Health Co-Benefits from NDC Implementation in China

REPORT

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Acronyms and Abbreviations

CI	confidence interval
COPD	Chronic Obstructive Pulmonary Disease
CVD	cardiovascular disease
DALY	Disability-Adjusted Life Year
FYP	Five-Year Plan
GHG	greenhouse gas
IEA	International Energy Agency
IMF	International Monetary Fund
NCD	non-communicable diseases
NDC	Nationally Determined Contribution
NDRC	National Development and Reform Commission
OECD	Organisation for Economic Co-operation and Development
$PM_{2.5}$	particulate matter of 2.5 micrometres or less in diameter
PV	photovoltaic
VSL	value of statistical life
WHO	World Health Organization

1.0 Introduction

Over the past few years, China has shown strong determination to shift to a low-carbon economy. In addition to committing to peaking its greenhouse gas (GHG) emissions by around 2030 (People's Republic of China, 2015a), the country has committed to phasing out inefficient fossil fuel subsidies as part of the G20 (Organisation for Economic Co-operation and Development [OECD], 2016) and defined a reform plan to achieve this (People's Republic of China, 2015b). In 2017, Premier Li Keqiang pledged to "make the skies blue again" in recognition of the need to tackle air pollution (Bloomberg News, 2017). In its National 13th Five-Year Plan (FYP) (2016–2020), China has prioritized environmental and energy sustainability, both within national borders and as part of the Belt and Road Initiative (People's Republic of China, n.d.). China's current national environmental policies, which include measures to slow down or stop coal power plant expansions, are expected to have a positive impact on health. For instance, in the 13th FYP for the Development of the Coal Industry, the National Development and Reform Commission (NDRC) and the National Energy Agency have planned to phase out excessive production capacity by 800 million tonnes per year and to increase more advanced and cleaner production capacity by 500 million tonnes per year through reduction and replacement during the 13th FYP period. NDRC, Ministry of Industry and Information Technology, et al. (2018b) states that China has reduced coal-fuelled electricity capacity by 65 million kW in 2017 and has reduced coal production by over 500 million tonnes in 2016 and 2017 (combined).

There is strong evidence of the links between health and climate change. Climate change and air pollution from the combustion of fossil fuels (which are also a major cause of climate change) are linked to several serious non-communicable diseases (NCDs) including cardiovascular and respiratory diseases, cancer, malnutrition and diseases linked to the fallout from natural disasters (Smith et al., 2014). China has recognized the links between health and environment in the 12th and 13th FYPs and reflected these in recent policies and budget allocations.

The objective of this report is to summarize the policy efforts that China is already undertaking to achieve its Nationally Determined Contribution (NDC) targets, and the related expected health co-benefits, based on recent scientific literature. It shows that there is a large set of policies aligned with the country's NDC targets that focus mostly on the reduction of fossil fuel use and the expansion of cleaner forms of energy. This report also looks at relevant Chinese budget allocations to health, environment and fossil fuels, concluding that subsidies to fossil fuels still represent a large part of China's budget when compared to public allocations to health and other environmental programs.

The report will start by summarizing the main health impacts related to climate change and air pollution in China (Chapter 2). Chapter 3 will identify and evaluate the main Chinese policies that are expected to have positive effects on public health and summarize existing literature that evaluates the health co-benefits of China's NDC targets and related policies. Chapter 4 will present an economic comparison of the public budget to health and environment with the public budget that China devotes to fossil fuels. Finally, main conclusions and recommendations will be presented in the last chapter. Annexes 1 and 2 summarize, respectively, the list of climate-friendly policies analyzed in Chapter 3.1 and the list of models evaluated in Chapter 3.2.

2.0 Understanding the Health Impacts of Climate Change and Coal Energy Consumption in China

Climate change affects human health in a variety of ways. According to the Intergovernmental Panel on Climate Change's report, *Climate Change 2014: Impacts Adaptation, and Vulnerability* (Smith et al., 2014), there are three main ways in which climate change impacts human health:

1. Direct impacts, which refer to health impacts resulting from changes in frequency of extreme weather, such as heat, drought and heavy rainfall.
2. Ecosystem-mediated impacts, also called indirect impacts. These refer to increased morbidity and mortality from increased exposure to vector-borne and other infectious diseases, food- and water-borne infections, air pollution and aeroallergens.
3. Human-mediated impacts, for example from poor nutrition, occupational health, mental health, violence and conflict.

The combustion of fossil fuels for the generation of electricity, heating or transportation is a major cause of air pollution and climate change, which are also interrelated. Fossil fuel energy use is related to climate change as the primary source of carbon dioxide emissions.[1] Climate change induces higher temperatures, which increase the harm of small particles released by the combustion of fossil fuels. Therefore, climate change exacerbates air quality issues and is projected to lead to an increase in premature deaths (Silva et al., 2017). It is estimated that, in 2013, 99.6 percent of the Chinese population lived in areas where the World Health Organization's (WHO) fine particulate matter ($PM_{2.5}$) guideline of 10 μg/m^3 was exceeded (GBD MAPS Working Group, 2016).

Table 1 summarizes the main environmental health impacts and diseases that are relevant to China. Vulnerable population groups—that is, children, young people, pregnant women, the elderly and the poor—are at increased risk of suffering from climate-related injury and illness (Smith et al., 2014).

Table 1. List of main climate change-related diseases and health impacts in China

Health impacts of climate change	Main cause	Source
Cardiovascular disease (CVD), including diseases that pertain to the heart and blood vessels, such as stroke, ischemic heart disease and heart attack	Risk of CVD is increased by air pollution and extreme temperatures. For instance, climate change is responsible for extreme cold and extreme heat, increased ozone formation and concentration due to higher temperatures, and increased particulate matter. These factors all directly affect the occurrence of CVD.	Friel et al., 2011; National Institute of Environmental Health Sciences, 2017a; WHO, n.d.a.

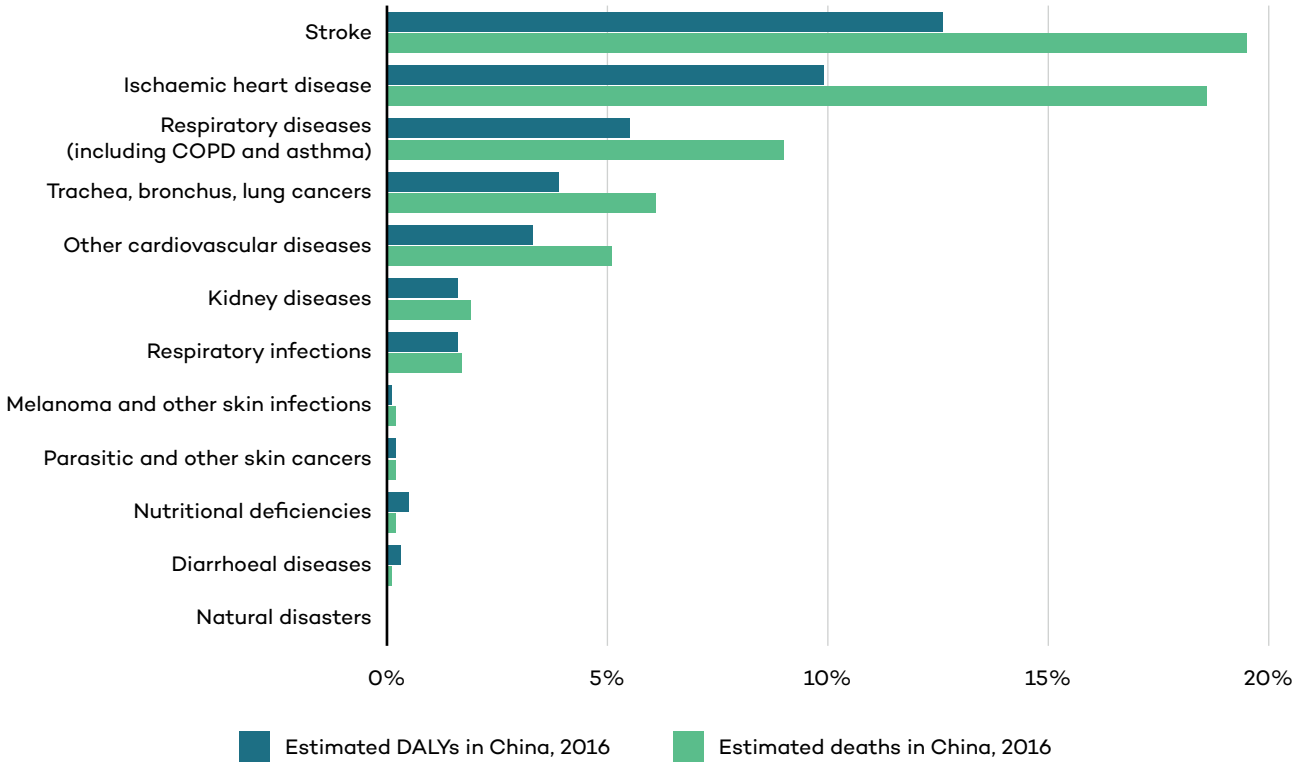
[1] In China, due to the heavy dependence on coal, the energy sector remains the largest carbon emitter (NDRC, 2016; Liu et al., 2018).

Health impacts of climate change	Main cause	Source
Respiratory diseases, including asthma, respiratory allergies and airway diseases such as chronic obstructive pulmonary disease (COPD)	Respiratory health is influenced by air quality, notably through allergens, ozone, fine particles and dust. In general, changing climate conditions and increasing temperatures will compromise outdoor air quality by increasing the production of tropospheric ozone. Ozone exposure contributes to increased respiratory tract irritation, chronic pulmonary disease hospitalizations, lung diseases and asthma. The fine particulate air pollution arising from the combustion cycles for fossil fuels enters the respiratory tract, increasing the risk of acute respiratory infections, including asthma.	Friel et al., 2011; D'Amato et al., 2013; National Institute of Environmental Health Sciences, 2018; WHO, n.d.a.
Cancer in respiratory tracts (lunch, trachea and bronchus)	Burning fossil fuels (such as coal for electricity, diesel and gasoline for transportation) releases fine particles ($PM_{2.5}$ and smaller) that can enter the lungs and have been associated with cancer of the lungs and other respiratory tracts (trachea and bronchus). Higher temperatures associated with climate change increase the volatilization of toxic chemicals and air pollutants, worsening their effects on human health.	Friel et al., 2011; National Institute of Environmental Health Sciences, 2018; WHO, n.d.a.
Infectious diseases, including water-borne, food-borne and air-borne diarrheal diseases	Climate change has an impact on both pathogens and the transmission of infectious diseases. Higher temperatures may extend the life cycle of pathogens. While changes in precipitation can have an effect on the dissemination of water-borne pathogens, humidity can further be a factor in the transmission of air-borne diseases. The indirect impact of climatic change on human systems (e.g., food and water storage) can change transmission patterns and disease burden.	Wu et al., 2016; Palmgren, 2009; Smith et al., 2014.
Skin cancer	Global climate change affects ultraviolet radiation, temperature, precipitation and cloud coverage, which all alter sun exposure behaviour. Ultraviolet radiation and sun exposure are linked to ultraviolet-related health outcomes, including skin cancer.	National Institute of Environmental Health Sciences, 2018.

Health impacts of climate change	Main cause	Source
Parasitic and vector-borne diseases (e.g., malaria, dengue fever, yellow fever, Japanese encephalitis, Lyme disease, tick-borne encephalitis, echinococcosis and schistosomiasis)	Changes in local temperatures, humidity, wind and precipitation can have an influence on the ecology of vectors and parasites and might, for example, extend transmission cycles and geographic spread of vector-borne diseases in previously colder regions or higher latitudes. The indirect effects of climate change on human systems and practices (e.g., changes in agricultural practices, irrigation and population movement) will additionally affect vectors and human exposure to parasitic and vector-borne diseases. Interaction of these factors is complex and the effect of climate change on disease burden will vary across diseases and locations.	Campbell-Lendrum et al., 2015 ; Wu et al., 2016; Bai, Morton & Liu, 2013; Tokarevich et al., 2011; Zhou et al., 2008.
Health impacts from extreme weather events and natural disasters (e.g., heat wave-related diseases such as heat stroke and kidney diseases; diseases and injuries caused by natural disasters such as physical injuries and post-traumatic stress syndrome)	Climate change increases the frequency of extreme weather events and related natural disasters such as floods, storms and droughts. "Prolonged exposure to extreme heat can cause heat exhaustion, heat cramps, heat stroke, and death, as well as exacerbate pre-existing chronic conditions, such as various respiratory, cerebral, and cardiovascular diseases" (Muanya, 2019). Recurrent dehydration and heat stress can further cause acute renal failure and exacerbate existing chronic kidney diseases. Natural disasters from extreme weather events creates threats of traumatic injuries (e.g., cuts, bruises, wound infections) and drowning. Victims of natural disasters may additionally suffer from post-traumatic stress disorders. Extreme weather events and overcrowding due to displacement in the aftermath of a disaster can sometimes cause or exacerbate the outbreak of infectious diseases, yet impacts are hard to predict.	National Institute of Environmental Health Sciences, 2017b; Kjellstrom et al., 2010; Ghazali et al., 2018.
Indirect human-mediated health impacts (e.g., nutritional deficiencies, mental health conditions, occupational health, violence and conflict)	Indirect human-mediated impacts of climate change on society and the human environment can have various health consequences that are hard to predict. Climate impacts on the agricultural system can have a detrimental influence on the quality and quantity of agricultural produce and may lead to food insecurity and undernutrition in some populations. Climatic changes can further cause or exacerbate occupational health risks, particularly heat strain and heat exhaustion. Forced displacement due to climate change may entail stress-related psychiatric and anxiety disorders and spark violence and conflict with potentially severe effects on health and society.	Smith et al., 2014; Ghazali et al., 2018.

While it is likely that climate change has already had an impact on human health, the current global burden of ill health from climate change is comparatively small compared to other stressors and not yet well quantified (Smith et al., 2014, p. 713). This is also the case for China. Given the lack of quantifiable data on disease-specific health burdens attributable to climate change and air pollution, Figure 1 draws from the total health burden of the main diseases and impacts depicted in Table 1 and shows their relative importance for China in 2016 (as a percentage of total Disability-Adjusted Life Years [DALYs[2]] and premature deaths). The data mean that, for example, almost 20 per cent of all the deaths estimated in China in 2016 were caused by a stroke.

Figure 1. Estimated DALYs and deaths in China in 2016 from different causes of disease that could be linked to climate change and air pollution[3] (in percentage of total DALYs and total deaths, respectively).



Source: Authors' elaboration of data from WHO, 2018a.

[2] One DALY is considered one year of "healthy life" lost. It is a measure for the burden of a specific disease, considered as "the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability" (WHO, n.d.b).

[3] Figure 1 is based on the total number of cases for the respective diseases from all possible causes, including (but not limited to) climate change and air pollution. The total burden of the diseases presented in Figure 1 in 2016 in China was 6.5 million deaths (WHO, 2018a).

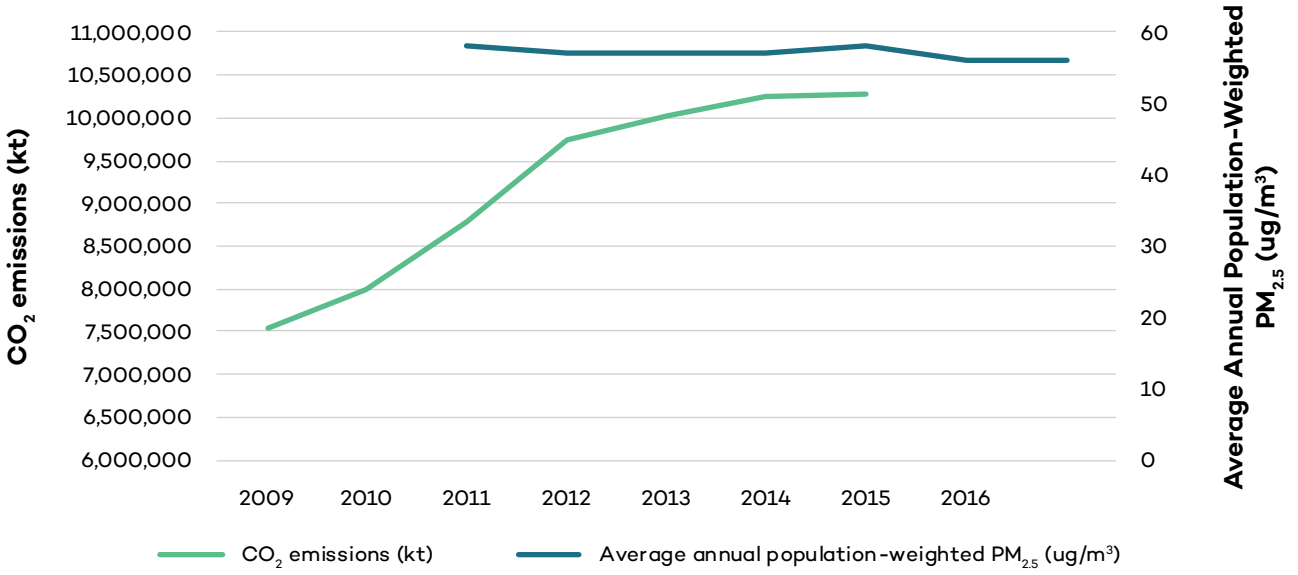
Stroke, ischemic heart disease, COPD and lung cancer were among the top causes of death in China in 2016 (IHME, 2018; WHO, 2018a). These diseases are strongly linked to air pollution caused by particles released by the combustion of fossil fuels, including particulate matter of 2.5 micrometres or less in diameter ($PM_{2.5}$), which can access human respiratory and cardiovascular systems. More than 70 per cent of China's electricity is sourced from coal (World Bank, 2017), which is associated with more particulate emissions than any other major source of electricity generation. The WHO (2018b) estimates that ambient air pollution contributed to 1.1 million deaths in 2016 in China.[4] The emissions from coal are likely to account for a significant proportion of these deaths, though it is extremely challenging to reliably quantify the impact on public health from coal-related emissions.

[4] The WHO estimate indicates 81 deaths attributable to ambient air pollution in China in 2016 per 100,000 inhabitants. China's population in 2016 was 1.379 billion.

3.0 Climate-Friendly Policies and Health Impacts

In recent years, the Chinese government has undertaken significant efforts to reduce air pollution, mitigate the increase in GHG emissions, reduce the use of the most damaging fossil fuels (such as coal) and improve the quality of fuels used for transportation. This has been reflected in significant progress in stabilizing carbon dioxide emissions and a slight improvement in some air pollution measures, such as the average annual population-weighted $PM_{2.5}$ (see Figure 2).

Figure 2. Evolution of carbon dioxide emissions (thousand tonnes) and air pollution ($PM_{2.5}$ concentration) in China, 2008–2016 (Note: carbon dioxide emissions data available only until 2014).



Sources: Authors' elaboration with data from Health Effects Institute and the Institute for Health Metrics and Evaluation, 2018; World Bank, 2018.

In June 2015, China submitted its first NDC under the Paris Agreement, committing to the following four targets by 2030 (People's Republic of China, 2015a):

a) "To achieve the peaking of carbon dioxide emissions around 2030 and making best efforts to peak early;
b) to lower carbon dioxide emissions per unit of GDP by 60% to 65% from the 2005 level;
c) to increase the share of non-fossil fuels in primary energy consumption to around 20%; and
d) to increase the forest stock volume by around 4.5 billion cubic meters on the 2005 level."

To achieve these targets, China's NDC identified 15 different areas to implement efforts. These areas go from general strategies on climate change to more concrete actions linked to financing or engagement of stakeholders.[5]

This paper has looked at the 15 action areas of China's NDC and identified policies that have been implemented or issued after the submission of China's NDC, placing particular emphasis on policies having a direct or indirect impact on air pollution and climate change, in accordance with the linkages outlined in the previous section. The objective is to compare them with the NDC targets and estimate their health impacts. The report groups the relevant policies into seven categories (see Section 3.1). The estimate of health impacts will be based on existing quantitative models specific to China, as explained in Section 3.2.

3.1 China's Climate-Friendly Policies

Public policies have big potential to mitigate climate change and limit the associated negative health impacts. In the past few years, China has published several laws and regulations that demonstrate a strong commitment to addressing climate change. This section reviews the climate policies that have been issued and implemented in the past five years, grouped into seven categories: climate change, fossil fuel consumption, renewable energy, industry, transportation, air pollution and forestry.[6] Figure 3 summarizes the most relevant policies per category and their targets related to the four NDC targets listed above.

Most of the relevant policies are in the categories of renewable energy, fossil fuel consumption and air pollution, notably in improving air quality, demonstrating the importance that China is placing on climate change and its effects. The targets expressed in the different policies observed are consistent with each other and aligned with NDC targets. Most targets in current policies are lower than the ones set by the NDC because NDC targets are set for 2030, whereas the analyzed Chinese policies have targets set up to 2020 (see Figure 4). However, recent Chinese initiatives and announcements imply that there is room to update these targets with more ambitious figures (see Box 1).

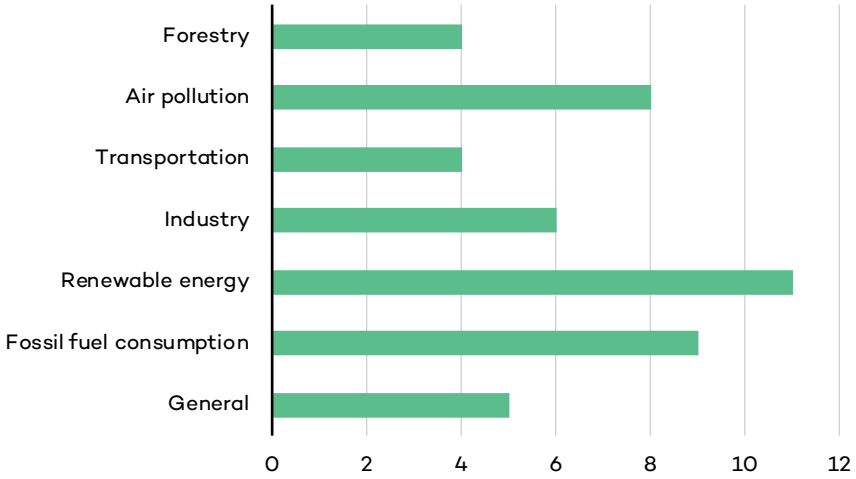
The policy analysis carried out also shows that, in most of the categories, such as energy or industry, a large number of institutions are involved, pointing to an ongoing coordination of agencies, in line with the nature of combating climate change and reducing air pollution. For instance, in terms of mitigating emissions from fossil fuels, three national agencies—NDRC, the National Energy Agency and the Ministry of Environmental Protection—promulgated the Coal-Fired Electricity Energy Saving, Emission Reduction, and Upgrade and Transformation Action Plan (2014-2020) in 2014. At the end of 2014, the National Energy Agency, the Ministry of Environmental Protection and the Ministry of Industry and Information Technology issued Opinions on Promoting Safe and Green

[5] China's NDC categorizes the policies needed to achieve its objectives in the following groups: A. Implementing Proactive National Strategies on Climate Change; B. Improving Regional Strategies on Climate Change; C. Building Low-Carbon Energy System; D. Building Energy Efficient and Low-Carbon Industrial System; E. Controlling Emissions from Building and Transportation Sectors; F. Increasing Carbon Sinks; G. Promoting the Low-Carbon Way of Life; H. Enhancing Overall Climate Resilience; I. Innovating Low-Carbon Development Growth Pattern; J. Enhancing Support in terms of Science and Technology; K. Increasing Financial and Policy Support; L. Promoting Carbon Emission Trading Market; M. Promoting Carbon Emission Trading Market; N. Improving Statistical and Accounting System for GHG Emissions; O. Broad Participation of Stakeholders; P. Promoting International Cooperation on Climate Change.

[6] Annex 1 contains the full list of policies analyzed. The policies are consistent with China's NDC.

Development, Clean and Efficient Use of Coal, which also addresses emission mitigation in the fossil fuel industry. This internal consistency within government should allow the policy implementation process to be highly efficient.

Figure 3. Number of implemented policies in China that support the country's climate change objectives and the main 2020 targets that these policies include

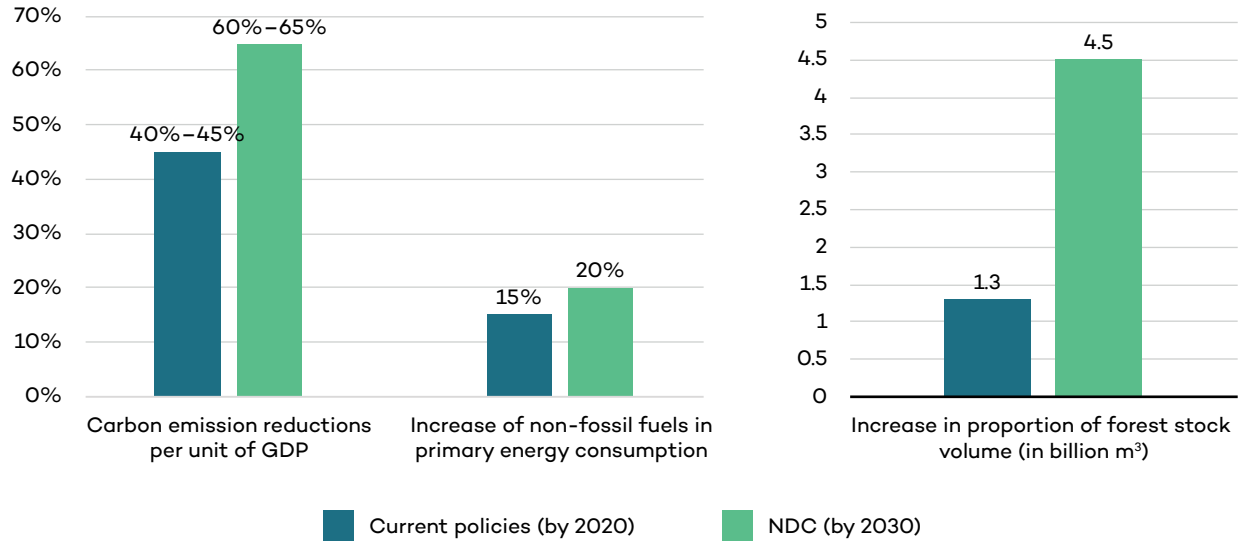


Main 2020 targets
(Related to 2030 NDC targets):

- Reduction of carbon emissions per unit of GDP by 40 to 45% by 2020
- Increase the share of non-fossil fuels in the total mix of primary energy consumption to 11.4% by 2015, 13% by 2017 and 15% by 2020
- Increase the proportion of forest stock volume by 1.3 billion m^3 by 2020 and by 4.5 billion m^3 by 2020

Source: Authors' elaboration based on Annex 1's list of climate-friendly policies.

Figure 4. Comparison of NDC's and other Chinese policies' targets



Source: Authors' elaboration based on Annex 1's list of climate-friendly policies.
Note: Percentages are by 2020 in the case of current policies and by 2030 in the case of the NDC.

Box 1. Are China's NDC targets ambitious enough?

According to China's NDC, the country aims to peak carbon dioxide emissions by 2030 and increase the share of non-fossil fuels in primary energy consumption to 20 per cent. In 2016, this share was almost 10 per cent (International Energy Agency [IEA], 2017).

Recently, China announced targets on clean cars and achievements on renewable energy that are expected to ease the path to its NDC's objectives. China expects that 20 per cent of new car sales by 2025 will be "new energy vehicles," which would represent 7 million hybrid or electric cars (Reuters, 2017). The country's investment in renewable energy is booming, reaching USD 127 billion in 2017, that is, around 45 per cent of the global investment in renewables in that year (Hodges, 2018). Furthermore, China introduced a green electricity certificate-trading scheme in 2017 and has been pushing broader reforms, such as fossil fuel taxation, to address environmental externalities[7] (Qi, 2018). These initiatives are still too recent to determine their impacts, but their outcomes are expected to support the NDC objectives.

These initiatives, together with the strong price reductions that renewable technologies are seeing, would be expected to accelerate the uptake of clean renewable technologies by 2030. A recent draft plan from the NDRC indicated that China is revising the definition of its target for renewable energy to supply at least 35 per cent of total electricity consumption by 2030 (Bloomberg News, 2018)—around 10 per cent more than the 2016 share (IEA, 2017). Furthermore, coal demand is expected to peak around 2025, according to the think tank CNPC Economics and Technology Research Institute,[8] following a steep increase in renewable, nuclear and natural gas capacity (Reuters, 2019).

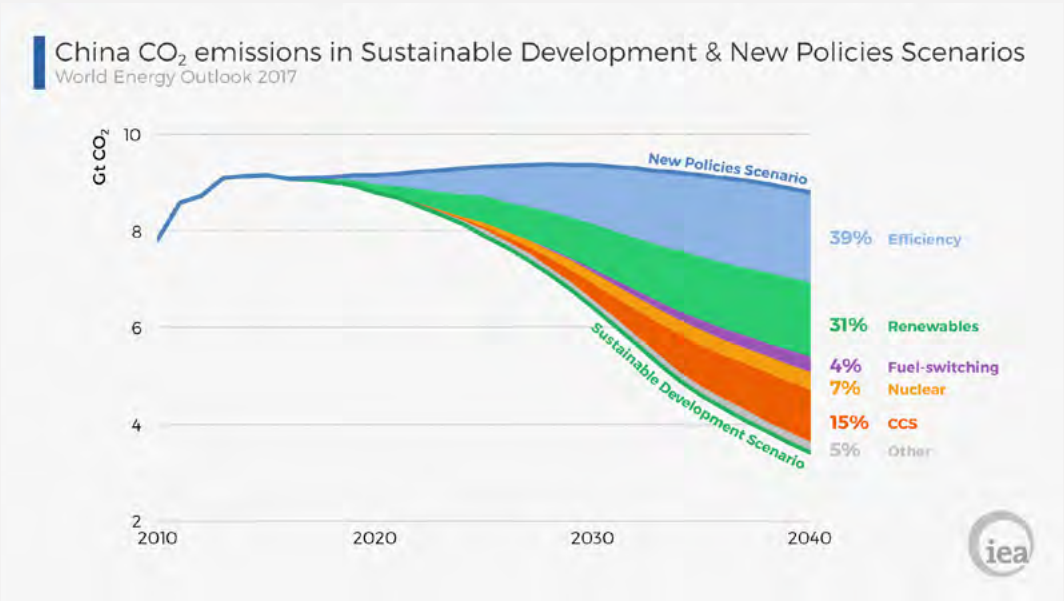
The implementation of the previous energy policies and initiatives is expected to have an important impact in curbing China's GHG emissions. The IEA (2017) estimates that, under their "New Policies Scenario,"[9] carbon dioxide emissions in China are expected to peak around 2030. Under their "Sustainable Development Scenario" (which requires important increases on energy efficiency and the share of renewables, as well as carbon capture and storage technologies), significant carbon dioxide emission reductions could be achieved by 2040 (see Figure 5). A study by Gallagher et al. (2019) finds that, if China applies all current policies in full, successfully concludes the power-sector reform and fully implements a national emission trading system for the power and industrial sectors after 2020, the country is likely to peak its emissions well in advance of 2030 and achieve its non-fossil fuel target.

[7] China has established a National Emission Trading Scheme and the Environmental Protection Tax Law, which are breakthroughs in China's environmental protection and climate change mitigation. The Environmental Protection Tax replaces the pre-existing mechanism of pollution discharge fees and has broader coverage of air pollutants, water pollutants, solid waste and noise. It aims to enforce the "polluter pays" principle. The National Emission Trading Scheme covers only the power generation sector in its first phase, but it is expected to expand to cover eight energy-intensive sectors across the Chinese economy.

[8] This think tank is run by the state-owned China National Petroleum Corp.

[9] This scenario incorporates existing energy policies as well as announced policy intentions at the time of evaluation (IEA, 2017)

Figure 5. IEA's Sustainable Development and New Policies scenarios for carbon dioxide emissions in China



Source: IEA, 2017.

Among all policy categories researched as part of this paper, the authors have focused attention on those concerning fossil fuel use, particularly coal and coal-fired power plants. Policies in this category generate direct climate change mitigation benefits and reductions in air pollution, which are related to several climate-sensitive health impacts, as seen in the previous chapter. The government has set targets to control coal consumption, increase efficiency of coal use and address the excess capacity of coal-fired power plants. It has set more stringent standards for civil and industrial use of coal. Some policies, such as the Work Program to Strengthen Air Pollution Prevention in Energy Industry (NDRC, National Energy Agency, & Ministry of Environmental Protection, 2014a) and the Coal-Fired Electricity Energy Saving, Emission Reduction, and Upgrade and Transformation Action Plan (2014–2020) (NDRC, National Energy Agency, & Ministry of Environmental Protection, 2014b), explicitly address the topic or air quality and emission reductions (see Annex 1 for more details).

In the 13th FYP, the government has also recognized the importance of the interconnection between health and environment and has promulgated specific policies to address the issue. For instance, the latest National Work Plan of Environmental Protection and Health (For Trial Implementation[10]) (Ministry of Environmental Protection, 2018b) suggests that the government is placing increasing emphasis on addressing the health impacts of the environment. For example, the Ministry of Environmental Protection was mandated to coordinate national environmental health risk monitoring work, develop monitoring plans and coordinate nationwide implementation. The provincial environmental protection departments are then responsible for carrying out environmental health risk monitoring within their respective administrative area in accordance with relevant technical specifications for national environmental health risk monitoring.

[10] "Trial implementation" means that the regulation is not finalized but at a trial stage. It is as effective as a formal regulation but may be subject to revision.

3.2 Health Impacts of Climate-Friendly Policies

China's comprehensive policy package to mitigate climate change and reduce air pollution (aligned with NDC's targets) is expected to result in a series of positive health co-benefits. It is too early to directly observe these positive effects, but there are several models that estimate the health impacts and co-benefits of achieving China's NDC targets in the middle and long terms. This report does not model these effects. Instead, it collects and summarizes recent literature on the topic. Annex 2 summarizes the results and assumptions under each of the models used in this section.

Existing literature focuses on estimating the long-term health co-benefits and associated costs of climate policies by comparing different climate scenarios with a business-as-usual scenario. Other models analyzed study the health co-benefits of adopting particular policies, specifically the expansion of solar photovoltaic (PV) and electrification. The models that monetize the health co-benefits all conclude that these benefits well outweigh the cost of implementing climate policies, especially in the long term (to 2050). Table 2 summarizes the modelling results from the scientific literature, focusing on scenarios that model the achievement of China's NDC targets where possible.

Table 2. Summary of main modeling results of direct health benefits and co-benefits of implementing air pollution reduction and climate-friendly policies

Study	Scenario	Direct health benefits for China[11]	Health co-benefits[12] for China
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 (Cai, et al., 2018)	Implementation of China's NDC targets compared to a scenario with no climate policy	19,962 premature deaths avoided in year 2030 and 368,568 in year 2050	Between USD 0.83 billion and USD 3.05 billion in 2030; between USD 17.38 billion and USD 55.55 billion in 2050, in terms of life value savings[13]

[11] Unless specified otherwise, the number of deaths indicated in this column indicate the reduction of deaths in the given year under the scenario and reference described in the column "scenario." The same applies to the estimates for the health co-benefits column.

[12] Note that these numbers cannot be compared directly with the International Monetary Fund (IMF, 2018) estimate of the externality costs, since the figures in this table consider the gains resulting from each specific scenario, including more clean energy sources as well as other underlying assumptions.

[13] These values consider the median value of other value of statistical life (VSL) estimates for China, which offers a conservative estimate.

Study	Scenario	Direct health benefits for China[11]	Health co-benefits[12] for China
Health Co-Benefits From Air Pollution and Mitigation Costs of the Paris Agreement: A modelling study (Markandya et al., 2018)	Implementation of China's NDC targets[14] compared to a scenario with no climate policy	Between 2.1 million and 2.4 million premature deaths avoided between 2020 and 2050 (cumulative)	Approximately, USD 6.5 trillion saved between 2020 and 2050 (cumulative)
Air Quality Co-Benefits for Human Health and Agriculture Counterbalance Costs to Meet Paris Agreement Pledges (Vandyck et al.,2018)	Achievement of China's NDC targets compared to a reference scenario based on current and announced energy and climate policies up to 2020 and no additional implementation of air pollution abatement technologies from 2010 onwards[15]	61,000 premature deaths from air pollution ($PM_{2.5}$ and ozone) avoided in year 2030 and 250,000 in year 2050	n/a[16]
Co-Benefits of Climate Mitigation on Air Quality and Human Health in Asian Countries (Xie et al., 2018)	Air pollution reduction ($PM_{2.5}$ and ozone concentration) from achievement of the 2°C climate mitigation goal, compared to a scenario that extrapolates actual policy developments and population growth by 2050	225,000 premature deaths avoided in 2050—a reduction of premature deaths of 1.455 million in 2050 compared to 2005	USD 720 billion in 2050 in terms of life value savings

[14] This study evaluates multiple climate scenarios with varying temperature objectives consistent with the Paris Agreement (NDCs, 2°C, or 1.5°C). This table collects only the results of the NDC-related modelling. Details on the models, scenarios and results are shared in Annex 2.

[15] This study evaluates multiple climate scenarios considering different levels of ambition in policies to control air pollution. The results presented in this table correspond to the highest value of premature deaths avoided, which corresponds to the less ambitious air pollution control scenario and which considers no additional implementation of air pollution abatement technologies from 2010 onward. Annex 2 includes more details about the model and the scenarios.

[16] The co-benefits estimated in this study include the value of avoided premature mortality as well as the co-benefits of the labour and agricultural markets. These are not comparable to the other estimates in this table, which only include the health co-benefits. Therefore, they have not been included.

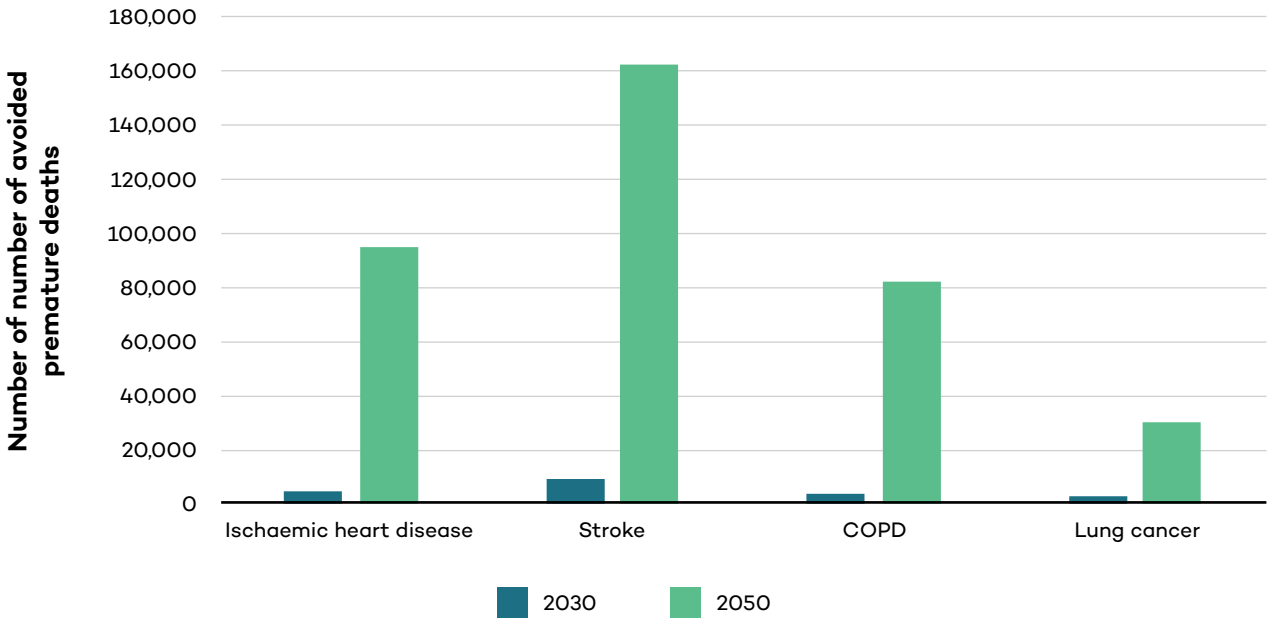
Study	Scenario	Direct health benefits for China[11]	Health co-benefits[12] for China
Climate, Air Quality and Human Health Benefits of Various Solar Photovoltaic Deployment Scenarios in China in 2030 (Yang, Li, Peng, Wagner, & Mauzerall, 2018)	Deployment of distributed PV in the east together with inter-provincial transmission[17] compared to a coal-intensive power sector projection scenario	10,000 annual avoided premature mortalities associated with $PM_{2.5}$ reductions	n/a
Potential Co-Benefits of Electrification for Air Quality, Health, and CO_2 Mitigation in 2030 China (Peng, Yang, Lu, & Mauzerall, 2018)	Switch to a half-decarbonized power supply for electrification of the transport and/or residential sectors[18] compared to a non-electrified, coal-intensive, business-as-usual scenario	Between 55,000 and 69,000 premature deaths avoided annually	n/a

The benefits listed by the evaluated models are mostly the result of a strong reduction of the use of fossil fuels, mostly for power generation (coal), which would lead to a significant reduction of carbon dioxide emissions and $PM_{2.5}$ levels, consequently improving air quality in the country. The reduced air pollution is expected to significantly improve health, reducing the number of cases of strokes, ischemic heart diseases, COPD and lung cancer. An estimated 370,000 premature deaths would be avoided in 2050 from these diseases (see Figure 6) (Cai et al., 2018).

[17] This study is based on China's government goal of 400 GW installed capacity by 2030. The results displayed in the table are for the optimal scenario, as indicated in Table 2. Annex 2 includes more details about the model and assumptions.

[18] The study evaluates different scenarios to control air pollution from the electricity sector. The results displayed in the table are for the optimal scenario. Annex 2 includes more details about the model.

Figure 6. Avoided premature deaths from main respiratory and cardiovascular diseases in China in 2030 and 2050 if China's NDC targets are achieved



Source: Authors' elaboration with data from Cai et al., 2018. The data represented are the mean values (95% CI [confidence interval]) of the results from Cai et al., 2018.

4.0 Economic Comparison of the Savings From Planned Reforms of Fossil Fuel Subsidies and Public Health Expenditures

China's commitment to mitigating climate change and reducing air pollution is further demonstrated by the assignation of part of the public budget to climate change, environment and support to clean energy sources. Nationwide, the country has dedicated budget lines for environment, both at the central and local[19] levels. The tax sharing system and budgeting system in China[20] make it hard to calculate the exact level of total government spending on environmental protection. As a reference, the Chinese government spent CNY 561.733 billion (USD 83 billion) in 2017 on the general-level category of Energy Saving and Environmental Protection within the national general public expenditure, which represents 2.77 per cent of the national budget (Ministry of Finance 2018b). The Energy Saving and Environmental Protection category consists of items relevant to prevention and management of pollution, emission mitigation, renewable energy development, etc., and the absolute amount assigned to this category increased in 2017 from CNY 480.29 billion (USD 77 billion) in 2015 and CNY 473.48 billion (USD 71 billion) in 2016 (Ministry of Finance 2016b, 2017b).

In 2017, China spent USD 83 billion on Energy Conservation and Environmental Protection nationwide.[21] There is no specific budgetary allocation to the policies analyzed in Chapter 3; however, China has specific budget lines for climate- and environmentally friendly policies. For instance, the central government established the Renewable Energy Development Fund in 2011, which is sourced from a combination of the Special Fund for Renewable Energy Development (funded by the central government) and revenue from electricity users. This Renewable Energy Development Fund is earmarked to support research and development of renewable energy and to subsidize production and transmission for renewable electricity (Ministry of Finance, 2011). According to the Ministry of Finance (2016a, 2017a, 2018a), the central government spent CNY 71.21 billion (USD 10.5 billion) on subsidizing renewable electricity in 2017, a significant increase from previous years: CNY 57.96 billion (USD 9.3 billion) in 2015 and CNY 59.51 billion (USD 9 billion) in 2016. The central government also transfers payments to local governments to support the Special Fund for Air Pollution Control (State Council, 2013), the Energy Saving and Emission Reduction Subsidy Fund (Ministry of Finance, 2015) and the Special Fund for Renewable Energy Development (Ministry of Finance, 2011). For example, and as a reference for comparison, the Special Fund for Renewable

[19] In the case of China, the local level includes provinces, prefectures, counties and villages.

[20] At the national level, the Chinese government distributes public spending through three major channels: the general public budget expenditure, the central government-managed funds expenditure and budgets for state capital operations. The central government and local governments at different administrative levels, such as provincial and municipal, all have their respective general public budget. The central government budget includes both central government spending and transfer payments to local governments. Within the transfer payments to local government, there are several special funds earmarking budgets for special purposes, such as air pollution control. At the same time, the central government directly controls the revenue and spending of several central government-managed funds, which are excluded from the general public budget. The only relevant expenditure within this category is the expenditure on additional subsidies for renewable energy electricity prices.

[21] This amount is within China's national general public budget. Central and regional budget expenditures are not included, but their amount is much smaller, representing an insignificant impact on the conclusions of this section. See Footnote 19 for details about Chinese budget structure.

Energy Development received CNY 4.63 billion (USD 0.7 billion) from the central government in 2017 (Ministry of Finance, 2018b).

A study by Markandya et al. (2018) estimates that meeting the NDC targets would cost around USD 0.2 trillion between 2020 and 2050. This suggests that maintaining current spending would lead to greater spending than what is estimated to be needed to meet the country's NDC targets (however, this does not necessarily imply that all NDC targets will be met).

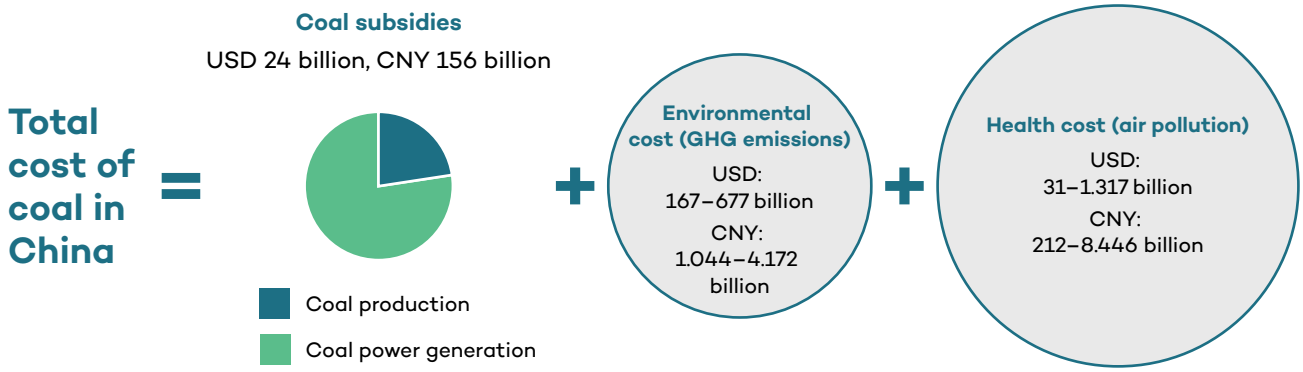
However, China also devotes a relatively important part of its public budget[22] to financing polluting fossil fuels, including coal, the main source of air pollution-related diseases and principal contributor to climate change. In 2017, fossil fuel consumption subsidies in China reached USD 40 billion (IEA, 2019). The largest part of consumption subsidies offered targeted compensation to the groups most affected by the reforms and consequent increases in fuel prices in 2008 and 2009, such as taxi drivers, public transportation in urban and rural areas, and fuel consumers in the forestry and fisheries sectors[23] (OECD, n.d.). The production of fossil fuels also receives substantial subsidies in China (USD 2.6 billion in 2017, according to OECD estimates [OECD, n.d.]).

In 2016, China released its peer review for fossil fuel subsidies, estimating a total of CNY 96.8 billion (USD 15.42 billion) in government support to fossil fuels (OECD, 2016). The International Monetary Fund (IMF) estimates the cost of the externalities associated with the use of fossil fuels. In 2017, the total value of subsidies in China, including externalities, was USD 1.79 trillion, according to the IMF (2018). This is almost 30 times the general public budget allocated to environmental protection in the country. Local air pollution externalities were responsible for most of that cost (USD 1.094 billion), followed by the impacts on global warming (USD 449 billion) (IMF, 2018). Subsidies to coal in China are still very relevant, being offered to coal production and use to generate electricity. Figure 7 presents estimates of the total cost of coal in China, including externalities. In addition, China's public finance to international coal production and coal power plants outside China's borders represented an average of CNY 66 billion (USD 9.8 billion) between 2016 and 2017 (Chen & Gencsu, 2019).

[22] China's public budget in 2017 was CNY 20.308 billion (USD 3.004 billion) (Ministry of Finance 2018c). IEA's estimate for consumption subsidies was USD 40 billion in the same year (IEA, 2009). OECD estimated that subsidies to production of fossil fuels in China in 2017 were at least USD 2.6 billion (OECD, n.d.). In total, consumption and production subsidies represent at least 1.4 per cent of Chinese total public budget.

[23] In 2016, the central government modified the implementation of these subsidies to reduce the amount given and improve the efficiency of the measure. The value of subsidies is reduced every year using 2014 as a benchmark and aiming at a 60 per cent reduction by 2019. After 2020, further policies will regulate the measure (OECD, n.d.).

Figure 7. Total cost of coal in China, including subsidies (to production and consumption) and externalities (environmental and health costs)

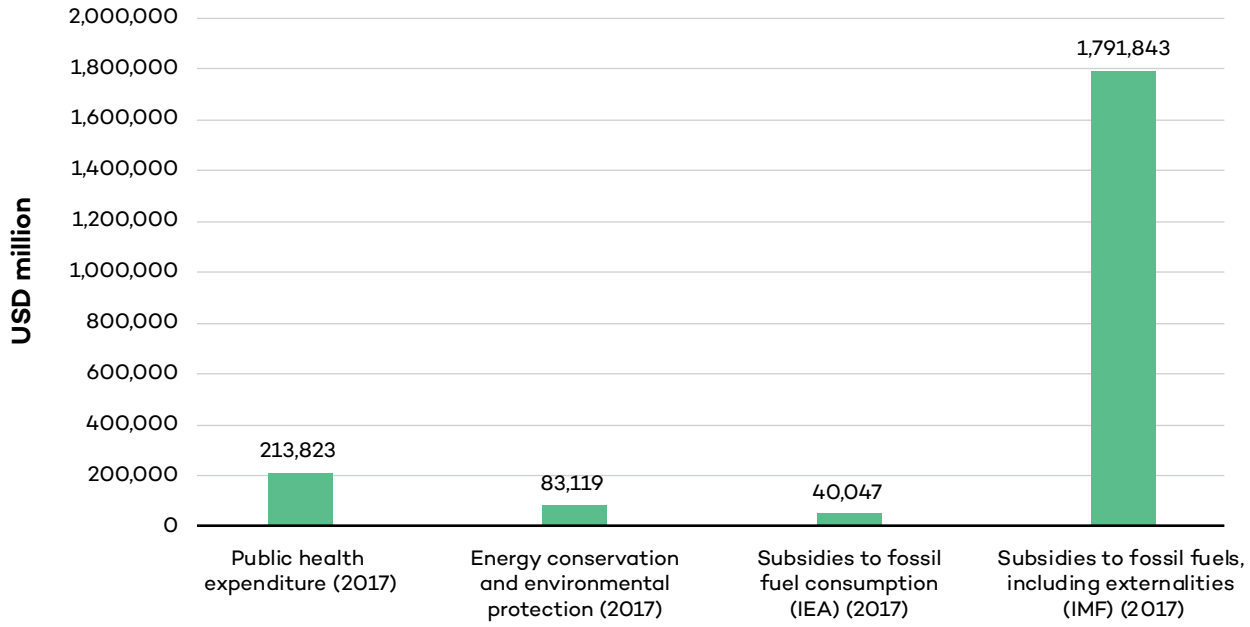


Source: Global Subsidies Initiative, n.d.

To put all the previous numbers in perspective, it is interesting to compare them with the country's public health budget. In 2017, China spent USD 214 billion on public health;[24] this amount has increased over the past few years, although it is still well below the cost of health externalities from the use of fossil fuels estimated by the IMF (2018). Comparing different public expenditures in China in 2017, Figure 8 shows that subsidies to the consumption of fossil fuels (excluding externalities) are around 19 per cent of the budget allocation to public health in that year. When externalities are considered, the total cost of fossil fuel subsidies in China is over eight times higher than the country's public health budget.

[24] See footnote 20.

Figure 8. Comparison of Chinese spending on health, energy conservation and environmental protection, subsidies to fossil fuel consumption, and value of fossil fuel externalities at the general budgetary level (2017, in USD million)[25]



Source: Author's elaboration based on IEA, 2019; IMF, 2018; Ministry of Finance, 2018d.

The previous values show that there are several problems with subsidizing fossil fuels:

i) They come at a high cost to the environment and to society, as estimated by the high cost of the related externalities.

ii) They artificially decrease the cost of polluting energy sources, making them more competitive than other non-polluting sources such as renewable energy technologies, and could cancel out the effect of other government programs that aim to promote clean energy.

iii) They could be devoted to other sustainable development areas, particularly those that are underbudgeted or that support sustainability targets that need additional financial support.

If subsidies to fossil fuels in China were removed, the Global Subsidies Initiative estimates that the country's carbon dioxide equivalent emissions could be reduced by 1.1 per cent by 2025 against a business-as-usual scenario. They could be further reduced by 6.53 per cent by 2030 compared to business as usual if a modest energy tax were introduced[26] and a part of the fiscal savings and additional revenues were devoted to renewable energy (10 per cent of revenues from subsidy removal and taxation) and energy efficiency (20 per cent of revenues) (Global Subsidies Initiative, 2019). This means that fossil fuel subsidies have an important opportunity cost and their reform could significantly support China's climate ambitions, as presented in the country's NDC.

[25] See footnote 20.

[26] The model assumes an energy tax of 10 per cent from 2025 until 2030.

5.0 Key Messages and Conclusions

The previous chapters summarize the main policy efforts that China is already undertaking to achieve its NDC targets, as well as the expected health benefits (number of avoided premature deaths) and economic co-benefits of achieving those targets. A large set of the country's policies are aligned with its NDC targets, specifically those that focus on the reduction of fossil fuel use and the expansion of cleaner forms of energy. Given the recognized strong link between climate change and health, these policies are expected to lead to important health improvements, notably, decreasing premature deaths from cardiovascular and respiratory diseases such as stroke, ischemic heart disease, COPD and lung cancer, which are among the most deadly in the country.

The information gathered and analyzed in this report can be summarized in the following key messages:

- **Climate-related health impacts negatively affect the Chinese population,** resulting in an already high (and increasing) number of deaths per year. Climate change-related diseases in China represent a significant part of the total burden of disease in the country.[27] Air pollution is a major cause of respiratory and cardiovascular disease in China.
- **China has made strong commitments to tackling climate change and air pollution, as reflected in the country's NDC targets and its current national policies.** China has defined a set of policies over the past few years that address climate change and the use of fossil fuels that are expected to have significant positive impacts on public health. The expansion of renewable energy, the limitation and reduction of fossil fuel use, and policies to address air pollution are among the major ones. Recent research models estimate that between 225,000 and 368,000 premature deaths could be avoided in 2050 if NDC targets are achieved.
- **China allocates an important part of its budget to environmental and air pollution control measures,** which, if well allocated, could easily cover the implementation cost of policies to reach the NDC targets. In China, climate finance is led by government spending, and it has been directed toward mitigation activities—for example, renewable energy and energy conservation. Air pollution has also received substantial funding at both the central and local levels.
- **The health co-benefits are higher than the cost of implementing climate policies in China to achieve the country's NDC targets, with significant economic and health gains expected by mid-century.** When taking into account the externalities of fossil fuel use and the co-benefits of mitigation action in its economic analysis of policy decisions, China could justify more stringent budgetary mitigation efforts than it currently has in place.
- **Subsidies to fossil fuels in China remain a main environmental challenge and have an important opportunity cost.** In 2017 China spent USD 40 billion in fossil fuel consumption subsidies. That is around 19 per cent of the budget allocation to health and 48 per cent of the general budget to environmental protection. In addition, the use of fossil fuels has an associated cost of USD 1.79 trillion due to externalities (mostly health and climate change costs). Phasing out fossil fuel subsidies and dedicating savings to energy efficiency and renewables would result

[27] This is based on WHO's ill health burden estimates for 2016 (WHO, 2018a) for all causes for the respective diseases, including—but not limited to—climate change and air pollution. For more information, see Section 2 of this report.

in significant GHG emission reductions, economic and health gains, and faster implementation of the NDC targets.

To better understand the health co-benefits of Chinese policies to address climate change and air quality, further research and quantitative modelling are needed. This report provides the basis for that additional research, listing the main related policies (Annex 1) and looking at possible models that researchers have applied so far (Annex 2).

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Annex 1. List of Climate-Friendly Policies

GENERAL

Major policies	Environmental Protection Law National 13th Five-Year-Plan National Plan on Climate Change (2014-2020) National Total Emission Control Program during the Thirteenth National Five-Year Plan The 13th Five-Year Plan for the Protection of Ecological Environment China's Nationally Determined Contribution (under Paris Agreement)
Description and highlights	These policies, national plans and legislation serve as national guidance for China's commitment to environmental protection, with a focus on climate change mitigation.
Participatory institutions	National Development and Reform Commission (NDRC), State Council, Ministry of Foreign Affairs, National People's Congress
Time scope	2014 (Environmental Protection Law) 2016 (all other policies)

GENERAL

Specific targets linked to NDC[28]	1. The Environmental Protection Law, ratified in 2014 before the Paris Agreement, laid down the foundation (capacity and willingness) for China to fulfill its Nationally Determined Contribution (NDC) commitments. 2. The National Plan on Climate Change (2014–2020) is in line with Goals B, C, and D in the NDC. It sets the goal of "controlling greenhouse gas emissions: by 2020, to cut carbon emissions per unit of GDP by 40-45% from 2005 levels, to increase the percentage of non-fossil fuels in primary energy consumption to 15%, and to increase the proportion of forest area and stock volume by 40 million ha and 1.3 billion m^3 respectively from a 2005 baseline." 3. The National Total Emission Control Program during the 13th National Five-Year Plan (FYP) is in line with Goals B, C and D. It sets a comprehensive list of targets: • By 2020, the total energy consumption will be limited to 5 billion tonnes of standard coal. The energy consumption per unit of GDP will fall by 15% compared with 2015, and the proportion of non-fossil energy will reach 15%. Control of carbon dioxide emissions by large-scale power generation will be within 550 grams of carbon dioxide/kWh. • In 2020, the industrial added value of carbon dioxide emissions per unit will be 22% lower than that in 2015. • By 2020, achieve 340 million kW of conventional hydropower installed capacity, 200 million kW of wind power installed capacity, 100 million kW of photovoltaic (PV) installed capacity, 58 million kW of nuclear power installed capacity, and have more than 30 million kW of clean capacity under construction. • By 2020, the proportion of natural gas in total energy consumption will increase to about 10%. • By 2020, forest coverage will reach 23.04% and forest stocks will reach 16.5 billion m^3.
Impacts on health/NCD	Yang, et al (2018) suggests that climate mitigation policies, taking the 3.4 W/m^2 emissions pathway specifically, could generate health co-benefits of 0.22 million avoided premature deaths by 2050.

[28] This row includes only the policies with targets that directly refer to the NDC targets. The other policies listed in row "Major Policies" of this table address issues relevant to the NDC but do not address the NDC targets directly.

FOSSIL FUEL CONSUMPTION

Major policies	Fossil Fuel Consumption - Air Pollution Control and Prevention Action Plan Work Program to Strengthen Air Pollution Prevention in the Energy Industry Notice of the General Office of the State Council on Issuing the Program of Action for the Energy Development Strategy (2014-2020) Coal-Fired Energy-Saving Emission Reduction Upgrade and Transformation Action Plan (2014-2020) The Action Plan for Clean and Efficient Use of Coal (2015-2020) Work Plan for Strengthening the Control of Total Coal Consumption in Key Cities With Air Pollution Control The 13th FYP for the Development of Coal Industry Thermal Power Plant Pollution Prevention Technology Policy Notice on How to Resolve Excess Capacity in Key Sectors in 2017/2018
Description and highlights	These national policies aim to curb the use of fossil fuels and to restrain air pollution and emissions from fossil fuel use. In particular, the focus is on coal and coal-fired power plants. The government has been setting targets of control coal consumption, promoting clean and efficient use of coal, resolving the excess capacity of coal-fired power plants and setting more stringent standards for civil and industrial use of coal. The policies set yearly targets of capacity reduction, promote the use of new technologies, and improve the efficiency and emissions of existing power plants. In addition, oil quality upgrading, substituting coal with natural gas and alternative sources are all priority issues. Moreover, this bundle of policies is also characterized with a differentiation per geographical area.
Participatory institutions	State Council, NDRC, National Energy Agency, Ministry of Environmental Protection, Ministry of Industry and Information Technology, and more ministries
Time scope	2013–2018; we observe a couple of policies are published every year

FOSSIL FUEL CONSUMPTION

Specific targets linked to NDC	1. The Work Program to Strengthen Air Pollution Prevention in the Energy Industry is consistent with Goal C. The near-term target suggests that, in 2015, the proportion of non-fossil energy consumption is to increase to 11.4%, and the proportion of natural gas (excluding coal-based gas) consumption is to reach 7%. The medium-term target suggests that, in 2017, the proportion of non-fossil energy consumption is to increase to 13%, the proportion of natural gas (excluding coal-to-gas) consumption is to increase to over 9%, and the proportion of coal consumption is to fall below 65%. 2. Notice of the General Office of the State Council on Issuing the Program of Action for the Energy Development Strategy (2014–2020) is consistent with Goal C. It describes how China plans to restructure its energy mix and develop clean energy with the following target: by 2020, non-fossil energy will account for 15% of primary energy consumption, natural gas will account for more than 10% and coal consumption will be controlled within 62%. 3. Coal-Fired Electricity Energy Saving, Emission Reduction, and Upgrade and Transformation Action Plan (2014–2020) is consistent with Goal C. Under the premise of implementing stricter energy efficiency and environmental protection standards, by 2020, the proportion of coal in primary energy consumption will be reduced to less than 62%. 4. The 13th FYP for the Development of the Coal Industry is consistent with Goal C. Its targets stipulate that, by 2020, non-fossil fuel consumption should reach around 15%, natural gas consumption should reach 10% and coal consumption should be reduced to 58%. More specifically, it suggests that during the 13th FYP period, the excess production capacity will be eliminated by 800 million tonnes/year, and advanced production capacity will be increased by 500 million tonnes/year through reduction and replacement. By 2020, coal output will be 3.9 billion tonnes and coal consumption will be 4.1 billion tonnes. 5. The Guiding Opinions on Energy-related Work in 2017 is consistent with Goal C, in the sense that it sets the target: by the end of the year, the proportion of non-fossil energy consumption should increase to about 14.3%, the proportion of natural gas consumption should increase to about 6.8%, and the proportion of coal consumption should fall to about 60%.

FOSSIL FUEL CONSUMPTION

Impacts on health/NCD	Existing research looks at the health benefits of China's NDCs in the electric power generation sector. Cai et al. (2018) assumes that, under the Chinese NDC scenario (Goals A and C), dramatic structural changes would happen in the country's power generation sector, such as the peaking of power generation from coal-fired units in 2025–30 and gradual decline afterwards. Meanwhile, the total share of the renewables and nuclear power would increase drastically from 20% in 2010 to about 80% in 2050. As a result, an average of 19,962 premature deaths could be avoided in 2030 and an average of 368,568 premature deaths could be avoided in 2050 in China. Markandya et al. (2018) also build upon the Chinese NDC assumptions that carbon dioxide emissions will peak around 2030, and it will lower carbon dioxide emissions per unit of GDP by 60% to 65% from the 2005 level. As a result, China could achieve health co-benefits ranging from USD 2.31 trillion (in the 1.5°C scenario) to 6.36 trillion (2°C NDC scenario). In addition, West et. al (2013) find that reduction in $PM_{2.5}$ and ozone through climate policies could generate significant health benefits. They conclude that China could avoid between 0.13 million and 0.4 million premature deaths as a result. This is based on the assumption that greenhouse gas (GHG) emissions are reduced by decreasing fossil fuel use substantially (replacing it with nuclear and renewable energy, primarily wind), reducing energy demand modestly, and increasing forest cover and use of biofuels. Carbon capture and geologic storage is assumed to increase its importance such that it applies to nearly all electricity generation from fossil fuels and biofuels by 2100.

RENEWABLE ENERGY

Major policies	Air Pollution Control and Prevention Action Plan Notice of the General Office of the State Council on Issuing the Program of Action for the Energy Development Strategy (2014-2020) Notice on Wind Power Generation VAT Policy Measures for Full Guaranteed Acquisition of Renewable Energy Power Generation (2016) Notice on Continued Implementation of Photovoltaic Value Added VAT Policy (2016) Notice on Photovoltaic Power Generation VAT Policy The 13th Five-Year Plan for Renewable Energy Development The 13th Five-Year Plan for Energy Technology Innovation The 13th Five-Year-Plan for Energy Development Notice on Reducing the Tax Burden of Enterprises in the Field of Renewable Energy (2017, 2018) NDRC Opinions on Comprehensively Deepening the Reform of Price Mechanism
Description and highlights	Climate policies related to renewable energy focus on technology (considering mostly solar PV, wind and other new renewable technologies) and financing (offering subsidies, prioritizing dispatch and supporting infrastructure). Overall, there is a strong motivation to meet the Paris Agreement commitments by increasing the share of renewable energy in the total energy mix.

RENEWABLE ENERGY

Participatory institutions	NDRC, State Council, Ministry of Finance, State Administration of Taxation, National Energy Agency
Time scope	China's renewable energy policy dates back to the 2000s, and here we emphasize policies in the last five years. China has frequently updated its preferential fiscal policy for renewable energy since 2013.
Specific targets linked to NDC	1. Notice of the General Office of the State Council on Issuing the Program of Action for the Energy Development Strategy (2014–2020): By 2020, non-fossil energy will account for 15% of primary energy consumption; natural gas will account for more than 10%; and coal consumption will be controlled within 62%. 2. The 13th FYP for Renewable Energy Development is consistent with Goal C: By 2020, the annual utilization of all renewable energy will be 730 million tonnes of standard coal; all renewable energy power generation capacity will be 680 million kilowatts and power generation will be 1.9 trillion kWh, accounting for 27% of total power generation; all types of renewable energy heating and civil fuel will replace 150 million tonnes of standard coal in fossil energy; and the proportion of non-hydro renewable energy generation should be significantly increased. 3. The 13th FYP for Energy Technology Innovation is also consistent with Goal C. It proposes using energy technology innovation to support the strategic goal of non-fossil fuel energy accounting for 15% of the total energy mix in 2020.
Impacts on health/NCD	See notes on the "fossil fuel consumption" policies.

INDUSTRY

Major policies	Action Plan of Industries Addressing Climate Change (2012-2020) Green Building Action Plan General Regulation of Verification and Reporting of Industrial Enterprises Greenhouse Gas Emission National Key Energy Saving Low Carbon Technology Promotion Catalogue (2016 and 2017) Notice on How to Resolve Excess Capacity in Key Sectors in 2017 and 2018 Main points about Resolving Excess Capacity in Steel in 2017and 2018
Description and highlights	Similar to the fossil fuel sector, industry-related climate policies focus on reducing excess capacity and upgrading technology to reduce air pollutants and emissions. Steel is the major focus. In addition, they introduce a catalogue approach to regulating the use of “clean” and “polluting” technologies to promote innovation.
Participatory institutions	NDRC, Ministry of Housing and Urban-Rural Development, National Technical Committee for Carbon Emission Management Standardization, NDRC Resource Conservation and Environmental Protection Division, Ministry of Industry and Information Technology, Ministry of Science and Technology, Ministry of Finance and more ministries

INDUSTRY

Time scope	2012 to 2018 These policies are less frequently issued/ updated.
Specific targets linked to NDC	These industrial policies in general support the NDC Goal B as they aim for emission reductions in the industrial production process.
Impacts on health/NCD	See notes on the "fossil fuel consumption" policies.

TRANSPORTATION

Major policies	"Car, Boat, Road, Port" - the Special Action of Thousands of Enterprises Low Carbon Transportation The 13th Five-Year Plan for Energy Saving and Emission Reduction of Civil Aviation Industry Guideline About Strengthening the Supply and Supervision of Low Sulfur Fuel Used For Maritime (13 ministries) 2018-2020 Three-year Action Plan for Winning the Blue Sky War
Description and highlights	The transportation sector is essential to the reduction of both air pollution and GHG emissions in general. Within this bundle of policies, the Chinese government has several focuses, including setting standards, monitoring and enforcing the quality of fuel (both gasoline and diesel) (similar to those identified above in the fossil fuel consumption sector), regulating cargo transportation (maritime, truck, aviation), technological upgrade of vessels, and encouraging public transportation. Transportation is also integrated in most national plans to combat climate change and air pollution.
Participatory institutions	Ministry of Transportation, National Energy Agency, Civil Aviation Administration of China, State Council
Time scope	2013, 2017 (majority)

TRANSPORTATION

Specific targets linked to NDC	1. The 13th FYP for Energy Saving and Emission Reduction of Civil Aviation Industry is consistent with Goals A and B. Its objectives include reducing transportation's energy consumption and carbon dioxde emissions by more than 4% than what was achieved in the 12th FYP. It also aims to reduce the five-year average of energy consumption per airport passenger by more than 15% compared to the level at the end of the 12th FYP. 2. The policy supporting air pollution control is consistent with NDC Goals A and C. It sets the target that, by the end of 2020, the number of alternative fuel vehicles in urban public transport, taxis and urban distribution should reach 600,000, and all the buses in the municipalities, provincial capitals and planned cities in the key areas will be replaced with alternative fuel vehicles. 3. The 2018–2020 Three-year Action Plan for Winning the Blue Sky War also has provisions related to Goals A, B and C, including speeding up the upgrade of ships and boats and promoting the use of vehicles employing alternative fuels. In 2020, the production and sales volume of alternative fuel vehicles should reach 2 million. Other targets include vigorously eliminating outdated vehicles that do not meet the National III (and lower) emission standards, speeding up the upgrading of oil quality and putting emphasis on controlling the pollution of diesel trucks.
Impacts on health/NCD	See notes on the "fossil fuel consumption" policies.

AIR POLLUTION

Major policies	The Action Plan for Air Pollution Prevention and Control Notice on Preparing for Prevention and Control of Air Pollution in Winter and Spring (2015) (2016) Law of the People's Republic of China on the Prevention and Control of Atmospheric Pollution Notice of the General Office of the State Council on Issuing the Implementation Plan for the Permit System for Controlling Pollutants Emission Notice of the Ministry of Environmental Protection on Issuing the Interim Provisions on the Administration of Pollutant Discharge Permits The Catalogue for High-Pollution Fuel The Catalogue for Fixed Pollution Source Discharge Permit (2017) Measures for Pollutant Discharge Permitting Administration 2018-2020 Three-year Action Plan for Winning the Blue Sky War
Description and highlights	China has been coping with the air pollution problem since the 2000s, with increased action since 2013, when the air pollution in Northern China caught the public's attention. Many regulations specifically address air pollutant issues, with a particular focus on coal, the winter and spring seasons, and the regions of Jing-jin-ji, Pearl River Delta, and Yangtze-River Delta. The government has been experimenting with innovative approaches to addressing the pollution problem, including creating a catalogue for potential polluting sources and regulating pollutant discharge permits.

AIR POLLUTION

Participatory institutions	State Council, National People's Congress, Ministry of Environmental Protection
Time scope	2013, 2015–2018; frequent updates to policies have been issued
Specific targets linked to NDC	Although mainly addressing the air pollution issue, these policies are also related to climate change and NDC Goals A and C, due to the interlinkage between coal, air pollution and emissions. 1. China's National Action Plan on Climate Change mentions a target to increase the share of gas in the total primary energy supply to 10% in 2020, in the context of the "reasonable control of total coal consumption."
Impacts on health/NCD	Existing research looks at the co-benefits of climate policies on air pollutant reduction. Controlling air pollution leads to health benefits. For instance, Cai et al. (2018) suggests that reduction of $PM_{2.5}$ linked to reforms in electric power generation could prevent 19,962 premature deaths in 2030 and 368,568 premature deaths in 2050. The distribution of air pollutants such as $PM_{2.5}$ is influenced by the optimization of power plants and interregional transmission among grids.

FORESTRY

Major policies	Key Points Of Forestry Response to Climate Change During the 13th Five-Year Plan Forestry Adaptation to Climate Change Action Plan (2016-2020) Regulation plan for Wetland Protection and Restoration Provincial Forestry Work Plan for Climate Change Mitigation (2017-2018)
Description and highlights	Increasing forest stock is part of China's NDC commitment, and new policies came up following the Paris Agreement. The major focuses are wetlands, forest coverage and using forests for carbon storage and sinks.
Participatory institutions	State Forestry Administration State Council
Time scope	2016, 2017, relatively recent

FORESTRY

Specific targets linked to NDC	These policies all contribute to Goal D of China's NDC in terms of the direct impact of forestry on carbon storage and mitigation. 1. Key Points of Forestry Response to Climate Change during the 13th FYP sets several 2020 targets: By 2020, the forest land will reach 312.3 million hectares; the forest area will increase by 40 million hectares on the basis of 2005; the forest coverage rate will reach 23%; the forest stock volume will reach more than 16.5 billion cubic metres; and the wetland area will be no less than 800 million mou.[29] More than 50% of the desertified land can be managed, and the total carbon storage of forest vegetation can reach about 9.5 billion tonnes. The carbon sequestration capacity of forest and wetland ecosystems continues to increase. 2. Forestry Adaptation to Climate Change Action Plan (2016–2020) also sets targets specific to forest adaptation in line with the "Key Points" policy, above. 3. Regulation Plan for Wetland Protection and Restoration targets include: by 2020, the national wetland area should not be less than 800 million mu—of which the natural wetland area is not less than 700 million mu, the newly added wetland area is 3 million mu and the wetland protection rate is increased to over 50%. 4. Provincial Forestry Work Plan for Climate Change Mitigation (2017–2018) mandates that provinces should increase forest carbon sinks and "increase the forest area by 40 million hectares by 2020 and increase the forest accumulation by about 4.5 billion cubic meters by 2030."
Impacts on health/NCD	None of the models look at forestry policy.

[29] The mou is a Chinese unit of land measurement commonly equivalent to 666.5 m^2, although its value varies with location.

Annex 2. Summary of Model Assumptions and Results: Quantitative studies of the health co-benefits of China's NDC

The following table summarizes the assumptions behind and the results of the studies that quantify the health co-benefits of China's NDC and other climate-friendly policies and that were considered in this paper.

Title	Model Assumptions	Results (focused on impacts in China)
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 (Cai et al., 2018)	Applies the NDC targets to several models (e.g., Multi-regional model for Energy Supply system and their Environmental Impacts, the Multi-resolution Emission Inventory for China model, the offline-coupled Weather Research and Forecasting model, the Community Multiscale Air Quality model, and the Integrated Health Impact Assessment model with a time scope from 2010 to 2050) to evaluate $PM_{2.5}$ effects in terms of $PM_{2.5}$ concentration, health impacts and implementation costs. Considers two scenarios that reflect carbon dioxide and air pollution emissions—the reference scenario (no climate policy) and the NDC scenario (100% realization of NDC targets).	The paper assumes that, under the Chinese Nationally Determined Contribution (NDC) scenario, dramatic structural changes would happen in the power generation sector, such as the peaking of power generation from coal-fired units in 2025–30 and a gradual decline afterwards paired with a massive increase in clean energy sources to about 80% of the total energy mix in 2050. It concludes that, under the Chinese NDC scenario, 19,962 (95% CI 9,013–31,320)[30] premature deaths could be avoided in 2030 and 368,568 premature deaths (178,317–569,973) could be avoided in 2050 due to the reduction of fine particulate matter ($PM_{2.5}$) pollution in China.

[30] The numbers in brackets indicate the 95 per cent confidence interval results.

Title	Model Assumptions	Results (focused on impacts in China)
Health Co-Benefits From Air Pollution and Mitigation Costs of the Paris Agreement: A modelling study (Markandya et al., 2018)	This research evaluates the health co-benefit under three scenarios: the NDC scenario (carbon dioxide emissions peak around 2030 and carbon dioxide emissions per unit of GDP are reduced by 60% to 65% from the 2005 level); the 2°C stabilization target; and the 1.5°C stabilization target (both stabilization targets are objectives for the year 2100). It uses the Global Change Assessment Model (GCAM) to quantify the greenhouse gas pathways and the related mitigation costs of each climate target scenario and mitigation strategy. GCAM also reports the emissions of air pollutants in the different regions, including China.	The paper finds that, under the NDC scenario, China could avoid around 2.1 million–2.4 million premature deaths[31] between 2020 and 2050 (cumulative). The monetized health co-benefits would largely compensate the implementation cost by around USD 6.36 (3.06–9.66)[32] trillion, with an estimated value of health co-benefits of around USD 6.5 trillion.[33] It also shows that the achievements of the NDC scenario could be heavily improved by following a more ambitious climate policy (the 1.5°C or the 2°C stabilization targets). The paper also shows global results, comparing regions.

[31] These estimates are calculated from the report results. In the NDC scenario evaluated in the report, the number of deaths decreases by around 5 per cent relative to the reference, which anticipates around 130 million premature deaths. The largest proportions of premature deaths are in China (33–37 per cent of the global deaths).

[32] The values in parentheses are the range of results based on the lower and the upper bounds of the VSL.

[33] This estimate is calculated from the report results. Total health co-benefits are estimated at around USD 12 trillion. In the NDC scenario, China accounts for 55 per cent of these co-benefits.

Title	Model Assumptions	Results (focused on impacts in China)
Air Quality Co-Benefits For Human Health and Agriculture Counterbalance Costs to Meet Paris Agreement Pledges (Vandyck et al., 2018)	The study assess the global and regional mortality, morbidity and agricultural air quality co-benefits considering the transformation of the energy system implied by the emission reduction pledges in the NDCs and in a scenario where countries ratchet up ambition levels in order to curb global GHG emissions to reach the 2°C temperature goal. In addition, they consider three additional scenarios for air pollution policies that are likely to develop in parallel with climate policies. A POLES-JRC model is used to do the global sectoral energy and greenhouse gas emissions projections, considering 54 individual countries and 12 regions, including China. For mortality estimates, the model uses non-linear exposure-response functions based on *Global Burden of Disease 2015*.	This study looks at the avoided premature mortality due to lower $PM_{2.5}$ concentrations and ozone mixing ratio. It considers the benefits of improved air quality including avoided premature mortality due to related cardiovascular and respiratory diseases and lung cancer. The highest level of avoided premature mortality is achieved for the air pollution scenario that considers no additional implementation of air pollution abatement technologies from 2010 onwards. This scenario reduces mortality by 250,000 avoided deaths in 2050 in the NDC scenario and by 536,000 avoided deaths in 2050 for the 2°C scenario. The avoided premature deaths in 2030 are 61,000 and 130,000, respectively. Co-benefits include the value of avoided premature mortality as well as the co-benefits on the labour and agricultural markets via avoided work days lost and improved crop yields, respectively.
Co-Benefits of Climate Mitigation on Air Quality and Human Health in Asian Countries (Xie, et al., 2018)	This research evaluates the long-term health and economic impacts caused by ambient $PM_{2.5}$ and ozone pollution under different climate mitigation and shared socioeconomic pathway scenarios in Asian countries. It uses a model that combines the Community Multiscale Air Quality (CMAQ) model, a health assessment model and the Asia-Pacific Integrated Assessment/ Computable General Equilibrium (AIM/CGE) model. For the health economic evaluation, it uses the number of lost working days and the cost of additional medical costs.	Overall, achieving air pollution reduction through climate change mitigation under the 2°C climate goal could avoid 220,000 premature deaths in China in 2050, for a life value savings of approximately USD 720 billion (3% of GDP). Morbidity will decrease by 26,000 cases in 2050 due to mitigation measures. Considering the implementation cost of climate mitigation measures, the net benefit (total benefit–cost) is USD 330 billion in 2050.

Title	Model Assumptions	Results (focused on impacts in China)
Climate, Air Quality and Human Health Benefits of Various Solar Photovoltaic Deployment Scenarios in China in 2030 (Yang, Li, Peng, Wagner, & Mauzerall, 2018)	This research investigates, quantifies and compares the climate, air quality and related human health benefits of various photovoltaic (PV) deployment scenarios for 2030 in China. Using a coal-intensive power sector projection as the base case (which assumes the implementation of China's 12th Five-Year Plan through 2015 with no additional new air pollution or climate mitigation policies), they estimate the climate, air quality and related human health benefits of various 2030 PV deployment scenarios. They use the 2030 government goal of 400 GW installed capacity but vary the location of PV installation and the extent of inter-provincial PV electricity transmission.	Deploying distributed PV (displacing coal-fired power plants) in the east together with interprovincial transmission would maximize carbon dioxide reductions and air quality-related health benefits, resulting in national carbon dioxide emission reductions of 4.2%. Air pollution-related premature deaths would decrease by 1.2% compared to the base case, which projects a total of 880,000 premature deaths due to $PM_{2.5}$ in the 2030 base case. The changes in mortality are estimated for four respiratory and cardiovascular diseases that are associated with long-term ambient $PM_{2.5}$ exposure: chronic obstructive pulmonary disease, lung cancer, ischemic heart disease and ischemic stroke.
Potential Co-Benefits of Electrification for Air Quality, Health, and CO2 Mitigation in 2030 China (Peng, Yang, Lu, & Mauzerall, 2018)	This paper evaluates the potential health co-benefits of different paths of electrification in China. The results are based on an integrated assessment using the regional air pollution model WRF-Chem and epidemiological concentration–response relationships.	Coal-intensive electrification (75% coal) does not reduce carbon emissions but can bring significant air quality and health benefits (41,000–57,000 avoided deaths in China annually). In comparison, switching to a half-decarbonized power supply (~50% coal) for electrification of the transport and/or residential sectors leads to a 14–16% reduction in carbon emissions compared to business as usual, as well as greater air quality and health co-benefits (55,000–69,000 avoided deaths in China annually) than coal-intensive electrification.

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