the cities achieved joint decreases in carbon intensity and $PM_{2.5}$ concentrations, an increase of 13 per cent over the previous five-year period. However, 41 per cent of the cities still experienced a decrease in carbon intensity and an increase in $PM_{2.5}$ concentrations, indicating a need to further tighten controls on fossil-fuel consumption and end-of-pipe pollutant emissions in other sectors.

2.4 China's carbon trading market

In October 2011, China launched its pilot carbon market in two provinces, Guangdong and Hubei Provinces, and five cities, Beijing, Chongqing, Shanghai, Shenzhen and Tianjin. These seven pilot regions have been trading on the market since June 2013 (Table 2.3). As of May 2019, trading in these seven pilots had covered more than 20 industries, including power generation, cement, iron and steel, and chemical production. Nearly 3,000 key emitting entities participated in trading, with an accumulated turnover of almost 580 million tonnes of CO_2 or just more than RMB 12 billion.

In December 2017, China officially launched its national carbon-trading programme, which is expected to cover an estimated volume of more

Table 2.4 Measures for co-governance in the power industry

Category	Measures
Cap CO_2 emissions	Carbon market
Source control	Promote the deployment of energy from renewable sources and nuclear power
	Coal pre-combustion treatment
	Encourage importation of clean electricity from other provinces
	Optimize the structure of coal-fired power units – develop large coal-fired power units and phase out obsolete capacity
	Promote the deployment of combined heat-and-power units
Energy efficiency improvement	Promote advanced technologies
	Retrofit energy conservation technology
	Resource recycling – for example, waste heat recycling
System optimization	Coal plant flexibility retrofit, intelligent scheduling
	Full process optimization, information management

Source: Gu *et al*., 2016; Wang, 2015; Wang et al., 2015; Hou and Shi, 2014; Mao *et al*., 2012.

than 3 billion tonnes of CO_2, making China the largest carbon market in the world. The national carbon market takes fossil fuel-based power generation industry as a starting point and will expand to others, including the chemical, petrochemical, iron and steel, non-ferrous metals, building materials, paper and aviation industries step by step. The estimated covering volume will account for approximately 45 per cent of the country's total CO_2 emissions.

The carbon trading pilot programme has generated synergistic benefits including enhancing the development quality of local economies, promoting energy conservation and emissions reductions, raising awareness of low carbon transformation, improving carbon-asset management capacity, and expanding financing channels for research and development in low-carbon technology and low-carbon projects. Meanwhile, the carbon market has incentivized the development of supporting services such as emissions verification, carbon accounting, carbon auditing, carbon-assets management, carbon financing, and carbon trading, all of which have created new employment opportunities.

China's carbon market pilot has also created synergies for ecological and environmental protection and poverty alleviation. Agricultural and forestry projects in poverty-stricken areas in Hubei Province, for example, have generated a total income of RMB 12.78 million by trading on the carbon market. In particular, the 55 household biogas projects traded on the carbon market have promoted the application of clean energy in rural areas while a bamboo carbon-sink project has helped alleviate poverty in mountainous areas of Hubei Province.

2.5 Sectoral action: electricity generation

The power industry, the largest source of carbon emissions in China, plays a crucial role in the country's low-carbon energy transformation. In 2018, China's power industry generated 6,994 terawatt hours (TWh) of electricity, approximately one quarter of the world's total electricity generation. In 2016, power generation and heat supply accounted for more than 40 per cent of China's energy-related carbon emissions. Although China's electricity consumption has continued to grow, carbon emissions in the power sector have generally stabilized since 2013, despite slight increases in 2017 and 2018, due to the rapid growth of clean power generation and increased efficiency of thermal power units. The growth of carbon emissions in the power sector has been much slower than that of electricity consumption and generation.

Electricity generation accounts for approximately 50 per cent of coal consumption in China; therefore, the power industry has always been a major focus of energy conservation and emissions reduction policy. Starting from the 11th FYP period, the Chinese government has strengthened the synergetic management of energy conservation and pollution reduction in response to increasingly serious environmental problems. For instance, the NDRC and NEA have issued the *Medium and Long-Term Development Plan for Renewable Energy* and the *Notice on Speeding-up the Shutdown of Obsolete Coal-fired Power Units*. China's State Environmental Protection Agency (later upgraded to the MEE) issued the *11th Five-Year Plan for Sulphur Dioxide Control in Existing Coal-fired Power Plants* and comprehensively promoted energy conservation and emissions reduction in the power industry.

As a result of various policy measures, the power industry has made substantial progress in energy conservation and pollution reduction, generating significant co-benefits of CO_2 emissions reduction. According to the China Electricity Council (CEC), the share of SO_2 emissions from the power industry fell from 51 per cent in 2005 to 9.7 per cent in 2016, and the share of NO_x emissions from 54.9 per cent in 2005 to 8.7 per cent in 2016. At the same time, the power industry reduced CO_2 emissions by 13.7 billion tonnes in the 2006–2018 period relative to 2005. The potential for further reductions in CO_2 emissions through traditional energy-saving and retrofitting energy-efficient technologies is very limited. The way forward is to shift from conventional pollution control and energy efficiency to CO_2 emissions mitigation (Wang, 2019).

Studies have shown that source control, energy efficiency and system optimization measures have significant co-benefits for CO_2 emission reduction whereas end-of-pipe control measures such as flue gas desulphurization and denitrification, generate negative impacts on CO_2 emissions. More stringent SO_2 pollutant control policies for coal-fired power generation and the steel sector, for example, will increase coal use for desulfurization, and the desulfurization processes will lead to higher CO_2 emissions (Gu, 2016). This demonstrates the importance of conducting multi-criteria impact analyses of specific policies and seeking more effective and integrated approaches. Table 2.4 provides a list of measures for effective co-governance of climate and the environment in the power industry.

The specific co-governance policies and measures taken by the Chinese government include the following:

Promote the deployment of energy from renewable sources and nuclear power: the *Renewable Energy Law* and the feed-in tariff effectively facilitated the deployment of energy from renewable sources in China. The nuclear power industry is committed to the adoption and research and development of new technologies. As a result, the proportion of installed capacity contributed by non-fossil energy increased from 24.3 per cent in 2005 to 40.8 per cent in 2018, and the proportion of non-fossil power generation increased from 18.2 per cent in 2005 to 30.9 per cent in 2018.

Optimize the structure of coal-fired power generating units: in 2005, small coal-fired power, those generating units of 100 MW or less, in total 115 gigawatts (GW), accounted for 29.4 per cent of China's total coal-fired power generation capacity. These small units produced 35 per cent of China's total SO_2 emissions and 52 per cent of total smoke and dust emissions. The Chinese government has decided to replace small coal-fired power generating units with larger, more efficient ones. In 2007, the *Notice on Speeding Up the Shutdown of Obsolete Coal-fired Power Units* was promulgated. By the end of 2016, China had shut down 110 GW capacity from small coal-fired units, equivalent to 1.2 times the installed capacity of Germany (China Electricity Council, 2017). Meanwhile, the capacity and performance of newly built coal-fired power generating units have continued to improve. The proportion of large coal-fired power units of 300 MW or above reached 80.1 per cent in 2018 (China Electricity Council, 2018). Although the shutdown of small units has produced significant environmental benefits, these came at the cost of enormous economic losses and unemployment.

Promote the deployment of combined heat and power (CHP) units: the environmental and climate change impacts of CHP units are less than those of conventional industrial and heating boilers. The Chinese government encourages the replacement of coal-fired heating boilers with CHP units. The share of total installed capacity of CHP units increased from 17.8 per cent in 2005 to 43.6 per cent by the end of 2018 (Wang, 2019).

Provide fiscal support for retrofitting energy-saving technologies: the Chinese government has established a special fund to support the deployment of industrial energy-saving technologies and the development of energy-saving service industry. Energy-saving technologies such as steam turbine passage flow, frequency conversion retrofitting of pumps and fans, and plasma ignition have been widely promoted (Wang, 2015). Between 2006 and 2014, the central government's subsidy for energy conservation technological retrofitting in the industrial sector reached RMB 57.2 billion (US$ 8.5 billion)[6].

References:

Beijing Environmental Protection Bureau (Former). 2014. *Beijing officially publishes the research results of $PM_{2.5}$ source apportionment analysis*. http://sthjj.beijing.gov.cn/bjhrb/index/tpxw/606141/index.html [Chinese] (accessed 27 August 2019).

Beijing Municipal Commission of Development and Reform. 2018. *Beijing energy development report 2017*. Beijing Energy Conservation and Environmental Protection Center [Chinese].

Beijing Municipal Ecological Environment Bureau. 2018. *A new round of new scientific research results of source apportionment analysis*. http://sthjj.beijing.gov.cn/bjhrb/xxgk/jgzn/jgsz/jjgjgszjzz/xcjyc/xwfb/832588/index.html [Chinese] (accessed 27 August 2019).

BJX Power. 2016. *National energy administration supported the establishment of national demonstration counties of high-proportion renewable energy in Anhui Province*. http://news.bjx.com.cn/html/20160118/702244.shtml [Chinese] (accessed 27 August 2019).

BJX Power. 2018. *Program of Work of the Establishment of a National Demonstration County of High-proportion Renewable Energy in Jinhu, Jiangsu: To Reach Photovoltaic Installed Capacity of 500MW and above by 2020*. http://guangfu.bjx.com.cn/news/20180820/922052.shtml [Chinese] (accessed 27 August 2019).

Center for Climate Change and Environmental Policy, Chinese Academy for Environmental Planning. 2018. CITYGHG. http://www.cityghg.com/index.html (accessed 27 August 2019).

Cai W., Hui J., Wang C., Zheng Y., Zhang X., Zhang Q. and Gong, P. 2018. The Lancet countdown on $PM_{2.5}$ pollution-related health impacts of China's projected carbon dioxide mitigation in the electric power generation sector under the Paris Agreement: a modelling study. *Lancet Planetary Health* 2(4), pp. 151-161. https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(18)30050-0/fulltext (accessed 9 September 2019).

China Electricity Council. 2017. *Report on Clean Development of Coal-fired Power Industry in China*. China Electric Power Publishing House [Chinese].

China Electricity Council. 2018. *The 2018 Annual Report on the Development of China's Power Industry*. http://www.cec.org.cn/yaowenkuaidi/2018-06-14/181765.html [Chinese] (accessed 27 August 2019).

Chen N. and Zhuang G. 2018. Effective Evaluation on Low-carbon Pilot Cities of China. *Urban Development Studies* 25(10), pp. 94-101.

China Business News. 2019. The Central Government Launched Comprehensive Pilot Projects of the Energy Revolution: Why Include Shanxi? http://www.sohu.com/a/317491988_114986 [Chinese] (accessed 27 August 2019).

Clean Air Asia. 2018a. *Breakthroughs: China's path to clean air 2013–2017*. http://www.allaboutair.cn/a/reports/2018/1227/527.html (accessed 27 August 2019).

Clean Air Asia. 2018b. *China air 2018. Air pollution prevention and control progress in Chinese cities*. http://allaboutair.cn/uploads/soft/181227/ChinaAir2018_EN.pdf (accessed 27 August 2019).

DRC of Yinchuan. 2019. Deepening Understanding by Learning, Thinking, Practicing and Comprehending, Brave in Shouldering Responsibilities with Fortitude and Resolution, Driving the High-quality Development and Reform in Yinchuan. http://fgw.yinchuan.gov.cn/fzgggz/hgjj/201903/t20190319_1319831.htm [Chinese] (accessed 28 August 2019).

Energy Statistics Division of National Bureau of Statistics. 2018. China Energy Statistical Yearbook 2013–2017. http://tongji.cnki.net/overseas/engnavi/HomePage.aspx?id=N2012020066&name=YCXME&floor=1 [Chinese] (accessed 28 August 2019).

Gu A., Teng F. and Feng X. 2016. Effects of pollution control measures on carbon emission reduction in China: evidence from the 11th and 12th Five-Year Plans. *Climate Policy* 18(2), pp. 1-12. https://doi.org/10.1080/14693062.2016 [Chinese] (accessed 27 August 2019).

Health Effects Institute. 2019. *State of Global Air 2019*. www.stateofglobalair.org (accessed 29 August 2019).

6. Based on data from the Annual Review of Low-carbon Development in China (2014), and China's Policy and Action on Climate Change released in 2013, 2014 and 2015.

Hou J. and Shi D. 2014. Driving factors for the evolution of carbon dioxide emissions from electricity sector in China. *China Industrial Economics* 6, pp. 44-56 [Chinese].

Mao X., Xing Y., Hu T., Zeng A. and Liu S. 2012. An environmental-economic analysis of carbon, sulfur and nitrogen co-reduction path for China's power industry. *China Environmental Science* 32(4), pp. 748–756 [Chinese].

MEP, NDRC, MIIT, MoF, MOHURD, NEA. 2013. Implementation Details for the Action Plan of the Prevention and Control of Air Pollution in Beijing, Tianjin, Hebei and the Surrounding Areas. http://www.mee.gov.cn/gkml/hbb/bwj/201309/t20130918_260414.htm [Chinese] (accessed 27 August 2019).

MEE. 2019. *2018 Reports on the state of the ecology and environment in China*. Ministry of Ecology and the Environment. http://www.mee.gov.cn/hjzl/zghjzkgb/lnzghjzkgb/201905/P020190619587632630618.pdf [Chinese] (accessed 27 August 2019).

MEP. 2016. 2015 Report on the state of the environment in China. Ministry of Environmental Protection. http://english.mee.gov.cn/Resources/Reports/soe/Report/201706/P020170614504782926467.pdf [Chinese] (accessed 27 August 2019).

National Bureau of Statistics. 2018. National Data. http://data.stats.gov.cn/easyquery.htm?cn=C01 [Chinese] (accessed 28 August 2019).

National Bureau of Statistics. 2019. *Series of reports on the achievements of economic and social development on the 70th Anniversary of the founding of New China*. http://www.stats.gov.cn/ztjc/zthd/bwcxljsm/70znxc/201907/t20190701_1673373.html [Chinese] (accessed 29 August 2019).

NEA. 2014. *Notice of National Energy Administration on Publication of the List of (the first batch of) Demonstration Cities (industrial parks) of New Energy Creation*. National Energy Administration. http://zfxxgk.nea.gov.cn/auto87/201402/t20140212_1762.htm [Chinese] (accessed 27 August 2019).

NDRC and MOHURD. 2017. *Notice on Printing and Distribution of Pilot Construction Projects of Climate-adaptive Cities*. http://www.ndrc.gov.cn/zcfb/zcfbtz/201702/t20170224_839212.html [Chinese] (accessed 27 August 2019).

NDRC. 2010. *Notice of National Development and Reform Commission on Launching of Low-carbon Provinces and Cities Pilot Projects*. http://www.ndrc.gov.cn/zcfb/zcfbtz/201701/t20170124_836394.html [Chinese] (accessed 27 August 2019).

NDRC. 2012. *Notice of National Development and Reform Commission on Launching of the Second Batch of Low-carbon Provinces and Cities Pilot Projects*. http://www.ndrc.gov.cn/gzdt/201212/t20121205_517506.html [Chinese] (accessed 27 August 2019).

NDRC. 2017. *Notice of National Development and Reform Commission on Launching of the Third Batch of Low-carbon Provinces and Cities Pilot Projects*. http://www.ndrc.gov.cn/zcfb/zcfbtz/201701/t20170124_836394.html [Chinese] (accessed 27 August 2019).

Research Group of Dispersed Coal Governance in China Coal Consumption Cap Plan and Policy Research Project. 2018. *China Dispersed Coal Governance Report 2017*. http://coalcap.nrdc.cn/pdfviewer/web/?15180772751437518672.pdf [Chinese] (accessed 27 August 2019).

Shenzhen Municipal Bureau of Statistics. 2018. *2019 National Economic and Social Development Statistical Bulletin*. http://www.sz.gov.cn/cn/xxgk/zfxxgj/tjsj/tjgb/201904/t20190419_16908575.htm [Chinese] (accessed 27 August 2019).

Shenzhen Transportation Bureau. 2018. *16,359 electric buses have been introduced and the franchised buses will also have become all electric*. http://jtys.sz.gov.cn/zwgk/jtzx/gzdt/gjdt_80994/201712/t20171228_10630454.htm [Chinese] (accessed 3 August 2019).

State Council Office. 2015. *Guidance of General Office of the State Council on Promoting the Construction of the Sponge Cities*. http://ghs.ndrc.gov.cn/zttp/xxczhjs/ghzc/201605/t20160505_800852.html [Chinese] (accessed 27 August 2019).

The People's Government of Hebei Province. 2018. *Work plan of eliminating production capacity of Iron and Steel industry in Hebei Province (2018–2020)*. http://www.sohu.com/a/239403485_100142901 [Chinese] (accessed 27 August 2019).

UN Environment. 2019. *A Review of 20 Years' Air Pollution Control in Beijing*. United Nations Environment Programme.

van Donkelaar, A., Martin, R.V., Brauer, M., Hsu, N.C., Kahn, R.A., Levy, R.C., Lyapustin, A., Sayer, A.M. and Winker, D.M. 2018. Global Annual $PM_{2.5}$ Grids from MODIS, MISR and SeaWiFS Aerosol Optical Depth (AOD) with GWR, 1998–2016. NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/H4ZK5DQS (accessed 27 August 2019).

Wang C., Guan D. and Cai Wenjia. 2019. Grand challenges cannot be treated in isolation. *One Earth* 1(1) (forthcoming).

Wang C., Lin J., Cai W. and Zhang, Z. 2013. Policies and practices of low carbon city development in China. *Energy & Environment* 24(7&8), pp. 1347-1372.

Wang C., Yang Y., Zhang J. 2015. China's sectoral strategies in energy conservation and carbon mitigation. *Climate Policy* S1, pp. S60–S80.

Wang J., Wan J., Wang Q., Su J., Yang L., et al. 2018. The development of China's ecological and environmental planning in forty years of reform and opening-up. *Chinese Journal of Environmental* Management10:5-18. [Chinese].

Wang, Z. 2015. The Current problems and policy suggestions on Low-carbon Development of China's Power Sector. *China Energy* 7, pp. 5-10 [Chinese].

Wang H., Mei C., Liu J. and Shao W. 2018. A new strategy for integrated urban water management in China: Sponge city. *Science China Technological Sciences* 61(3), pp. 317-329.

Wang, Z. 2019. Several key issues in the construction of China's national carbon market. Electric Power Decision-making and Public Opinion Reference. *Issues* 28 [Chinese].

Xie, Z. 2019. China's historical evolution of environmental protection along the reform and opening-up over the last forty years. *Chinese Journal of Environmental* Management 11(4), pp. 5–10 [Chinese].

Xu, L. 2019. Will air pollution control and carbon emission control affect economic development? See how Shenzhen does it. *The Paper*. https://www.thepaper.cn/newsDetail_forward_3650853 [Chinese] (accessed 27 August 2019).

Chapter 3 China's future strategies

3.1 Introduction

In 2012, the 18th National Congress of the Chinese Communist Party (NCCCP) put the construction of an ecological civilization at the centre of the Party's political ideology through the articulation of a vision of a Beautiful China. This vision is integrated into all aspects of economic, political, cultural and social construction. At the same time, the vision of a Beautiful China was included in the national 13th Five-Year Plan (FYP), which emphasizes the protection of the ecological environment while pursuing other socio-economic goals. In 2017, the 19th NCCCP put forward a two-stage development strategy for 2035 and 2050, in which the ecological environment will be fundamentally improved and the goal of building a Beautiful China will be basically attained by 2035, with new heights of ecological advancement reached by 2050.

China's goal of coordinated governance for climate change and the environment is intended to facilitate the realization of the vision of a Beautiful China as soon as possible. The previous chapter detailed the work that China has undertaken to establish a comprehensive framework of integrated co-governance of connected environmental and climate problems. Despite the tremendous success achieved so far, China continues to face substantial challenges in tackling air pollution, mitigating climate change and realizing the vision of a Beautiful China. Driven in large part by a surge in fossil-energy consumption, China has become the largest emitter of greenhouse gases in the world. At the same time, the annual average population-weighted $PM_{2.5}$ concentration in 2017 was 66 micrograms per cubic metre (μg/m^3), which, although down by about half since 2003, is still higher than the World Health Organization (WHO) guideline. This chapter focuses on China's medium- and long-term air quality and climate mitigation policies and commitments and highlight additional synergies and opportunities for co-governance to achieve the vision of a Beautiful China.

3.2 China's medium- and long-term goals for clean air

3.2.1 The evolution of China's air quality standards

China promulgated its first Environmental Protection Law (Trial) in 1979. This was followed by the first ambient air quality standard issues in 1982 (GB 3095-82), which was revised for the first time in 1996 (GB 3095-1996), amended in 2000 and revised again in 2012 (GB 3095-2012), following several rounds of consultation (Figure 3.1). The 1982 Ambient Air Quality Standards (GB 3095-82) covered only total suspended particulate matter (TSP), sulphur dioxide (SO_2), nitrous oxides (NO_x) and photochemical oxidants; the 1996 standards included more pollutants such as particulate matter with an aerodynamic diameter equal to or less than 10 micrometres (PM_{10}), ozone (O_3) and nitrogen dioxide (NO_2). The 2012 Standards added two more pollutant indicators: particulate matter with an aerodynamic diameter equal to or less than 2.5 micrometres ($PM_{2.5}$) concentrations and an 8-hour average concentration limit for O_3. The revisions to the air quality standard show that China's air pollution control strategy focuses not only on TSP, SO_2, and NO_2, but also $PM_{2.5}$

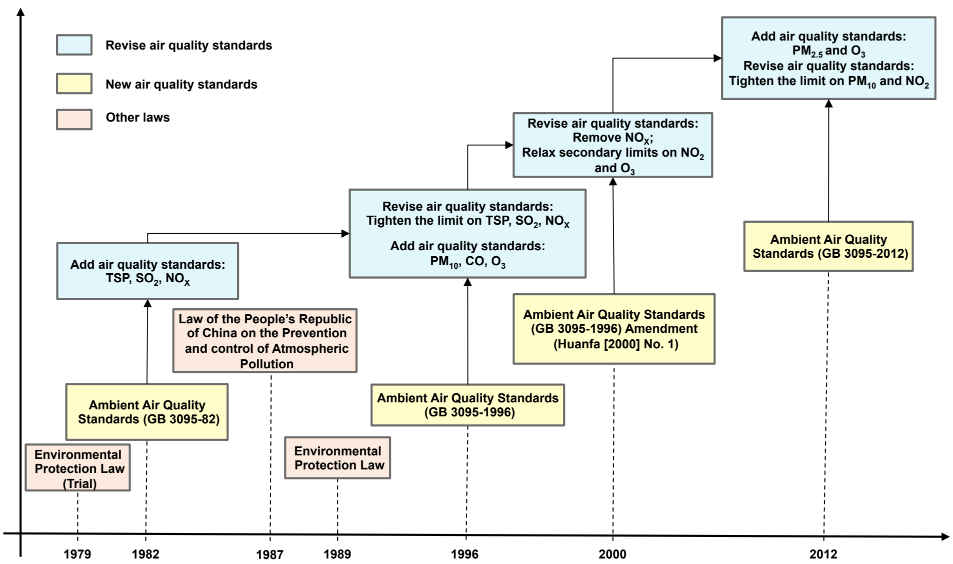

Figure 3.1 The evolution of China's air quality standards
Source: MEP Standards for Atmospheric Environment.
http://kjs.mee.gov.cn/hjbhbz/bzwb/dqhjbh/dqhjzlbz/[Chinese]

and O_3. The revisions were also incorporated in each FYP, which reflect increasing coordination between China's environmental policy and social and economic development.

In revising the ambient air quality standards, China drew on the experiences of many developed countries, regions and international organizations, including most prominently the United States of America, the European Union (EU) and the (WHO). The air quality standards are in line with China's current economic status and the characteristics of its atmospheric environmental pollution.

3.2.2 China's potential medium- and long-term clean air goals

China's medium- and long-term goals for clean air are important components of its vision of a Beautiful China. Following the adoption of the two-step strategy for 2035 and 2050 of the 19th NCCCP, a quantitative index will be researched and formulated so that the "*ecological environment will be fundamentally improved and the goal of building a Beautiful China will be basically attained,*" and "*new heights of ecological advancement attained.*" He Kebin, professor of the School of Environment at Tsinghua University

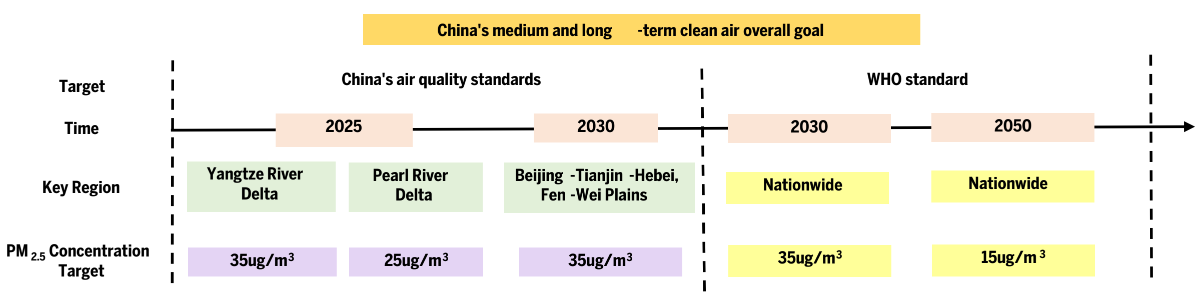

Figure 3.2 China's medium- and long-term clean air targets
Source: Tsinghua University, 2017

and principal investigator on this index, put forward potential clean medium- and long-term air goals which could maximize health and other developmental benefits.

China's medium- and long-term targets for clean air are divided into two phases (Figure 3.2) (Tsinghua University, 2017). The first phase target is to reach the $PM_{2.5}$ standard of 35 μg/m³ by 2030 in major cities and areas, and the second phase target is to reach 15 μg/m³ by 2050. At the same time, air quality targets and the corresponding deadlines have been established for the four key regions, the Beijing-Tianjin-Hebei region and surrounding areas, the Yangtze River Delta, the Fen-Wei Plains and the Pearl River Delta, which take into account their different stages of development. The $PM_{2.5}$ concentration target for the Pearl River Delta region in the first phase is 25 μg/m³ by 2025. In the Yangtze River Delta region, the average concentration of $PM_{2.5}$ in 41 cities including Shanghai and cities in Jiangsu, Zhejiang and Anhui Provinces was 44 μg/m³ in 2018, higher than the national standard. Therefore, the first-phase target for the region is to reach the national standard by 2025. Similarly, the first-phase target in the Fen-Wei Plains and Beijing-Tianjin-Hebei and surrounding areas is to reach the national standard by 2030, as their current air quality, with average $PM_{2.5}$ concentrations in 2018 of 58 and 60 μg/m³ respectively, is far from the national standard.

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, including most prominently its *Air Pollution Prevention Action Plan* (SCPRC, 2013), the *Three-Year Action Plan to Win the Blue-Sky Defense War* (SCPRC, 2017) and the *Comprehensive Work Plan for Energy Saving*

Table 3.1 Action to achieve clean air goals under different sectors

Sector	Action
Power	• control the scale of coal power; • accelerate the development of new and renewable energy; • reduce coal consumption per unit of power generation and increase the distribution of wind energy and solar power; • continue to promote the transition to ultra-low emissions technologies in coal-fired power plants.
Industry	• adjust the industrial structure, optimize the distribution of industry, control industries with over-capacity, eliminate obsolete production capacity, retrofit heavily polluting enterprises; • increase investment in research and development in energy intensive industries and improve their energy efficiency; • promote desulphurization, denitrification and dust removal in key industries, such as steel and cement, and strengthen end-of-pipe treatment.
Transport	• optimize the transport structure by transferring large cargos from road to rail transport; • raise emissions standards for cars and off-road machinery; • improve compliance and enforcement of vehicle emission standards; • accelerate the replacement of vehicles certified to outdated emissions standards.
Residential	• continue to promote clean heating in northern China; • replace coal with electricity and natural gas as heating fuel in rural areas; • accelerate the retrofit and upgrade of coal-fired boilers for central heating in urban areas; • control the ammonia emissions from dust and agriculture, volatile organic compounds (VOC).

and Emission Reduction (SCPRC2018) (Table 3.1).

The action to achieve clean air targets will require the support of relevant policies. It is, for example, necessary to formulate and revise emission standards for pollutants in relevant industries and strictly control pollutant emissions from related enterprises. It is also necessary to formulate fiscal and other policies that make full use of both market mechanisms and administrative measures. At the same time, the relevant legislation on pollutant control needs to be strengthened to prevent environmentally damaging action.

3.3 China's commitments and activities to climate mitigation

3.3.1 China's international commitments to climate change mitigation

During the fifteenth session of the Conference of the Parties (COP 15) in Copenhagen in 2009, the Chinese government put forward an independent emissions reduction target to reduce national carbon dioxide (CO_2) intensity by 40–45 per cent compared to 2005 levels by 2020; to increase the share of non-fossil energy in China's primary energy mix to 15 per cent; and to increase forest stocks by 1.3 billion m^3 compared to 2005 levels. In 2016 the Chinese government submitted its Nationally Determined Contribution (NDC) mitigation pledges under the 2015 Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC). In its NDC, China pledged to reduce CO_2 intensity by 60–65 per cent compared to 2005 levels by 2030, to increase the share of non-fossil energy in the national primary energy consumption to 20 per cent and to reach peak CO_2 emissions around 2030 or earlier.

3.3.2 Domestic policy measures and their effects in addressing climate change

In order to fully implement the 2020 emission reduction commitment, the Chinese government established national climate targets in its FYP. In the 11th FYP, a binding target for reducing the national energy intensity by about 20 per cent was set to reverse the rising trend of energy intensity during the 10th FYP period. The 12th and 13th FYPs set binding targets for the reduction of energy intensity by 16 and 15 per cent, respectively, and reductions of CO_2 intensity by 17 and 18 per cent.

By the end of 2018, the decline of China's CO_2 intensity had exceeded the upper limit target of 45 per cent compared with 2005, and the share of non-fossil energy in China's primary energy reached 14.3 per cent. By 2020, CO_2 intensity is expected to drop by more than 50 per cent compared to 2005 levels, and the share of non-fossil energy in national primary energy is likely reach above 15 per cent, exceeding the emission reduction commitments made at the COP 15.

The pre-2020 emissions reduction achievements will lay a solid foundation as China implements its 2030 NDCs. Based on the anticipated trend of economic growth and the optimization of the energy structure, Wang and He (2019) pointed out that the national carbon intensity in 2030 would be more than 65 per cent lower than in 2005, and CO_2 emissions would peak before 2030, given the following assumptions: the average annual growth of GDP falls back to around 4.0–5.0 per cent by 2030, the annual declining rate of energy intensity remains at 3.0–3.5 per cent, and the shares of coal, oil, natural gas and non-fossil energy in China's primary energy consumption are 46, 15, 17 and 22 per cent respectively. The peak level of CO_2 emissions would be lower if the downward trend in economic growth and the growth of the low-carbon energy structure are more significant. Through effective implementation of the 14th and 15th FYPs, China is likely to further strengthen its 2030 NDC.

By the end of 2020, China will fully demonstrate and put forward a low-carbon development strategy for significant carbon reductions by the middle of this century. Formulating a medium- and long-term strategy for greenhouse gas emissions reduction is not only China's response to international pressures on global warming, but also a strategic

Photograph credit: UNEP

choice under domestic constraints of resources and the environment. Under the guidance of a long-term low-emissions development strategy, China will avoid the lock-in effect of a carbon-intensive infrastructure; accelerate the construction of a clean, low-carbon energy system; promote research and development and industrialization for such advanced technologies as hydrogen, energy storage, smart grids, and CO_2 capture and storage; and foster low-carbon lifestyles and consumption patterns.

3.4 China's medium- and long-term strategy for co-governance

Coordinated governance of climate and the environment in the medium-and long-term can bring significant synergies for China. Historically, air pollution control policies around the world and in China have focused primarily on end-of-pipe controls for pollutants, such as diesel particulate filters to reduce emissions of particulate matter from diesel engines. However, end-of-pipe control measures often do not reduce emissions of greenhouse gases and in some cases may even increase them.

On the other hand, climate mitigation policies typically focus on large-scale changes in energy, transport and industrial systems such as replacing fossil fuels used in power plants with new and renewable energy. Such systemic changes are necessary to meet long-term climate targets and have the co-benefit of eliminating co-emitted air pollutants. As a result, adjustment of the energy, industrial and transport structures will become the new focus of coordinated emissions reduction. Adjusting these structures requires years and decades, however, making it difficult to reduce air pollution in the near-term.

In China, if the emissions control policies are adopted to reduce SO_2 and NO_X by 8 and 10 per cent every five years during the 2015–2050, respectively, then these policies will achieve synergistic CO_2 emissions reductions of up to 20 billion tonnes by 2050 (Nam *et al.*, 2013). If China achieves its full range of NDCs by 2030, SO_2, NO_X and $PM_{2.5}$ emissions will also be reduced by 78.85, 77.56 and 83.32 per cent, respectively (Yang *et al.*, 2017). Economic policies such as a carbon tax can provide positive feedbacks to energy consumption and technological upgrades and bring about coordinated reductions of pollutants. If decreasing rate of China's carbon intensity is reduced by 4 per cent per year in the 2015–2030 period under a carbon tax, it will result in a 25 per cent reduction in SO_2 and 19 per cent reduction in NO_x emissions compared to a carbon-tax-free scenario. The national population-weighted average $PM_{2.5}$ concentrations will also fall by 12 per cent, avoiding about 94,000 premature deaths (Li *et al.*, 2018).

To achieve co-governance in the medium-and long-term, it is important to comprehensively consider the timelines for clean air and carbon emissions reduction targets and propose an overall plan for coordinated governance. To realize the clean air target before 2030, considering the severity of China's air pollution and the pressure of environmental governance, environmental governance should be taken as the starting point, which will help identify the carbon emission reduction targets. After 2030, China's environmental problems are expected to have fundamentally improved. China must also assume the responsibility for carbon emissions reduction in line with its stage of development, and it is necessary to use climate control to drive further improvements in the domestic environment. All in all, the path for the coordinated management of climate and the environment in the medium- to long-term is "*the blue sky drives carbon mitigation before 2030, and carbon mitigation drives the blue sky after 2030*".

3.5 Achieving climate and environmental synergies in China's energy sector

In 2018, China's primary energy consumption reached 3.25 billion tonnes of oil equivalent (toe), 59 per cent of which came from coal followed by 18.9 per cent from oil and 7.8 per cent from gas (NBSC, 2019). Fossil fuels represent a significant proportion of China's primary energy consumption, and the resulting emissions of greenhouse gases and air pollutants including NO_x, $PM_{2.5}$ and CO_2 have become a major challenge for the environment and climate. Therefore, synergetic action in the energy sector is important to achieve both environmental and climate goals in China.

3.5.1 Current co-governance policies and measures

In China, energy consumption is the main source of atmospheric pollutants and greenhouse gas emissions. Rapid industrialization and urbanization have led to a rapid increase in total energy consumption in China from 1.03 billion toe in 2000 to 3.25 billion toe in 2018, an average annual growth rate of 6.6 per cent. China's 13th FYP introduced many policies and measures to optimize the structure of its energy and industrial sectors, and requires "*the shares of non-fossil fuels, natural gas and coal in China's total primary energy consumption in 2020 reach more than 15 per cent, over 10 per cent and below 58 per cent respectively*".

China's energy consumption intensity peaked in 2005, followed by a downward trajectory as a result of its climate policies. In the 2005–2017 period, energy intensity decreased by 39.6 per cent at an average annual rate of 4.3 per cent. These improvements have been brought about through continuous innovations in energy efficiency technologies and improved structure of China's national energy mix. Between 2008 and 2018, the national average thermal efficiency for coal-fired power generation, including auxiliary power, dropped from 345 grams of coal equivalent per kilowatt hour (gce/kWh) to 308 gce/kWh. Between 2000 and 2018, the share of natural gas and non-fossil energy in national energy consumption increased from 2.2 to 7.3 per cent and 7.5 to 14.3 per cent, respectively. At the same time, the share of coal fell from 72 to 59 per cent.

Since 2005, due to its coal cap policies, China's phase-out of small thermal power units has avoided more than 950 million tonnes of coal consumption, equivalent to saving RMB 616.9 billion. This translates into a reduction of approximately 15.18 million tonnes of SO_2 emissions and more than 2 billion tonnes of CO_2 emissions (Yang and Teng, 2018). China's energy transformation has effectively curbed the excessive growth in the emissions of energy-related pollutants and CO_2.

In 2017, the National Development Reform Commission (NDRC) issued the *Guidelines for Key Products and Services in the Strategic Emerging Industries (2016 Edition)* to restructure the energy sector and foster the steady growth of China's strategic emerging industries. From the perspective of implementation effects, the goals of energy and industrial restructuring will be exceeded. In terms of industrial restructuring, the value added of emerging industries above designated size increased by a year-on-year growth of 11 per cent in 2017, and the value added of high-tech manufacturing increased by 13.4 per cent, which together accounted for 12.7 per cent of the value added of industries above designated size.

In terms of energy efficiency improvement, in

2018 the NDRC announced a total of 260 energy-saving technologies in 13 industries in the *National Promotion Catalogue for Key Energy-Saving Low-carbon Technologies*. In 2017, the plan for *Circular Development Leading Action* was released, which provides guidance for accelerating the development of a circular economy. In 2017, the transport industry issued the *Implementation Plan for Promoting the Construction of Ecological Civilization in the Transportation Sector* and a guidance document entitled the *Opinions on Comprehensively Promoting the Development of Green Transportation*, which guide the investment in green transport infrastructure and promote the innovation of clean, efficient transport equipment and methods.

In order to accelerate the energy transition, China has, since 2014, implemented its five-in-one energy development strategy – energy consumption reform, energy production reform, energy technology reform, energy system reform and strengthened international cooperation on energy. Through conserving energy, improving efficiency, establishing multiple energy supply systems, promoting technological innovation, restructuring the energy market and a system of effective competition and making effective use of international energy resources, this strategy has raised public awareness of energy conservation and efficiency, which has effectively helped curb the rapid growth of energy consumption in recent years. It has also facilitated investment in research and development and expansion of green, low-carbon energy technologies, which in turn accelerate the decarbonization of China's energy mix. As key components of energy reform, energy conservation, improved energy efficiency and decarbonization of the energy mix will jointly reduce China's fossil-fuel consumption and improve China's air quality, laying a solid foundation for building a Beautiful China and enabling China to actively participate in global climate governance and fulfill its international commitments to emissions reduction.

3.5.2 Future co-governance policies and measures

The report to the 19th NCCCP proposed a national plan to basically realize socialist modernization[7] by 2035. By then, the environment will have fundamentally improved and the goal of Beautiful China met. The goal of achieving socialist modernization by 2035 and the 2030 NDC under the Paris Agreement of the UNFCCC essentially overlap.

In 2016, China promulgated its *Energy Production and Consumption Reform Plan (2016-2030)*, which proposes the establishement of a clean, low-carbon, safe, efficient and modern energy system by 2030. The new energy system is expected to significantly improve the quality of the environment; reduce the emission of major pollutants; effectively prevent water, soil, and air pollution; and promote the green and harmonious development of energy and the environment. The plan sets strict targets for capping China's total energy consumption in 2030 below 6 billion tonnes of coal equivalent (tce), with the share of electricity from non-fossil fuels reaching about 50 per cent in total electricity production, and non-fossil energy and natural gas reaching about 20 and 15 per cent in total primary energy consumption, respectively. The plan also sets ambitious goals and measures for controlling coal consumption to ensure a 60–65 per cent decrease of CO_2 intensity in 2030 compared to the 2005 level and make CO_2 emissions peak around 2030 or earlier. In 2030, the installed hydro, wind and solar power capacity will be more than 500 gigawatts (GW). The average annual decrease of CO_2 intensity will be more than 5 per cent, which could ensure that CO_2 emissions peak around 2030 with annual

7. The political report to the 18th NCCCP has charted a grand blueprint for bringing about a moderately prosperous society in all respects, accelerating socialist modernization, and achieving new victories for socialism with Chinese characteristics in new historic circumstances. It is a political proclamation and action plan with which the Party will rally and lead the Chinese people of all ethnic groups in marching along the path of Chinese socialism and complete the building of a moderately prosperous society in all respects. It guides the work of the current central leadership (Xi, 2014).

Photograph credit: CAEM

GDP growth of 4.0–5.0 per cent. Strengthening pollution prevention and control measures and implementing end-of-pipe treatments for fossil-fuel consumption also constitute a feasible roadmap for city clusters, such as the Beijing-Tianjin-Hebei region, to achieve their goal of reducing $PM_{2.5}$ concentration to 35 $\mu g/m^3$, the current emissions standard, by around 2030 (Tong *et al.*, 2019).

The report of the 19^{th} NCCCP also states that China will strive to achieve its second phase goal of socialist modernization[8] in the 2035–2050 period and build a strong, democratic, civilized, harmonious, beautiful and modernized socialist country by 2050. By then, people's living environment is expected to have improved fundamentally, and the vision of a Beautiful China achieved. Implementation of this long-term goal is consistent with the global effort to achieve significant decarbonization by the middle of the 21^{st} century.

Building a green, low-carbon modern energy system is an integral part of the roadmap for achieving these two goals. Such an energy system will play a critical role in achieving the synergetic goals of air quality improvement and greenhouse gas reduction. To date, the Chinese government has not yet promulgated a long-term energy development plan for 2050, but its *Energy Production and Consumption Reform Plan (2016–2030)* sketches an outline for China's 2050 energy reform and low-carbon development: by 2050 total energy consumption in China will be stabilized at below 6 billion tce; the share of non-fossil energy will exceed 50 per cent and the share of coal will fall below 20 per cent. Based on this rough estimate, CO_2 emissions in 2050 can be reduced by about 50 per cent compared to the emissions peak (He, 2018). At present, in order to implement the Paris Agreement's goal of limiting temperature rise to well below 2 °C above pre-industrial levels, China will work even harder to implement stricter policies for decarbonization and strive to build a zero carbon energy system based fully on new and renewable sources of energy as soon as possible. By that time, pollutants such as SO_2, NO_x and $PM_{2.5}$ will be more effectively controlled. A fully decarbonized energy system is the fundamental solution to China's target of reducing $PM_{2.5}$ concentrations to 15 $\mu g/m^3$ by 2050 (Li *et al.*, 2019).

3.6 Case studies in specific sectors in China

3.6.1 Electricity sector

The coal-fired electricity sector in China is a major source of greenhouse gases and air pollutants. Coordinated governance in the electricity industry mainly focuses on structural adjustment and efficiency enhancement of power generation. Structural adjustments mainly refer to decreasing the share of coal-fired power while increasing the share of power generation from new and renewable sources. Efficiency enhancement includes the upgrading of coal-fired power plants, shutting down small,

8.Second phase goal of socialist modernization: "modern socialist country; prosperous, strong, democratic, culturally advanced and harmonious – China has set the following goals for its future development: by 2020, it will double its 2010 GDP and per person income of urban and rural residents and realize a moderately prosperous society in all respects; and by the mid-21st century, it will have turned itself into a modern socialist country, prosperous, strong, democratic, culturally advanced and harmonious" (Xi, 2014).

outdated generating units and improving gross coal consumption in new, large generating units.

To increase power generation efficiency, China may increase the share of installed capacity contributed by large generating units of more than 600 megawatts (MW) to over 80 per cent of the total in 2030 by phasing out small, inefficient ones, which have operated for less than 40 years. Compared to the scenario in which small, inefficient generating units are eliminated after 40 years' service, an early phase-out of these units can reduce CO_2 and SO_2 emissions by approximately 5 and 25 per cent respectively (Tong *et al.*, 2018).

Through the optimization of the structure electricity generation and the enhancement its efficiency, the share of non-fossil fuel generated power will increase to 50 per cent in the total electricity generation in 2030. By then, CO_2 and SO_2 emission per unit of electricity will have fallen by a third compared to 2015 levels. If the capacity of solar photovoltaic power generation reaches 400 GW in 2030, CO_2 emissions will fall by 4.2 per cent, and premature deaths from air pollution by 1.2 per cent compared to the baseline scenario – a 2030 coal-intensive power sector projection developed by the International Institute for Applied System Analysis (IIASA) (Yang *et al.*, 2018). When the capacity of coal-biomass energy gasification system reaches 410 MW, CO_2 and $PM_{2.5}$ emissions will fall by 9.3 and 12 per cent, respectively (Lu *et al.*, 2019).

3.6.2 Industrial sector

China's industrial sector accounts for the majority of the nation's energy consumption and has the highest energy intensity among all economic sectors. Coordinated governance within the industrial sector involves two key components: reducing energy demand through technological upgrades and increasing the ratio of clean energy use through fuel substitution. According to the 2017 cement energy efficiency benchmarking, clinker energy efficiency of leading companies reached 95.7 kilograms of coal equivalent per tonne (kgce/t), fulfilling the 105 kgce/t target proposed in the *Building Materials Industry Development Plan (2016-2020)* three years ahead of schedule. This benchmarking indicates the large potential for energy-efficiency improvement in the cement industry.

Research shows that, with a demand for 640 million tonnes of steel in 2030, 190 million tonnes of steel scrap could be recycled if the recycling rate of steel scrap increases by 50 per cent, potentially reducing CO_2 emissions by 67.7 million tonnes compared to the baseline scenario of continuing the existing trends in China's steel sector without imposing any energy-saving or emission–reduction targets. In addition, emissions of SO_2, NO_2 and PM_{10} would fall by about 110,000, 20,000 and 30,000 tonnes, respectively. Moreover, the health and economic benefits of coordinated governance in the industrial sector are significant. Air pollution control could prevent about 28,500-71,000 premature deaths, equivalent to an avoided economic loss of US$ 386–854 million (Ma *et al.,* 2016).

3.6.3 Transport sector

In recent years, with the rapid growth of car ownership, particularly among the urban population, energy consumption in the transport sector has quickly risen, resulting in massive emissions of air pollutants and greenhouse gases. Energy efficiency improvement and structural optimization of the transport sector should be combined to reduce carbon emissions and improve environmental quality. Energy consumption per unit turnover of passenger highway transport, freight highway transport, water transport and civil aviation will decrease by 3, 7, 6 and 4 per cent every five years into the future, respectively. Moreover, the average annual per unit energy consumption of the private transport, railway and public transport sub-sectors will be reduced by 1, 0.1 and 0.1 percent, respectively. Optimization of the transport structure can be achieved by reducing the use of private vehicles and taxis, promoting public transport and non-fossil fuel vehicles and increasing the number electric trains. By 2050, compared to the baseline scenario in which energy efficiency and transport modes are maintained at the 2010 levels, improving energy efficiency and optimizing transport structure could reduce CO_2 emissions from the transport sector by 38 per cent and 35 per cent, respectively, and avoid about 120,000 and 102,000 premature deaths caused by air pollution, respectively (Liu *et al*., 2018).

3.6.4 Residential sector

Energy use in residential buildings imposes heavy pressure on China's environmental and climate governance. The key to coordinated governance of climate and the environment in this sector is to address the problem of massive use of scattered coal in the rural areas through fuel substitution. This involves replacing all solid fuels used in business activities in urban and rural areas with natural gas and replacing biomass fuels used for cooking in rural areas with liquefied petroleum gas (LPG) and wind power. Such fuel substitutions could benefit both air quality and human health. If these fuel substitutions were adopted between 2010 and 2030, premature deaths related to air quality would fall by 4 per cent, and premature deaths due to indoor air pollution by 31 per cent (Liu *et al*., 2018).

References:

He, J. 2018. New Idea on China's Long-term Strategy of Addressing Climate Change and Low-carbon Development for New Era. *Wuhan University Journal Philosophy and Social Science* 71(4), pp.13-21.

Liu, J., Kiesewetter, G., Klimont, Z., Cofala, J., Heyes, C., Schöpp, W., Zhu, T., Cao, G., Sanabria, A.G., Sander R., Guo, F., Zhang, Q., Hguyen, B., Bertok, I., Rafaj, P. and Amann, M. 2019. Mitigation pathways of air pollution from residential emissions in the Beijing-Tianjin-Hebei region in China. *Environment International* 125, pp. 236–244. https://doi.org/10.1016/j.envint.2018.09.059 (accessed 29 August 2019).

Liu, L., Wang, K., Wang, S., Zhang, R. and Tang, X. 2018. Assessing energy consumption, CO_2 and pollutant emissions and health benefits from China's transport sector through 2050. *Energy Policy* 116(C), pp. 382–396. https://doi.org/10.1016/j.enpol.2018.02.019 (accessed 29 August 2019).

Li, M., Zhang, D., Li, C-H., Mulvaney, K.M., Selin, N.E. and Karplus, V.J. 2018. Air quality co-benefits of carbon pricing in China. *Nature Climate Change* 8, pp. 398–403.

Li, N., Chen, W., Rafaj, P., Kiesewetter, G., Schoepp, W., Wang, H., Zhang, H., Krey, V. and Riahi, K. 2019. Air Quality Improvement Co-benefits of Low-Carbon Pathways toward Well Below the 2° C Climate Target in China. *Environmental Science and Technology* 53(10), pp. 5576-5584.

Lu, X., Cao, L., Wang, H., Peng, W., Xing, J., Wang, S., Cai, S., Shen, B., Yang, Q., Nielsen, C.P. and McElroy, M.B. 2019. Gasification of coal and biomass as a net carbon-negative power source for environment-friendly electricity generation in China. *Proceedings of the National Academy of Sciences of the United States of America* 116(17), pp. 8206–8213. https://doi.org/10.1073/pnas.1812239116 (accessed 29 August 2019).

Ma, D., Chen, W., Yin, X. and Wang, L. 2016. Quantifying the co-benefits of decarbonisation in China's steel sector: An integrated assessment approach. *Applied Energy* 162, pp. 1225-1237.

Nam, K.M., Waugh, C.J., Paltsev, S., Reilly, J.M. and Karplus, V.J. 2013. Carbon co-benefits of tighter SO_2 and NO_x regulations in China. *Global Environmental Change* 23(6), pp. 1648-1661.

National Bureau of Statistics of China (NBSC). 2019. *China Statistical Abstract 2019*. China Statistics Press. [Chinese]

NDRC. 2017. Guidelines for Key Products and Services in the Strategic Emerging Industries, 2016 edition. National Development and Reform Commission. http://www.ndrc.gov.cn/gzdt/201702/t20170204_837246.html [Chinese] (accessed 29 August 2019)

SCPRC. 2013. Notice of the General Office of the State Council on Issuing the Air Pollution Prevention and Control Action Plan. State Council of the People's Republic of China website. http://www.jingbian.gov.cn/gk/zfwj/gwywj/41211.htm [Chinese] (accessed 29 August 2019).

SCPRC. 2017. Notice of the Energy Saving and Reduction Comprehensive Work Plan during the 13th Five-Year Plan Period. State Council of the People's Republic of China. http://www.ndrc.gov.cn/gzdt/201701/t20170105_834501.html [Chinese] (accessed 29 August 2019).

SCPRC. 2018. Notice of the State Council on Issuing the Three-Year Action Plan for Winning the Blue Sky Defense Battle. State Council of the People's Republic of China website. http://www.gov.cn/zhengce/content/2018-07/03/content_5303158.htm [Chinese] (accessed 29 August 2019).

Tong, D., Geng, G., Jiang, K., Cheng, J., Zheng, Y., Hong, C., Yan, L., Zhang, Y., Chen, X., Bo, Y., Lei, Y., Zhang, Q. and He, K. 2019. Energy and emission pathways towards $PM_{2.5}$ air quality attainment in the Beijing-Tianjin-Hebei region by 2030. *The Science of the Total Environment* 692, pp. 361-370. https://doi.org/10.1016/j.scitotenv.2019.07.218 (accessed 29 August 2019).

Tong, D., Zhang, Q., Liu, F., Geng, G., Zheng, Y., Xue, T., Hong, C., Wu, R., Qin, Y., Zhao, H., Yan, L. and He K. 2018. Current Emissions and Future Mitigation Pathways of Coal-Fired Power Plants in China from 2010 to 2030. *Environmental Science and Technology* 52(21), pp. 12905–12914.

Tsinghua University. 2017. How to Reach Air Quality Standard of $PM_{2.5}$ in China by 2030 – a numerical simulation discussion based on energy and end-of-pipe control scenarios. Energy Foundation (China Office).

Wang, H. and He, J. 2019. China's pre-2020 CO_2 emission reduction potential and its influence. *Frontiers in Energy* 13(3),pp.571-578. https://doi.org/10.1007/s11708-019-0640-0 (accessed 29 August 2019).

Xi, J. 2014. The Governance of China, Volume 1. ICP Intercultural Press.

Yang, J., Li, X., Peng, W., Wagner, F. and Mauzerall, D.L. 2018. Climate, air quality and human health benefits of various solar photovoltaic deployment scenarios in China in 2030. *Environmental Research Letters* 13(6), 064002. https://pennstate.pure.elsevier.com/en/publications/climate-air-quality-and-human-health-benefits-of-various-solar-ph (accessed 29 August 2019).

Yang, X. and Teng, F. 2018. Air quality benefit of China's mitigation target to peak its emission by 2030. *Climate Policy* 18(1), pp. 99-110. https://doi.org/10.1080/14693062.2016.1244762 (accessed 29 August 2019).

Chapter 4 Global case studies

4.1 Introduction

This chapter provides case studies – from Chile, Finland, Norway, the United Kingdom (UK), Ghana, and Mexico – that address air, climate, and environmental pollution as an integrated problem. While these countries are at different stages of economic development and may have different national priorities, there is a common willingness to synergize climate and air pollution action, measures and policies. Integrated planning and action harmonize the implementation of the 2030 Sustainable Development Goals (SDGs) and Paris Agreement, and encourages nations to consider climate and air pollution impacts within an integrated framework.

4.2 Case studies

4.2.1 Chile

Chile has long pursued integrated policies to both improve domestic air quality and achieve international climate change goals. Chile joined the Climate & Clean Air Coalition (CCAC) in 2013 to advance action that leverages synergies between climate and clean air policies.

In the 1990's, the Santiago Metropolitan Region established its Metropolitan Region Decontamination Plan to reduce air pollution emissions from the transport sector (Ministry of Environment of Chile, 2014). This led to diesel fuel desulphurization and increasingly stringent vehicle emissions standards. As a result, average annual concentrations of particulate matter with an aerodynamic diameter equal to and less than 2.5 micrometres (µm) ($PM_{2.5}$) in Santiago decreased by nearly 70 per cent compared to 1992 levels. Despite these successes, population growth and increasing vehicle ownership requires the Plan be regularly updated and strengthened to sustain and strengthen the air quality gains. In 2017, the Plan was updated to specifically address the inherent climate co-benefit from actions to improve air quality. For example, efforts in the Plan to address $PM_{2.5}$ have the co-benefit of reducing the region's high levels of black carbon (BC) emissions. In 2017, Chile also instituted a new Green Tax designed to reduce greenhouse gas and air pollutant emissions from major industrial sources (Box 4.1).

Chile's 2015 Nationally Determined Contribution (NDC) to the Paris Agreement is an example of how the country included air pollution in its international climate commitments. Chile recognized the multiple benefits of addressing emissions of short-lived climate pollutants (SLCPs) for sustainable development, urban air quality and climate mitigation by including BC in its 2015 NDC (Government of Chile, 2015). Chile will build on its 2015 pledge by including a quantified BC reduction target in its updated 2020 NDC.

These efforts show how integrated policy spreads action across multiple levels of government, influences both domestic and international policy, and brings the air pollution and climate mitigation communities together. For countries such as Chile, faced with large development and air pollution challenges, and relatively low greenhouse gas emissions, changing political, economic and social priorities can significantly impact the domestic

Box 4.1 Chile's Green Tax

In 2017, Chile established a Green Tax to reduce air- and climate-polluting emissions from large emitting sources and new light- and medium-duty passenger vehicles (Departamento de Estudios, 2018). The government also established an emissions reporting and verification system, and a series of regulatory instruments and measurement protocols. For large industrial sources, the Green Tax levies a fee based on total annual emissions of particulate matter (PM), nitrogen oxides (NO_x), sulphur dioxide (SO_2), and carbon dioxide (CO_2). The tax rates for PM, NO_x, and SO_2 are based on a number of variables including local ambient concentrations of each pollutant, the number of people exposed to the emissions, and the social cost of the impacts of exposure. For emissions of CO_2, the rate is US$ 5 per tonne.

In April 2018, companies covered by the Green Tax paid an assessed US$ 168 million for their CO_2 emissions, 79 per cent of which was the result of coal combustion. Emissions of PM, NO_x, and SO_2 raised an additional US$ 23 million.

For new light- and medium-duty vehicles, the tax, which is levied at the time of purchase, is based on the vehicle's urban fuel-efficiency and its NO_x emissions. In 2017, the Green Tax on vehicles raised US$ 99 million, 40 per cent from diesel and 60 per cent from gasoline vehicles. Average emissions of NO_x from Chile's vehicle fleet have fallen by 10.5 per cent compared to 2015.

climate agenda. Linking climate, air quality and development agendas across multiple levels of government and among multiple ministries can improve coordination and insulate policies from changing political priorities.

4.2.2 Finland

In 2016, The Finnish Environment Institute (SYKE) conducted an environmental impact assessment for Finland's National Energy and Climate Strategy (Ministry of Economic Affairs and Employment of Finland, 2017) and medium-term climate change policy plan (Ministry of the Environment of Finland, 2017). The main objective of the study was to assess the impact of the two policies on air pollution emissions of $PM_{2.5}$, nitrogen dioxide (NO_2), NO_x, non-methane volatile organic compounds (NMVOCs) and BC, and the impact of changes in $PM_{2.5}$ concentrations on public health. Similar environmental impact assessments were developed for the 2005, 2008 and 2013.

National Energy and Climate Strategies, but air pollution was only included in the 2013 Strategy, while the 2016 Strategy was the first to include a detailed assessment of health impacts.

Using the Finnish Regional Emission Scenarios (FRES) model (Karvosenoja, 2008), the assessment found that neither the strategy nor the policy plan would substantially reduce domestic BC emissions, which are expected to decrease from 5.3 kilotonnes (kt) in 2015 to 3.4 kt in 2030 regardless of climate policies. Similarly, both policies had little impact on expected premature deaths due to exposure to $PM_{2.5}$.

The study, however, identified residential wood combustion as the single largest source of $PM_{2.5}$ emissions in Finland, and consequently the largest contributor to poor health (Table 4.1). Residential wood combustion is often considered a climate-friendly heating method, but the negative health impacts highlighted in this and similar studies increased national interest in reducing emissions from this source.

The study results were used as a basis for the Finnish National Air Pollution Control Programme (NAPCP) which is designed to implement air quality plans established under the European Union's (EU) Air Quality and National Emissions

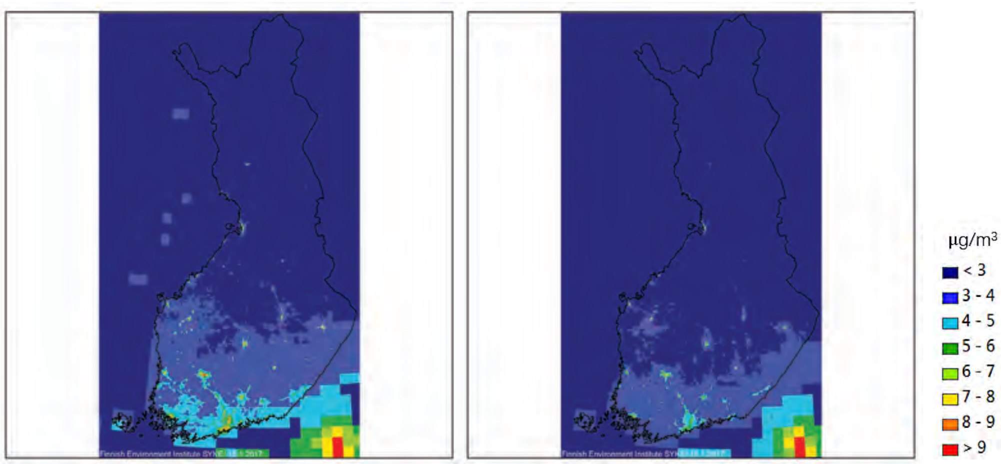

Figure 4.1 $PM_{2.5}$ concentration in 2015 (left) and under additional climate measures in 2030 (right) based on the health impact assessment. for the national climate strategy and policy plans
Source: (Karvosenoja et al. 2017)

Table 4.1 Premature deaths from $PM_{2.5}$ exposures in Finland

	2015	With decided climate measures		With additional climate measures*	
Deaths from		Current population	Projected 2030 population	Current population	Projected 2030 population
Energy production and industry	9	7	8	7	8
Small-scale combustion	205	186	208	186	208
Road traffic	77	11	13	10	11
Machinery and off-road transport	74	10	12	10	12
Traffic dust	55	58	67	53	61
Other sources	53	55	64	55	64
Total from Finnish sources	473	327	372	321	364
Long-range sources	961	834	931	834	931
Total	1434	1161	1303	1155	1295

Source: Karvosenoja *et al.* (2017)
*Main differences to premature deaths between existing legislation and additional measures is the result of more electric and gas cars, changes in modes of transport such as more cycling and walking, and vehicle efficiency increases.

Ceiling Directives (Directive 2016/2284/EU). Several programmes were developed under the NAPCP to reduce emissions and impacts from residential wood combustion. These include an awareness campaign and guidance for citizens, and updated instructions for local officials in problem situations. Finally, a process was started to develop emission-measurement standards which will serve as a basis for emissions regulations for wood sauna stoves.

This case study shows how an integrated assessment of climate, air pollution, and health impacts can influence public opinion and policy making, even in a country such as Finland with relatively good air quality. The inclusion of public health impacts in a national climate policy assessment resulted in greater public awareness and improvements in the Finnish NAPCP.

4.2.3 Norway

In 2013, the Norwegian Environment Agency, on behalf of the Ministry of the Environment, published an integrated assessment of the short- and long-term climate, health and environmental

Figure 4.2 Finnish small-scale combustion   *Photograph credit: HSY/Justiina Niemi*

impacts of mitigation measures for Norwegian emissions of SLCPs (Norwegian Environment Agency, 2013). As the global climate impacts of SLCPs depend on where the emissions take place, the Norwegian Environment Agency modelled the global climate effects of Norwegian emissions. A new climate metric, GTP10-Norway, was adopted in order to assess the cost-efficiency (cost per unit of CO_{2e}) 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 Norway's proximity to the Arctic and to BC deposition on snow and ice (Hodnebrog *et al*., 2013). Norwegian SLCP emissions have a strong short-term climate impact, but the short-term climate effect of Norwegian CO_2 emissions is higher than that of its combined SLCPs. 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.

The 2013 study did not assess greenhouse gas measures, but given the high short-term climate effect of CO_2, hypothesized that such measures could be as efficient in reducing SLCPs as targeted SLCP-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.

To acknowledge this, Norwegian Environment Agency has subsequently performed several integrated studies including of both SLCPs and greenhouse gases. In the latest study (Norwegian Environment Agency, 2019) the Norwegian Environment Agency highlighted that measures that reduce methane (CH_4) and/or BC have a substantially higher climate impact in the short-term than in the long-term. Such measures include reducing food waste, reducing venting in the petroleum sector and transitioning to cleaner stoves for household heating. 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.

Integrated assessments of climate measures

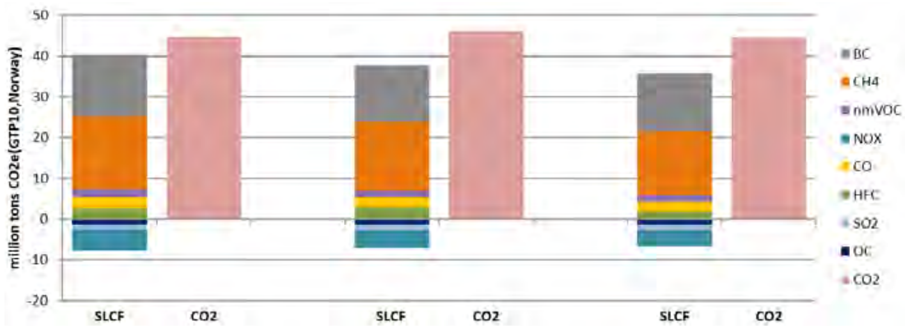

Figure 4.3 Global climate effect of Norwegian SLCP emissions compared to that of Norwegian CO_2 emissions in 2011, 2020 and 2030
Source: orwegian Environment Agency (2013)

are important to highlight measures that have important shor-term effects, but fail to contribute substantially to long-term climate goals. This type of analysis assists in compiling a portfolio of measures that contributes 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 measures have become increasingly a part of their regular evaluation. An analysis to evaluate the climate effect in the short-term, for example, will be undertaken for measures identified in an on-going greenhouse gas analysis commissioned by the Norwegian government. The analysis will assess measures and instruments that can cut Norwegian emissions not covered by the EU's Emissions Trading Scheme (EU-ETS) by at least 50 per cent by 2030 relative to 2005. It has 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) and Norway's submission to the 2018 UNFCCC Talanoa Dialogue called for the application of a multiple-benefit methodology

Figure 4.4 Bearded seal in Kongsfjorden, Spitsbergen *Photograph credit: Vigdis Vestreng*

which analyses all greenhouse gases and SLCPs in both the short and long term (Government of Norway, 2018).

4.2.4 The United Kingdom

The UK's climate and air-quality policies have historically not been well integrated, although this has recently begun to improve. The 2008 UK Climate Change Act (CCA) obliges the country to reduce its greenhouse gas emissions by 80 per cent by 2050 compared to 1990 (UK Climate Change Act, 2008). In parallel with the CCA, the UK is also subject to air quality legislation, notably the EU's Air Quality Directive (EU Directive 2008/50/EC) and the National Emissions Ceilings Directive (NECD) (Directive 2016/2284/EU).

Meeting the CCA's original ambitious emission reduction target requires fundamental changes in the energy and transport infrastructure of the UK. While many of these changes are likely to result in substantial co-benefits for air quality and public health, a recent integrated assessment of the actions underpinning the CCA found that some could result in substantial downsides for air quality and public health. Three future scenarios were modelled: (i) no further climate action beyond that currently agreed at the fourth carbon budget; (ii) a cap on nuclear building, which will limit nuclear capacity in 2050 to current levels; and (iii) no policy cap on nuclear build.

Scenarios (ii) and (iii) met the CCA target but clearly scenario (i) did not. Scenarios (ii) and (iii) contained significant increases in the use of biomass (wood) with consumption peaking in 2035. A key element in all CCA-compliant scenarios was the substantial electrification of the car fleet which resulted in large reductions in urban NO_2 concentrations (Table 4.2).

While total $PM_{2.5}$ concentrations are projected to decrease substantially by 2050, the study found the promotion of domestic small-scale wood burning substantially increased human exposure to $PM_{2.5}$, with the increase peaking in 2035. Furthermore, the study found that increased $PM_{2.5}$ and NO_2 exposure would be highest among socio-economically disadvantaged populations and would remain through 2050 (Williams *et al.*, 2018). There are potential benefits to CO_2 emission reductions from biomass burning but to minimize the downsides for air quality and health, if biomass must be burned then it is preferable to do so in large installations such as power plants where combustion is more efficient and emission abatement technologies can be used.

The study highlights the need for careful consideration of the potential benefits and disadvantages of climate mitigation policies in order to reach optimal policy choices that are well informed and achieve multiple benefits, particularly for the most vulnerable groups. While there has been little action in the past to systematically assess synergies and avoid conflicts between climate and air-pollution policies, the situation is improving. In January 2019 the UK government published its Clean

Table 4.2 NO_2 and $PM_{2.5}$ concentrations under different scenarios

	NO_2 (µg/m³)	$PM_{2.5}$ (µg/m³)
2011	9.53–14.4	9.31
2050		
Baseline scenario (i)	6.43–11.25	5.77
Nuclear power scenario (ii)	2.55–7.08	5.36
Low greenhouse gas scenario (iii)	1.33–5.65	5.20

Source: Williams et al. 2018

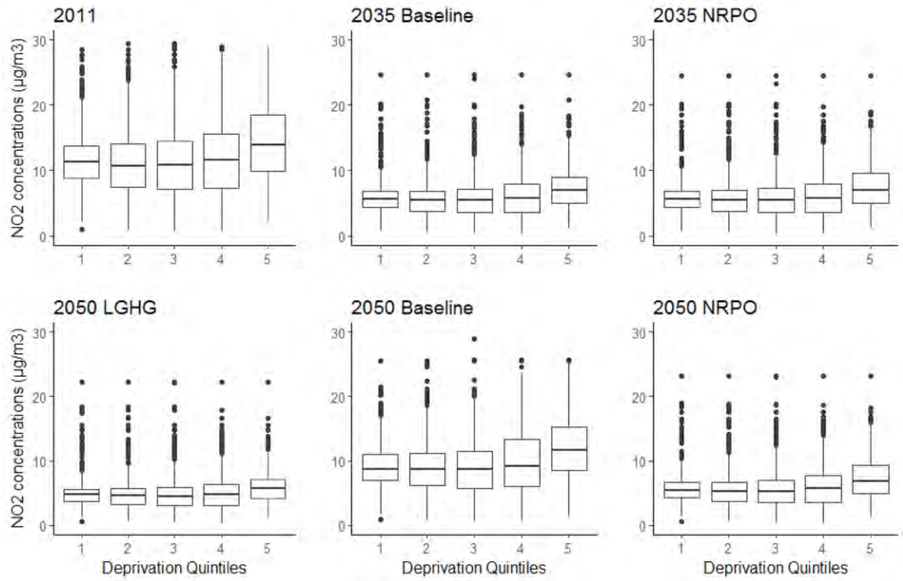

Figure 4.5 Distribution of 2011 level NO_2 concentrations, Carstairs 2011 deprivation quintile at 2011 baseline and other scenarios, index 1 = least deprived, 5 = most deprived; NRPO: Nuclear power scenario, LGHG: Low greenhouse gas scenario
Source: Williams et al., 2018

Air Strategy (Defra,2019) which, *inter alia*, committed to measures to reduce domestic biomass burning and to further integrate policies on air quality and climate change. For example, in the wake of the Paris Agreement, in 2019 the UK Climate Change Committee published a report which set out the case for a net-zero climate policy and which highlighted the importance of quantifying the air pollution benefits of more ambitious mitigation scenarios (UK CCC, 2019). In the last days of Prime Minister Theresa May's premiership, the UK government increased its greenhouse gas reduction ambition by amending the Climate Change Act to commit to a 100 per cent reduction in net CO_2-equivalent emissions by 2050 (Climate Change Act Amendment, 2019)

4.2.5 Ghana

Ghana, as other lower-middle income nations, is grappling with many complex and linked economic, social and environmental issues. These development challenges are exacerbated by the impacts of deteriorating air quality and climate change on public health and the general well-being of the Ghanaian people in the long run. Ghana's climate change strategy is outlined in the National Climate Change Policy (NCCP) (MEST of Ghana, 2012) and its Nationally Determined Contributions (NDCs) (Government of Ghana, 2015). The overall aim of the NCCP and NDCs is to align Ghana's future development with a sustainable pathway capable of delivering economic growth, better air quality and mitigate climate change. To continue advancing these policies Ghana established a coordinated climate change and air quality management strategy to foster a sustainable development pathway that delivers economic growth, better air quality and a safe climate (Government of Ghana, 2018).

As a first step, the government established a multi-disciplinary inter-ministerial team to identify data sources and reached consensus on which datasets and modeling tools to use for an integrated assessment[9]. This proved to be

9. The team consists of Ministries of Environment, Energy, Transport, Finance, and Health, the Energy Commission, the National Development Planning Comission and the Forestry Commission with the Environmental Protection Agency in the role of technical facilitator.

critical for the process because it allowed for the development of common scenarios and results which reflected the policy realities in each sector and facilitated the speedy uptake of the results by each ministry to inform their respective policies. The Ministry of Finance was a critical participant because it was able to quickly incorporate identified mitigation measures in their internal and external resource-mobilization strategy.

Assessing all climate and air pollutant emissions using the Long-range Energy Alternatives Planning Integrated Benefits Calculator (LEAP-IBC) tool, the team quantified the climate, air pollution, public health and agricultural impacts of Ghana's current policies, and identified a priority list of policies to achieve Ghana's NDC mitigation pledge (Government of Ghana, 2015) and additional policies targeting emissions of SLCPs (Table 4.3).

By assessing the multiple impacts of Ghana's climate-focused NDC mitigation pledges, the study was able to comprehensively show that Ghana's measures would result in a substantial benefit for near-term air quality, public health, food security and avoided warming (Figure 4.6). Similarly, the analysis shows that air pollution focused SLCP measures can also reduce CO_2 emissions by almost an additional 20 per cent beyond the full implementation of the NDC measures.

The results of the analysis proved to be an important planning and communication tool for the government. This shows that well designed action taken primarily to achieve local development objectives can still result in meaningful contributions to the global common good of mitigating climate change. The results, supported by the institutional buy-in fostered by Ghana's multi-sectoral working group, have garnered significant attention within government and several of the identified measures are currently being implemented. For example, Ghana has lowered the sulphur content in diesel fuel from 300 parts per million (ppm) to 50 ppm, and more than 2 million clean cookstoves have been distributed to homes throughout the country.

This focus on integrated solutions is also having an impact on Ghana's international cooperation and reporting. For example, although as a developing Ghana is not required

Table 4.3 Selected mitigation measures

Emissions scenario	Description	Abatement Measures
NDC measures (Policy and measures (PAM) +)	Policy actions contained in Ghana's 2015 NDC	Liquified petroleum gas (LPG) for cooking
		Solar systems
		Reduced forest burning
		Institutional Biogas
		Promote compressed natural gas (CNG) buses
		Stop open burning
		Landfill gas management
		Improved cookstoves
		Natural gas for electricity
		Eco-friendly electricity
		Efficient charcoal kilns
Additional SLCP measures (PAM++)	Addition incremental SLCP measures adopted and effectively implemented	Quality livestock feeding
		Vehicle testing standards
		Cutting-edge stoves
		Gas in plastic industry

Source: Ghana's National Action Plan to Mitigate Short-lived Climate Pollutants, 2018 (Government of Ghana, 2018)

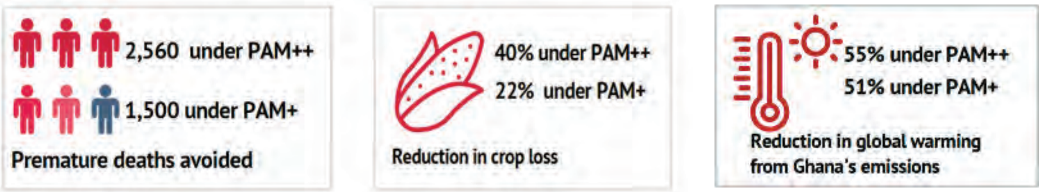

Figure 4.6 Emission impacts of policy packages
Source: Government of Ghana (2018)

to establish inventories or report to the UNFCCC on emissions of precursor and air pollutant emissions, Ghana's 4th National Inventory Report to UNFCCC includes on emissions of precursor gases, SLCPs and air pollutants. Furthermore, Ghana expanded the scope of its inventory stating that the additional substances are crucial because they "enhance the utility and relevance of the results beyond climate change to the impacts of SLCPs and air pollution on human lives, agricultural productivity, ecosystems, and sustainable development". (Ghana NIR4, 2019).

Ghana is now focused on ensuring that all measures are quickly and effectively implemented and identifying appropriate resources to support their implementation and evaluate them after implementation.

4.2.6 Mexico

Recognizing the importance of mitigation of greenhouse gases and SLCPs relatively early, Mexico has become a leader in Latin America and the Caribbean, taking a series of steps towards a coherent integrated mitigation strategy. As a co-founder of the Climate & Clean Air Coalition (CCAC) in 2012, Mexico produced the first comprehensive national diagnosis of greenhouse gases and SLCPs in 2013. The studies in the national planning report (INECC, 2013) provided support to Mexico's decision to set an ambitious emissions reduction target in its first NDC and become the first country to establish a quantified emission reduction target for BC - 51 per cent by 2050. Mexico first approved a federal-level Climate Change Law (*Ley General de Cambio Climático*) in 2013, most recently amended in 2018, aiming to coordinate public policy and strategies to adapt to and mitigate climate change from national to municipal levels. The Climate Change Law mandates the creation of an inter-ministerial commission for climate change with the main objective of promoting and coordinating climate change action and strategies among ministries and federal agencies. The recognition of SLCPs as climate forcers allows Mexico to tackle climate change and air quality through a comprehensive approach outlined in the National Climate Change Strategy (*Estrategia Nacional de Cambio Climático*) and the National Air Quality Strategy (*Estrategia Nacional de Calidad del Aire*). The harmonization of these must be articulated in air quality management and state climate change action programmes where control strategies for the same sources should provide multiple benefits to air quality, climate change, adaptation and health.

National planning activities allow Mexico to establish a pathway to achieving multiple benefits in air quality, public health, climate change and energy efficiency. A number of studies of the sectoral emissions and the potential co-benefits of different mitigation strategies have been carried out. These studies are integrated assessments of the impacts of combined air quality and climate change factors on health, vegetation and ecosystems, and provide estimates of the benefits of implementing different mitigation action in the sector responsible for emissions.

The transport sector, particularly in the main conurbations, was selected early on as one of the priority targets for emissions mitigation (Molina and Molina, 2006). Action has been taken to improve mobility in Mexico City and reduce ozone (O_3) and particulate (PM) levels and their climate impacts. Mexico is now pursuing urban electric mobility as a critical next step, which, combined with more stringent energy efficiency, will strengthen the commitment to BC mitigation. Energy efficiency, indoor health impacts, air quality and climate change mitigation, as well as meeting the main BC targets of the NDC, are also being addressed together through updating multiple technologies used for household heating, cooling and cooking and introducing less polluting fuels.

Mexico's second-generation national planning document, which will be released in late 2019, identifies a number of new actions which will help the country achieve multiple benefits while meeting its mitigation commitments (CCAC-INECC, 2019). Included are specific recommendations to address emissions from the sugar cane industry, which is the third highest energy-using sector in Mexico and a large contributor of BC emissions, mainly from the combustion of bagasse[10] and fuel-oil. Scenarios to estimate which specific mitigation measures provide the greatest co-benefits were developed based on recommendations from five studies either prepared or commissioned by the federal government [CONUEE/ CRE/ GTZ, 2009], [INECC-BID, 2012], [CRUZADO, 2017], [CONUEE/ EUEI PDF/ GIZ, 2018] or developed in academia [Rojas, 2014]. These measures include the following.

Installing control systems to reduce particle emissions. Installing 90 per cent efficient particle filters gradually – in 40 per cent of plants by 2020 and 60 per cent by 2025.

Improving energy efficiency by processing bagasse before combustion through drying it to lower its moisture content from the current 50 per cent to either 41 or 35 per cent.

Improving efficiency in energy generation by increasing vapour pressure in combustion chambers to either 42 or 65 bar.

Different combinations of filters, reductions in moisture content and pressure levels resulted in nine specific measures being evaluated. This identified that the optimal combination of measures to minimize BC emissions involves introducing particle filters, reducing the moisture content of bagasse to 41 per cent and increasing vapour pressure to 65 bar in the on-site power generation plants. Implementing these measures can reduce the sugar cane industry's BC emissions by 88 per cent by 2030.

These types of integrated assessments can provide insights into the best way to progress, but more research needs to be done into the actual barriers

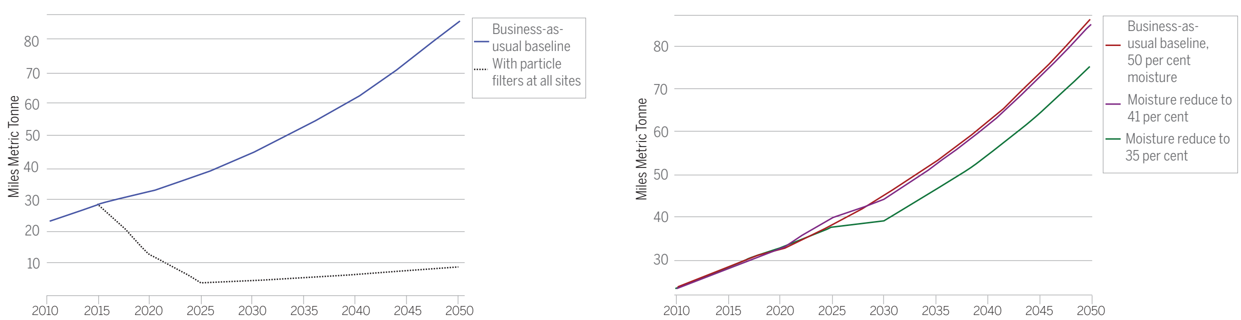

Figure 4.7: Reductions in sugar industry BC emission by introducing particle filters at all sites by 2030 (left) and by lowering the moisture content in bagasse from 50 to 41 and 35 per cent (right), 2010–2051
Source: LEAP-IBC-Mexico

10. residue that remains after sugarcane stalks have been crushed to extract their juice

to implementation and estimates of economic benefits would provide more concrete incentives to industry to transition and implement the identified measures.

4.3 Conclusions and implications

These case studies show that a growing number of countries see integrated co-governance of climate, air pollution and development as a key strategy for achieving their domestic development agendas while simultaneously meeting international commitments to sustainable development and the mitigation of climate change. While the countries are at different levels of economic development, have different internal objectives and have taken different paths to integrated co-governance, there are similarities in their experience and good practice that can be drawn on.

Each of the countries carried out integrated assessments of policies or measures, using a variety of tools and methodologies, to help them to assess the co-benefits for climate change mitigation, health, socio-economic development and delivering the SDGs. To ensure coordinated action delivers the maximum benefit and reduces the risk of policy failure, integrated assessments of all air pollutant and greenhouse gas emissions are needed. Both Ghana and Mexico state that the integrated assessment of SLCPs and greenhouse gases enabled to them to reduce co-emissions while Norway's case emphasizes the usefulness of integrated assessments in identifying both win-win and win-lose situations. All the countries found that integrated assessments aided robust decision making and monitoring those decisions once they had been implemented.

For many countries, the local benefits and immediate results of action, both for air quality and climate change mitigation, are important development concerns and are a key ingredient for developing greater ambitions for emissions reductions. Quantifying impacts on public health are a key driver for action in all cases, even in countries such as Finland which have relatively low air pollution emissions. Highlighting the distributional impacts of action, particularly the burden on socio-economically vulnerable populations, was a key conclusion in the UK.

Specific local or regional vulnerabilities to emissions can play an important role in policy making and can be a driver for integrated action. For both Finland and Norway, the vulnerability of the Arctic region to BC and other emissions is a crucial driver of coordinated climate mitigation and air pollution action.

Norway's study highlights the importance of assessing the impact of policies over multiple time scales. It found that measures addressing NO_x emissions cause short-term warming but provide health and environmental benefits. It shows that although near-term public health benefits are substantial incentives for action, the implications for climate change could help policy makers balance objectives to either enhance action in other areas to offset the impacts or chose alternative policies to achieve a better mix of positive results. In either case, the analysis can strengthen decision making and build policy makers' confidence that they are committing resources efficiently and effectively.

A number of cases highlight the importance of a cross- or whole-of-government approach to achieve efficient and sustainable co-governance. In Ghana's case, the formation of a multi-sectoral working group was key both to delivering harmonized data and scenarios for an integrated assessment, and for the quick acceptance and uptake of the results across the government. Similar working groups were developed in Mexico and Norway. Chile's case highlights the importance of the multi-stakeholder and multiple-benefits approach for ensuring the broad acceptability and sustainability of policies. This opens up the possibility of closing the huge gap between analysis on paper and practical action.

These case studies also show that integrated assessments and co-governance approaches are powerful tools for developing cost effective and coherent policy decisions. This saves public money and increases the chance of success. By analyzing and tracking the impact of climate change mitigation and air pollution measures in an integrated way, the results identify win-win or win- lose solutions. It also identifies different benefits from mitigation. which can prevent poor decision making based on incomplete information and help build confidence and support for mitigation from the general public, business and policy makers; justify the allocation of financial, technical and human resources; and convince politicians of the need to move decisively and rapidly.

References:

CCAC-INECC. 2019. *Estrategias integradas en contaminates climáticos de vida corta para mejorar la calidad del aire y reducir el impacto al cambio climático*. Under review. Climate & Clean Air Coalit – Instituto Nacional de Ecología y Cambio Climático.

Climate Change Act. 2008, UK, Order 2019, 2050 Target Amendment. United Kingdom.

Defra. 2019. Clean Air Strategy 2019. Department for Environment, Food and Rural Affairs, United Kingdom.

Departamento de Estudios. 2018. *Principales aspectos legales del Impuesto Verde a las Fuentes Fijas*. Biblioteca del Congreso Nacional de Chile.

Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe. *Official Journal of the European Union, L 152/1.*

Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC. *Official Journal of the European Union, L 344/1.*

Hodnebrog, Ø., Aamaas, B., Berntsen, T.K., Fuglestvedt, J.S., Myjre, G., Samset, and B.H. and Søvde, A. 2013. *Klimaeffekt av norske utslipp av kortlevde klimadrivere*, CICERO report to the Norwegian Climate and Pollution Agency (KLIF).

Government of Chile. 2015. Intended Nationally Determined Contribution of Chile Towards the Climate Agreement of Paris 2015. United Nations Framework Convention on Climate Change.

Government of Ghana. 2015. Ghana's Intended Nationally Determined Contribution and accompanying explanatory note. United Nations Framework Convention on Climate Change.

Government of Ghana. 2018. National Action Plan to Mitigate Short-lived Climate Pollutants. Republic of Ghana.

Government of Mexico. 2013. National Climate Change Strategy, 10-20-40 Vision. Federal Government of Mexico.

Government of Mexico. 2015. Intended Nationally Determined Contribution. United Nations Framework Convention on Climate Change.

Government of Norway. 2019. Talanoa-dialogue Norway. United Nations Framework Convention on Climate Change.

INECC. 2013. *Apoyo a la Iniciativa de Planificación Nacional sobre Contaminantes Climáticos de Vida Corta en México*. Molina Center for Energy and the Environment - Instituto Nacional de Ecología y Cambio Climático. (MCE2 – INECC). Mexico City, Mexico.

Karvosenoja, N. 2008. *Emission scenario model for regional air pollution*. Monographs of the Boreal Environment Research 32.

Karvosenoja N., Savolahti M., Lanki T., Salonen R. and Tiittanen. Luku Vaikutukset ilmanlaatuun. Raportissa: Soimakallio S., Hildén M., Lanki T., Eskelinen H., Karvosenoja N., Kuusipalo H., Lepistö A., Mattila T., Mela H., Nissinen A., Ristimäki M., Rehunen A., Repo A., Salonen R., Savolahti M., Seppälä J., Tiittanen P., Virtanen S. 2017. *Energia- ja ilmastostrategian ja keskipitkän aikavälin ilmastopolitiikan suunnitelman ympäristövaikutusten arviointi* (Environmental impact assessment of the Energy and Climate strategy and Medium-term Climate Change Policy Plan). *Valtioneuvoston selvitys ja tutkimustoiminnan julkaisusarja 59/2017.*

MEST of Ghana. 2012. Ghana National Climate Change Policy. Ministry of Environment, Science and Technology, Republic of Ghana.

Ministry of Environment of Chile. 2014. Planes de Descontaminación Atmosférica Estrategia 2014–2018.

Ministry of Economic Affairs and Employment of Finland. 2017. *Government Report on the National Energy and Climate Strategy for 2030.*

Ministry of Environment of Finland. 2017. *Government Report on Medium-term Climate Change Plan for 2030 – Towards Climate-Smart Day-to-Day Living.*

Mugica-Alvarez, V., Santiago-de la Rosa, N., Figueroa-Lara, J., Flores-Rodríguez, J., Torres-Rodríguez, M. and Magaña-Reyes, M. 2015. Emissions of PAHs derived from sugarcane burning and processing in Chiapas and Morelos México. *Science of the Total Environment.* DOI 10.1016/j.scitotenv.2015.04.089.

Norwegian Environment Agency. 2013. Proposed Action Plan for Norwegian emissions of short-lived climate pollutants. M98/2013.

Norwegian MTC. 2017. Meld. St. 33 (2016–2017) Report to the Storting (white paper), National Transport Plan 2018–2029. Norwegian Ministry of Transport and Communications.

Schreier, M., Mannstein, H., Eyring, V. and Bovensmann, H. 2007. Global ship track distribution and radiative forcing from 1 year of AATSR data. *Geophysical Research Letters* 34:17. https://doi.org/10.1029/2007GL030664.

Williams, M.L. 2012. Tackling climate change: what is the impact on air pollution? *Carbon Management* 3:5, pp. 511-519.

Williams, M.L., Lott, M.C.L., Kitwiroon, N., Dajnak, D., Walton, H., Holland, M., Pye, S., Fecht, D., Toledano, M.B. and Beevers, S.D. 2018. The Lancet Countdown on health benefits from the United Kingdom Climate Change Act: a modelling study for Great Britain. *The Lancet Planetary Health* 2(5), pp. E202-E213.

UK CCC. 2019. *Net Zero: The UK's contribution on stopping global warming*. UK Committee on Climate Change.

UK Climate Change Act. 2008. Part 1.1 The target for 2050.

Chapter 5 Conclusion and policy recommendations

5.1 Conclusion

Climate change and air pollution are two of the greatest environmental challenges of our time. Decades of scientific evidence has established a strong case that climate change and environmental pollution are inexorably connected. Many air pollutants have impacts on the climate, and they are often emitted from the same sources as greenhouse gases, such as CO_2. This link provides an opportunity to design policies and actions that mitigate climate change and reduce air pollution simultaneously, which increases benefits and minimizes costs. The efficiencies achieved through co-governance can increase policy acceptability, policy coherence, sustainability, and spur greater mitigation ambition.

Despite the clear benefits of co-governance, governments have historically managed environmental pollution and climate change separately. The case studies presented in this report, however, show that a growing number of countries see integrated co-governance of climate, air pollution and development as a key strategy to achieve their domestic agendas while simultaneously meeting international sustainable development and climate commitments.

By developing policies, institutions and management methodologies that support co-governance, China has made significant progress towards achieving its environmental and development targets, including capping energy consumption, expanding non-fossil fuel energy development, addressing per person carbon emissions and improving air quality, although challenges still remain. China has demonstrated that climate change and air pollution co-governance can be accomplished (Chapter 2) by setting national targets, creating collaborative decision-making mechanisms across related government ministries like climate and the environment, and implementing best-fit policies by considering regional and sectoral differences.

The international cases from Chile, Finland, Norway, Mexico, Ghana, and the UK show that environmental and climate co-governance is also advancing rapidly all over the world, and in countries at every stage of economic development. These examples indicate that this is an iterative process and that there are multiple paths to realizing the objectives of climate, environmental and development co-governance.

The examples presented in this report represent a small sample of the great wealth of experience and energy being put into developing and deploying integrated co-governance approaches around the world. While examples like these are increasing in frequency, they are still not an international norm. Succeeding at meeting our common goals for the climate, environment and sustainable development requires that we continue to build on these examples to unlock greater ambition for mitigation in all sectors.

5.2 Policy recommendations for China

1. Embed a medium- to long-term co-governance strategy in the 14th Five-Year Plan

China will formulate a medium to long-term co-governance strategy to achieve its Nationally Determined Contributions (NDCs) while addressing domestic targets. Such a strategy is in line with the national targets set by the 19th National Congress, which developed the *Beautiful China Blueprint* for a "*rich, strong, democratic, culturally advanced and harmonious country*". This long-term two-step strategy proposes that the ecological environment will be fundamentally improved and the goal of building a Beautiful China will be basically attained by 2035, with new heights of ecological advancement reached by 2050 (IEA, 2019).

Specifically, before 2035, China will focus on maximizing domestic environmental benefits, as reducing air pollution concentrations, through policies that simultaneously promote climate change governance for the Paris Agreement target. China should make efforts to decouple economic growth from carbon and air pollution emissions by accelerating the adoption of low- and zero-carbon energy, and the process to reach peak carbon emissions as soon as possible.

After 2035, China's strategy shifts its focus towards international climate change governance and the phase-out of fossil energy. The strategy aims to achieve the *Beautiful China Blueprint* through deep decarbonization in line with the global goals for climate action. Based on this strategy of targeting key sectors and developing key technologies, China can identify problems and achievable developmental goals in different stages.

2. Expand the coal cap programme, achieve early peaking of carbon emissions in coastal provinces and cities and encourage deep decarbonization in energy intensive sectors.

The 14th Five-Year Plan Period (2021-2025) is critical for revolutionary transformation of energy systems needed for sustainable development and for fulfillment of air pollution and greenhouse gas reduction goals. This will be brought about in two ways. The first is to dramatically improve energy efficiency and economic output to slow down the growth in energy demand while ensuring economic growth; the second is to develop new and renewable energy sources like hydropower, wind, solar, biomass and nuclear energy; optimize the mix of energy resources; and limit CO_2 emissions by reducing the proportion of fossil energy sources, while ensuring the energy supply. It is also necessary to control total energy consumption, especially by strengthening the cap on coal consumption. Carbon pricing should be used to promote energy conservation and incentivize investment in low carbon technologies.

China is actively preparing its 14th FYP and setting targets for sustainable development from 2021 to 2025. Introducing more ambitious climate and environmental targets and accelerating the energy transition is important for the period. The new plan should consider expanding the current coal-cap programme from the most polluted regions to a much wider geographical area and eventually to the whole country; accelerating the transformation of energy systems and the earlier peaking of carbon emissions in the coastal provinces and cities as well as for energy intensive industries.

3. Accelerate development of China's national carbon market and expand coverage to all major emitting sectors

The government should establish a carbon pricing mechanism and further improve the national carbon market. China established carbon market pilot projects in seven provinces and municipalities in 2011. A national carbon market was officially launched in December 2017, but it only covers the fossil-fuel based power generation industry. The national carbon market should gradually expand in a stepwise process to other sectors, including the chemical, petrochemical, iron and steel, non-ferrous metals, building materials, paper and aviation industries.

4. Strengthen the Ministry of Ecology and Environment's capacity to support co-governance

The newly established Ministry of Ecology and Environment (MEE) is now responsible for combating climate change, taking over the responsibility from the National Development and Reform Commission (NRDC). The restructuring provides a great opportunity to integrate monitoring of climate change and air pollutantion and improve co-governance on environment and climate change, taking advantage of the MEE's network of environmental monitoring and data reporting.

The MEE should consider adding CO_2, CH_4 and other greenhouse gases into their inventory and pollutant monitoring system, establishing an open database for air pollution and climate change for public participation. The MEE should promote technological innovations for precise measurements of air pollutants through comparisons between traditional inventory methods and point-source measurements through cross-validation between meteorological retrieval of atmospheric measurements and ground-level measurements.

5. Promote co-governance in the Green Belt and Road Initiative

Building the Belt and Road Initiative (BRI) should strengthen co-governance approach with high environment standards. Green Investment Principles for the BRI should be followed as norms, and investor responsibility should be emphasized.

Meanwhile, the Chinese government should strengthen the supervision of overseas investment projects to prevent environmental and climate impacts, especially stopping investment in coal-fired power plants. Through international cooperation, China should actively promote capacity building in Belt and Road countries to prevent climate and environmental risks. Responding to demands for poverty elimination and development along the Belt and Road, China could offer systematic solutions for capital, technology and planning.

5.3 Recommendations for the world

1 Governments should continue to explore and implement co-governance approaches to harmonize climate and environmental policy

Now, more than ever, harmonized co-governance approaches that work to achieve multiple benefits are needed to meet the climate, environmental and development challenges of our time. The Intergovernmental Panel on Climate Change (IPCC) *Global Warming of 1.5°C* report stated that achieving the goals of the Paris Agreement "*involves inclusive processes, institutional integration, adequate finance and technology, and issues of power, values, and inequalities to maximize the benefits of pursuing climate stabilization at 1.5°C and the goals of sustainable development at multiple scales of human and natural systems from global, regional, national to local and community levels*" (IPCC, 2018). As the case studies in this report show, many governments are actively exploring options for co-governance; this should continue and be expanded.

Countries should integrate their air pollution and greenhouse gas inventories and modelling so that the impact of climate and air quality activities can be more easily assessed. Governments can also collaborate with one another to share good practices, tools and experience. There are formal conventions and UN mandates through which this can be pursued: at the UN Environment Assembly, World Health Assembly, the UN Framework Convention on Climate Change (UNFCCC), just to mention some. There are regional conventions and voluntary partnerships, including the Climate & Clean Air Coalition; those involving local governments and city leaders, like C40 Cities and Local Governments for Sustainability (ICLEI), and global campaigns like BreatheLife to raise awareness for policy and behaviour change. These are all examples of organizations and initiatives that support co-governance and information sharing. Governments could also collaborate through their international aid programmes and bilateral or multilateral agreements.

The process of developing and submitting national mitigation pledges through NDCs to the Paris Agreement presents a significant near-term opportunity for national governments to promote co-governance. To enhance the ambitions of the next round of NDCs, it would be beneficial if countries employ comprehensive strategies to assess the multiple-impacts and benefits of climate change mitigation and adaptation policies. This can help countries unlock the political motivation needed to achieve the Paris Agreement.

The convening of a Global Climate Action Summit in September 2019 by UN Secretary-General provides an opportunity to showcase a leap in collective national political ambition and demonstrate real movement in economies, in which the co-governance aspects will be key to sustaining the ambition to achieve the objectives of the Paris Agreement and the Sustainable Development Goals.

2 International and regional organizations and agencies should share good practice and tools among nations and regions

International and regional cooperation is a critical enabler for countries to strengthen their capacity for co-governance. International and regional institutions and agencies should work to support and communicate examples of good practice of integrated policy in co-governance, and support capacity-building at all levels of government including through the development and application of integrated tools. Collaborative platforms can help governments identify co-governance strategies that work best for their circumstances.

Climate and development finance institutions need to play a bigger role by assessing and reporting on the multiple benefits of financed projects and establishing funds that support projects designed to achieve multiple benefits. Financial institutions can build multiple-benefits indicators into their evaluation criteria for new projects and require funded projects to evaluate and report on more than one benefit. For example, in 2013 the Green Climate Fund (GCF) proposed that funded mitigation projects report on at least one co-benefit beyond tonnes of greenhouse gas emissions reduced (GCF, 2013). By requiring projects to report on expected climate and public health benefits from the co-control of air pollutants, the GCF would incentivize the application of tools and methodologies that support integrated co-governance approaches at a local level.

3 Integrated assessments of climate and air quality strategies should become common practice to support robust and harmonized policymaking

Integrated assessments can be powerful tools that provide decision makers with the information needed to understand, compare and communicate the impacts of their action on global temperature and air quality over time. This is an important first step to effective co-governance and can help governments harmonize climate and air quality policies and identify strategies that can maximize health improvements and other key local development priorities, while at the same time significantly reducing greenhouse gas emissions and reducing the rate of warming in the near and long-term.

Integrated assessment tools, such as the Long-range Energy Alternatives Planning Integrated Benefits Calculator (LEAP-IBC) (Kuylenstierna *et al.*, 2017) which was used to support the integrated planning in Chile, Ghana and Mexico (Chapter 4) and the multiple-benefits pathway framework (CCAC, 2019), developed by the Chile, Ghana and Mexico (Chapter 4), are among many that can help countries conduct integrated assessments to support robust policy making.

References:

CCAC. 2019. Multiple Benefits Pathway Framework. Climate & Clean Air Coalition. https://www.ccacoalition.org/en/content/multiple-benefits-pathway-framework (accessed 5 September 2019).

IEA. 2019. *China power system transformation – assessing the benefit of optimized operations and advanced flexibility options*. International Energy Agency.

IPCC. 2018. *Global Warming of 1.5° C*. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/sr15/ (accessed 5 September 2019).

GCF. 2013. *Business Model Framework: Objectives, Results and Performance Indicators*. Green Climate Fund. https://www.greenclimate.fund/documents/20182/24934/GCF_B.04_03_-_Business_Model_Framework__Objectives__Results__and_Performance_Indicators.pdf/961512a9-1ba3-4023-a5e4-2aa4e48054bb (accessed 5 September 2019).

Kuylenstierna, J.C.I., Heaps, C., Malley, C.M., Vallack, H.W. and Hicks, W.K. 2017. *The Long-range Energy Alternatives Planning – Integrated Benefits Calculator (LEAP-IBC)*. Factsheet. Stockholm Environment Institute. https://www.sei.org/mediamanager/documents/Publications/SEI-Factsheet-LEAP-IBC-2.pdf (accessed 5 September 2019).

Abbreviations and units of measure

Abbreviations

BC	black carbon
BEV	battery electric vehicles
BRI	Belt and Road Initiative
BTH	Beijing-Tianjin-Hebei region
CCA	Climate Change Act (UK)
CCAC	Climate & Clean Air Coalition
CCP	The Chinese Communist Party
CEC	China Electricity Council
CH_4	methane
CHP	combined heat and power
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CO_{2eq}	carbon dioxide equivalent
EIA	environmental impact assessment
EU	European Union
EU-ETS	EU's Emissions Trading Scheme
FRES	Finnish Regional Emission Scenarios
FYP	National Five-Year Plan of for Economical and Socia Development, China
GCF	Global Climate Fund
GDP	gross domestic product
GHG	greenhouse gas
HFC	hydrofluorocarbon
ICCSD	Institute of Climate Change and Sustainable Development (Tsinghua University, China)
ICLEI	Local Governments for Sustainability
IEA	International Energy Agency
IIASA	International Institute for Applied System Analysis
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contributions to the Paris Agreement (within the United Nations Framework Convention on Climate Change)
INECC	National planning report (Mexico)
IPCC	Intergovernmental Panel on Climate Change
LEAP-IBC	Long-range Energy Alternatives Planning (LEAP) – Integrated Benefits Calculator (IBC)

LPG	liquefied petroleum gas
MEE	Ministry of Ecology and Environment (China)
MEP	Ministry of Environmental Protection (China)
MoF	Ministry of Finance (China)
MOHURD	Ministry of Housing and Urban-Rural Development (China)
MIIT	Ministry of Industry and Information Technology (China)
NAPCP	Finnish National Air Pollution Control Programme
NCCP	National Climate Change Policy (Ghana)
NCCCP	National Congress of the Chinese Communist Party
NDC	Nationally Determined Contributions to the Paris Agreement (within the United Nations Framework Convention on Climate Change)
NDRC	National Development and Reform Commission (China)
NEA	National Energy Administration (China)
NEC	National Emissions Ceiling
NECD	EU's National Emissions Ceilings Directive
NH_3	ammonia
NIR4	The 4th National Inventory Report (Ghana)
NMVOCs	non-methane volatile organic compounds
NO	nitrogen monoxide
N_2O	nitrous oxide
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
O_3	ozone
OC	organic carbon
OECD	Organisation for Economic Co-operation and Development
PAM	policy and measures
pb	lead
PFCs	perfluorocarbons
PHEV	plug-in hybrid electric vehicles
PM	particulate matter
$PM_{2.5}$	particulate matter with an aerodynamic diameter equal to or less than 2.5 μm
PM_{10}	particulate matter with an aerodynamic diameter equal to or less than 10 μm
ppm	parts per million
R&D	research and development
RMB	renminbi
SCPRC	State Council of the People's Republic of China
SDG	Sustainable Development Goals
SF_6	sulphur hexafluoride
SLCF	short-lived climate forcer
SLCP	short-lived climate pollutants
SO_2	sulphur dioxide
SYKE	The Finnish Environment Institute
TSP	total particulate matter

NAPCP	Finnish National Air Pollution Control Programme
UK	United Kingdom of Great Britain and Northern Ireland
UK CCC	UK Climate Change Committee
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VOCs	volatile organic compounds
WHO	World Health Organization
WMO	World Meteorological Organization

Units of measure

C	centigrade
gce	gram of coal equivalent
GW	gigawatts
kg	kilogram
kgce	kilogram of coal equivalent
kt	kilotonne (1,000 tonnes)
kW	kilowatt (1,000 watts)
kWh	kilowatt hour
m	metre
m^2	square metre
m^3	cubic metre
mg	milligram
mt	million tonnes
Mtce	million tonnes of carbon equivalent
Mtoe	million tonnes of oil equivalent
MW	megawatts (a million (10^6) watts)
t	tonne
tce	tonnes of coal equivalent
toe	tonnes of oil equivalent
TW	terawatt (one million million (10^{12}) watts)
TWh	terawatt hour(s)
µg	microgram (one millionth of a gram)
µm	micrometer (one millionth of a metre)

Glossary

Air Pollution Prevention and Control Action Plan

The Action Plan of Air Pollution Prevention and Control, also known as the Ten Articles of the Air Quality, was formally released in 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 the national level that sets air quality targets for China.

Air Pollution Prevention and Control Law

The Air Pollution Prevention and Control Law of the People's Republic of China was passed in 1988 and amended in 1995, 2000, 2015 and 2018. The Law aims to protect and improve the environment, prevent and control air pollution, safeguard public health, promote the construction of ecological civilization and promote sustainable economic and social development. The Law went through a major revision in 2015 with strengthened rules and standards for air pollution control.

Black carbon

Operationally defined aerosol species based on measurement of light absorption and chemical reactivity and/or thermal stability. It is sometimes referred to as soot. Black carbon (BC) is mostly formed by the incomplete combustion of fossil fuels, biofuels and biomass but it also occurs naturally. It stays in the atmosphere only for days or weeks. It is the most strongly light-absorbing component of particulate matter (PM) and has a warming effect by absorbing heat into the atmosphere and reducing the albedo when deposited on snow or ice.

Carbon dioxide equivalent (CO_{2e})

A way of placing emissions of various radiative forcing agents on a common footing by accounting for their effect on climate. It describes, for a given mixture and amount of greenhouse gases, the amount of CO_2 that would have the same global warming ability, when measured over a specified time period. For the purpose of this report, greenhouse gas emissions (unless otherwise specified) are the sum of the basket of greenhouse gases listed in Annex A to the Kyoto Protocol, expressed as CO_{2e} assuming a 100-year global warming potential.

Co-benefits

The positive effects that a policy or measure aimed at one objective might have on other objectives, without yet evaluating the net effect on overall social welfare. Co-benefits are often subject to uncertainty and depend on, among others, local circumstances and implementation practices. Co-benefits are often referred to as ancillary benefits.

Energy Conservation Law

The Energy Conservation Law of the People's Republic of China was adopted in 1997 and amended in 2007, 2016 and 2018. The Law aims to promote energy conservation, improve energy efficiency, protect and improve the environment and promote comprehensive, coordinated and sustainable development of the economy and society. This Law includes general provisions on energy conservation, stipulates energy conservation requirements for industries, transportation, buildings, public institutions and key energy-using entities, encourages energy-saving technological advancement and defines incentives and related legal responsibilities for energy conservation.

Greenhouse gases

The atmospheric gases responsible for causing global warming and climatic change. The major greenhouse gases are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Less prevalent, but very powerful, greenhouse gases are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and Sulphur hexafluoride (SF_6).

Governance

A comprehensive and inclusive concept of the full range of means for deciding, managing, implementing and monitoring policies and measures. Whereas government is defined strictly in terms of the nation-state, the more inclusive concept of governance recognizes the contributions of various levels of government (global, international, regional, sub-national and local) and the contributing roles of the private sector, of nongovernmental actors, and of civil society to addressing the many types of issues facing the global community.

Intended Nationally Determined Contribution

Intended Nationally Determined Contributions (INDCs) are submissions from countries describing the national actions it intends to take to reach the Paris Agreement's long-term temperature goal of limiting warming to well below 2°C. Once a country has ratified the Paris Agreement, its INDC is automatically converted to its NDC (see below), unless it chooses to further update it.

Nationally Determined Contribution

Nationally Determined Contributions (NDCs) are submissions by countries that have ratified the Paris Agreement which presents their national efforts to reach the Paris Agreement's long-term temperature goal of limiting warming to well below 2°C. New or updated NDCs are to be submitted in 2020 and every five years thereafter. NDCs thus represent a country's current ambition/target for reducing emissions nationally.

Paris Agreement

The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) was adopted on December 2015 in Paris, France, at the 21st session of the Conference of the Parties (COP) to the UNFCCC. The agreement, adopted by 196 Parties to the UNFCCC, entered into force on 4 November 2016 and as of May 2018 had 195 Signatories and had been ratified by 177 Parties. One of the goals of the Paris Agreement is "*holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels*", recognizing that this would significantly reduce the risks and impacts of climate change. Additionally, the Agreement aims to strengthen the ability of countries to deal with the impacts of climate change. The Paris Agreement is intended to become fully effective in 2020.

Renewable Energy Law

The Renewable Energy Law of the People's Republic of China is formulated to promote the development and utilization of renewable energy, increase energy supply, improve energy structure, ensure energy security, protect the environment and achieve sustainable economic and social development. The Law was adopted in 2005 and revised in 2009. The Law clearly lists the development and utilization of renewable energy as a priority of energy development and promotes the establishment and development of renewable energy market by setting total targets of renewable energy development and taking corresponding measures.

Sponge city

Sponge cities are also called water-resilient cities. The term refers to city that has the capacity to mainstream urban water management into urban planning policies and designs. A sponge city should have the appropriate planning and legal frameworks and tools in place to implement, maintain and adapt the infrastructure systems to collect, store and treat (excess) rainwater. A sponge city not only deals with the problem of "too much water," but also reuses rain water to help mitigate the problems of "too little" or "too dirty" water.

Sustainable Development Goals

The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries - developed and developing - in a global partnership. The SDGs recognize that ending poverty and other deprivation must go hand-in-hand with strategies that improve health and education, reduce inequality and spur economic growth – all while tackling climate change and working to preserve our oceans and forests.

The National Five-Year Plan for Economic and Social Development

The National Five-Year Plan (FYP) sets out overall goals for social and economic development for the following five years in China. The central government released the first national FYP in 1953, and recently released its 13th FYP. The formulation of each five-year plan usually takes more than two years. During the initial research stage, the National Development and Reform Commission (NDRC) raises important issues, invites public bidding from the whole of society, directly commissions research, as well as conducts internal research within the NDRC. The research phase involves thousands of experts and researchers who conduct research on hundreds of topics relevant to the FYP. Following the research stage, the FYP goes through stages of idea formation, drafting, the formation of special plans and solicitation of comments, until it is finalized and submitted to the National People's Congress for discussion and consideration.

United Nations Framework Convention on Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in May 1992 and opened for signature at the 1992 Earth Summit in Rio de Janeiro, Brazil. It entered into force in March 1994 and as of May 2018 had 197 Parties (196 states and the European Union). The UNFCCC's ultimate objective is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". The provisions of the Convention are pursued and implemented by two treaties: the Kyoto Protocol and the Paris Agreement.

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