Unofficial Translation

For Reference Use Only

The People's Republic of China

Fourth National Communication on Climate Change

December 2023

Foreword

Climate change is a global issue that poses extensive and profound challenges to the survival and development of humanity. Recalling Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC), each Party shall submit its national communication. Decision 1/CP.24 adopted at COP24 stresses that Parties to the Paris Agreement shall continue to fulfill their obligations related to national communications under the UNFCCC. Decision 1/CP.16 adopted at COP16 in 2010 provides that non-Annex I Parties shall submit biennial update reports starting in 2014. The People's Republic of China (hereinafter referred to as China) has actively fulfilled its obligations as a non-Annex I Party to the UNFCCC. It submitted three national communications (NCs) and two biennial update reports (BURs), in which details on its major policies and actions in response to climate change were comprehensively provided, and the national greenhouse gas (GHG) inventories for 1994, 2005, 2010, 2012 and 2014 were reported.

This report was prepared in accordance with the guidelines for the preparation of national communications for non-Annex I Parties and, as appropriate, the modalities, procedures and guidelines (MPGs) for the enhanced transparency framework under the Paris Agreement. It was approved by the State Council after multiple revisions based on broad comments and submitted by the Ministry of Ecology and Environment.

The People's Republic of China's Fourth National Communication on Climate Change, approved by the Chinese government, consists of eight parts: National Circumstances and Institutional Arrangements, National Greenhouse Gas Inventory, Climate Change Impact and Adaptation, Climate Change Mitigation Policies and Actions, Finance, Technology and Capacity-Building Needs, Other Relevant Information for Achieving the UNFCCC Targets, Basic Information of Hong Kong Special Administrative Region (SAR) on Addressing Climate Change, and Basic Information of Macao SAR on Addressing Climate Change, presenting a full picture of China's national efforts on addressing climate change. This report does not include information about the Taiwan region. According to the relevant decisions of the UNFCCC and in light of China's national circumstances and the information reported by the Third National Communication on Climate Change, the National GHG Inventory presented herein is based on the data of 2017, while the description of relevant conditions given in other chapters is generally updated to the end of 2020. In accordance with the Basic Law of the Hong Kong Special Administrative Region and the Basic Law of the Macao Special Administrative Region, the basic information of these two SARs on addressing climate change in this report is provided by the Environmental Protection Department of the Hong Kong SAR Government, and by the Meteorological and Geophysical Bureau of the Macao SAR Government respectively.

Climate change concerns the survival, development, and well-being of humanity, calling for efforts from a solidary international community. In 2020, China announced that it would aim to have carbon dioxide (CO_2) emissions peak before 2030 and achieve carbon neutrality before 2060. In 2021, China officially updated its Nationally Determined Contributions (NDCs). These goals require China to make its best efforts, which have fully demonstrated its international obligations as a responsible developing country. In October 2021, the Chinese government issued the Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy and the Action Plan for Carbon Dioxide Peaking Before 2030, under which relevant national authorities have formulated implementation plans and supportive policies for different areas and industries. All provinces, autonomous regions and municipalities directly under the central government have also formulated their respective implementation plans for peaking carbon emissions. The "1+N" policy framework for peaking carbon emissions and achieving carbon neutrality has taken shape.

The Chinese government will continue, as always, to fulfill its own obligations under UNFCCC on the basis of equity and in accordance with common but differentiated responsibilities and respective capabilities (CBDR–RC). China will faithfully implement its new NDC targets and measures, actively participate in negotiations on climate change, promote the establishment of an equitable, rational, cooperative and win-win global governance, deepen multilateral and bilateral dialogue and pragmatic cooperation on climate change, advance South-South cooperation, support other developing countries to enhance their capacity building in response to climate change, and work with other countries to foster a community of life for man and nature.

Contents

Part I National Circumstances and Institutional Arrangements

China is a country with a huge population, a vast territory, complex climatic conditions and a vulnerable eco-environment. It is one of the most vulnerable countries to the adverse impacts of climate change. The Chinese government has pursued with firmness the vision of innovative, coordinated, green, open and shared development, promoted economic, political, cultural, social, and ecological advancement in a coordinated way, and made every effort to build a moderately prosperous society in all respects. As a responsible developing country, China attaches great importance to the issue of global climate change, and has sets up national, local and relevant organizations and institutions to address climate change. It has also established core expert and technical support teams as important assurance for the preparation and submission of the National Communication on Climate Change and the Biennial Update Report on Climate Change.

Chapter 1 Natural Conditions and Resources

Situated in the eastern part of Asia, on the west coast of the Pacific Ocean, China has a total land area of about 9.6 million square kilometers (Mkm^2) and a total sea area of 4.73 Mkm^2. China shares about 22,000 kilometers of land borders with other countries, and its coastline runs for approximately 18,000 kilometers. There are 7,600 islands scattered in China's sea area, of which the largest one is Taiwan Island with a land area of 35,759 square kilometers. Currently, China has 34 provincial-level administrative regions, including 23 provinces, 5 autonomous regions, 4 municipalities directly under the central government and 2 special administrative regions (Figure 1-1).

审图号：GS(2019)1818号 自然资源部 监制

Figure 1-1 Map of the People's Republic of China

1.1 Natural Conditions

1.1.1 Topography

China's terrains vary significantly. The five major terrains, namely plateau, hill, mountain, basin, and plain are all distributed, among which mountains, plateaus and hills account for about 67% of the total land area, and basins and plains for 33%. The land descends in three steps like a terrace from west to east. The first step of this three-step "staircase" is the Qinghai-Xizang Plateau, with an average elevation of over 4,000 meters above sea level. On its northern and eastern edges are the Kunlun, Altyn-Tagh, Qilian, and Hengduan mountains. These mountains form a line between the first and second steps of China's geography. The second step has an average altitude of 1,000 to 2,000 meters, and is dotted with large basins and plateaus, including the Inner Mongolia Plateau, the Loess Plateau, the Yunnan-Guizhou Plateau, the Tarim Basin, the Junggar Basin, and the Sichuan Basin. The eastern edge of the second step is scattered with the Greater Hinggan Mountain, the Taihang Mountain, the Funiu Mountain, the Wu Mountains, and the Xuefeng Mountains among others. They form the dividing line between the second and third steps of China's geography. The third step is mainly made up of plains, interspersed with hills and low mountains, most of which are below 500 meters above sea level. The Liaodong Hills, the Shandong Hills, the Jiangnan Hills, the Northeast China Plain, the North China Plain, the Plain of the Middle and Lower Reaches of the Yangtze River, and the Pearl River Delta Plain are located in the third step. To the east of China's land, there is the Bohai Sea, an inland sea, and three marginal seas, namely the Yellow Sea, the East China Sea and the South China Sea, with their depth increasing from north to south. The vast continental shelf extends along the long coastline (Figure 1-2).

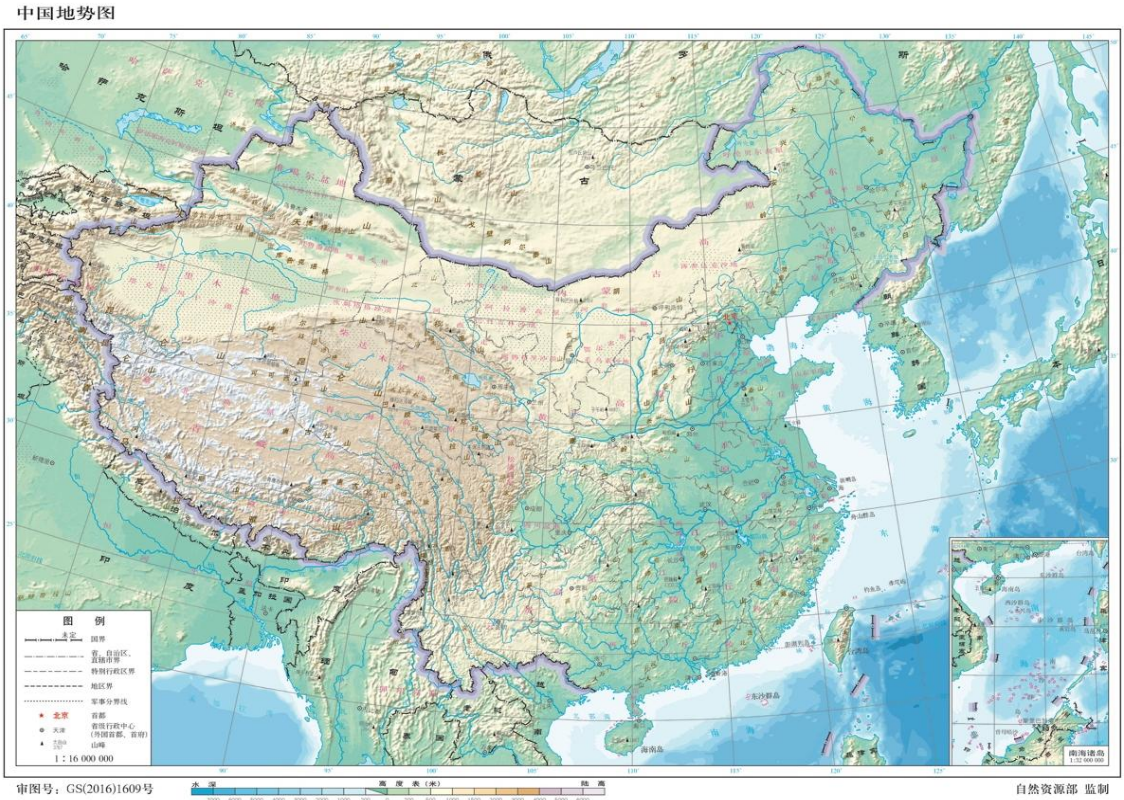


Figure 1-2 Topography Map of China

1.1.2 Climate and Climatic Disasters

China's climate features complexity and diversity. The eastern region has a monsoon climate, the northwestern region has a temperate continental climate, and the Qinghai-Xizang Plateau falls into an alpine climate category. China's climate is characterized by hot and rainy summers, cold winters with little rain, and the coincidence of high-temperature periods and rainy periods. With 6,592.65 billion cubic meters (m^3) of total annual precipitation and an average precipitation of 694.8 millimeters, China had more precipitation in 2020 than in previous years, making it an exceptionally high-flow year for China. In 2020, China's average temperature was 10.25℃, 0.7℃ higher than that of previous years. Seasonal average temperatures were higher than normal in most parts of the country in all four seasons. The annual count of hot days was higher than average. Many parts of the country reported record-high temperatures.

China is subject to frequent disastrous weather, with droughts, floods, cold spells, and typhoons being major disastrous weather with considerable influence for China. The northern part of China is prone to droughts, while the southern part of the country is prone to both floods and droughts. In summers and falls, especially between June and September, the coastal areas in Southeast China are often stricken by tropical storms. In falls and winters, the pulses of cold air from Mongolia and Siberia moves southward, resulting in cold spells and causing such disaster as low temperature, gales, sandstorms, and frost. In the wake of climate change, many places in China were struck by rainstorms and floods in 2020. The country reported a total of 37 localized heavy rainfall events. Regions were impacted by repeated rainfalls during the flood season, bringing regional and periodic drought. Some places were hit by drought episodes. Severe convective weather was distributed in a concentrated manner both spatially and temporally. Fewer than average typhoons were formed or made landfall in China. The impact of cold spells, winter storms and snow disasters on the country was relatively small.

1.2 Natural Resources

1.2.1 Land Resources

China's land resources are characterized by complexity and diversity in types, and arable lands, forest lands, grasslands, deserts and tidal flats are distributed extensively in the country, but the per capita arable cropland is small. Land resources are unevenly distributed. The Northeast China Plain, the North China Plain, the Middle and Lower Reaches of the Yangtze River, the Pearl River Delta Plain and the Sichuan Basin are the areas where croplands mostly concentrate, while grasslands are mainly distributed in northern and western China, and forests mainly concentrate in the Northeast, Southwest and South China.

As of the end of 2019, China had 128 million (M) hectares (ha) of arable land, 20.172 million ha of parkland, 280 million ha of forest land, 260 million ha of grasslands, 35.306 million ha of land for urban, rural, industrial and mining activities, and 36.288 million ha[1] of land used for water and water conservancy facilities. The average quality grade of arable land in China is 4.76[2]. Arable land with a quality score of 1-3, 4-6, and 7-10 account for 31.24%, 46.81%, and 21.95% of China's total arable land, respectively.

1.2.2 Water Resources

China is one of the countries with the most rivers and lakes. It has over 1,500 rivers that drain an area of more than 1,000 sq km and over 2,800 natural lakes with a surface area of over 1 sq km. Water resources are unevenly distributed in China in either temporal or spatial sense. In temporal sense, the water resources are rich in summer and fall, fewer in winter and spring, and significantly vary on an annual basis; in spatial sense, they are rich in the eastern and southern regions, and fewer in western and northern regions. China's per capita water resources are only a quarter of the global average. In 2020, China's total stock of water resources stood at 3,160.52 billion m^3, including 3,040.70 billion m^3 of surface water and 855.35 billion m^3 of groundwater (between the two, there was an overlap of 735.53 billion m^3); the per capita water resources stood at 2,239.8 m^3; the total water supply was 581.29 billion m^3, accounting for 18.4% of the total stock of water resources

[1] Data source: Data used in this section come from the Third National Land Survey. Data for 2019 were most recently updated. Unless otherwise noted, data used in this report come from the National Bureau of Statistics of China.

[2] The quality of arable land is rated on a 1-10 scale (with 1 being the best quality and 10 being the worst quality) in accordance with Arable Land Quality Evaluation (GB/T 33469-2016). Arable land with a score of 1-3, 4-6, and 7-10 is known as high-quality land, moderate-quality land, and low-quality land, respectively. Data for 2019 were most recently updated.

of the year [3].

China boasts the largest potential hydropower capacity in the world. The country's exploitable hydro energy potential is concentrated in the Yangtze River Basin, the Yarlung Zangbo River Basin and the Yellow River Basin. Sichuan, Yunnan and Xizang in the southwest part of the country are the largest three provinces in terms of hydro energy resources in China.

1.2.3 Forests and Grasslands

According to the results of the Ninth National Forest Inventory (2014-2018), China had a total forest area of 220 million ha (which is equivalent to 22.96% of China's land area), including 80.0310 million ha of plantation. The total growing stock volume in China was 19.007 billion m^3. China's forest growing stock volume was 17.560 billion m^3, accounting for 92.39% of the country's total growing stock volume.

In 2020, China had approximately 400 million ha of grasslands. The total output of fresh forage from natural grasslands in the country was 1.1 billion tons. Approximately 56.1% of natural grasslands was covered by vegetation. China implemented grazing prohibitions on grasslands of 82 million ha, achieved balance between forage and animal on 174 million ha, built fences for restoring grazing to grassland on 1.685 million ha [4], and spread good grass seeds on 170,000 ha, and established artificial grassland of 70,000 ha.

1.2.4 Marine Resources

According to the relevant provisions of the United Nations Convention on the Law of the Sea, China claims jurisdiction over three million sq km of marine space. These oceans are treasure troves. In 2020, China's gross marine product stood at 8,001.0 billion yuan, to which the marine industry and marine-related industries contributed 5,295.3 billion yuan and 2,705.6 billion yuan respectively in the added value. Northern, Eastern, and Southern Marine Economic Zones accounted for 29.2%, 32.1%, and 38.7% of China's gross marine product, respectively [5].

China has delineated 14 national marine reserves with a total area of approximately 394,000 ha, and 67 national marine parks with a total area of approximately 737,000 ha [6]. In 2020, China's coastal sea levels were 73 mm higher than that in the previous years, the third-highest since 1980 [7].

1.2.5 Biodiversity

China is home to a wide range of terrestrial ecosystems, including 212 types of forests, 36 types of bamboo forests, 113 types of shrubs, 77 types of meadows, 52 types of deserts, and 30 types of natural wetlands in China. China also has diverse coastal and marine ecosystems, including mangroves, coral reefs, seagrass beds, islands, bays, estuaries and upwellings, and artificial ecosystems, including farmland, artificial forests, artificial

[3] Data source: China Water Resources Bulletin 2020.
[4] Data source: China Vegetation Cover Bulletin 2020.
[5] Data source: China Marine Economic Statistical Bulletin 2020.
[6] Data source: China Marine Ecological and Environmental Statistical Bulletin 2020.
[7] Data source: China Sea Level Statistical Bulletin 2020.

wetlands, artificial grasslands, and cities [8].

China is home to 122,280 species and infraspecies. In terms of diversity of genetic resources, there were 1,339 cultispecies in 528 categories, over 1,000 economic tree species, 7,000 ornamental species ingenuous to China, and 948 domestic animal species [9]. In 2020, China monitored the health of 24 typical coastal and marine ecosystems, including estuaries, bays, tidal wetlands, coral reefs, mangroves, and seagrass beds. Results showed that, as a result of climate change and human activities, seven ecosystems were in a healthy state, 16 in a state of suboptimal health, and one in an unhealthy state. During China's Five-Year Plan (FYP) period (2016-2020), coral reefs and seagrass beds were switched between healthy and suboptimal health states [10].

In terms of the development of natural reserves, as of the end of 2020, China had delineated 474 national nature reserves, with a combined land area of approximately 983,400 sq km, 244 national scenic spots, with a combined land area of approximately 106,600 sq km, and 281 national geological parks, with a combined land area of approximately 46,300 sq km. China had launched 10 national park pilot projects, including Northeast Tiger and Leopard, Qilian Mountains, Giant Panda, Sanjiangyuan, Hainan Tropical Rainforest, Wuyi Mountain, Shennongjia, Pudacuo, Qianjiangyuan, and Nanshan national park pilot projects, with a combined area of more than 220,000 sq km, accounting for approximately 2.3% of China's land area[11].

[8] Data source: China Ecological and Environmental Statistical Bulletin 2020.
[9] Data source: See [8].
[10] Data source: China Marine Ecological and Environmental Statistical Bulletin 2020.
[11] Data source: China Ecological and Environmental Statistical Bulletin 2020.

Chapter 2 Social and Economic Development

China's society and economy have undergone tremendous changes in the 21st century. China became the world's second largest economy in 2010 and the world's largest trader of goods in 2013. After 2012, China's economy gradually shifted from high-speed growth to high-quality development. In 2020, as China worked hard to coordinate COVID-19 containment and its socioeconomic development, its economy rebounded, making it the only major economy in the world to achieve positive economic growth. The county has also made remarkable progress in promoting employment, reducing poverty, improving livelihood, and protecting the environment.

2.1 Social Development

2.1.1 Population

As of the end of 2020, the total population of the Chinese mainland stood at 1.412 billion, including 902 million urban residents and 510 million rural residents. Eastern China had a population of 564 million, accounting for 39.93% of the total population of the Chinese mainland; Central China had a population of 365 million, accounting for 25.83% of the total of the Chinese mainland; Western China had a population of 383 million, accounting for 27.12% of the total of the Chinese mainland; and Northeastern China had a population of 99 million, accounting for 6.98% of the total of the Chinese mainland[12].

China rolled out the family planning policy in the 1970s. Its natural population growth dropped from 25.83‰ in 1970 to 4.93‰ in 2015, significantly lower than the global average of 11.86‰. To help address the aging issue, China has begun implementing the two-child policy for couples where either the husband or the wife is a single child in 2013, and enacted the universal two-child policy in 2015. China's natural population growth rate in 2020 was 1.45‰ (Figure 1-3).

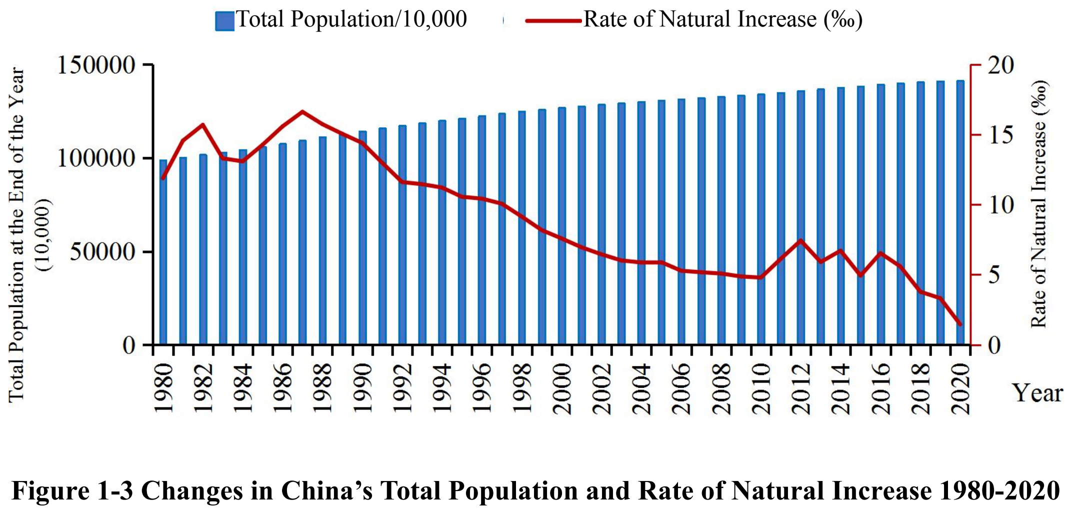


Figure 1-3 Changes in China's Total Population and Rate of Natural Increase 1980-2020

In 2020, with the improvement of living standards, education, and health care, the average life expectancy of China's population increased to 77.13 years old, higher than the world's

[12] Data source: Communiqué of the Seventh National Population Census (No. 3), National Bureau of Statistics.

average. The proportion of the aging population is growing gradually. In 2020, people aged 65 years and over made up about 13.5% of China's total population. China's urbanization rate is increasing. In 2020, the percentage of China's population living in cities increased to 63.89%, an increase of 20.89 percentage points from 2005.

2.1.2 Education and Health

In 2020, China had 3.140 million postgraduate students, 32.853 million undergraduate and junior college students, 16.634 million students receiving secondary vocational education, 24.945 million regular high school students, 49.141 million junior middle school students, 107.254 million primary school students, 881,000 students receiving special education, and 48.183 million children enrolled in kindergartens. The completion rate of compulsory education in China reached 95.2%, and the gross enrollment rate[13] in senior secondary education reached 91.2%.

As of the end of 2020, China had 1.023 million healthcare facilities with 9.101 million sickbeds. It also had 4.086 million licensed physicians and licensed assistant physicians, and 4.709 million registered nurses. The total number of annual visits was 7.74 billion and that of discharges stood at 230 million.

2.1.3 Employment

In 2020, the number of employed people in China stood at 750.64 million. The number of employed people in the primary, secondary and tertiary industries was 177.15 million, 215.43 million and 358.06 million, accounting for 23.60%, 28.70% and 47.70% of the country's total employed population, respectively (Table 1-1). There were 462.71 million employed people in urban areas and 287.93 million employed people in rural areas.

Table 1-1 Change in the Composition of Employees in China, 2005, 2010, 2015, 2020

Employment structures	2005	2010	2015	2020
Proportion of employees in the primary industry (%)	44.8	36.7	28.0	23.6
Proportion of employees in the secondary industry (%)	23.8	28.7	29.7	28.7
Proportion of employees in the tertiary industry (%)	31.4	34.6	42.3	47.7

2.1.4 Poverty Eradication

Since the 1990s, China has launched a number of plans and programs to alleviate poverty, including the Priority Poverty Alleviation Program (1994-2000) and the Outline for Development-Oriented Poverty Alleviation for China's Rural Areas (2001-2010). After entering the 21st century, the Chinese government announced that it would finish the building of a moderately prosperous society in all respects by 2020 and rolled out a series of new policies and measures to promote poverty alleviation and development. In 2011, the Chinese government launched the Outline for Development-Oriented Poverty Alleviation for China's Rural Areas (2011-2020). In November 2015, it issued the Decision on Winning the Fight Against Poverty, which highlighted the strategy of targeted

[13] Gross enrollment rate is total enrollment in a specific level of education, expressed as a percentage of the eligible official school-age population corresponding to the same level of education in a given school year.

poverty alleviation as a way to lift people out of poverty more rapidly. At the end of 2020, President Xi Jinping declared victory in China's fight against poverty in the new era, claiming that the 98.99 million people in rural areas who had lived below the current poverty threshold were lifted out of poverty and that all 832 impoverished counties and 128,000 impoverished villages had been removed off the poverty list, and basically solving the problem of regional overall poverty [14].

2.1.5 Eco-Environmental Protection

China's environment has continued to improve. In 2020, the country reported 3.1822 million tons of sulfur dioxide emissions from exhaust gases, 6.1335 million tons of particulate matter emissions, and 11.8165 million tons of nitrogen oxide emissions. It monitored precipitation levels in 465 cities (districts and counties), of which 34% were acid rain-plagued cities, mainly in the category of sulfuric acid rain. Acid rain pollution mainly spread in the area south of the Yangtze River and east of the Yunnan-Guizhou Plateau[15].

In 2020, China emitted 984,000 tons of ammonia nitrogen, 3.2234 million tons of nitrogen, and 336,700 tons of phosphor. China's urban sewage treatment plants could dispose of 193 million m^3 of wastewater; 97.53% (55.73 billion m^3) of wastewater discharged was treated throughout the year; 98.2% of black and fetid water bodies in built-up areas of cities at and above prefecture level had been eliminated [16].

In 2020, 3.675 billion tons and 2.038 billion tons (55.46%) of non-hazardous industrial solid waste were produced and recycled, respectively. A total of 235 million tons of municipal solid waste (MSW)[17] were generated. China has 1,287 waste treatment facilities that treat 963,500 tons of waste per day (337,800 tons dumped into landfills, 567,800 tons incinerated, and 57,800 tons disposed of in other ways). Approximately 99.7% of MSW was safely disposed of.

In 2020, the annual average concentration of PM2.5 in 337 cities at or above the prefecture level was 33 $\mu g/m^3$, down by 8.3% from the previous year. The percentage of days with good air quality in these cities was averaged 87.0%, and 202 cities met air quality standards, accounting for 59.9% of all cities [18].

In 2020, 96.8% of the sea areas under China's jurisdiction met Grade I water quality standards; 77.4% of China's coastal waters met Grade I and Grade II quality standards; of China's estuaries, 0.5% are water sections with bad quality water below Grade V. None of the 49 state-controlled estuaries in the Bohai Economic Rim remained sections with bad quality surface water below Grade V. China restored 8,891 ha of coastal wetlands and 132

[14] Data source: Poverty Alleviation: China's Experience and Contribution.
[15] Data source: China Ecological and Environmental Statistical Bulletin 2020.
[16] Data source: China Urban and Rural Development Statistical Yearbook 2020.
[17] MSW refers to solid waste generated in daily life of city dwellers or activities that provide services to city dwellers, and other solid waste that should be regarded as municipal domestic waste according to legal and administrative regulations, including domestic waste, waste generated in commercial activities, waste in marketplaces and streets, waste in public places, and waste generated by institutions, schools, factories, and mines.
[18] Data source: China Ecological and Environmental Statistical Bulletin 2020.

km of coastline throughout the year[19].

2.2 Economic Development

2.2.1 Economic Growth

In 2020, China's GDP was 101,598.62 billion yuan, an increase of 2.3% over the previous year, to which the primary, secondary, and tertiary industries contributed 7,775.41 billion yuan, 38,425.53 billion yuan, and 55,397.68 billion yuan in added value. China's per capita GDP stood at 72,000 yuan[20]. In 2005, the ratio of the primary, secondary, and tertiary industries was 11.6 : 47.0 : 41.3, which, after economic structural improvement, turned to 7.7 : 37.8 : 54.5 (Table 1-2) in 2020. From 2005 to 2020, the share of GDP attributed to the primary and secondary sectors continued to decrease, while that of the tertiary sector increased by 13.2 percentage points.

Table 1-2 China's GDP and Industrial Structure (2005, 2010, 2015, 2020)

Sector		2005	2010	2015	2020
GDP (billion yuan)		18,731.89	41,211.93	68,885.82	101,598.62
Primary sector (billion yuan)		2,180.67	3,843.08	5,777.46	7,775.41
Secondary sector (billion yuan)		8,808.22	19,162.65	28,133.89	38,425.53
Tertiary sector (billion yuan)		7,743.00	18,206.19	34,974.47	55,397.68
Industrial structure	**Primary sector (% of GDP)**	11.6	9.3	8.4	7.7
	Secondary sector (% of GDP)	47.0	46.5	40.8	37.8
	Tertiary sector (% of GDP)	41.3	44.2	50.8	54.5
Per capita GDP (yuan)		14,368	30,808	49,922	72,000

2.2.2 Industrial Development

(1) Agriculture, Forestry, Animal Husbandry, and Fishery

In 2020, the gross output of agriculture, forestry, animal husbandry and fishery industries was 13,778.22 billion yuan, of which agriculture, forestry, animal husbandry and fishery contributed 52.1%, 4.3%, 29.2% and 9.3%, respectively. China had 167.487 million ha of cropped area, in which 69.7% (116.768 million ha) was used for growing crops. The country grew 23.380 million ha of wheat, 30.076 million ha of rice, 41.264 million ha of corn, 3.169 million ha of cotton, 13.129 million ha of oil plants, and 1.568 million ha of sugar crops. In 2020, China produced 669.492 million tons of grain, including 211.860 million tons of rice, 134.254 million tons of wheat, and 260.665 million tons of corn; 5.910 million tons of cotton, 35.864 million tons of oil crops, 11.984 million tons of sugar beets, and 108.121 million tons of sugarcane, and 2.932 million tons of tea; 77.484 million

[19] Data source: China Marine Ecological and Environmental Statistical Bulletin 2020.
[20] GDP data are reported in current prices.

tons of meat, 65.490 million tons of aquatic products, and 102.570 million m^3 of timber.

In 2020, China possessed a total of 1,056.221 million kW agricultural machinery power with 4.773 million large and medium-sized agricultural tractors and 17.276 million small agricultural tractors. China used 52.507 million tons of agricultural fertilizers, of which 18.339 million tons (or 34.9%) were nitrogen fertilizers.

(2) Industry and Construction

In 2020, China's industrial added value was 31,307.11 billion yuan, accounting for 30.8% of China's GDP, 10.8 percentage points lower than that in 2005. China has launched a series of policies to promote industrial restructuring, and has made remarkable progress in industrial upgrading. Among industries above designated size, the added value of high-tech manufacturing industry increased by 7.1%, accounting for 15.1% of the total added value of industries above designated size; the added value of equipment manufacturing industry increased by 6.6%, accounting for 33.7% of that of the total.

In 2020, China's installed electricity generation capacity was 2,202.04 million kW, including 1,246.24 million kW of thermal power, 370.28 million kW of hydropower, 49.89 million kW of nuclear power, 281.65 million kW of wind power, and 253.56 million kW of solar power.

In 2020, the added value of China's construction industry stood at 7,299.57 billion yuan. The general and professional contracting construction enterprises qualified in China realized a profit of 830.3 billion yuan.

(3) Tertiary Industry

The tertiary industry encompasses industries such as retail and wholesale, finance, real estate, transport, etc. In 2020, the contribution of China's transport, storage and post industries to the tertiary sector was significantly lower than in 2005, while the contribution of finance increased significantly (Table 1-3).

Table 1-3 Structure of China's Tertiary Sector, 2005, 2010, 2015, 2020 (%)

Industry	2005	2010	2015	2020
Retail and wholesale	18.0	19.7	19.3	17.3
Transport, storage and post	13.8	10.3	8.7	7.5
Accommodation and catering	5.4	4.2	3.5	2.9
Finance	9.7	14.1	16.1	15.2
Real estate	11.0	12.8	12.2	13.5
Other service industries	41.0	37.7	39.2	42.8

In 2020, China's total retail sales of consumer goods stood at 39,198.1 billion yuan. The retail sales of consumer goods in urban areas were 33,911.9 billion yuan, and those in rural areas were 5,286.2 billion yuan. The total retail sales were 35,245.3 billion yuan. The annual revenue of the catering industry amounted to 3,952.7 billion yuan. Online retail sales of physical goods amounted to 9,759 billion yuan, accounting for 24.9% of China's total retail sales.

In 2020, China's aggregate financing to the real economy (AFRE) (flow) reached 34.8 trillion yuan, and savings deposits in Renminbi and foreign currencies in all items of financial institutions totaled 218.4 trillion yuan, of which the savings deposit in Renminbi stood at 212.6 trillion yuan. Outstanding balance of loans in Renminbi and foreign currencies in all items of financial institutions reached 178.4 trillion yuan, of which outstanding balance of loans in Renminbi were 172.7 trillion yuan. The outstanding balance of domestic household consumption loans in Renminbi in all financial institutions was 49,566.8 billion yuan. Funds raised through A-shares issued on Shanghai and Shenzhen Stock Exchanges reached 1,541.7 billion yuan. The issuance of corporate credit bonds amounted to 14.2 trillion yuan. The premium of primary insurance received by the insurance companies amounted to 4,525.7 billion yuan.

China has built a comprehensive transport network integrating highway, railway, air and waterway transport. From 2005 to 2020, the mileage of all modes of transport has increased to varying degrees (Table 1-4). In 2020, China's total length of operating high-speed rail lines in service reached 37,929 km, ranking first in the world. In 2020, 9.67 billion trips were made in China, of which 6.89 billion were made through highways, accounting for 71.3% of China's total. The total freight was 47.30 billion tons, in which the freight through highways accounted for 72.4%, followed by the freights through waterways and railway, respectively, which accounted for 16.1% and 9.6%, and the freights through pipelines and air aviation accounted for less than 2%. The freight turnover was 20,221.1 billion ton-km. China's ports handled 14.55 billion tons or 264.3 million TEUs of cargo.

Table 1-4 Length of Transport Lines in China, 2005, 2010, 2015, 2020 (10,000 km)

Item	2005	2010	2015	2020
Railways	7.54	9.12	12.10	14.63
Including: High-speed railways	-	0.51	1.98	3.79
Highway	334.52	400.82	457.73	519.81
Including: Expressways	4.10	7.41	12.35	16.10
Inland waterways	12.33	12.42	12.70	12.77
Regular flights	199.85	276.51	531.72	942.63
Oil (gas) pipelines	4.40	7.85	10.87	13.41

2.2.3 Income and Consumption

In 2020, the per capita disposable income of residents nationwide was 32,188.8 yuan, that of urban residents was 43,833.8 yuan, and rural residents 17,131.5 yuan. The average annual spending for residents nationwide was 21,209.9 yuan per person, that for urban residents was 27,007.4 yuan per person, and rural residents 13,713.4 yuan per person. The proportion of food is relatively high in household consumption expenditure, for which the Engle coefficient was 0.302, and that in urban and rural areas were 0.292 and 0.327, respectively.

Imbalanced and uncoordinated socioeconomic development remains a major issue in China. Income levels in the eastern part of the country are significantly higher than those in other parts of the country. In 2020, per capita disposable income in East China was 41,239.7 yuan, Northeast China 28,266.2 yuan, Central China 27,152.4 yuan, and West China 25,416.0 yuan.

2.2.4 Foreign Trade

In 2020, China's goods imports and exports totaled 32,221.52 billion yuan, of which the value of goods exports was 17,927.88 billion yuan and goods imports 14,293.64 billion yuan, creating a trade surplus of 3,634.24 billion yuan. China's services imports and exports totaled US$661.72 billion, of which the value of services exports was US$280.63 billion and services imports US$381.09 billion, creating a trade deficit of US$100.46 billion. The US, the EU and the ASEAN are China's top export destinations, and the ASEAN, the EU and Japan are China's top import markets.

In 2020, 38,570 newly established enterprises in China received foreign direct investments (excluding banks, securities and insurance). The actual use of foreign direct investments was US$144.37 billion. Outward foreign direct investment amounted to US$153.71 billion. The accomplished turnover of China's foreign contracted projects throughout the year was US$155.94 billion.

Chapter 3 National Development Strategies and Targets

China has been actively reconfiguring its growth model to better adapt to the new normal in accordance with the national development strategies. To succeed in the building of a moderately prosperous society in all respects, the Chinese government has embraced the development philosophy of innovation-driven, coordinated, green, open, and shared growth. In 2015, it officially announced its NDC targets. In 2021, it submitted its updated NDC and Mid-Century Long-Term Low Greenhouse Gas Emission Development Strategy.

3.1 National Development Strategies

After adopting the policy of reform and opening up, China laid out the three-step development strategy for achieving socialist modernization. The first two goals – ensuring that people’s basic needs are met and enabling the people to enjoy a moderately prosperous life – have been accomplished ahead of time. Building on this, the Communist Party of China (CPC) proposed the vision to build China into an economically more strong, democratic more robust, scientifically and educationally more advanced, culturally more prosperous, and socially more harmonious moderately prosperous (*xiaokang*) society where people enjoy better quality of life by the time the CPC celebrated its centenary in 2021. After this, with another 30 years of work, by the centenary of the People’s Republic of China, we will have realized basic modernization and built China into a modern socialist country. After comprehensively analyzing the international and domestic situation, the Chinese government proposed a two-stage development plan for the period from 2020 to the middle of this century.

In the first stage from 2020 to 2035, China will build on the foundation of a moderately prosperous society with another 15 years of hard work to see that socialist modernization is basically realized. The vision is that by the end of this stage, the following goals will have been met: China’s economic and technological strength has increased significantly; China has become a global leader in innovation. The rights of the people to participate and to develop as equals are adequately protected; the rule of law for the country, the government, and society is basically in place; institutions in all fields are further improved, and the modernization of China’s system and capacity for governance is basically achieved. Social etiquette and civility are significantly enhanced and China’s national soft power has grown much stronger. People are leading more comfortable lives, and the size of the middle-income group has grown considerably; disparities in urban-rural development, in development between regions, and in living standards are significantly reduced. equitable access to basic public services is basically ensured; solid progress has been made toward prosperity for everyone. A modern social governance system has basically taken shape and the society is vibrant, harmonious and orderly. There is a fundamental improvement in the environment; the goal of building a Beautiful China is basically attained.

In the second stage from 2035 to the middle of the 21st century, China will, building on having basically achieved modernization, work hard for another 15 years and develop into a great modern socialist country that is prosperous, strong, democratic, culturally advanced, harmonious, and beautiful. By the end of this stage, the following goals will have been met: New heights are reached in every dimension of material, political, cultural and ethical, social, and ecological advancement. Modernization of China's system and capacity for governance is achieved. China has become a global leader in terms of composite national strength and international influence. Common prosperity for everyone is basically achieved. The Chinese people enjoy happier, safer, and healthier lives. The Chinese nation will become a proud and active member of the community of nations.

3.2 Economic and Social Development Targets

According to the new target requirements of building a moderately prosperous society in all respects, China's major economic and social development targets during the 13th FYP period [21] are as follows:

Medium-high rate of economic growth. Based on improved balance, inclusiveness and sustainability of economic development, the GDP and per capita income of urban and rural residents are doubled by 2020 relative to 2010. While the key economic indicators are balanced and coordinated, the development will be significantly better in terms of quality and efficiency. Industries achieve a medium- to high-end level, agricultural modernization makes significant progress, the integrated development level of industrialization and informatization improves further, the development of advanced manufacturing industry and strategic emerging industries accelerates, new industries and new business forms grow constantly, and the proportion of the service industry increases further.

Remarkable success of innovation-driven development. The implementation of an innovation-driven development strategy deepens, entrepreneurship and innovation develop vigorously, and total factor productivity improves significantly. Science and technology are deeply integrated with economy, the allocation of innovation elements is more efficient, major breakthroughs are made in core technologies in major areas and key links, independent innovation capability is strengthened comprehensively, and China becomes an innovative country and a strong country by talent.

Development has become significantly more coordinated. Consumption makes growing contribution to economic growth, resulting in significantly increased investment and business efficiencies. The quality of urbanization improves significantly, and the urbanization level of registered population increases. A new regional coordinated development pattern is basically in place to optimize the spatial distribution of development. China opens up to the outside world more extensively and profoundly, the capability for allocating resources worldwide is further enhanced, the import and export structure is further optimized, and international payments are basically balanced.

Comprehensive enhancement of people's well-being. More adequate public service systems in the fields of employment, education, culture, social security, health care and housing are established, ensuring equitable access to basic public services. Important progress is made in modernizing education and the schooling years of working-age

[21] The period covered by the 13th Five-Year Plan (FYP) is from 2016 to 2020.

population increase significantly. Relatively sufficient jobs are created. Income gap is narrowed and the proportion of middle-income population increases. The rural poverty population under the current Chinese standard is lifted out of poverty, all impoverished counties succeed in eradicating poverty, and regional poverty is eliminated.

Higher overall caliber of the population and better social civility. The Chinese dream and core socialist values enjoy greater popularity; patriotism, collectivism and socialist ideology are widely spread; the social morals of making progress, being honest and helping each other become more popular; national cultural literacy and health of citizens are improved; and legal awareness are enhanced across the society. The public cultural service system is basically completed, and the cultural industry becomes a pillar of the economy.

Better eco-environment. People embrace environmentally friendly production and green lifestyle, ensuring the low-carbon development. Energy resources are developed and utilized more efficiently. Energy and water resource consumption, construction land and total carbon emission are effectively controlled, and the total emission of major pollutants decreases significantly. Major functional areas and ecological safety barriers are basically delineated.

Improved systems in all respects. Great progress is made in advancing the modernization of governance systems and capabilities, and basic institutional systems for all respects have taken shape. People's democracy is further improved, a law-based government is basically in place, and public judiciary credibility improves significantly. Human rights are practically assured, and proprietary rights are effectively protected. An open economic system is basically formed. The modern military system with Chinese characteristics is further improved. Party-building efforts are institutionalized.

3.3 NDC Targets

According to the requirements of the relevant decisions adopted at COPs, the Chinese government submitted the Enhanced Action on Climate Change: China's Intended Nationally Determined Contributions in June 2015, stating its NDC targets for 2030: China will peak its carbon dioxide emissions around 2030 and strive to make it as early as possible, lower its carbon dioxide emissions per unit of GDP by 60% to 65% from the 2005 level, increase the share of non-fossil fuels in primary energy consumption to around 20%, and increase its forest standing stock by around 4.5 billion m^3 from the 2005 level.

In October 2021, according to the relevant resolutions adopted at COPs and the relevant requirements under the Paris Agreement, China updated its NDC document and submitted China's Achievements, New Goals and New Measures for Nationally Determined Contributions, stating its goals as follows: aims to have CO_2 emissions peak before 2030 and achieve carbon neutrality before 2060; to lower CO_2 emissions per unit of GDP by over 65% from the 2005 level, to increase the share of non-fossil fuels in primary energy consumption to around 25%, to increase the forest stock volume by 6 billion cubic meters from the 2005 level, and to bring its total installed capacity of wind and solar power to over 1.2 billion kilowatts by 2030.

3.4 China's Mid-Century Long-Term Low Greenhouse Gas Emission Development Strategy

China submitted its Mid-Century Long-Term Low Greenhouse Gas Emission Development Strategy to the Secretariat of the UNFCCC in October 2021 in accordance with the relevant requirements under the Paris Agreement. The document summarizes China's remarkable progress in controlling GHG emissions, puts forward the basic principles, strategic vision, strategic priorities and policy guidance for China's long-term low-emission development, and expounds its principles and propositions relating to global climate governance.

China will resolutely implement the declarations of President Xi Jinping; roll out action plans for peaking CO_2 emissions before 2030 and achieving carbon neutrality before 2060; ramp up its efforts to enable a green, circular, low-carbon economy and a clean, safe, efficient, and low-carbon energy system; encourage technological innovation aimed at driving the low-carbon-oriented transition and support the development of low-carbon industries; promote green and low-carbon production mode as well as lifestyle across the board; improve the health and stability of ecosystems; and put forward its best efforts to contribute to the long-term goals set in the Paris Agreement.

Advancing energy production and consumption revolution. China will seek to strengthen the control of energy intensity and consumption, improve energy efficiency, strictly control fossil energy consumption, and give priority to the development of non-fossil energy. By 2030, the share of non-fossil fuels in China's energy consumption will increase to around 25%, and the country's total installed capacity of wind and solar power will increase to over 1.2 billion kW. By 2060, with a clean, safe, efficient, and low-carbon energy system in place, China will become one of the most energy-efficient countries in the world and the share of non-fossil fuels in its energy consumption will reach more than 80%.

Accelerating the green and low-carbon transition of the secondary sector. China will propel industries such as steel, construction materials, non-ferrous metals, petrochemicals, and chemicals to peak CO_2 emissions, continue to reduce CO_2 emissions from industrial processes, accelerate the construction of green and zero-carbon industrial parks, and launch green and zero-carbon supply chain demonstration projects. By 2030, key industries in China will meet the most stringent international standards for energy efficiency; decarbonization and digitalization will become two major engines of economic growth, driving fundamental changes in the manufacturing sector.

Promoting green and low-carbon urban and rural development. China will promote the construction of green and low-carbon buildings and accelerate energy optimization in buildings. By 2025, all new buildings in urban areas in China will meet green building standards; at least 8% of the energy used in buildings in urban areas will be renewable; and 60% of new factories and public sector buildings will be installed with rooftop solar panels.

Accelerating the low-carbon transition in the transport sector. China will seek to increase the use of electricity, hydrogen, natural gas, and advanced liquid biofuels in the transport sector. By 2030, around 40% of newly added vehicles each year will be powered by renewable and clean energy sources; CO_2 emissions intensity of public transport per unit of turnover will decrease by about 9.5% from the 2020 level; energy consumption of rail transport per unit of turnover will decrease by 10% from the 2020 level. China will strive to reach peak oil consumption in land transport before 2030.

Promoting nature-based solutions. China will incorporate the sustainable use of natural resources into the policy and action framework for addressing climate change and harness the power of nature to build resilience of fields such as forestry, agriculture, oceans, water resources, and ecosystems to climate change. By 2030, forests will cover approximately 25% of China's total land.

Promoting a simple, moderate, green, and low-carbon vision and a green production and life style. China will put in place laws, institutions, policies, and standards for climate actions, bring the market mechanism into play, and create internal driving forces for green and low-carbon transformation.

Chapter 4 National Institutional Arrangements

The Chinese government is well aware of the importance of institutional arrangements for addressing climate change. It has built relevant institutional frameworks at national, local and sectoral levels and continuously improved them. It has also established standing expert and technical support teams to support the preparation of national communications and biennial update reports.

4.1 National Institutions

To practically strengthen the leadership for addressing climate change and energy conservation and emission reduction, the Chinese government set up the National Leading Group on Climate Change, Energy Conservation and Emissions Reduction (hereinafter referred to as the Leading Group) in June 2007, as a national cross-department coordination organization. The main tasks of the Leading Group are: to develop national major strategies, policies and countermeasures on climate change, make overall arrangements on the work of climate change, study and review international cooperation and negotiation counterproposals and coordinate in solving major problems found in the work on climate change; organize the implementation of the policies of the State Council on energy conservation and emission reduction, make overall arrangements of energy conservation and emission reduction work, study and review major policy suggestions, and coordinate in solving major problems in the work. The concrete work of the Leading Group is done by China's National Development and Reform Commission (NDRC).

In 2008, in order to improve the organizational structure of climate change response, the NDRC established the Department of Climate Change. In 2012, the National Center for Climate Change Strategy and International Cooperation (NCSC) was established. As required in the plan on reforming Party and state institutions in 2018, the functions of the NDRC relating to climate change were transferred to the newly established Ministry of Ecology and Environment. The Department of Climate Change and the NCSC were transferred to the Ministry of Ecology and Environment. In 2019, the State Council adjusted the organizational structure and staffing program of the Leading Group in response to changes as needed [22]. Some responsibilities were transferred to the Ministry of Ecology and Environment and the NDRC (Figure 1-4).

[22] Data source: Notice of the General Office of the State Council on Adjusting the Staffing of the National Leading Group on Climate Change, Energy Conservation and Emissions Reduction (GBH [2019] No. 99).

Figure 1-4 National Leading Group on Climate Change

4.2 Local and Sectoral Institutions

Member units of the Leading Group, as governmental authorities in respective industries, have appointed leaders and major responsible departments and bureaus for addressing climate change, meanwhile strengthening the guidance to respective industry associations. Under the guidance of the central government of China, the provincial, autonomous region and municipal governments have in succession established Provincial Leading Groups on Climate Change, which are chaired by their top leaders and participated in by relevant departments and serve as the cross-departments, comprehensive deliberation and coordination bodies in climate change. After 2008, many provinces started to set up divisions and offices under the departments of addressing climate change as the administrative body of provincial-level competent department on climate change; meanwhile, local scientific research institutes on climate change have been strengthened, so have their science and technology support capacity to the local government's decision-making on climate change.

4.3 National Communications and Biennial Update Reports

The tasks on preparing and submitting National Communications and Biennial Update Reports, including the National GHG Inventories, gradually further. Since the Initial National Communication on Climate Change, the Chinese government has preliminarily established a national system for the task and formed a relatively stable team for the preparation of National Communications on Climate Change and Biennial Update Reports (Table 1-5) as well as a regular team for the preparation of the National GHG Inventories

(Table 1-6). According to the work divisions for climate change response, the national competent department is responsible for the preparation of National GHG Inventories, while the relevant governmental authorities provide basic data and information, collect materials from relevant trade associations and typical enterprises, and establish database to support the inventory preparation and data management.

Upon completion, National Communications on Climate Change and Biennial Update Reports are reviewed and approved by the State Council before being submitted to the Secretariat of the UNFCCC.

Table 1-5 Organizations Involved in the Preparation of National Communications and Biennial Update Reports

Tasks	Responsible Organization(s)	Other organizations involved
National Circumstances and Institutional Arrangements	NCSC	Energy Research Institute (ERI) under the NDRC, National Energy Conservation Center (NECC), National Marine Information Center (NMIC), Environmental and Sanitation Engineering Center (ESEC) under the Ministry of Housing and Urban-Rural Development (MOHURD), China Land Surveying and Planning Institute (CLSPI), and member units of the steering committees for the preparation of national communications and biennial update reports.
National Greenhouse Gas Inventory	NCSC	Tsinghua University (TSU), Institute of Environment and Sustainable Development in Agriculture (IEDA) under the Chinese Academy of Agricultural Sciences (CAAS), Institute of Forest Ecology, Environment and Protection (IFEEP) under the Chinese Academy of Forestry (CAF), Institute of Atmospheric Physics (IAP) under the Chinese Academy of Sciences (CAS), Chinese Research Academy of Environmental Sciences (CRAES), and member units of the steering committees for the preparation of national communications and biennial update reports.
Climate Change Impacts and Adaptation	NCSC and CAAS	National Climate Center, NMIC, TSU, and member units of the steering committees for the preparation of national communications and biennial update reports.
Climate Change Mitigation Policies and Actions	NCSC and TSU	ERI, NECC, ESEC, China Center for Information Industry Development (CCID), and member units of the steering committees for the preparation of national communications and biennial update reports.
Finance, Technology and Capacity-Building Needs	NCSC and the Administrative Centre for China's Agenda 21 (ACCA21)	Foreign Environmental Cooperation Center (FECO) under the Ministry of Ecology and Environment, China CDM Fund Management Center, TSU, and member units of the steering committees for the preparation of national communications and biennial update reports.
Other Relevant Information for Achieving the UNFCCC Targets	NCSC and the National Climate Center	ERI, NECC, NMIC, National Marine Environmental Forecasting Center (NMEFC), Renmin University of China (RUC), Chinese Academy of Meteorological Sciences (CAMS), China Association for NGO Cooperation. (CANGO), and member units of the steering committees for the preparation of national communications and biennial update reports.
Basic Information of Hong Kong SAR on Addressing Climate Change	Environmental Protection Department of the Hong Kong SAR	NCSC and others
Basic Information of Macao SAR on Addressing Climate Change	Macao Meteorological and Geophysical Bureau	NCSC and others

Table 1-6 Organizations Involved in the Preparation of National GHG Inventories

Tasks	Responsible Organization(s)	Other organizations involved
Energy Sector	NCSC	ERI, TSU, China Building Materials Federation (CBMF), China Petroleum and Chemical Industry Federation (CPCIF), China Metallurgical Industry Planning and Research Institute (CMIPRI), China Nonferrous Metals Industry Association (CNMIA), China National Petroleum Corporation (CNPC), China Petrochemical Corporation (Sinopec), China National Offshore Oil Corporation (CNOOC), Shaanxi Yanchang Petroleum Group, and China Oil and Gas Pipeline Network Corporation (PipeChina).
Industrial Processes	TSU, FECO, and Suzhou Innovation Research Institute (SIRI) of Beihang University	CBMF, CPCIF, CMIPRI, and CNMIA.
Agriculture (Livestock)	IEDA	National Animal Husbandry Station, Animal Husbandry Stations in major livestock production provinces, China Agricultural University, Henan Agricultural University, and Inner Mongolia Agricultural University.
Agriculture (Crop)	IAP	Rural Energy and Environment Agency (REEA) under the Ministry of Agriculture and Rural Affairs, IEDA, Satellite Application Center for Ecology and Environment (SACEE) under the Ministry of Ecology and Environment, and Institute of Agricultural Resources and Regional Planning (IARRP) under the Chinese Academy of Agricultural Sciences.
Land Use, Land Use Changes and Forestry (LULUCF)	IFEEP and Land Consolidation and Rehabilitation Center (LCRC) under the Ministry of Land and Resources	Forestry and Grassland Inventory and Planning Institute (FGIPI) under the National Forestry and Grassland Administration, China Aero Geophysical Survey & Remote Sensing Center for Land and Resources (AGRS), Institute of Ecosystem Protection and Restoration (IEPR) under the CAS, Research Institute of Forestry (RIF) under the CAS, Resources Information Institute (RII) under the CAS, and IEDA.
Waste Disposal	CRAES	Research Center for Eco-Environmental Sciences (RCEES) under the CAS, ESEC, China Urban Construction Design & Research Institute, SACEE, China National Environmental Monitoring Centre (CNEMC), Institute of Urban Environment (IUE) under the CAS, Guangzhou Institute of Energy Conversion (GIEC) under the CAS, Institute of Process Engineering (IPE) under the CAS, Institute of Rock and Soil Mechanics (IRSM) under the CAS, TSU, RUC, Beijing Normal University (BNU), China Everbright Environment Group Limited, and Beijing Enterprises Water Group Limited.

Part II National Greenhouse Gas Inventory

In accordance with relevant decisions adopted by the UNFCCC and China's national circumstances, the National GHG Inventory of 2017 (NGI2017) covers six gases, namely carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6) from Energy, Industrial Processes, Agriculture, Land Use, Land-Use Change and Forestry (LULUCF) and Waste. According to the implementation requirements of the Paris Agreement, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (hereinafter referred to as the 2006 IPCC Guidelines) will be applicable from 2024 in preparing reports and inventories. For better technical and capacity-building preparation of the forthcoming compliance requirements, the methodology adopted for the current round of inventory has gradually been updated in accordance with the 2006 IPCC Guidelines. The Inventory mainly follows the 2006 IPCC Guidelines, the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (hereinafter referred to as the Revised 1996 IPCC Guidelines), the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (hereinafter referred to as GPG 2000), and GPG 2000 for Land Use, Land-Use Change and Forestry (hereinafter referred to as GPG-LULUCF). Activity data are mainly from official statistics, while emission factors are primarily from China's country-specific parameters, followed by the defaulted IPCC emission factor.

Chapter 1 National Greenhouse Gas Inventory 2017

1.1 Overview of Greenhouse Gas Inventory

In 2017, China's total GHG emissions (with LULUCF) were approximately 11,550 million tons CO_2 equivalent (Mt CO_2 eq) (see Table 2-1), of which CO_2, CH_4, N_2O, and Fluorinated gases (F-gases) accounted for 80.9%, 11.8%, 5.1%, and 2.2%, respectively (see Table 2-2). LULUCF removals were 1,258 Mt CO_2 eq. China's total GHG emissions (without LULUCF) in 2017 were estimated to be 12,808 Mt CO_2 eq, of which CO_2, CH_4, N_2O, and F-gases accounted for 83.5%, 10.0%, 4.6%, and 2.0%, respectively.

Table 2-1 China's GHG Emissions and Removals by Sector in 2017 (Mt CO_2 eq)

	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Total
Energy	9271	602	117				9990
Industrial Processes	1415	0	135	164	20	67	1800
Agriculture		519	304				823
LULUCF	-1342	84	0				-1258
Waste	3	155	37				194
Total (without LULUCF)	10689	1276	593	164	20	67	12808
Total (with LULUCF)	9347	1359	593	164	20	67	11550

Notes: 1. Shaded cells do not require entries;
2. 0 indicates that the calculation result is less than 0.5 Mt CO_2 eq ;
3. Due to rounding, the aggregation of various items may be slightly different from the total;
4. Values for the Global Warming Potentials (GWP) are primarily from 100-year time-horizon GWP values from the IPCC Second Assessment Report (Table 2-3).

Table 2-2 China's GHG Emissions by Gas in 2017

Gas	With LULUCF		Without LULUCF	
	Emissions / Sink (Mt CO_2 eq)	Percentage (%)	Emissions / Sink (Mt CO_2 eq)	Percentage (%)
CO_2	9347	80.9	10689	83.5
CH_4	1359	11.8	1276	10.0
N_2O	593	5.1	593	4.6
F-gases	250	2.2	250	2.0
Total	11550	100.0	12808	100.0

Note: Due to rounding, the aggregation of various items may be slightly different from the total.

Table 2-3 Global Warming Potentials Used in the Inventory (100-Year Time Horizon)

Gas	GWP	Gas	GWP
CO_2	1	**HFC-152a**	140
CH_4	21	**HFC-227en**	2,900
N_2O	310	**HFC-236fa**	6,300
HFC-23(CHF_3)	11,700	**HFC-245fa**	1,030
HFC-32	650	**HFC-365mfc**	794
HFC-125	2,800	**PFC-14(CF_4)**	6,500
HFC-134a	1,300	**PFC-116(C_2F_6)**	9,200
HFC-143a	3,800	**SF_6**	23,900

Note: the 100-year time-horizon GWP values of HFC-245fa and HFC-365mfc are from the IPCC AR4.

In 2017, China's GHG emissions from Energy, Industrial Processes, Agriculture, and Waste were 9,990 Mt CO_2 eq, 1,800 Mt CO_2 eq, 823 Mt CO_2 eq, and 194 Mt CO_2 eq, respectively, accounting for 78.0%, 14.1%, 6.4%, and 1.5% of China's total GHG emissions (without LULUCF) in the same year (see Figure 2-1).

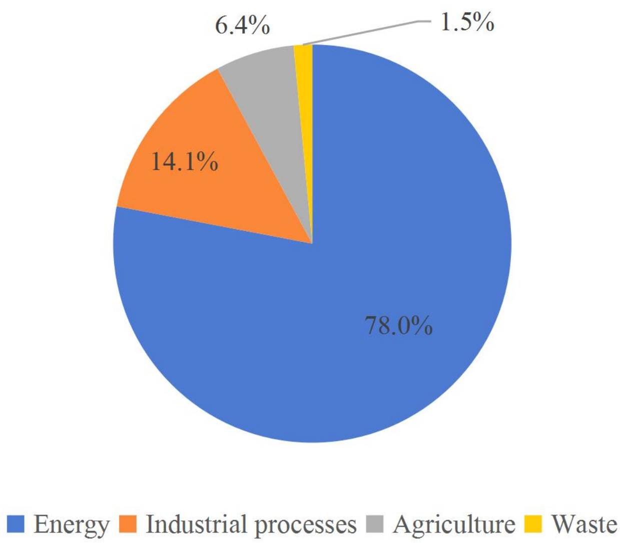


Figure 2-1 China's GHG Emissions by Sector (without LULUCF), 2017

China's GHG emissions from international bunkers (international aviation and navigation) in 2017 were approximately 74.67 Mt CO_2 eq (see Table 2-4).

Table 2-4 China's CO_2, CH_4, and N_2O Emissions and Removals in 2017 (kt)

Source and sink categories	CO_2	CH_4	N_2O
Total (without LULUCF)	10688613	60751	1913
Total (with LULUCF)	9346898	64736	1914
1. Energy	9271022	28677	377
— Fuel combustion	9271022	1777	377
♦Energy industries	4187481	94	263
♦Manufacturing industries and construction	3357179	301	71
♦Transport	964974	133	21
♦Other sectors	761388	1248	22
— Fugitive emissions		26900	
♦Solid fuels		25187	
♦Oil and natural gas		1714	
2. Industrial Processes	1414893	5	435
— Mineral industry	964744		
— Chemical industry	274422		435
— Metal industry	173138	5	NO
— Non-energy products from fuels and solvent use	2589		
— Consumption of halocarbons and SF_6			
3. Agriculture		24708	982
— Enteric fermentation		11123	
— Manure management		3548	220
— Rice cultivation		9628	
— Agricultural soils			752
— Field burning of agricultural residues		410	11
4. LULUCF	-1341714	3985	1
— Forest land	-928420	1	0
— Cropland	-96433	IE	IE

Source and sink categories	CO_2	CH_4	N_2O
— Grassland	-121013	1	1
— Wetlands	-85863	3983	NE
— Settlements	-1028		
— Other land	1183		
— Harvested wood products	-110140		
5. Waste	2697	7361	118
— Landfill		4433	
— Biological treatment		21	2
— Wastewater treatment		2906	113
— Incineration	2697	1	4
6. Memo items			
— International aviation	42802	0	1
— International navigation	31171	3	1
— CO_2 emissions from biomass	296913		

Notes: 1. Shaded cells do not require entries;
2. 0 indicates that the value is less than 0.5 kt;
3. NE (not estimated) indicates emissions and removals of existing source are not estimated, IE (included elsewhere) indicates the emission source is estimated and included in other sub-categories, and NO (not occurred) indicates the emission source doesn't exist;
4. Due to rounding, the aggregation of various items may have slight differences with the total;
5. Memo items are not counted in the total emissions.

1.2 Carbon Dioxide

Energy and Industrial Processes are two main sources of CO_2 emissions in China. In 2017, China's CO_2 emissions (without LULUCF) were 10,689 Mt, of which 9,271 Mt (86.7%) were emitted from Energy, 1,415 Mt (13.2%) from Industrial Processes, and 3 Mt from Waste. The LULUCF absorbed 1,342 Mt of CO_2 and China's CO_2 emissions (with LULUCF) in 2017 were 9,347 Mt.

1.3 Methane

Energy and Agriculture are main sources of CH_4 emissions in China. In 2017, China's CH_4 emissions were 64.736 Mt (1,359 Mt CO_2 eq), of which the Energy emitted 28.677 Mt (44.3%), Agriculture 24.708 Mt (38.2%), waste 7.361 Mt (11.4%), and LULUCF 3.985 Mt (6.2%).

1.4 Nitrous Oxide

Agriculture and Industrial Processes are main sources of N_2O emissions in China. In 2017, China's N_2O emissions were 1.914 Mt (593 Mt CO_2 eq), of which Agriculture emitted 0.982 Mt (51.3%), Industrial Processes 0.435 Mt (22.7%), Energy 0.377 Mt (19.7%), Waste 0.118 Mt (6.2%) , and LULUCF 0.9 kt (less than 0.1%).

1.5 Fluorinated gases

China's fluorinated gases emissions are emitted from Industrial Processes. In 2017, total emissions of the three types of fluorinated gases, namely HFCs, PFCs, and SF_6, were approximately 250 Mt CO_2 eq (see Table 2-5).

Table 2-5 China's Emissions of HFCs, PFCs, and SF_6 2017 (kt)

Source	HFCs										PFCs		SF_6
	HFC-23	HFC-32	HFC-125	HFC-134a	HFC-143a	HFC-152a	HFC-227ea	HFC-236fa	HFC-245fa	HFC-365mfc	CF_4	C_2F_6	
Total	1.6	22.1	22.9	40.3	2.3	0.7	1.5	0.1	0.4	0.0	2.6	0.3	2.8
Energy													
Industrial Processes	1.6	22.1	22.9	40.3	2.3	0.7	1.5	0.1	0.4	0.0	2.6	0.3	2.8
- Mineral industry													
- Chemical industry	1.6	0.8	0.7	0.8	0.1	0.2	0.1	0.0	0.1		0.0	0.0	0.1
- Metal industry											2.6	0.3	NO
- Non-Energy Products from Fuels and Solvent Use													
- Consumption of Halocarbons and SF_6	0.0	21.3	22.2	39.5	2.2	0.6	1.4	0.1	0.4	0.0	0.3	0.0	2.7
Agriculture													
LULUCF													
Waste													

Notes: 1. Shaded cells do not require entries;
2. 0.0 indicates that the value is less than 0.5 kt;
3. NO (not occurred) indicates the emission source doesn't exist;
4. Due to rounding, the aggregation of various items may have slight differences with the total.

Chapter 2 GHG Emissions by Sectors

2.1 Energy

2.1.1 Scope

For national GHG inventories, GHG emissions from the Energy are divided into two main categories: fuel combustion and fugitive emissions. Fuel combustion includes CO_2, CH_4 and N_2O emissions from energy industries, manufacturing industries and construction, transport, and other sectors. CH_4 and N_2O emissions from incineration of municipal solid waste and CO_2 emissions from fossil sources not reported in the Waste are reported under the energy industries. Fugitive emissions include CH_4 emissions from solid fuels and oil and natural gas. CO_2, CH_4 and N_2O emissions from international bunkers and CO_2 emissions from biomass are reported as memo items.

2.1.2 Methodologies

As part of the reporting requirements under the Paris Agreement, starting from 2024, developing countries will be required to report national GHG inventories following the 2006 IPCC Guidelines. To prepare ourselves for the transition from the 1996 IPCC Guidelines and the IPCC GPG 2000, following which China's Third National Communication was prepared, to the 2006 IPCC Guidelines, the emissions and removals estimates under Energy presented in the NGI2017 were calculated using methodologies consistent with those recommended in the 2006 IPCC Guidelines.

The sectoral approach was used to calculate CO_2, CH_4 and N_2O emissions from fossil fuel combustion in the NGI2017. Macro-level estimates calculated using the reference approach were used to validate the results of the Tier 2 methods. The Tier 2 methods were used to calculate CH_4 and N_2O emissions from power generation and heating, and the Tier 1 methods were used for the calculation of CH_4 and N_2O emissions from other stationary combustion sources. Among mobile combustion sources, emissions from road transportation were estimated using the COPERT model (Tier 3); emissions from aviation were calculated using the Tier 2 methods; emissions from railways, navigation, and other transportation were calculated using the Tier 1 methods. Estimates of CH_4 emissions from residential biomass burning and incineration of waste were calculated using the Tier 2 methods. CH_4 emissions from other types of biomass burning were estimated using the Tier 1 methods.

Fugitive CH_4 emissions from underground mining and post-mining activities were estimated using the Tier 2 methods; the Tier 1 methods were used to estimate fugitive CH_4 emissions from surface coal mines; the Tier 3 methods were used to estimate fugitive CH_4 emissions from abandoned underground coal mines. Fugitive CH_4 emissions from well completion and oil and natural gas transport were estimated using the Tier 3 methods, while emissions from other activities in oil and natural gas systems were calculated using the Tier 1 methods.

2.1.3 Activity Data and Emission Factors

Fuel combustion data are largely derived from energy statistics provided by the National Bureau of Statistics and other relevant government departments, including the China Energy Statistical Yearbook 2018. Activity data required for the estimation of fugitive emissions from coal mining mainly come from the China Energy Statistical Yearbook 2018 and the Research Report on the Development of Global Coal Industry 2020. Activity data used for the estimation of fugitive emissions from oil and natural gas systems are mainly derived from statistics provided by the National Bureau of Statistics and major oil and natural gas groups in China. Data for major Energy used when preparing the NGI2017 are shown in Table 2-6.

Table 2-6 China's Major Activity Data on Energy in 2017

	Activity data		Activity data
Coal Consumption (Mtce)	2,762	Underground Coal Production (Mt)	2,974
Oil consumption (Mtce)	862	Surface Coal Production (Mt)	550
Natural Gas Consumption (Mtce)	315	Domestic Natural Gas Production (M m^3)	148,035

The carbon content per unit calorific value and carbon oxidation rate of coal combustion in the electricity industry were based on the measured data of power companies in the national carbon market. The carbon content per unit calorific value of natural gas and liquefied natural gas was based on the measured data of major oil and natural gas fields and imported natural gas and liquefied natural gas. The national average level of emission factors of CH_4 from underground coal mining and post-mining activities were based on the national coal mine gas classification information while other emission factors were the same as those in the NGI2014 or the defaulted value in the 2006 IPCC Guidelines.

2.1.4 Inventory Results

In 2017, GHG emissions from Energy in China totaled 9,990 Mt CO_2 eq, of which 9,425 Mt CO_2 eq (94.3%) were from fuel combustion and 565 Mt CO_2 eq (5.7%) were fugitive emissions. CO_2 emissions were 9,271 Mt, accounting for about 92.8% of China's total GHG emissions from Energy. CH_4 emissions were 602 Mt CO_2 eq, accounting for approximately 6.0% of the total GHG emissions from Energy. N_2O emissions were 117 Mt CO_2 eq, accounting for about 1.2% of the total GHG emissions from Energy (see Figure 2-2).

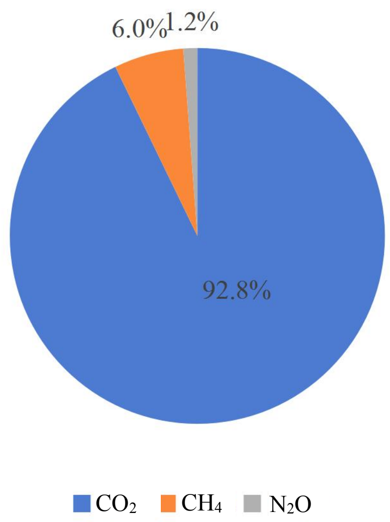


Figure 2-2 GHG Emissions from Energy in China, 2017

2.2 Industrial Processes

2.2.1 Scope

The Industrial Processes in 2017 includes GHG emissions from the mineral industry, the chemical industry, the metal industry, non-energy products from fuels and solvent use, and consumption of halocarbons and SF_6. GHG emissions from the mineral industry include CO_2 emissions from cement production, lime production, and glass production. GHG emissions from the chemical industry include CO_2, N_2O, HFCs, PFCs, and SF_6 emissions from the production of synthetic ammonia, nitric acid, adipic acid, caprolactam, calcium carbide, titanium dioxide, soda ash, methanol, ethylene, and fluorine-containing chemicals. GHG emissions from the metal industry include CO_2, CH_4 and PFCs emissions from the production of iron and steel, ferroalloys, aluminum, magnesium, lead, and zinc. To avoid the double counting of emissions from converter gas in the Energy, CO_2 emissions from converter steelmaking are no longer reported. Emissions from non-energy products from fuels and solvent use include CO_2 emissions from the use of lubricants and paraffin wax as non-energy products. Emissions from the consumption of halocarbon and sulfur hexafluoride include HFCs, PFCs, and SF_6 emissions from Industrial Processes that consume HFCs, PFCs, and SF_6.

2.2.2 Methodologies

This inventory was prepared following the 2006 IPCC Guidelines. Based on China's circumstances and available data, a methodology that combines the emission factor method and the carbon balance method was developed to account for GHG emissions in Industrial Processes. Emissions from production of ethylene, methanol, iron and steel were estimated using the carbon balance method, and emissions from other Industrial Processes were mainly calculated using the emission factor method. Emissions from the production of glass, caprolactam, soda ash, and ferroalloys and the use of lubricants and paraffin were estimated using the Tier 1 methods. Emissions from other sources in this sector were estimated using the Tier 2 methods.

2.2.3 Activity Data and Emissions Factors

Cement clinker production data come from the statistics provided by the National Bureau of Statistics. Synthetic ammonia, nitric acid, iron and steel, aluminum, magnesium, lead, and zinc production data primarily come from the China Industry Statistical Yearbook. Methanol and ethylene production data primarily come from the China Chemical Industry Statistical Yearbook. Calcium carbide production data are provided by the Calcium Carbide Industry Association. Lime production data are mainly from the Chinese Lime Industry Association, and soda ash and adipic acid production are primarily derived from the statistics of the relevant producer surveys. Data for major Industrial Processes used when preparing the NGI2017 are shown in Table 2-7.

Country-specific values for the year 2017 derived from the results of typical enterprise surveys are used for the emission factors for the production of synthetic ammonia, adipic acid, calcium carbide, methanol, ethylene, fluorine chemicals, and steel, and 2014 inventory data are used for the emission factors for aluminum, magnesium, and lead production. Default values presented in the 2006 IPCC Guidelines are used for the emission factors for other Industrial Processes.

Table 2-7 China's Activity Data for Major Industrial Processes in 2017

	Annual production		Annual production
Cement (Mt)	1,400.00	Methane (Mt)	45.29
Crude steel (Mt)	870.74	Aluminum (Mt)	33.29
Synthetic ammonia (Mt)	49.46	HCFC-22 (Mt)	0.647

2.2.4 Inventory Results

In 2017, China's total GHG emissions from Industrial Processes were 1800 Mt CO_2 eq, of which emissions from the mineral industry accounted for 53.6%, emissions from the chemical industry 24.1%, emissions from the metal industry 10.6%, emissions from non-energy products from fuels and solvent use 0.1%, and emissions from the consumption of halocarbons and SF_6 11.6%. Of the total GHG emissions from Industrial Processes, CO_2 accounts for 78.6%, N_2O 7.5%, HFCs 9.1%, PFCs 1.1%, SF_6 3.7%, and CH_4 less than 0.1% (see Figure 2-3).

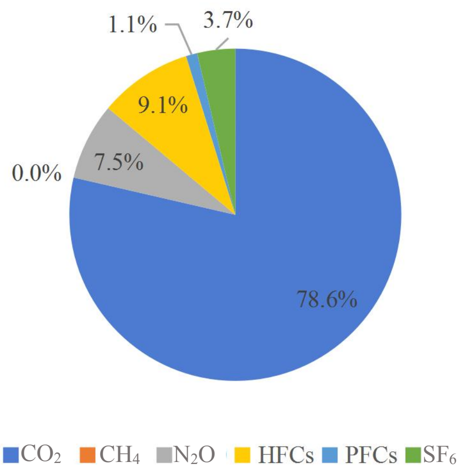


Figure 2-3 GHG Emissions from Industrial Processes in China, 2017

2.3 Agriculture

2.3.1 Scope

The Agriculture includes CH_4 emissions from enteric fermentation, CH_4 and N_2O emissions from manure management, CH_4 emissions from rice cultivation, N_2O emissions from agricultural soils, and CH_4 and N_2O emissions from field burning of agricultural residues. To be more specific, the NGI2017 reports CH_4 emissions from enteric fermentation in 12 types of livestock, including beef cattle, dairy cattle, goats, and sheep, etc. CH_4 and N_2O emissions from the management of manure of 14 types of livestock, including dairy cattle, beef cattle, goats, sheep, swine, and poultry,etc. CH_4 emissions from single-rice, double-rice, and winter-flooding rice cultivation; and direct emissions of N_2O from 11 types of agricultural soils, including year-round upland excluding vegetables,rice fields with different cropping regimes, vegetable fields, orchards, tea gardens, and grazing pasture, and indirect emissions of N_2O from nitrogen deposition, leaching and run-off.

2.3.2 Methodologies

The Tier 2 methods described in the 2006 IPCC Guidelines were used for the estimation of CH_4 emissions from enteric fermentation in key types of livestock such as beef cattle, dairy cattle, buffalo, sheep, and goats. CH_4 emissions from enteric fermentation in other types of livestock were calculated using the Tier 1 methods. CH_4 and N_2O emissions from the management of manure of key types of livestock such as swine, beef cattle, dairy cattle, poultry, buffalo, and goats were estimated using the Tier 2 methods in the 2006 IPCC Guidelines. Other emission sources are calculated using the Tier 1 methods. N_2O emissions from manure management include both direct emissions and indirect emissions from volatile nitrogen deposition and nitrogen deposition, leaching and runoff.

CH_4 emissions from rice planting season under single-cropping and double-cropping regimes were calculated using the Tier 3 methods (CH4MOD) in the 2006 IPCC Guidelines. This model sums up CH_4 emissions from rice cultivation in prefecture-level cities. CH_4 emissions from non-rice planting season of winter-flooding rice were estimated using an empirical formula. N_2O emissions from agricultural soils were calculated using the IAP-N model (i.e., Tier 2 methods in the 2006 IPCC Guidelines) which sums direct and indirect N_2O emissions from different types of agricultural soils in prefecture-level cities. CH_4 and N_2O emissions from field burning of agricultural residues were calculated using the Tier 1 methods in the 1996 IPCC Guidelines.

2.3.3 Activity Data and Emission Factors

The primary sources of activity data for enteric fermentation, manure management, rice cultivation, and agricultural soils include the China Statistical Yearbook 2018, the China Animal Husbandry and Veterinary Yearbook 2018, provincial and municipal statistical yearbooks, industry statistics, and the Third National Agricultural Census. Data for major agricultural activities used when preparing the NGI2017 are shown in Table 2-8.

Animal weight, feed intake, feed type, and other data required for emission factor estimation for enteric fermentation, as well as data for CH_4 and N_2O emission factors for different manure management methods, are derived from survey data. Nitrogen excretion data for swine, cattle, and poultry come from the animal husbandry industry data in the First National Pollution Survey. Nitrogen excretion data for sheep and goats used in this report are published research data. The default values given in the 2006 IPCC Guidelines were used for emission factors for indirect emissions of N_2O from manure management.

The planted area and production data of single-rice and double-rice are from the Institute of the Agricultural Information Institute (AII) of the Chinese Academy of Agricultural Sciences and the 2018 statistical yearbooks of provinces and cities. The planted area data for winter-flooding rice cultivation are published research data. The surveyed straw/residues returning rates of preceding crop of the early, middle and late rice in each province were acquired from REEA of the Ministry of Agriculture and Rural Affairs. The CH_4 emission factors for rice cultivation under single-rice and double-rice fields were calculated using CH4MOD, and those of non-rice planting season of winter-flooding rice fields were estimated using an empirical formula.

The planted area and production of 16 major crops, total land area of orchards and tea gardens, arable land area, nitrogen fertilizer consumption, compound fertilizer consumption, and rural population, etc. are from the AII, the China Statistical Yearbook 2018, statistical yearbooks of provinces and cities in 2018, and the Third National Agricultural Census. The surveyed straw/residues returning rates of nine major crops (rice, wheat, and corn, etc.) in each province were acquired from REEA of the Ministry of Agriculture and Rural Affairs. Data on sanitation lavatory access rate are from the China Environmental Statistical Yearbook 2018. Factors for nitrogen loss via volatilization, runoff, and leaching were calculated based on data collected through field observation. The Regional Nitrogen Cycling Model IAP-N was used to calculate amounts of nitrogen inputs including chemical fertilization, manure incorporation, and crop residues returning in different types of agricultural soils. The direct N_2O emission factors of agricultural soils were derived from more than 600 field observations and summarized into 11 types of agricultural soils in 6 regions (including non-vegetable dryland, paddy fields with different crop rotations, vegetable fields, orchards and tea gardens, etc.) according to the planting system in China. The indirect N_2O emissions factors,via nitrogen deposition, leaching and run-off, are from the default values of the 2006 IPCC Guidelines.

The default factors in the 1996 IPCC Guidelines were used in calculating CH4 and N2O emissions from field burning of agricultural residues. The crop residues field burning rate was determined using satellite data and data from the First National Pollution Survey.

Table 2-8 China's Major Activity Data on Agricultural Activities in 2017

	Activity data		Activity data
End-of-year cattle in stock number (million)	90.39	Grain crop planted area (M ha)	117.99
End-of-year swine in stock number (million)	441.59	Rice planted area (M ha)	30.75
End-of-year poultry in stock number (million)	6,053.02	Nitrogen fertilizer consumption (Mt of nitrogen)	22.22
End-of-year sheep/goat in stock number (million)	302.32	Compound fertilizer consumption (Mt)	22.20
Crop planted area (M ha)	166.33		

2.3.4 Inventory Results

In 2017, GHG emissions from the Agricultural in China were approximately 823 Mt CO2 eq, of which enteric fermentation emitted 234 Mt CO2 eq (28.4%), manure management 143 Mt CO2 eq (17.3%), and rice cultivation 202 Mt CO2 eq (24.6%), agricultural soils 233 Mt CO2 eq (28.3%), and field burning of agricultural residues 12 Mt CO2 eq (1.4%) (see Figure 2-4). CH4 and N2O emissions accounted for 63.0% and 37.0% of total GHG emissions from the Agricultural in the country.

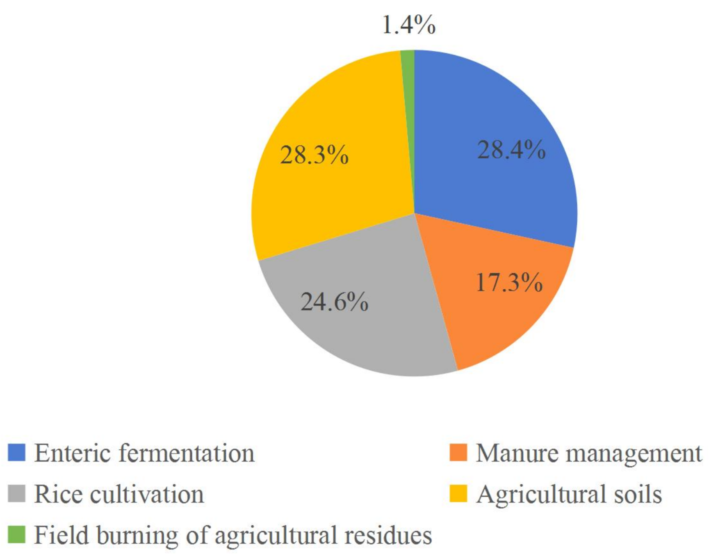


Figure 2-4 GHG Emissions from Agricultural Activities in China, 2017

2.4 LULUCF

2.4.1 Scope

In 2017, the LULUCF reported emissions and removals from six broad land-use categories, namely forest land, cropland, grassland, wetlands, settlements and other land. Each land-use category is further divided into land remaining in the same category and land converted to a new category during 1997-2017. The net changes of carbon pools in aboveground biomass (AGB), belowground biomass (BGB), litters (LI), dead woods (DW), and soil organic carbon (SOC) in each land-use category were estimated for the

LULUCF. Also reported for the LULUCF are net changes in carbon stocks in harvested wood products (HWP), CH4 emissions from wetlands, and emissions of non-CO2 gases from forest and grassland fires.

2.4.2 Methodologies

Emissions and removals from the LULUCF reported by the NGI2017 were estimated compliant with the 2006 IPCC Guidelines, the IPCC GPG 2000, GPG-LULUCF, and the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands.

CO2 emissions and removals from forest land, which is further subdivided into arbor, bamboo, shrubs and other forests, orchards, tea farms, and other tree plantations, were estimated using the stock change method (Tier 2). GHG inventory for this sector involves the estimation of carbon stock changes in five carbon pools (i.e., AGB, BGB, DW, LI and SOC) in forest land as well as in AGB and BGB of scattered trees or bamboo. Emissions from biomass burning in forest land were estimated using the Tier 1 methods.

A Tier 3 method, Agro-C, was used in accounting for carbon stock changes in SOC in cropland, which is caused by residue, roots and organic fertilizers inputting the soil and the soil respiration process which releases CO2 from soil as a result of the decomposition of soil organic matter.

Stock changes of SOC in grassland, CO2 emissions or removals and CH4 emissions from wetlands, and CO2 emissions or removals from settlements and other land were estimated using the Tier 2 methods. Emissions from biomass burning in grassland were estimated using the Tier 1 methods.

Carbon stock changes in HWP were estimated using the production method (Tier 2).

2.4.3 Activity Data and Emission Factors

Land use in the NGI2017 is classified in accordance with the Technical Regulations for the Third Nationwide Land and Resource Survey (TD/T 1055-2019). The area of each land-use category was calculated based on data released by the Ministry of Natural Resources (formerly the Ministry of Land and Resources). Data on forest types and stand volume of living trees are from national continuous forest resources inventories and national forest and grassland ecosystem monitoring and evaluation reports. Activity data for the LULUCF used in the NGI2017 are shown in Table 2-9.

Table 2-9 China’s Major Activity Data on LULUCF in 2007

	Area		Area
Arboreal Forests (M ha)	183.24	Cropland (M ha)	129.37
Bamboo Forests (M ha)	6.55	Grassland (M ha)	267.36
Shrubland (M ha)	55.43	Wetlands (M ha)	54.09
Other forest land (M ha)	21.46	Settlements (M ha)	44.02

Emission factors and related parameters were calculated based on national industry standards, published research data, and measurement data. Meteorological data, soil data and vegetation data released by the relevant authorities were used in model and parameter calibration.

2.4.4 Inventory Results

In 2017, China's LULUCF absorbed 1,342 Mt of CO_2 and emitted 3.985 Mt of CH_4 and 0.001 Mt of N_2O. Net removals of GHGs from the LULUCF reported 1,258 Mt CO_2 eq. Forest land, cropland, grassland, wetlands, settlements, and wood products absorbed 928 Mt, 96 Mt, 121 Mt, 2 Mt, 1 Mt, and 110 Mt CO_2 eq of GHGs, respectively. Other land uses emitted 1 Mt of CO_2.

2.5 Waste

2.5.1 Scope

In 2017, the Waste reported CH_4 emissions from landfill, CH_4 and N_2O emissions from biological treatment of solid waste and wastewater treatment, and CO_2, CH_4 and N_2O emissions from incineration of waste. Among them, only CO_2, CH_4 and N_2O emissions from the incineration of hazardous waste and medical waste and CH_4 and N_2O emissions from sludge combustion are reported under the incineration of Waste. CH_4 and N_2O emissions from municipal solid waste (MSW) incineration and CO_2 emissions from fossil sources are reported under Energy, and biogenic CO_2 emissions are reported as a memo item.

2.5.2 Methodologies

Emissions from landfill were estimated using the First-order decay method (a Tier 2 method). Emissions from biological treatment and incineration of waste were calculated using methods provided in the 2006 IPCC Guidelines.

Emissions from wastewater treatment were calculated following the 2006 IPCC Guidelines, but a simplified method was adopted to calculate the activity data for CH_4 emissions from domestic sewage treatment given the data availability constraint.

2.5.3 Activity Data and Emission Factors

Activity data for MSW landfills are derived from data in the China Urban Construction Statistical Yearbook and the China Population and Employment Statistical Yearbook. Data on waste disposed of via landfills and biological treatment are from the China Urban Construction Statistical Yearbook 2017. Hazardous waste data are from the China Environmental Statistical Yearbook 2018, and sewage sludge data are from the China Environmental Statistical Yearbook 2018 and the Annual Report on Environmental Statistics 2017.

The activity data for domestic sewage and industrial wastewater treatment are mainly from the China Environmental Statistical Yearbook 2018 and the China Environmental Statistical Yearbook 2017. Population data are from the China Statistical Yearbook 2018. Activity data for major activities in the Waste are shown in Table 2-10.

Table 2-10 Activity-related Data of the Waste in 2017

Major activities in the Waste	Activity data
Landfilled MSW (Mt)	120.38
Incinerated MSW (Mt)	84.63
Biological treated MSW (Mt)	5.33
COD in wastewater (Mt)	5.73

A country-specific emission factor was developed for CH_4 emissions from MSW landfills. Published research data on MSW collection and landfills in China were used to analyze the composition of MSW in China. The spherical coordinate conversion method and the back propagation (BP) neural network method were used to calculate MSW component data. The degradable organic carbon (DOC) of MSW in China was determined based on MSW component data as well as data collected via field research in some cities and landfill sites. A country-specific methane correction factor (MCF) was estimated. The country-specific half-life value of MSW used was verified through sampling and on-site surveys in southern and northern China.

Country-specific current year values were used for the emission factors for CH_4 and N_2O emissions from industrial wastewater treatment and domestic sewage treatment. The default values given in the 2006 IPCC Guidelines were used for the estimation of emission factors for CH_4 and N_2O emissions from biological treatment of waste.

The emission factors for CO_2, CH_4, and N_2O emissions from waste incineration were determined based on the default value range given in the 2006 IPCC Guidelines and country-specific circumstances.

2.5.4 Inventory Results

In 2017, China's total GHG emissions from the Waste were 194 Mt CO_2 eq, of which the landfill sector emitted 93 Mt CO_2 eq (48.0%), wastewater treatment 96 Mt CO_2 eq (49.5%), and waste incineration 4 Mt CO_2 eq (2.0%), and biological treatment of waste 1 Mt CO_2 eq (0.5%). CO_2, CH_4, and N_2O accounted for 1.4%, 79.7%, and 18.9% of the total GHG emissions from the Waste, respectively (Figure 2-5). In addition, emissions from MSW incineration were 26 Mt CO_2 eq, which was reported under Energy.

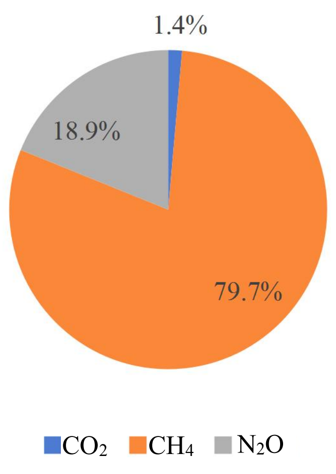


Figure 2-5 GHG Emissions from China's Waste, 2017

Chapter 3 Data Quality and Uncertainty Assessment

3.1 Quality Control

3.1.1 Data Collection and Verification

Our inventory compilers collected different categories of data, including statistical data and data for emission factors and other parameters, in accordance with the guidance provided by the 2006 IPCC Guidelines on the order of priority in data collection (see Table 2-11).

Table 2-11 Principle for the Collection of Authoritative Data and Overview of the Data Collection from Various Fields

Data Category	Priority of Data Source: Level of Authority	Data Sources by Sector
Activity data	The order of authoritativeness is the data from the national statistics authority, data from departments or industry associations, research data, and judgment by experts, with their uncertainties increasing from ±5% to±30%.	♦ Most of the statistical data for the Energy, Industrial Processes, Agriculture, LULUCF, and Waste are from the National Bureau of Statistics and relevant national departments (Ministry of Agriculture and Rural Affairs, National Forestry and Grassland Administration, the Ministry of Natural Resources, National Forestry and Grassland Administration, State Administration of Coal Mine Safety, and Ministry of Ecology and Environment); ♦ Some data that could be obtained from statistical agencies (such as energy consumption in the transportation, number of grazing animals in pastoral areas and manure used as fuel, soil data, and vegetation data) are from the industry associations.
Important parameters/ emission factors	The data of large sample testing/industry research adopting national/industrial standard methods (such as national/industrial general survey data) are the most authoritative; the data published by researchers institutions, with an uncertainty of a 95% confidence interval, are the second order; expert judgment and IPCC data are the third order, and their uncertainty shall be within IPCC data range.	♦ The carbon content per unit calorific value and carbon oxidation rate of coal combustion in the electricity industry were based on the measured data of power companies in the national carbon market. and data collected from industrial boiler surveys and tests; data for carbon content of gaseous fuels are primarily derived from measurement data provided by major oil and gas fields in China and natural gas importers. ♦ Data for annual nitrogen excretion of major livestock are from national pollution surveys conducted by the Ministry of Ecology and Environment; information on manure management methods in different regions is from surveys of typical counties.

The following three data verification activities were carried out to ensure the quality of the inventory:

First, verification of the consistency between the input data and original data of statistical data, parameters and emission factors used in various fields of the inventory.

Second, verification of the consistency between model parameters and other related modules. For example, checking the consistency between road traffic model parameters (such as annual average mileage and road condition share rate) and fuel balance module.

Third, verification of the consistency of data from different inventory sector. For example, checking the consistency of data in Agricultural sub-inventories, such as the quantity of grazed animals, the quantity of animal waste used as fuel in grazing pasture or in farming areas. For another example, checking the data of biomass fuel in the LULUCF and Energy. These checking actions have guaranteed the completeness, consistency, scientificity and comparability of inventory data in China's various emission fields (see Table 2-12).

Table 2-12 General Improvements of the Completeness, Consistency, Scientificity and Comparability of Inventory Data

Principle	General improvements
Completeness	♦ Energy: The number of sources under Manufacturing industries and construction increases from 10 to 13. New sources added under fugitive emissions from oil and natural gas activities: abandoned wells, venting and flaring. ♦ Industrial Processes: 6 new sources added. ♦ Agriculture: Estimates for indirect N_2O emissions from manure management and grazing animals are added. ♦ LULUCF: Estimates for non-CO_2 emissions from forest and grassland fires are added.
Accuracy	♦ Energy: ETS facility-specific data are used to verify activity data; country-specific data are used for estimation of carbon content of natural gas supplied by China's major energy groups' commercial gas, imported pipeline gas and imported liquefied natural gas; facility-specific measurement data are used to calculate oil and gas factors; the COPERT model for estimation of CH_4 and N_2O emissions from road traffic are improved, with a distinction made between peak hours and off-peak hours as well as between pure electric vehicles and hybrid EVs. ♦ Agriculture: To improve accuracy and reduce uncertainty in data used for the Agricultural, a survey was conducted to collect data on animal feed and manure management systems; this survey of the animal production sector covered 31 provinces; agricultural soil types were increased to 11 types.
Consistency	♦ Compared with the Third National Communication, the source/sink categories in the NGI2017 is more consistent with the 2006 IPCC Guidelines. ♦ To avoid double counting and omissions, special attention is paid to the delineation and basic data of overlapping sources and sinks: - Scope and data sources of the steel industry under Energy and Industrial Processes; - Animal manure and production data under Energy and Agriculture; - Data for cropping regimes, crop production, organic fertilizer consumption, and crop residues returning rate under Agriculture and LULUCF; - Delineation of incineration under the Energy and Waste.
Scientificity and comparability of inventory preparation methods	♦ The inventory was prepared using methods provided by the 2006 IPCC Guidelines, the 1996 IPCC Guidelines, the IPCC GPG 2000, and GPG-LULUCF ♦ Key Categories: Tier 2 or Tier 3 methods based on China's national circumstances;

Principle	General improvements
	♦ Non-Key Categories: Tier 1 methods; - Energy: The classification of emissions and removals is consistent with the 2006 IPCC Guidelines and International Standard Industrial Classification (ISIC); the industry categories under fuel combustion under Energy are aligned with the 2006 IPCC Guidelines to ensure the comparability of the inventory; - Industrial Processes: Sources and sinks are categorized in accordance with the 2006 IPCC Guidelines; - LULUCF: Data are from the Third National Land Survey, reorganized to align with the IPCC classification to ensure the comparability of the inventory; - Waste: Hazardous waste (including medical waste) is broken into two categories: hazardous waste and medical waste.

3.1.2 Documentation and Archiving

The inventory compilers have built databases for activity data, emission factors, parameters, data sources, and references in accordance with the guidance provided by the IPCC GPG 2000. They have also documented and archived information relating to the justification for methodological choices and improvements in the form of peer-reviewed technical reports.

3.2 Quality Assurance

The inventory compilers have asked member units of the National Leading Group and related industry associations for comments and suggestions to ensure that activity data are accurate and parameters, emission factors, and methodological choices are reasonable. They have also compared the result values in the inventory against related data published by domestic and international peer organizations to ensure the reliability and comparability of the inventory.

3.3 Uncertainty Assessment

3.3.1 Measures to Reduce Uncertainty

With the continuous improvement of China's GHG inventory system, the uncertainty of activity data is gradually decreasing. Local emission factors have been used as much as possible to reduce inventory uncertainty. Sectoral measures to reduce inventory uncertainty are displayed in Table 2-13.

Table 2-13 Measures taken by Various Sectors to Reduce the Uncertainty of Inventories

Sector	Measures to reduce the uncertainty of inventories
Energy	♦ CO_2 emissions from fuel combustion were estimated using the Sectoral Approach and checked using the Reference Approach. ♦ The COPERT model was improved to account for CH_4 and N_2O emissions from road traffic. ♦ Survey data were used where possible for carbon content, and oxidation rate. ♦ Compared with the previous GHG inventories of the Energy, the sample representativeness, coverage, and data quality of the NGI2017 of the Energy have been significantly improved, and the uncertainty in estimates of emissions from solid fuel combustion has been further reduced.
Industrial Processes	♦ Local emission factors were calculated using data collected through plant surveys in some key industries (such as synthetic ammonia, adipic acid, and calcium carbide manufacturing industries).

Sector	Measures to reduce the uncertainty of inventories
Agriculture	♦ The cattle classification (dairy cattle, beef cattle, buffalo, yak and other cattle) was refined to improve the quality of data used to estimate emission factors for methane emissions from enteric fermentation. ♦ The scope of the survey was expanded to cover 31 provinces, and data on productivity, feed structure, and manure management methods of major livestock types in typical counties were collected. ♦ The classification of agricultural soils (11 types) was refined to improve the accuracy of estimates of nitrous oxide emissions from agricultural soils.
LULUCF	♦ Data are from the Third National Land Survey, reorganized to align with the IPCC classification to ensure the comparability of the inventory; ♦ Annual biomass data of different tree species were calculated using an approach that combines national continuous forest resources inventories and species-specific growth models.
Waste	♦ Important parameters for emissions from MSW were estimated using data collected via literature review and statistical methods.

3.3.2 Uncertainty Assessment

The uncertainty of the NGI2017 was assessed following the 2006 IPCC Guidelines. Uncertainties associated with estimates of GHG emissions from road traffic, methane emissions from rice cultivation, changes in organic carbon stocks in cropland soils, and carbon stock change in wood products were quantified using Method 2 (Monte Carlo method). Method 1 (propagation of error) was used to quantify uncertainties associated with other emission sources. The total uncertainty in the NGI2017 is estimated at -4.8% - 5.0% (see Table 2-14).

Table 2-14 Results of Uncertainty Analysis of National GHG Inventory of 2017

	Emissions (Mt CO_2 eq)	Uncertainty
Energy	9990	-5.1% - 5.4%
Industrial Processes	1800	-3.7% - 3.7%
Agriculture	823	-14.1% - 14.1%
LULUCF	-1258	-13.1% - 13.1%
Waste	194	-23.0% - 23.0%
Total Uncertainty	-4.8% - 5.0%	

Part III Climate Change Impacts and Adaptation

Climate change poses growing challenges to China's environment, society, and economic growth. In the future, the adverse impacts of climate change on China's agriculture, water resources, ecosystems, coastal and offshore ecosystems, and people's health will be even more serious. China has incorporated addressing climate change into its national economic and social development programs, with equal emphasis on adaptation and mitigation. It has rolled out the National Climate Change Adaption Strategy to drive and guide climate change adaptation actions in key areas.

Chapter 1 Climate Change: Features, Causes, and Trends

1.1 Features and Causes of Climate Change

1.1.1 Temperature

From 1901 to 2020, China's annual average surface temperature increased by 1.6°C (Figure 3-1), which is close to the increase in the global average surface temperature over the same period. The country was warming at a rate of 0.15°C per decade, slightly higher than the rate of global warming, but from 1961 to 2020, China's annual average surface temperature rose at a rate of 0.26°C per decade. Significant increase in surface temperature began in the mid-1980s.

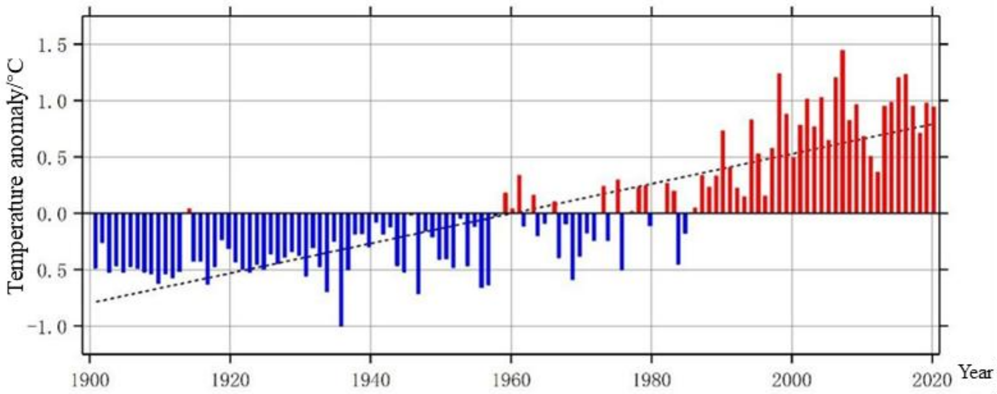


Figure 3-1 China's Annual Average Surface Temperature Anomalies, 1901-2020 [23]

Since the middle of the 20th century, pronounced signs of climate change have been observed in North China and the Qinghai-Xizang Plateau. The warming trend has been weaker in southwestern China, the Sichuan Basin, the Qinba Mountains, and the southern portion of the North China Plain. Since the beginning of the 21st century, the rising trend in China's annual average surface temperature has slowed down, mainly due to the slow-down in winter and spring warming. However, the average temperature in summer is still rising.

[23] A temperature anomaly is the difference from the baseline temperature which is the average surface temperature of the reference period (1961-1990), and the dotted lines represent linear trends.

1.1.2 Precipitation

Overall, China's annual precipitation has not changed very much since the beginning of the 20th century, but it did increase slightly from 1961 to 2020, and the increase in the past 10 years has been quite obvious (see Figure 3-2). Trends in annual average precipitation since 1961 have varied widely across the country. Northwest China, the Qinghai-Xizang Plateau, and the northern part of Northeast China saw significant increases in annual average precipitation, and South China and the Jianghuai and Jiangnan regions saw slight increases, while North China and the southern and southwestern parts of Northeast China saw sharp decreases. Precipitation changes in China show obvious seasonality. During the period from 1961 to 2020, winter precipitation increased, autumn precipitation decreased, and summer precipitation increased in South China and decreased in North China.

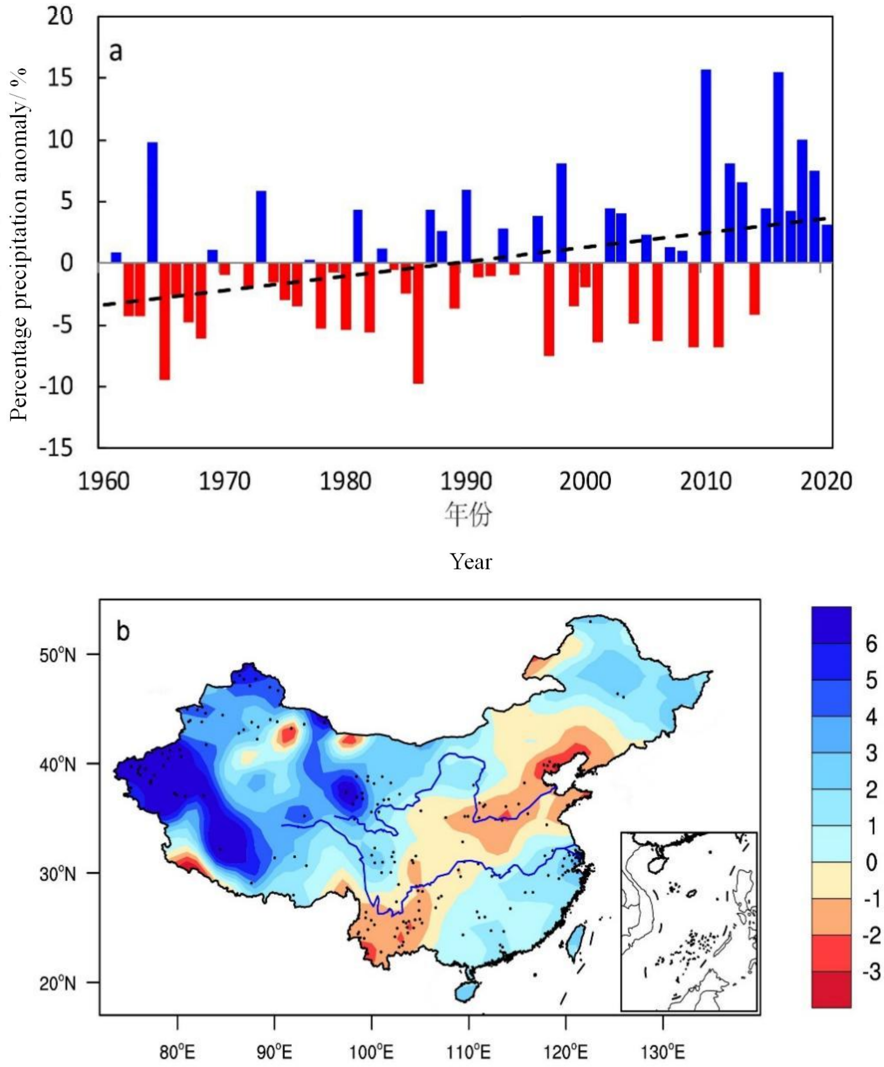


Figure 3-2 Percentage Precipitation Anomalies and Spatial Pattern of Precipitation Trends in China, 1961-2020 [24]

[24] (a) Precipitation time series; (b) Spatial pattern of precipitation trends; the dashed line in (a) represents the linear trend, and an anomaly is the difference relative from the average precipitation of the reference period (1961-2020); the black dots in (b) indicate significant trends at $p < 0.05$, and precipitation trends are presented in percentage change per decade.

1.1.3 Solar Radiation and Wind Speed

There is a lack of historical data on other climate elements dating back to 100 years ago. From 1961 to the early 1990s, sunshine duration (Figure 3-3) or solar radiation was on a significant downward trend in most areas of China. The downward trend has slowed down since the early 1990s. The decline in sunshine duration in North China and the middle and lower reaches of the Yangtze River was more obvious than in other parts of the country, especially before the early 1990s.

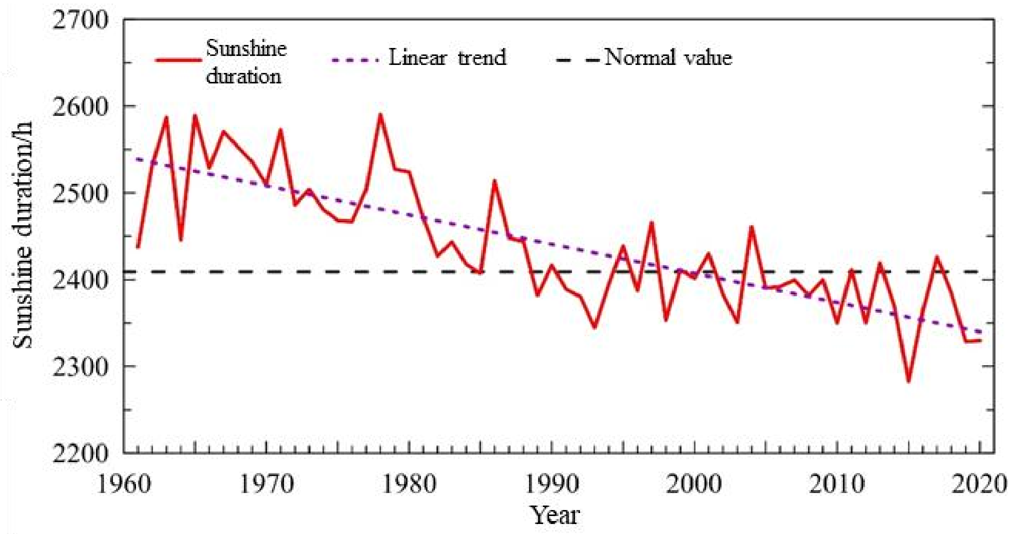


Figure 3-3 Changes in Average Annual Sunshine Duration in China, 1961-2020 (hours)

Since 1961, China's average annual near-surface wind speed has been on a significant downward trend. The downward trend was particularly strong from the 1970s to the late 1990s. Since the start of the 21st century, the decline has slowed down (Figure 3-4). The decrease in wind speed was most obvious in the Eastern Monsoon Region.

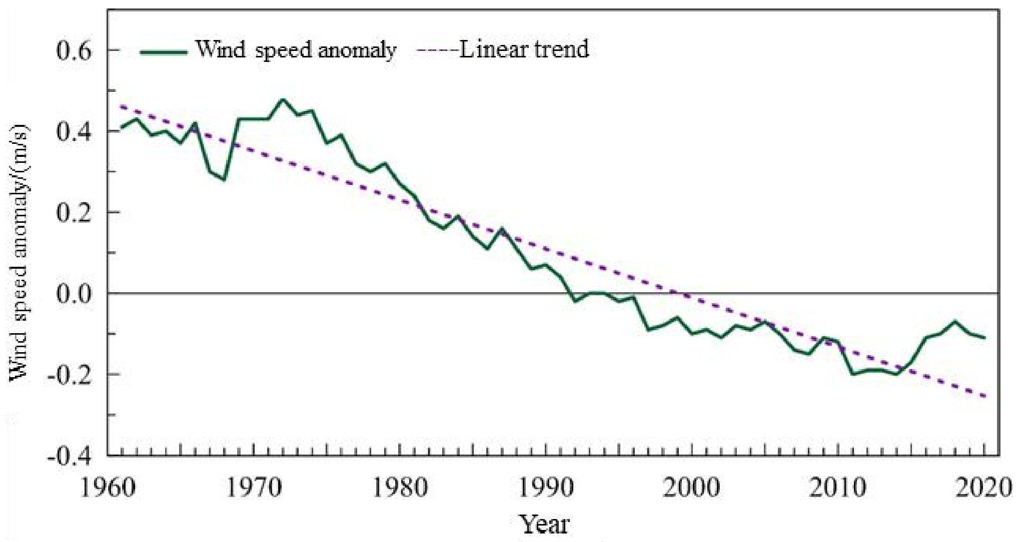


Figure 3-4 Average Annual Near-Surface Wind Speed in China, 1961-2020 (meters/second)

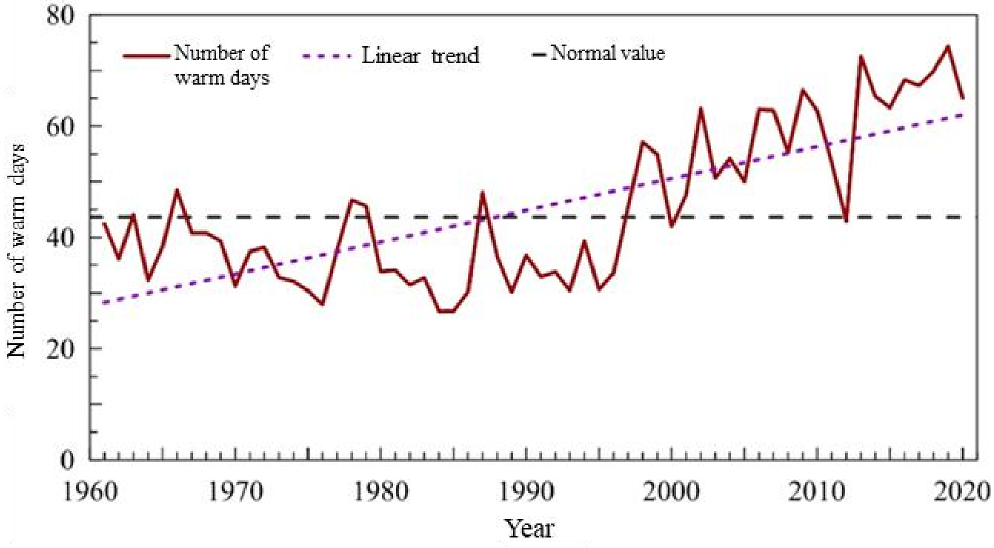
1.1.4 Causes of Climate Change

An increase in the atmospheric concentrations of greenhouse gases and the enhanced greenhouse effect arising therefrom may be the main reason for the significant rise in surface temperatures in China. The significant increase in urban heat islands (UHIs) due to urbanization is another major contributor to the rise in surface temperatures since 1961. However, even if we remove the heat island effect, we would still observe a significant upward trend in China's surface temperature over the past 60 years. Changes in precipitation in China can be attributed to natural phenomena. The decrease in sunshine duration and solar radiation is mainly related to increased aerosol and pollutant concentration in the atmosphere. The observed decline in near-surface wind speed is mainly caused by urbanization or the increase of obstacles around observation sites. Changes in atmospheric circulation caused by natural factors and large-scale changes in land use/land cover also play a role. The decrease in potential evaporation is directly related to the decreases in solar radiation and near-surface wind speed.

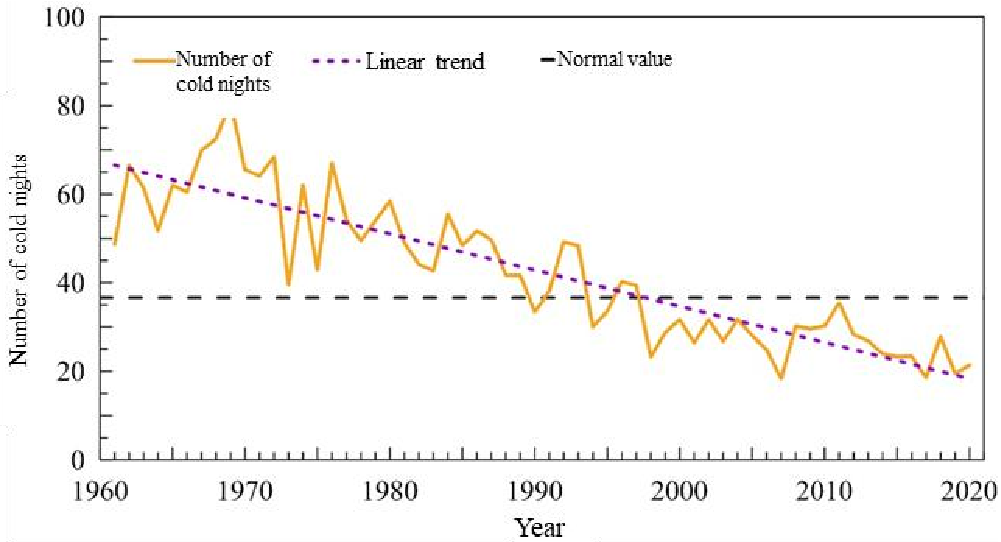
1.2 Extreme Climate Events

1.2.1 Extreme Cold and Heat Events

Since 1961, China's average maximum temperature has changed little, while the average minimum temperature has increased significantly. The frequency of extreme heat events in China has increased significantly, but the frequency of extreme cold events has continued to decrease (Figure 3-5). In East China, the frequency of heat waves has increased, while the frequency of cold spells has decreased. Obvious changes in the frequency of extreme cold and heat events have also been observed in northern China. Changes in the frequency of extreme cold and heat events are mainly caused by human-induced global warming. Urbanization is also a major contributor to these changes.



(a) Number of warm days



(b) Number of cold nights

Figure 3-5 Number of Warm Days (a) and Cold Nights (b) in China, 1961-2020

1.2.2 Extreme Precipitation

From 1961 to 2020, most areas of China, especially those south of the Yangtze River, saw an increase in annual precipitation from heavy rain (greater than or equal to 50 mm in a 24-hour period) (Figure 3-6). The maximum precipitation for 1-, 3-, and 5-day rainfall days had been on an upward trend, among which the maximum precipitation in a single day increased most notably. Annual precipitation from heavy rain in the western part of Northeast China and the region from North China to the Sichuan Basin had been on a downward trend. The frequency of heavy snowfall increased in the northeast and northwest.

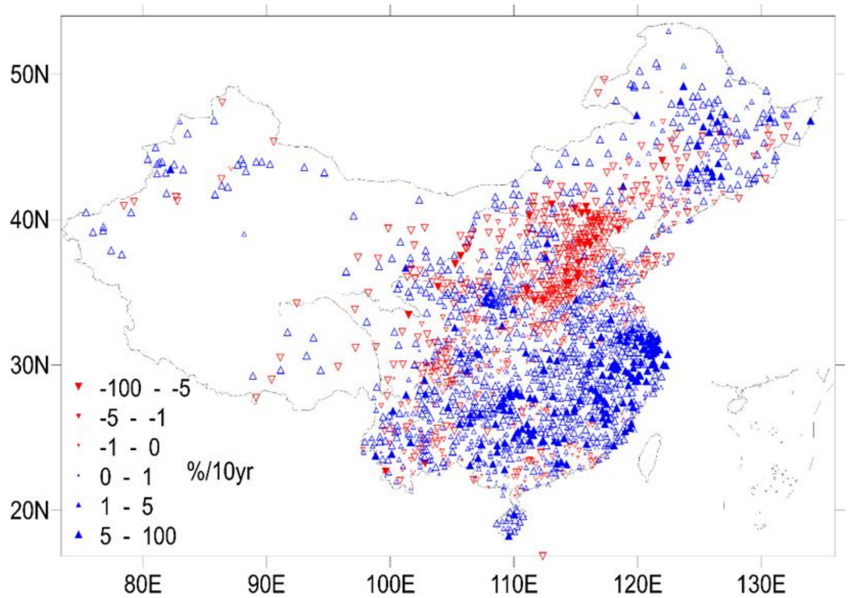


Figure 3-6 Changes in Annual Precipitation from Heavy Rain across China, 1961-2020 (percent per decade)

Since 1961, China has seen significant drops in both the number of days with light rain and the number of days with a trace of precipitation. These decreases are mainly attributable to the declining trends in the Eastern Monsoon Region.

1.2.3 Meteorological Drought

Overall, the frequency of meteorological drought events in China slightly increased from 1961 to 2020, but it did not change much in the past 40 years (Figure 3-7). Since the early 1960s, the frequency of meteorological drought events has decreased in Northwest China and increased in North China and the southern part of Northeast China. Since the start of the 21st century, the problem of meteorological drought has worsened in Southwest China.

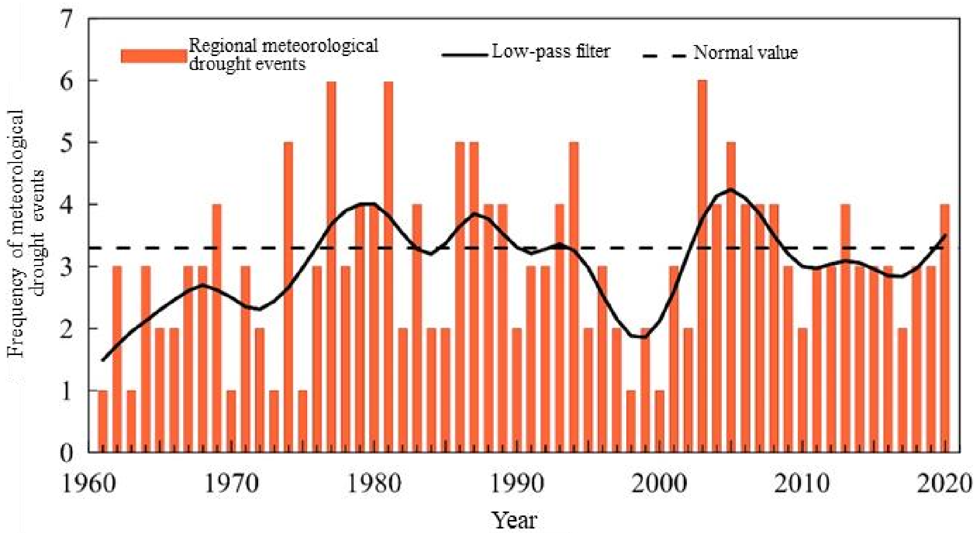


Figure 3-7 Frequency of Meteorological Drought Events in China, 1961-2020

1.2.4 Other Extreme Climate Events

Overall, the number of tropical cyclones (typhoons) affecting or making landfall in China each year has not changed much since the mid-20th century (Figure 3-8), but the precipitation they caused has decreased. The impact of typhoons on China has increased in the past 20 years.

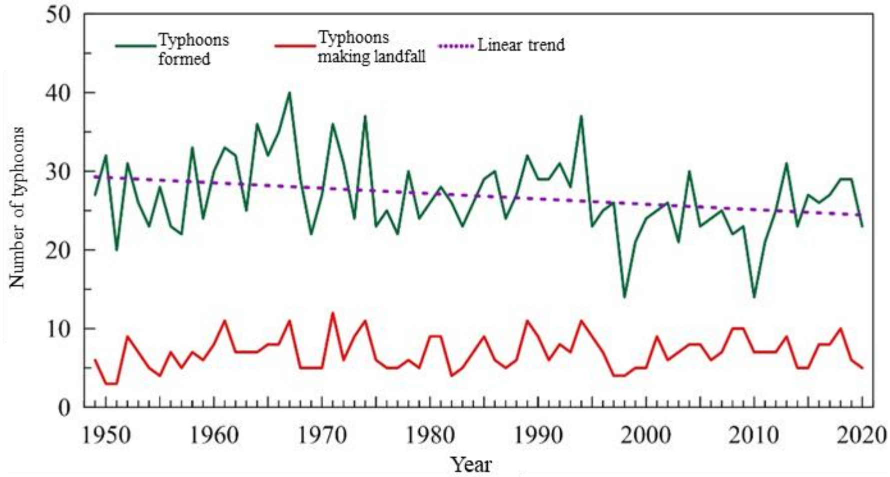


Figure 3-8 Annual Number of Typhoons Formed in the Northwest Pacific and South China Sea and Making Landfall in China, 1949-2020

Since 1961, the frequency of dust weather events and severe dust storms in northern China has significantly declined. This is mainly attributable to the significant decrease in the average near-surface wind speed and the number of windy days, as well as the increase in precipitation and vegetation cover in the dust source areas.

Since 1961, the frequency of small- and medium-scale severe convective weather events (i.e., thunderstorms, lightning, hail, and tornadoes) in China has been on a significant downward trend, and the average number of thunderstorm days per year decreased by 2.6 days every decade.

1.3 Future Climate Change

1.3.1 Temperature and Precipitation

In the future, China's annual average surface temperature is expected to continue to rise, and annual precipitation is expected to increase in most areas of the country. According to the projections based on the Coupled Model Intercomparison Project Phase 6 (CMIP6) multi-model simulations under three Shared Socioeconomic Pathways (SSPs), China's annual average surface temperature will continue to rise in the future (Figure 3-9). The temperature increase will be greater in northern China, most notably in the Qinghai-Xizang Plateau and the northern and northeastern parts of Xinjiang.

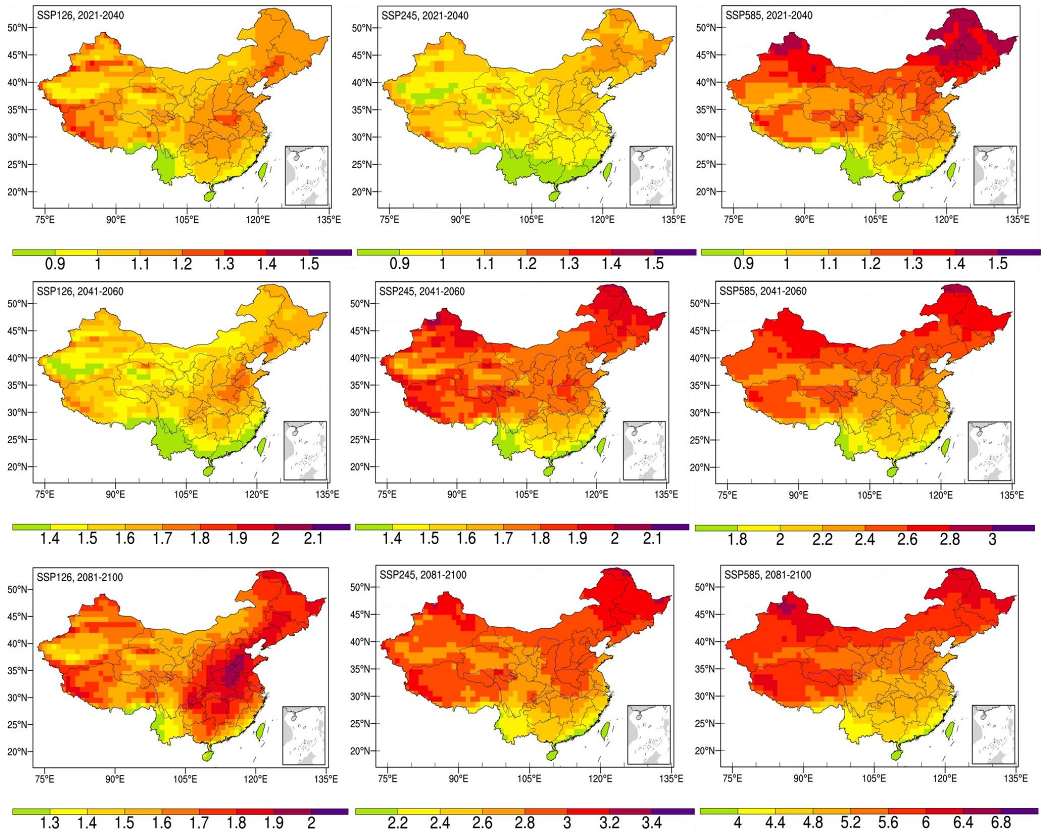


Figure 3-9 Projected Annual Average Surface Temperature Changes in China in Different Periods of the 21st Century Based on the CMIP6 Multi-GCM Simulations under Three SSPs (°C)

According to the projections based on the CMIP6 simulations, annual precipitation will increase in most areas in China. The national average increase is expected to be between 2% and 10% by the end of the 21st century. The northwest, north, and northeast parts are expected to see greater increases than the rest of the country.

1.3.2 Extreme Climate Events

The results of global and regional climate model simulations under different GHG emissions scenarios show that extreme heat events will increase and extreme cold events will decrease in China, and extreme precipitation events may increase in frequency and intensity in most areas of China (Figure 3-10). In East China, compared with rural areas, urban areas will experience greater increases in the frequency and intensity of extreme precipitation events.

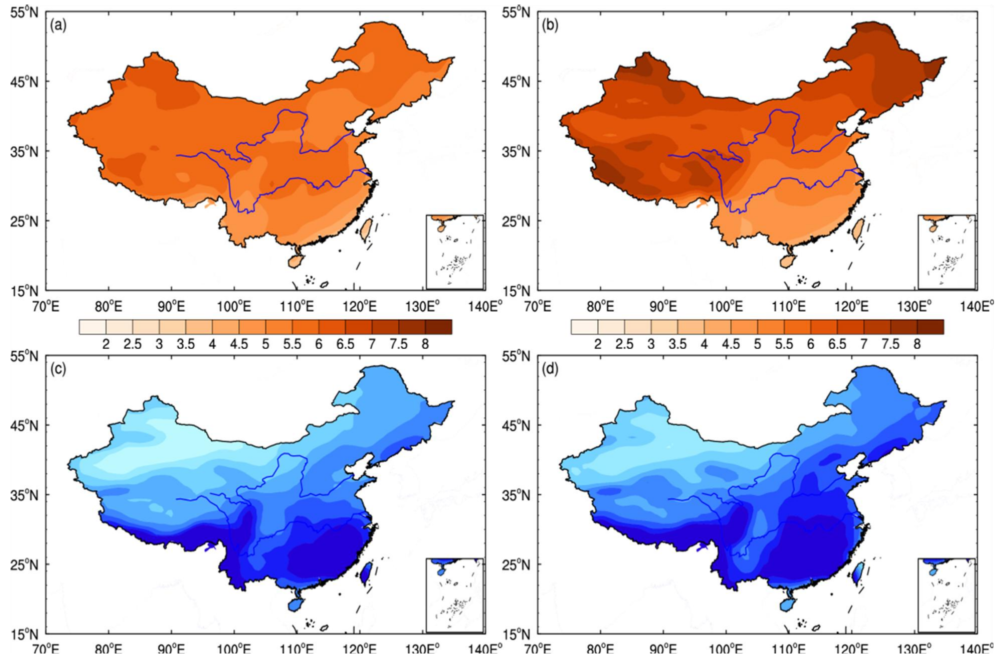


Figure 3-10 Projected Changes in Extreme Heat Events, Extreme Cold Events, Extreme Precipitation Events, and Total Precipitation in China under the High Emissions Scenario, 2081-2100[25]

1.3.3 Uncertainty in Climate Projections

There are biases in past climate observations, which mainly arise from the unavailability of historical data and the impact of urbanization on historical time series of surface climate elements. A conservative approach has been adopted to correct urban heat island biases in temperature records, but no bias correction has been made for other climate elements such as precipitation, sunshine duration or solar radiation, and near-surface wind speed.

There are still some shortcomings in the existing global and regional climate models. Their capabilities to stimulate future trends in real climate elements and natural variability still need to be improved. Uncertainty still exists in the research on the attribution of past climate changes, especially extreme climate events, and in the research on projections of future climate changes, especially changes in extreme climate events, based on a combination of climate model data and observational data.

To reduce uncertainty in climate change observation and the research on attribution and projections, more efforts should be made to correct historical data biases and urban heat island biases and improve climate models and testing methods. Observational constraints can reduce uncertainty in climate projections.

[25] (a) Extreme heat events (°C); (b) extreme cold events (°C); (c) extreme precipitation events (mm); (d) total precipitation (mm) (relative to 1995-2014 annual average).

Chapter 2 Climate Change Impact and Vulnerability Assessment

2.1 Agriculture

Climate change is affecting agricultural production systems, crop growth and yields, and plant pests and diseases through changes in sunshine duration, temperature, precipitation, and extreme weather events.

2.1.1 Observed Impacts on Agriculture

Changes in climate elements, especially temperature, caused by climate change, have significant impacts on cropping systems. From 1960 to 2019, in most areas (about 80%) of the country, the Effective Accumulative Temperature (EAT) of rice and corn increased by 100-300 Celsius degree-days, and the EAT of wheat increased by 150 to 350 Celsius degree-days. The increase in the EAT of the three major food crops was higher in northern China than that in southern China. Changes in effective precipitation were not significant. Sunshine duration showed a significant downward trend. Due to increases in temperature and improvement of varieties, the northern boundaries of agro-climate zones optimal for crop production have shifted northward. The northern boundaries of rice cultivation areas in Northeast China, winter wheat cultivation areas in North China and Northwest China, and corn cultivation areas in Northeast and Northwest China moved northward, and the northern boundaries of multi-cropped areas shifted toward higher elevations. Single-cropped areas moved 200-300 km northward, double- and triple-cropped areas moved 500 km northward, and the total land area used for multiple cropping expanded. The multiple cropping index increased at an annual rate of more than 1.29%. The agro-climate zones optimal for mid-maturing and mid-late maturing crop varieties expanded, with their northern boundaries moving northward. The total land area planted with heat-loving, drought-tolerant crops expanded. Varieties that require prolonged exposure to cold during winter (vernalization) were gradually replaced by varieties that require moderate or short periods of vernalization.

Pests and diseases pose a growing threat to crops and the difficulty of preventing and controlling them is increasing. Higher temperatures from global warming mean higher survival rates in overwintering insect pests and pathogens and more outbreaks over longer periods. They can lead to the expansion of populations of major pathogens and pests, thereby increasing the damage they cause to crops. The northern boundaries of areas with long-term presence of crop pests and diseases are moving northward. These areas are also expanding toward higher altitudes. The geographic distribution of crop pests and diseases is expanding. From 1970 to 2016, the percentage of crop planted areas affected by diseases and pests increased rapidly (Figure 3-11). Attribution analysis shows that global warming contributed to more than one-fifth of the increase. The contribution varied from province to province, ranging from 2% to 79%. The annual growth rates of the percentage of wheat, corn and rice planted areas affected by pests and diseases increased significantly.

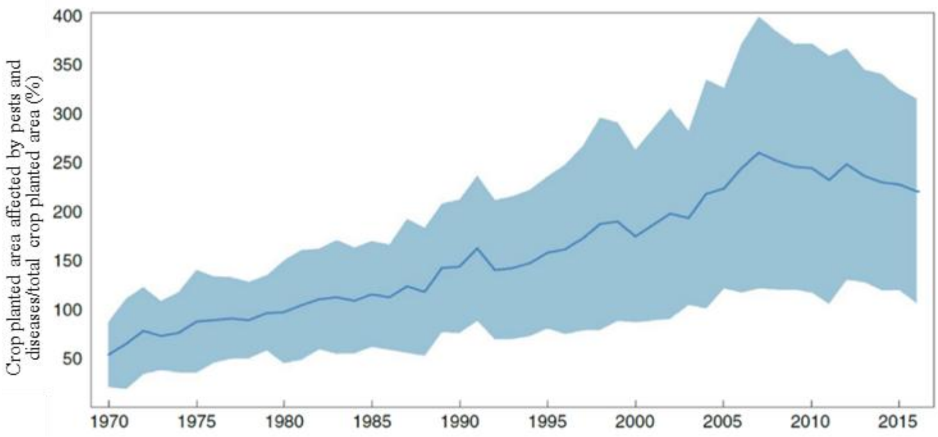


Figure 3-11 Percentage of Crop Planted Area Affected by Pests and Diseases, 1970-2016 [26]

Meteorological disasters that affect agriculture, including drought, floods, and extreme heat events, are increasing in both frequency and intensity. From 1961 to 2014, the damage caused by drought to agricultural production increased in both scope and intensity. Drought-induced agricultural production losses increased by about 0.5% every decade. The percentage of extreme precipitation events that caused flooding of agricultural areas increased in South China and declined in North China and was on an ascending trend in the country as a whole. Summer corn was the crop variety most affected by extreme heat events. The impact of extreme heat on other crops had also been increasing. For example, the photosynthetic efficiency of rice during heading and flowering periods significantly declined due to the impact of extreme heat events. Extreme heat events have also led to reductions in total factor productivity and the efficiency of input utilization in China's agriculture sector. Climate change has led to increases in the frequency and intensity of hot and dry winds, as well as in the total area affected by hot and dry winds. Hot and dry winds will bring increasing damage to grain filling and yield of wheat.

The impact of climate change on grain crops varies across regions and differs by crop. The results of a multi-site corn field experiment show that if the average temperature and the average minimum temperature during the growing season increase by 1℃, corn yields would decrease by 0.83 tons/ha and 0.67 tons/ha respectively; if diurnal temperature variation decreases by 1℃, corn yields would decrease by 1.0 tons/ha; and if cumulative photosynthetically active radiation (PAR) decreases by 100 MJ, corn yields will decrease by 0.85 tons/ha. With the same temperature increase, corn yield decreases in South China would be greater than that in North China. According to data from meteorological stations in agricultural production areas, compared with 1961-1970, the daily average temperature during 2009-2018 increased by 0.7°C, and yield losses of early- and late-maturing rice caused by extreme heat events increased by 110% and 88%, respectively. For every 1°C increase in temperature, early-maturing rice production decreased by 8%, while rising

[26] The dark blue line represents the national mean, and the light blue area shows one standard deviation on each side of the mean. Source: Wang C, Wang X, Jin Z, et al. Occurrence of crop pests and diseases has largely increased in China since 1970[J]. Nature Food, 2022, 3(1): 57 – 65.

temperatures had no negative impacts on late-maturing rice yields. From 1961 to 2010, China's winter wheat production decreased by approximately 5.5% due to rising average temperature during the growth period. Solar radiation is also a key factor in crop production. From 1981 to 2009, crop production under the rice-wheat cropping system decreased by 1.5%-8.7% due to declining solar radiation.

2.1.2 Future Impact and Vulnerability Assessment for Agriculture

Average temperatures during crop growth periods are expected to increase; crop growth periods will become shorter; most crop production zones will move northward. Compared with the 2000s, daily average temperatures during rice growing periods in China are expected to increase by 0.8-2.7°C, 1.7-3.4°C, and 2.3-4.1°C in the 2030s, 2050s, and 2070s, respectively. Under global warming scenarios of 1°C, 2°C and 3°C, China's corn growth periods will decrease by 4.3%-13.0%, 10.8%-22.5%, and 12.3%-30.3%, and wheat growth periods will decrease by 3.9%, 6.9%, and 9.7% under global warming scenarios of 1.5°C and 2.0°C, rice growth periods will decrease by 3-15 days and 4.5-18 days, respectively, and wheat growth periods will decrease by 6-15 days and 8-18 days, respectively. Rising temperatures will cause China's multi-cropping zones to continue to expand toward higher latitudes. Under the moderate emissions scenario (A1B Scenario)[27], compared with 1950-1980, agro-climate zones optimal for double and triple-cropping systems will continue to shift northward in 2011-2040 and 2041-2050.

In China, it is anticipated that the frequency of outbreaks of the majority of crop diseases and pests, the areas they affect, and the harm they cause will all rise. The timing of northward migrations of insect pests in spring will be advanced, and their southward migrations in autumn will be delayed. Their migration range is expected to expand and the severity of pest infestations is expected to increase. This will be beneficial to the overwintering and reproduction of crop pathogens, widen their geographical distribution, and cause them to spread into the temperate climate zone. At the same time, the risk of outbreaks of heat-loving, chill-susceptible insect pests will significantly increase. Under all future climate scenarios, the overwintering range of crop pests will expand northward by 1 to 3.5 degrees latitude, and the number of generations they undergo in one year will increase by one to two generations. Outbreaks of fruit tree pests, such as cherry fruit fly, grape leaf moth, and citrus psyllid, are expected to increase in areas of high- and moderate-suitability habitat in China.

The CO_2 fertilization effect cannot completely offset the negative impact of climate change on grain yields. Global warming will reduce the amount of protein in grains. Analysis of existing data shows that, under all future climate scenarios, if we do not account for the CO_2 fertilization effect, crop yields will decrease by more than 4%, 10%, and 20% in the 2020s, 2050s, and 2090s. If we account for the CO_2 fertilization effect, crop yields will increase before the 2050s, but after the 2050s, a decreasing trend will be observed because the CO_2 fertilization effect will no longer be able to offset yield decreases caused by climate change (Figure 3-12). Chinese scholars have also used a multi-model ensemble (climate and crop) to assess the impacts of global warming of

[27] A1B Scenario developed by the IPCC in the Special Report on Emission Scenarios.

1.5°C and 2.0°C on corn, wheat, and rice yields. Although the differences in temperature rise and CO_2 concentration in the two scenarios are small, differences in other input parameters lead to large differences in simulated crop yields. While rising CO_2 can significantly increase crop yields, it can also reduce the protein content in grain crops.

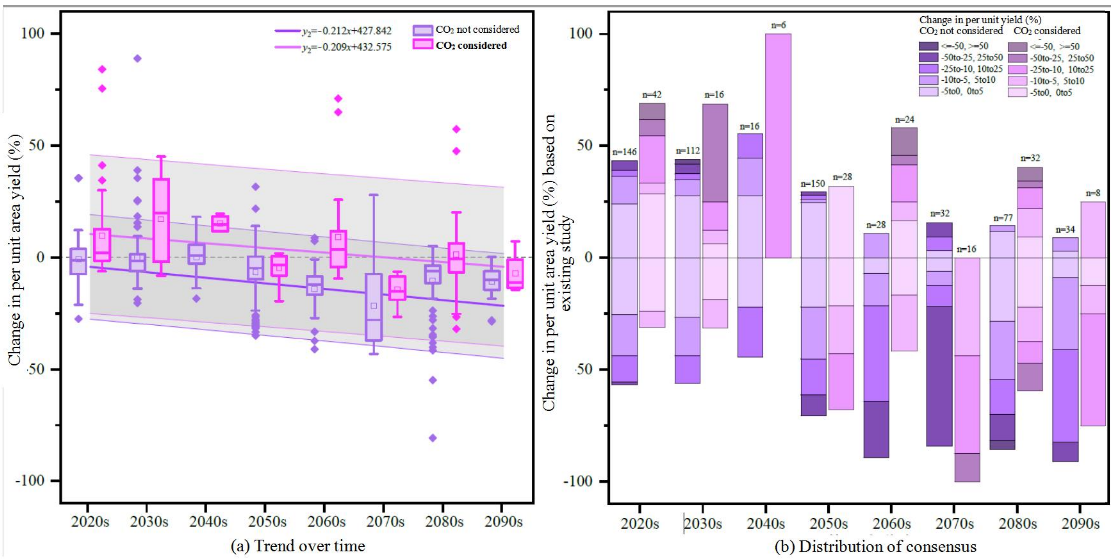


Figure 3-12 Impacts of Climate Change on Crop Yields in China [28]]

2.2 Water Resources

2.2.1 Observed Impacts on Water Resources

Since the start of this century, China's precipitation and water availability have shown regional changes due to the impact of climate change. Water availability has increased in the northwest region and declined significantly in the Yellow River, the Haihe River, the Liaohe River and other river basins. Different regional trends had been observed in water resources in China during 1956-2016. Areas reporting rising water availability during 1956-2016 were concentrated in Northwest and Southeast China, while those reporting declining water availability formed a strip running through the country from the northeast to the southwest. Since the start of this century, water resources in the Haihe River, the Liaohe River, the Songhua River, and the Yellow River basins have fallen by 22%, 12%, 10% and 10%, respectively, and the total water resources in river systems in Northwest and Southeast China have dropped by 13% and 5%, respectively.

Due to climate change and human activities, surface water in the Haihe River, the Liaohe River, the Songhua River, and the Yellow River basins has dropped. Climate change has affected annual precipitation and intra-annual precipitation variability. Areas reporting declining precipitation form a belt stretching across the country from the

[28] The box plot shows changes in grain yields. The line and small boxes inside the box plot indicate the median and the mean respectively. Pink indicates the CO_2 fertilization effect is accounted for and purple indicates it is not accounted for. The shaded area between the two pink lines represents the uncertainty interval when the CO_2 fertilization effect is accounted for, and the shaded area between the two purple lines represents the uncertainty interval when the CO_2 fertilization effect is not accounted for. Source: Huang C, Li N, Zhang Z, et al. What Is the Consensus from Multiple Conclusions of Future Crop Yield Changes Affected by Climate Change in China?[J]. *International Journal of Environmental Research and Public Health*, 2020, 17(24): 9241.

northeast to the southwest. Major changes have been observed in intra-annual precipitation patterns and patterns of individual precipitation events. Compared with 1956-2000, the amount of surface water in the Haihe River, the Liaohe River, and the Yellow River basins in 2001-2016 decreased by 16%, and the decrease in surface water had been significantly greater than the decrease in precipitation. Among them, the Haihe River Basin had the most notable decrease in water availability, with a 5% decrease in precipitation and a 36% decrease in surface water. In recent years, surface water in river basins in Northwest China has increased, mainly due to the increase in precipitation and glacier meltwater caused by global warming. Compared with the 1960s, the total area of glaciers in Northwest China has decreased by about one-fifth, and the weakening of the capacity of glaciers to provide vital ecosystem services (e.g., water storage and runoff regulation) will have an adverse impact on regional water availability. Changes in surface water resources in South China are mainly caused by climate change.

China's groundwater levels during 2001-2016 did not change much compared with that during 1980-2000. Groundwater levels in North China were generally stable, with some increases and decreases in different areas. Among them, the Huaihe River Basin, the Songhua River Basin, and river basins in Northwest China reported increases of more than 5%, 3%, and 3%, respectively, while the Liaohe River, the Haihe River, and the Yellow River basins reported decreases of 14%, 5%, and 4%, respectively. Groundwater levels in South China were relatively stable.

2.2.2 Future Impact and Vulnerability Assessment for Water Resources

In the 2030s, most extremely and highly vulnerable water systems will be concentrated in North China, Northeast China, Northwest China and Xizang. The increase in water resource vulnerability in Northwest China is mainly attributable to the elevation of the water resource vulnerability status of Xinjiang Uygur Autonomous Region from "moderate vulnerability" to "extreme vulnerability" and those of Gansu and Shaanxi provinces from "moderate vulnerability" to "high vulnerability". The status of Heilongjiang and Jilin provinces has been elevated from "low vulnerability" to "moderate to high vulnerability", which is the main reason for the increase in vulnerability in Northeast China. North China has the most notable increase in water resource vulnerability. The water systems in the Beijing-Tianjin-Hebei region and Shandong Province are extremely vulnerable, and those in Inner Mongolia Autonomous Region, Henan Province and Shanxi Province are highly vulnerable. Water resource vulnerability varies widely from province to province in East China. The water systems in Anhui and Jiangsu provinces and Shanghai are highly vulnerable. The water resource vulnerability status of Zhejiang and Fujian provinces has been changed from "low vulnerability" to "moderate vulnerability". The vulnerability of water systems in central China has increased. The water resource vulnerability status of Hubei Province has risen from "low to moderate vulnerability" to "moderate to high vulnerability", and those of Hunan and Jiangxi provinces have been raised from "low to moderate vulnerability" to "moderate vulnerability". Water resource vulnerability in South China remains generally stable. Water systems in Guangxi, Guangdong, and Hainan provinces are moderately vulnerable, only presenting a marginal rise compared to their previous vulnerability status. Water resources in Xizang are "moderately to highly vulnerable" and those of other provinces in Southwest China are "moderately vulnerable" or "slightly to moderately vulnerable." Sichuan and Yunnan provinces have the least vulnerable water resources under all future climate change scenarios. Compared with other provinces, their water security is at slightly less risk.

2.3 Terrestrial Ecosystems

2.3.1 Observed Impacts on Terrestrial Ecosystems

Climate change has already affected the phenological events of species, distribution of forest biomes, species composition, productivity, forest fires, and pests and diseases in forest ecosystems. Growing seasons of most plant species in forest ecosystems start earlier and end later than before. From 1960 to 2012, 94% of the 714 spring and summer phenological stages of woody plants advanced, at an average rate of 2.55 days/decade, while 77.5% of the 294 autumn phenological stages of woody plants were delayed, at an average rate of 1.98 days/decade. Climate change has contributed to the westward shift of woody plants. The distribution ranges of tree species, such as Dahurian larch, spruce, fir, and redwood in the Lesser Hinggan Mountain and in mountains in East China, have shifted northward. Between 1983 and 2012, the distribution ranges of 80% of woody plants in central and eastern regions shifted northward. Forest biomass in Northeast China, Qinling Mountains, and South China has increased. Net primary productivity (NPP) within forest ecosystems on the eastern edge of Northeast China and in southeastern Shaanxi, southern Yunnan, and eastern Guangxi has increased significantly. The increase in precipitation in the north since 2000 has led to the continuous improvement of the quality of vegetation in areas covered by the Three-North Shelterbelt Forest Program (TSFP). From 2000 to 2015, due to the continued decline in the intensity of solar radiation, the NPP in vegetation in karst areas declined, offsetting human efforts to increase vegetation in these areas.

Climate change has a significant impact on phenological events of species and productivity in grassland ecosystems. The growing seasons of grasses in grassland ecosystems have lengthened, with a slight advance in the vegetative phase and a delay in the senescent phase. The vegetative phases of *Leymus chinensis* and *Stipa baicalensis* in Hulunbuir's temperate meadows have advanced by 1.7 to 1.9 days/decade for every 1°C increase in spring temperature, while their senescent phase has delayed by 2.0 to 2.3 days/decade for every 1°C increase in summer and autumn temperatures. The vegetative phases of alpine meadows and alpine steppe on the Qinghai-Xizang Plateau have advanced by 7.8 days/decade and 7.2 days/decade respectively. From 1982 to 2012, grassland productivity in the Qinghai-Xizang Plateau and South China was on a significant upward trend, while the productivity of typical steppe and desert steppes showed a downward trend, with the largest decreases observed in central and eastern Inner Mongolia and southeastern Gansu. Rising temperatures and precipitation have affected forage production and the carrying capacity of grasslands in Western China. Southwestern Xinjiang and eastern Xizang have reported the greatest increases in pasture productivity.

Forage production and carrying capacity of grasslands in northern and eastern Xinjiang and southern Qinghai had declined, and precipitation increase in these regions had been less notable.

Climate change has affected the phenological events of species, distribution and ecological functions of wetlands. From 2001 to 2016, the average growing season starting date in wetland ecosystems in Northeast China advanced by 0.52 days per year. Due to global warming, the total area of wetlands primarily supplied by melted ice and snow has been increasing. For example, the total area of swamps, swampy meadows, and lakes in the Irtysh River Basin in Xinjiang has increased. The total area of wetlands in the Qiangtang Lake Basin has increased by 5,000 sq km. The total area of wetlands primarily supplied by precipitation had been decreasing and their functions are declining. For example, since the start of the 21st century, most wetlands in the middle and lower reaches of the Yangtze River, which are primarily supplied by precipitation, have been shrinking due to declining precipitation. From 1980 to 2015, the total area of swamps and wetlands in Northeast China decreased by 31%, the number of patches increased by nearly 70%, and the Habitat Alteration Index (HAI) increased. From 1987 to 2016, the increase in fragmentation led to a decrease of about 900 sq km in the area of the Ruoergai Marsh. Rising temperatures have been the main cause of the reduction in the size of the swamps and wetlands in Northeast China and the Ruoergai Marsh. Global warming has seriously threatened biodiversity within wetland ecosystems. It has caused a decline in the quality of wetland habitats and a reduction in populations of hygrophytes.

The impact of climate change on lake size varies across the country. From 1960 to 2015, the total surface area of lakes (of at least 1 sq km in surface area) in China increased by 5,858.06 sq km. Due to melted ice and snow, the total surface area of lakes in the Qinghai-Xizang Plateau and Xinjiang increased by 5,676.75 sq km and 1,417.15 sq km, respectively. The total surface area of lakes in Inner Mongolia decreased by 1,223.76 sq km.

Human activities and climate change have led to a decline in wild animal and plant species and affected their distribution. From 1950 to 2000, 27.2% of China's 252 vertebrate species listed as critically endangered or endangered at the national level disappeared, and the biodiversity loss was positively related to rising temperatures. Precipitation increase was negatively correlated with bird species loss, particularly in high-biodiversity areas. Global warming caused an increase in the distribution area of 35 out of 40 endangered herbaceous plants in the Sanjiangyuan area of the Qinghai-Xizang Plateau, and a decrease in the distribution area of 5 species.

2.3.2 Future Impact and Vulnerability Assessment for Terrestrial Ecosystems

Climate change will further affect the geographical distribution, composition, and functions of forest ecosystems. Global warming is expected to drive the expansion of forests into higher elevations and latitudes. The distribution ranges of boreal forests, deciduous temperate forests, temperate coniferous forests, and tropical forests will march northward. The area of tropical and temperate forests will show an increasing trend, while the area of temperate and boreal forests will show a decreasing trend. The forests in the

Lesser Hinggan Mountain will transition from a mixture of birch, coniferous and broad-leaved tree species to a mixture of deciduous, coniferous and broad-leaved tree species. Climate change will lead to changes in forest NPP. According to projections using multi-model ensembles, the area of forests with reduced NPP will decrease under the low emissions scenario; under the high emissions scenario, the area of forests with reduced NPP will increase after 2050, and high-risk areas will increase from 5.4% (2021-2050) to 27.6% (2071-2099) of the total forest area. Under RCP 4.5 and RCP8.5 scenarios, temperature and precipitation in North China will be on an ascending trend during 2011-2040 and 2041-2070, which will consolidate the achievements of the TSFP and grassland conservation efforts and accelerate ecological recovery in this region.

Future climate change is expected to influence the distribution and productivity of grassland ecosystems in China. Rising temperatures will cause expansion of alpine steppe to higher elevations. In the Qinghai-Xizang Plateau, rising temperatures are expected to cause a decrease in the total area of alpine meadows and temperate steppe and an increase in the area of alpine steppe. Compared with the baseline scenario (1987-2016), grassland biomass shows a significant downward trend under both RCP4.5 and RCP8.5 scenarios, and rising temperature is the main driving factor behind the decrease in grassland biomass. The NPP of alpine grassland ecosystems is expected to decrease. Grassland productivity in most areas of western Inner Mongolia will decline, and the productivity of meadows and typical steppe in Northeast China will increase. Soil carbon stocks in alpine meadows, alpine steppe, temperate meadow steppes, typical steppe, alpine deserts, and temperate deserts will be on a downward trend.

Climate change will continue to affect the distribution and area of wetlands. The area of wetlands in China is on a downward trend. Compared with 1961-1990, areas with the most suitable climatic conditions for wetlands in the three northeastern provinces of China will significantly decrease under the high emissions scenario during 2011-2040, and the remaining wetlands will face serious degradation. By 2050 and 2100, respectively, about 30% and 60% of the wetlands in the Greater Hinggan Mountain will disappear. The distribution of areas with the most suitable climatic conditions for wetlands in the Qinghai-Xizang Plateau will also be affected. Under the low emissions scenario, by 2050, the area of alpine wetlands in the Qinghai-Xizang Plateau will decrease by 35.7% and both wet meadows and salt marshes in the Qiangtang Basin will disappear. Compared to 2010, plant productivity in the wetlands in the Sanjiang Plain will increase significantly under the RCP2.6 scenario, remain basically unchanged under the RCP4.5 and RCP6.0 scenarios, and decrease under the RCP8.5 scenario. Important wetland functions, such as carbon sequestration, water storage, and wildlife habitats, will be at risk of degradation under all future climate scenarios.

Climate change will affect habitats, migration routes, and timing of migration of wild animals, including some endangered birds, wipe out habitats, and kill off species. Table 3-1 shows future climate change impacts and vulnerabilities for wildlife and wild plants in China.

Table 3-1 Future Climate Change Impacts and Vulnerabilities for Wildlife and Wild Plants in China

Category	Class	Potential Climate Change Impacts	Vulnerabilities
Wildlife	Birds	Birds may shift their ranges towards higher latitudes and/or altitudes. There will be a reduction in the distribution ranges of some species. Some of their habitats will be threatened by degradation.	Their distribution ranges will significantly decline and their habitats will be threatened by degradation. 5% to 20% of bird species will be endangered or face a high risk of extinction.
	Mammals	The distribution ranges of most mammals will decline. Some species may see an increase in their distribution ranges in the short term.	
	Amphibians	Their distribution ranges will increase in the short term and decline in the long term. The quality of their habitats may be affected by extreme weather events such as drought.	
	Reptiles	Some reptiles may shift their ranges towards higher latitudes. Their distribution ranges will decrease. Their habitats will become increasingly fragmented.	
Wild Plants	Algae	Climate change may lead to changes in algae biomass concentration, thereby causing environmental hazards.	Climate change may cause larger, more frequent harmful algal blooms, which are a serious threat to aquatic ecosystems.
	Bryophytes	The distribution ranges of bryophytes will decline. Their habitats will be threatened by degradation. Some bryophytes may shift their ranges westwards.	By 2050, 9% to 34% of bryophyte species will be critically endangered.
	Pteridophytes	Some pteridophytes may shift their ranges towards higher latitudes and/or altitudes. The distribution ranges of most pteridophytes will decrease.	
	Gymnosperms	Some gymnosperms may shift their ranges towards higher latitudes and in the northwest or northeast direction. Their survival may be threatened by habitat loss and fragmentation.	
	Angiosperms	Most angiosperms will shift their ranges westwards. The distribution ranges of most species will shrink. The abundance of angiosperms in the northwest and northeast of the country will increase, while the abundance in the east and southwest will decrease.	

2.4 Marine and Coastal Ecosystems

2.4.1 Observed Impacts on Marine and Coastal Ecosystems

Sea surface temperatures (SSTs) and sea levels in China’s nearshore waters have risen significantly. Since the 1960s, global warming has caused significant increases in China’s nearshore SSTs and sea levels. Sea level rises have become even more notable since the start of the 21st century. From 1958 to 2018, China’s nearshore SSTs increased by about 0.98±0.19℃, much faster than the increase in global average SST. The most notable increases were observed in the Bohai Sea, Yellow Sea, East China Sea, and the Taiwan Strait in winter (Figure 3-13). From 1980 to 2019, China’s nearshore sea levels rose at a rate of 3.4 mm/year, faster than the global average over the same period. The increases varied widely by region. For example, the sea level increases at Lusi and Haikou water level monitoring stations in the Yangtze River Estuary were higher than other regions.

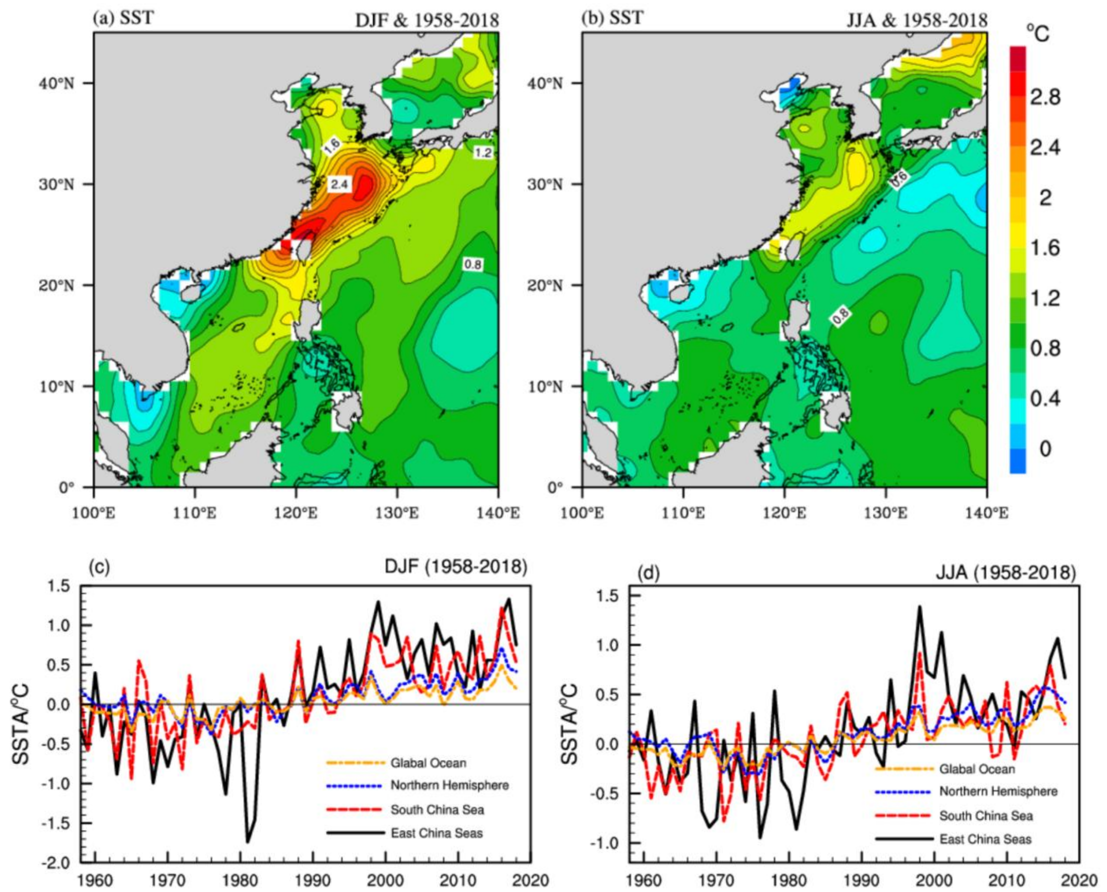


Figure 3-13 Linear SST Trends (a and b, measured in ℃) and Time Series of SST Anomalies (c and d, measured in ℃) in the Bohai Sea, Yellow Sea, East China Sea, and the South China Sea in Winter and Summer, 1958-2018[29]

[29] Winter is defined as December, January, February (DJF), while summer is June, July and August (JJA). Source: This figure is adapted from Cai R, Tan H, Kontoyiannis H. Robust surface warming in offshore China seas and its relationship to the East Asian monsoon wind field and ocean forcing on interdecadal time scales[J]. *Journal of Climate*, 2017, 30(22) : 8987-9005, with data from HadISST, updated to 2018.

China's nearshore waters continue to heat up, and the frequency of super typhoons and storm surges has increased significantly. Since the start of the 21st century, the frequency of super typhoons and storm surges affecting China has increased considerably. The number of (super) typhoons that made landfall in China during 2000-2019 was 36, more than double the number during 1980-1999 (15). Rising sea levels increase the odds of damaging floods from storm surges, especially when the advancing surge of water coincides with astronomical tides and heavy rain. For example, Typhoon Fitow and Typhoon In-Fa hit coastal cities in Fujian and Zhejiang provinces, including Xiamen, Ningbo, Zhoushan, and Jiaxing, in October 2013 and July 2021, damaging embankments, inundating urban areas, and causing loss of life and enormous economic losses. When Typhoon Fitow struck Yuyao, Ningbo, in October 2013, 70% of the city was flooded. The flood did not recede until several days later, affecting 830,000 people.

Rising ocean temperatures have affected marine and coastal ecosystems, causing a sharp decrease in China's nearshore fishery resources. Since 1980, rising ocean temperatures have disrupted the balance of important elements or nutrients in seawater, causing elevated acidity and expansion of low oxygen zones in China's nearshore waters, especially in the Yangtze River Estuary and the Pearl River Estuary and nearby waters. Elevated ocean temperatures have a significant impact on phenological events, species composition, and geographical distribution of species within marine ecosystems. They have also increased the frequency of harmful marine environmental events such as red tides, blue-green algae blooms, and jellyfish blooms. The number of red tide blooms per decade in the Yangtze River Estuary and nearby waters is on an ascending trend, and the vulnerability of the marine ecosystem in this region has significantly increased. As a result of the combined effects of elevated ocean temperatures and overfishing, China's nearshore fishery resources have significantly declined. Trends toward earlier age and smaller size at maturity have been observed in major commercially important fish species. These trends are particularly obvious in the Yangtze River Estuary Fishing Ground, Zhoushan Fishing Ground and Bohai Bay Fishing Ground. The average body length of the beltfish and the small yellow croaker in the Bohai Sea, Yellow Sea, and the East China Sea decreased by 23% and 32%, respectively. The majority of fish in the breeding populations are one year old, indicating that they reached maturity one year earlier than before. Some major commercially important species are close to depletion. The catchability of the small yellow croaker and the hairtail fish is near zero.

Coastal erosion and seawater intrusion in China's coastal areas, particularly seawater intrusion into estuaries, have been exacerbated by rising sea levels. Since the 1990s, about 22% of China's coastline has retreated, which translates into 224.48 sq km of coastal land loss. The retreat of the Yellow River Delta coastline is most notable. Coastal erosion is a severe problem in some coastal provinces of China. In the past 30 years, 4 km of mangrove coasts in Fangchenggang City, Guangxi Autonomous Region, have been affected by coastal erosion, with the maximum landward shift reaching 122 meters. From 2011 to 2015, the coastlines of Hebei, Shandong and other provinces bordering the Bohai Sea moved between 10 km and 43 km landward. Soil salinization has become a pressing issue in these coastal areas. Since 1990, seawater intrusion has contaminated drinking water sources in the Pearl River Estuary. China's coastal mangrove ecosystems face obvious threats from rapid sea level rise and an increase in severe typhoons. The combined effects of sea level rise and human activities, such as reclamation, have led to a sharp reduction in coastal wetlands, serious habitat degradation, and loss of biodiversity. In 2020, China monitored the health of 24 typical coastal and marine ecosystems, including estuaries, bays, tidal wetlands, coral reefs, mangroves, and seagrass beds. Results showed that, affected by climate change and human activities, seven ecosystems were in a healthy state, 16 in a state of suboptimal health, and one in an unhealthy state. During the 13th Five-year Plan period (2016-2020), the proportion of water quality monitoring sites rated as good or excellent (Class I and II) in China's estuaries and bays showed an increasing trend; the imbalanced nitrogen: phosphorus stoichiometric ratio was alleviated; sediment quality was generally good; habitat loss significantly slowed down; the diversity index of phytoplankton and zooplankton in most estuaries and bays was increasing, the percentage of diatoms was increasing; the percentage of copepods was decreasing, and the density of fish eggs and larvae was low. Tidal flat ecosystems were in a state of suboptimal health and the presence of vegetation in these areas maintained a level of stability. Mangrove ecosystems were in a healthy state. Mangrove communities in monitored sites increased in area and their structure was stable. The health status of coral reefs and seagrass beds was between "healthy" and "suboptimal health."[30]

2.4.2 Future Impact and Vulnerability Assessment for Marine and Coastal Ecosystems

Under low, medium and high emissions (RCP2.6, RCP 4.5, and RCP 8.5) scenarios, sea levels and sea surface temperatures in China's nearshore waters will further rise. By the end of the 21st century, under the high emissions scenario, surface temperatures of the Bohai Sea, Yellow Sea and the East China Sea will increase by 3.24℃, and the South China Sea 2.92℃, higher than SST rises in most of the world's oceans (see Table 3-2). Ocean warming is expected to exacerbate ocean acidification, cause further oxygen loss, and further disrupt the balance of elements and nutrients in seawater, and increase the vulnerability of marine ecosystems. It will cause more significant changes in the composition and distribution ranges of marine species. For example, some species will continue to move northwards. The frequency of harmful marine environmental events such as red tides, blue-green algae blooms, and jellyfish blooms will increase, and ecosystems such as coastal wetlands, mangroves, and warm-water coral reefs will be at higher risk of extinction (RCP 8.5). Major fishery centers of commercially important species such as the small yellow croaker and the anchovy in the Bohai Sea, Yellow Sea and East China Sea will move further north. Stocks of commercially important cold-water fish species, such as the Pacific Sand Lance and cod in the Yellow Sea and the Bohai Sea will further decline or even become depleted. The health of ecosystems in the Yangtze River Estuary Fishing Ground and the Yellow River Estuary Fishing Ground will notably deteriorate. By the middle of the 21st century, marine heat waves will become more frequent, and more than 70% to 90% of coral reefs in tropical seas may disappear.

[30] Data source: China Marine Ecological and Environmental Statistical Bulletin 2020.

Table 3-2 Average SST Changes (°C) in the Bohai Sea, the Yellow Sea, the East China Sea, and the South China Sea under RCP2.6, RCP 4.5 and RCP 8.5 Scenarios Relative to 1980-2005

Region	RCP2.6			RCP4.5			RCP8.5		
	2020－2029	2050－2059	2090－2099	2020－2029	2050－2059	2090－2099	2020－2029	2050－2059	2090－2099
The Bohai, Yellow and East China seas	0.63±0.41	0.71±0.30	0.74±0.49	1.01±0.49	1.36±0.51	1.75±0.65	1.07±0.62	1.73±0.72	3.24±1.23
South China Sea	0.58±0.35	0.65±0.41	0.69±0.50	0.87±0.38	1.16±0.40	1.51±0.45	0.89±0.42	1.47±0.44	2.92±0.77
Global Ocean	0.53±0.45	0.60±0.51	0.62±0.53	0.78±0.51	1.13±0.54	1.47±0.62	0.87±0.63	1.35±0.77	2.89±1.32

Under all emissions scenarios, (super) typhoons making landfall in the Chinese mainland will increase in both frequency and intensity, and their geographic range will expand poleward. Under RCP2.6, RCP 4.5 and RCP 8.5 scenarios, coastal areas in North China may be more frequently exposed to strong typhoons and storm surges, and the safety of infrastructure and facilities, such as nuclear power plants, airports, port projects, flood control and drainage projects, and oil platforms in coastal areas of China may be further threatened. Projections show that sea levels worldwide, including in China’s nearshore waters, will rise significantly in the future and the return period of extreme water levels in many coastal areas will be notably shortened. By 2050, Shanghai will sit below the high tide line. By 2100, in many coastal areas of China, such as the Lusi water level monitoring station at the Yangtze River Estuary and the Xiamen water level monitoring station in Fujian Province, extreme sea level events that used to occur once a century will strike once in several years or more than once a year (RCP8.5), which indicates the elevated vulnerability of these areas to natural disasters.

In summary, continued ocean warming and increased disaster risk factors will increase the exposure of coastal ecosystems and populations and assets in coastal areas in China to climate-related risks.

2.5 Human Health

2.5.1 Observed Impacts on Human Health

Climate change is the biggest health threat facing humanity in the 21st century. Elevated average surface temperatures, rising sea levels, changes in precipitation patterns, and increases in the frequency and intensity of extreme weather events caused by climate change pose growing threats to public health security. Climate change affects human health mainly in the following ways:

Climate change directly affects human health through the impacts of extreme climate and weather events. Climate change increases the frequency and intensity of extreme climate and weather events, such as extreme heat events, floods, droughts, typhoons, and wildfires, thereby increasing the risks of injury, illness, and death, especially among vulnerable populations, and causing huge economic losses. Extreme events are associated with elevated incidence of heat stroke, heat exhaustion, and heat cramps, and increased mortality. Extreme events have been shown to increase morbidity and premature death in patients with climate-sensitive diseases such as cardiovascular and cerebrovascular diseases. More intense heat waves are associated with higher mortality risk. Health impacts vary from region to region. Compared with 1986-2005, the average exposure for the Chinese population to heat waves increased by 4.5 days in 2020, and the number of premature deaths caused by heat waves increased by 92% (about 14,500 people). Changes in precipitation have increased the frequency and intensity of extreme weather and climate events, including floods in South China and droughts in North China. In 2018, 55.77 million people in China were affected by floods and droughts, and Sichuan Province was the most affected province. The immediate impacts of flooding include loss of human life. Drowning is a leading cause of death in floods. In July 2021, record rainfall inundated Henan, one of China's most populous and most flood-prone provinces, and more than 300 people died in floods, equivalent to nearly 80% of the total number of deaths caused by floods in China in 2018. Typhoons mainly affect the southern coastal areas of China. They can cause injuries and deaths. In recent years, they have shown signs of expanding inland.

Climate change can make conditions more conducive to the spread of climate-sensitive infectious diseases (CSIDs) through worsening water quality, by increasing the frequency and intensity of floods and by increasing the distribution ranges of disease vectors and pathogens through changes in natural ecosystems, thereby indirectly affecting individual and public health. Climate change increases the spread of many waterborne, airborne, vector-borne, and food-borne pathogens through systemic impacts on the environment, organisms and food, etc. Affected by global warming, the distribution of mosquitoes in China has expanded northwards and their populations have increased significantly, causing increases in the prevalence of tropical diseases. Compared with 2004-2007, the distribution ranges of the dengue vector *Aedes aegypti* in China had expanded by 2016-2019. The length of the season when *Aedes aegypti* is active had extended and its population had increased, putting more people at risk of dengue fever. The vectorial capacity of *Ae. aegypti* increased by 25%, resulting in a sharp increase in affected areas and intensity of dengue outbreaks. The geographic range of dengue is expanding to inland areas, to higher latitudes and higher altitudes. Dengue has become a serious threat to public health in China. By 2019, health losses caused by dengue in China had increased 21 times compared with 2005. Besides dengue, some water-borne diseases, respiratory diseases, and other CSIDs may also increase with rising temperatures. Floods may contaminate water sources, destroy disinfection facilities, and create a conducive environment for the development of pathogens and vectors, leading to an increase in the incidence of parasitic, water-borne, and vector-borne diseases. Drought can reduce access to clean water, forcing people to use contaminated water sources and thereby increasing the risk of food- and water-borne infectious diseases. Typhoons may damage basic infrastructure such as water supplies and safe shelter, thereby increasing the risk of infectious diseases. In addition, extreme weather events such as floods, droughts, and typhoons can also affect noncommunicable diseases (NCDs) such as circulatory and respiratory system diseases.

Climate change can indirectly affect health by undermining social systems. For example, frequent extreme weather events can lead to reduced labor productivity, economic losses and even displacement, which in turn can lead to stress, mental illness, malnutrition, and other health problems. In 2020, China lost 31.5 billion labor hours (equivalent to 1.3% of total working hours) because of heat exposure. Economic losses caused by the lost labor hours are equivalent to 1.4% of China's GDP in 2020. Guangdong and Guangxi were the most affected provinces, accounting for 27.5% of the country's total losses. Drought can cause chronic nutritional problems such as malnutrition and nutrient deficiencies through its impact on the availability of food.

Additionally, with rapid urbanization and population aging, the number of Chinese people with underlying health conditions is increasing. The health impacts of rising temperatures and increased extreme weather events are most felt by these vulnerable people.

2.5.2 Future Impacts on Human Health

People living in mid-latitude coastal areas in East China and the mid-latitude areas in West China are at greater risk of health impacts from extreme heat events, while those living in South China are at greater risk of health impacts from extreme cold events. Under future climate change scenarios, as population aging accelerates, the number of Chinese people with underlying health conditions will increase. These vulnerable people will be at greater risk of health impacts from rising temperatures and increased extreme weather events. In the Northeast, which has been the fastest-warming region in China over the past 50 years, health risks associated with extreme heat events may continue to increase. In South China, where people have low cold tolerance and lack heating facilities, people will be at greater risk of health impacts from extreme cold events. Increased floods will increase health hazards in East China and riverside areas.

The distribution ranges of CSIDs, such as dengue, schistosomiasis, bacillary dysentery, and hand, foot and mouth disease (HFMD), will continue to expand under most future climate change scenarios. For example, projections using the biologically driven model for dengue transmission show that, under different future emissions scenarios, areas at risk of dengue transmission will notably expand northward in China and populations at risk of dengue will increase significantly. During 2080-2090, future climate change will favor a northward expansion of Oncomelania along an eastern route in Hubei, leading to an expansion of the geographical range of schistosomiasis transmission. In most parts of China, cases of bacillary dysentery will be on the rise due to rising average temperatures. Compared with the baseline, North China, Northeast China, Inner Mongolia, Northwest China and South China will become high-risk areas for bacillary dysentery transmission in the future.

In the future, practical action will be taken to expand health education and health promotion services for vulnerable groups, such as older people, women (especially pregnant women), children, low-income earners, and people with underlying conditions, to help them adapt to climate change.

Chapter 3 Climate Change Adaptation Strategy and Targets

3.1 Integration of Climate Change Adaptation in the National Economic and Social Development Plan

China is committed to making climate change adaptation a national priority. It implements a proactive national climate change strategy with equal emphasis on adaptation and mitigation measures. The Chinese government has incorporated climate change adaptation targets into its FYP for national economic and social development.

The Outline of the 12th Five-Year Plan for National Economic and Social Development of the People's Republic of China is the first five-year national development plan to include a separate chapter on China's plan to adopt a proactive approach to climate change. In the section on enhancing capacity to adapt to climate change, the Chinese government outlines the following tasks: formulating a national climate change adaptation strategy; promoting climate change research, observation and impact assessment; considering the impacts of climate change when making productivity plans or designing and constructing infrastructure and other major projects; building capacity to adapt to climate change, especially to manage risks associated with extreme weather events; accelerating development and adoption of adaptation technologies; strengthening climate change adaptation measures in key sectors such as agriculture, forestry, and water resources, and in coastal and ecologically fragile areas; strengthening the monitoring, early warning, and prevention of extreme weather and climate events; and improving natural disaster prevention and mitigation capabilities.

The Outline of the 13th Five-Year Plan for National Economic and Social Development of the People's Republic of China (hereinafter referred to as the Outline of the 13th Five-Year Plan) also includes a chapter on China's "Respond to Global Climate Change". In the section "Adaptation to Climate Change", the Chinese government outlines the following tasks: "We will take climate change into full consideration in economic and social development efforts such as rural-urban development planning, infrastructure development, and productive force distribution. We will formulate and adjust technical standards in this regard at an appropriate time and put into effect an action plan for adapting to climate change. We will strengthen systemic observation and research on climate change, improve systems for forecasting and giving early warnings, and become better able to respond to extreme weather conditions and climatic events."

In the chapter "Coping with Climate Change" of the Outline of the 14th Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Long-Range Objectives Through the Year 2035 (hereinafter referred to as the Outline of the 14th Five-Year Plan), the Chinese government outlines new tasks for the next stage of climate change adaptation, including "We will intensify the observation and assessment of the impact of global warming on vulnerable areas in China, and enhance the capacity of urban and rural construction, agricultural production, and infrastructure, to adapt to climate change."

3.2 National Climate Change Adaptation Strategy (2014-2020)

In 2013, as part of China's effort to implement a proactive and coordinated approach to climate change, nine departments of the central government of China jointly issued the National Climate Change Adaptation Strategy 2020 (hereinafter referred to as the Adaptation Strategy 2020, implementation period: 2014-2020), outlining key climate actions relating to infrastructure, agriculture, water resources, coasts and ocean, forests and other ecosystems, human health, and tourism and other sectors. It plans land use based on the delineation of functional zones and proposes specific measures to adapt to the impacts of climate change on production and daily life in different zones. It divides the country into urban, agricultural, and protected areas and provides guidance for the planning and coordination of adaptation efforts. The Adaptation Strategy 2020 is China's first strategy focused on climate change adaptation. It has played an important role in improving the country's adaptive capacity.

The Adaptation Strategy 2020 sets clear priorities and emphasizes the importance of collaboration, stakeholder participation, and the adoption of a proactive and reasonably-designed approach. It sets the goal of significantly enhancing China's adaptive capacity, achieving all key adaptation targets, and adjusting the delineation of functional zones to better adapt to climate change by 2020 and provides guidance on coordination of the implementation of adaptation initiatives.

China's adaptive capacity has been significantly enhanced. The vulnerability of sectors, areas, and groups sensitive to climate impacts has been significantly reduced. Public awareness and knowledge about climate change adaptation have been significantly improved, and adaptation training and capacity building activities have been effectively carried out. Climate change basic research, observation, forecasting and impact assessment have been notably bolstered. Extreme weather and climate event early warning systems have been improved and the capacity to prevent and mitigate disasters has been strengthened. Funding for adaptation initiatives has been effectively guaranteed. The system for advancing adaptation technology has been put into place and related standards have been developed and promoted.

All key adaptation targets have been achieved. The first round of revision of infrastructure-related standards has been completed, and the capacity of infrastructure to cope with extreme weather and climate events has been significantly enhanced. All targets related to the adaptation of agriculture and forestry to climate change have been achieved. The capacity of industries to adapt to climate change has been significantly improved. Practical actions have been taken to effectively protect ecosystems such as forests, grasslands, and wetlands. Desertification has been effectively mitigated. A system for rational allocation and efficient utilization of water resources has taken shape, and the safety of rural and urban drinking water has been effectively guaranteed. Management of marine and coastal ecosystems has been significantly improved. Efforts have been made to ensure climate-affected individuals have the knowledge and skills to cope with health risks posed by climate change.

The delineation of functional zones has been adjusted to better adapt to climate change. In order to prevent production activities and daily life from being impacted, as well as to effectively guarantee an adequate supply of agricultural products and ecological security, urban, agricultural, and protected zones have been delineated in accordance with the national functional zone plan and using science-based methods.

3.3 National Climate Change Adaptation Strategy 2035

In 2020, the Ministry of Ecology and Environment established a task force to prepare the National Climate Change Adaptation Strategy 2035 (hereinafter referred to as the Adaptation Strategy 2035), a steering group to oversee the preparation, and an expert advisory committee to support the preparation. In June 2022, 17 departments of the central government of China including the Ministry of Ecology and Environment jointly issued the Adaptation Strategy 2035, setting out the guiding ideology, basic principles and primary objectives of China's efforts to adapt to climate change for the period 2022-2035. The Adaptation Strategy 2035 is guided by the new development philosophy, Xi Jinping Thought on Ecological Civilization, and the spirit of the 19th National Congress of the Communist Party of China (CPC) and all Plenary Sessions of the 19th CPC National Congress. It coordinates development and security and promotes a proactive approach to climate change with equal emphasis on mitigation and adaptation. It outlines the Hurunui's progress of China's planned actions to have CO_2 emissions peak before 2030 and achieve carbon neutrality before 2060, integrates climate change adaptation into the country's economic and social development plan, and promotes the modernization of China's climate adaptation governance system and governance capabilities. It seeks to strengthen the climate resilience of natural ecosystems and economic and social systems, adjust the delineation of functional zones for better adaption to climate change, effectively respond to the adverse effects and risks of climate change, minimize losses caused by extreme weather and climate events, advance the Ecological Civilization and Beautiful China campaigns, and drive high-quality growth,

The Adaptation Strategy 2035 is drafted on the basis of a thorough assessment of the risks of climate change and the challenges and opportunities associated with climate change adaptation. It lays out the principles for climate change adaptation: adaption must be proactive, preventive, scientific, systematic, and nature-based; actions should be prioritized in a reasonable way; efforts should be made to promote collaboration and co-governance. The strategy also sets out the following key tasks: strengthening climate change monitoring, early warning and risk management systems, improving the capacity of natural ecosystems to adapt to climate change, strengthening the capacity of economic and social systems to adapt to climate change, and adjusting regional land use plans for better adaption to climate change. It provides guidance for China's adaptation actions for the period 2022-2035, which is broken down into three phases: 2022-2025, 2026-2030, and 2031-2035.

By 2025, the policy system and institutional mechanisms for climate change adaptation will be put in place; the capacity to monitor and give early warning of climate change and extreme weather and climate events will be continuously enhanced; the capacity to assess climate change adverse impacts and risks will be effectively improved; significant progress will be made in modernizing the climate-related disaster prevention and control system and prevention capability; adaptation actions will have been effectively carried out in key sectors and areas; regional land use plans will have been adjusted for better climate change adaptation; significant progress will have been made in building pilot climate-resilient cities; advanced adaptation technologies will be applied and promoted; and society-wide consensus that everyone should consciously participate in climate change adaptation has been built.

By 2030, the policy system and institutional mechanisms for climate change adaptation will be further improved; climate change monitoring, forecasting, impact assessment, and risk management systems will have taken shape; the capacity to prevent major climate-related risks and disasters will be significantly improved; adaptation actions will have been carried out in all sectors and regions; vulnerability of natural ecosystems and economic and social systems to climate change will be significantly reduced; society-wide awareness of adaptation issues have been created; the system to advance adaptation technology and standards will have taken shape; and China will have made remarkable progress in building a climate-resilient society.

By 2035, China will have the world's strongest capabilities in terms of climate change monitoring and early warning; it will have put in place a mature climate risk management and prevention system; the risks of major climate-related disasters will be effectively prevented and controlled; the system to advance adaptation technology and standards will be further improved; society-wide climate resilience will be significantly improved and China will become a climate-resilient society.

The biggest differences between the Adaptation Strategy 2020 and the Adaptation Strategy 2035 are as follows: First, the Adaptation Strategy 2035 puts more emphasis on climate change monitoring, early warning and risk management, aiming to improve the climate change observation network, strengthen climate change monitoring, forecasting, early warning, impact and risk assessment capabilities, and bolster disaster prevention and mitigation measures. Second, the Adaptation Strategy 2035 outlines adaption actions for natural ecosystems and economic and social systems, including aquatic ecosystems, terrestrial ecosystems, marine and coastal ecosystems, agriculture and food security, health and public health, infrastructure and major projects, cities and human settlements, and climate-sensitive secondary and tertiary industries. Cities and human settlements are a newly added category of economic and social systems. Besides tourism, climate-sensitive secondary and tertiary industries also include meteorological services, finance, and energy. The goal is to incorporate climate change adaptation into every aspect of the society. Third, The Adaptation Strategy 2035 aims to build a multi-level regional climate resilient land use planning system, integrating climate change adaptation with land use planning. It takes into consideration regional differences in climate change impacts and vulnerability and sets out adaptation tasks for eight major regions and strategic regions such as the Beijing-Tianjin-Hebei Region, the Yangtze River Economic Belt, the Guangdong-Hong Kong-Macao Greater Bay Area, the Yangtze River Delta, and the Yellow River Basin.

Fourth, the Adaptation Strategy 2035 attaches more importance to mechanism establishment, cross-sectoral coordination, organization of adaptation actions, fiscal and financial support, scientific and technological support, capacity building, and international cooperation. (see Table 3-3).

Table 3-3 Comparison between the Adaption Strategy 2035 and the Adaption Strategy 2020

<table>
<tr><th></th><th colspan="2">Adaption Strategy 2035</th><th colspan="2">Adaption Strategy 2020</th></tr>
<tr><td rowspan="4">Strengthening climate change monitoring, early warning and risk management</td><td colspan="2">Improving the climate change observation network</td><td colspan="2" rowspan="4">-</td></tr>
<tr><td colspan="2">Strengthening climate change monitoring, forecasting and early warning</td></tr>
<tr><td colspan="2">Strengthening climate change impact and risk assessment</td></tr>
<tr><td colspan="2">Strengthening disaster prevention and mitigation</td></tr>
<tr><td rowspan="3">Improving climate resilience of natural ecosystems</td><td colspan="2">Water resources</td><td colspan="2">Water resources</td></tr>
<tr><td colspan="2">Terrestrial ecosystems</td><td colspan="2">Forests and other ecosystems</td></tr>
<tr><td colspan="2">Oceans and marine zones</td><td colspan="2">Marine zones and ocean regions</td></tr>
<tr><td rowspan="5">Strengthening climate resilience of economic and social systems</td><td colspan="2">Agriculture and food security</td><td colspan="2">Agriculture</td></tr>
<tr><td colspan="2">Health and public health</td><td colspan="2">Human health</td></tr>
<tr><td colspan="2">Infrastructure and major projects</td><td colspan="2">Infrastructure</td></tr>
<tr><td colspan="2">Cities and human settlements</td><td colspan="2">-</td></tr>
<tr><td colspan="2">Climate-sensitive secondary and tertiary industries (meteorological services, finance, energy, tourism, transport disaster prevention and emergency response)</td><td colspan="2">Tourism and other industries</td></tr>
<tr><td rowspan="9">Building a regional climate-resilient land use planning system</td><td colspan="2">Building a national climate resilient land use planning system</td><td colspan="2">-</td></tr>
<tr><td rowspan="8">Strengthening regional adaption actions</td><td>Northeast China</td><td rowspan="3">Urban Zones</td><td>Eastern Urban Zone</td></tr>
<tr><td>North China</td><td>Central Urban Zone</td></tr>
<tr><td>East China</td><td>Western Urban Zone</td></tr>
<tr><td>Central China</td><td rowspan="5">Agricultural Zones</td><td>Northeast Plain</td></tr>
<tr><td>South China</td><td>North China Plain</td></tr>
<tr><td>Northwest China</td><td>Yangtze River Basin</td></tr>
<tr><td>Southwest China</td><td>Fenwei Plain</td></tr>
<tr><td>Qinghai-Xizang Plateau</td><td>Hetao</td></tr>
</table>

<table>
<tr><td rowspan="7"></td><td rowspan="7">Improving climate resilience of major strategic regions</td><td>Beijing-Tianjin-Hebei Region</td><td rowspan="2"></td><td>Gansu and Xinjiang</td></tr>
<tr><td>Yangtze River Economic Belt</td><td>South China</td></tr>
<tr><td>Guangdong–Hong Kong–Macao Greater Bay Area</td><td rowspan="5">Protected Zones</td><td>Northeast Forest Belt</td></tr>
<tr><td>Yangtze River Delta Region</td><td>Northern Sand Control Belt</td></tr>
<tr><td rowspan="3">Yellow River Basin Region</td><td>Sichuan-Yunnan Ecological Barrier</td></tr>
<tr><td>Southern Hills Region</td></tr>
<tr><td>Qinghai-Xizang Plateau Ecological Barrier</td></tr>
</table>

3.4 Climate Change Adaptation Goals for the 14th FYP Period

China has entered a new stage in its effort to address climate change. During the 14th FYP period, it will step up adaptation actions and further improve risk management and climate resilience, develop adaption strategies and plans and set goals for sectors such as agriculture, water resources, forestry, oceans, and disaster prevention and mitigation, and implement actions to adapt to climate change impacts. The adaptation goals of the above climate-sensitive sectors are as follows:

Water resources: By 2025, China's capability to prevent floods and droughts, maintain water security, optimize the allocation of water resources, and protect rivers and lakes will be further strengthened and its water-use efficiency will be significantly improved. The total water consumption nationwide will be controlled within 640 billion cubic meters. Both water consumption per 10,000 yuan of GDP and water consumption per 10,000 yuan of industrial added value will have dropped by about 16% compared with 2020. Water use efficiency (WUE) of cropland irrigation water will rise to 0.58. The water resources allocation system will be further improved. China's water supply capacity will increase by 29 billion cubic meters by 2025. All cities at the prefecture level and above will have emergency backup water supplies. The percentage of rural populations with access to tap water will reach 88%. The total area of large-scale irrigation zones will reach 514 million *mu*[31] (with a land area of more than 10,000 *mu* each).

Terrestrial ecosystems: From 2022 to 2025, China will focus on the protection and restoration of key national protected areas, ecological red line areas, and key national nature reserves, and solve major ecological problems in key areas. By 2025, percentage of forest coverage in China will reach 24.1%, growing stock volume 19 billion cubic meters,

[31] 1 mu =1/15 hectare.

and percentage of land covered by major grassland types 57%; the area of protected wetlands will reach 55% of total area of wetlands in the country; natural reserves (most of which are national parks) will account for more than 18% of China's total land area; 100 million *mu* of land encroached by desertification will have been restored.

Marine ecosystems: By 2025, marine ecosystem deterioration will have been fundamentally curbed; damaged and degraded important marine ecosystems will have been comprehensively protected and restored; marine biodiversity will be effectively protected; marine ecological security and climate resilience will be continuously enhanced; the quality and stability of marine ecosystems will be steadily improved; the length of natural coastline of the Chinese mainland will be no less than 35% of the Chinese mainland's total coastline length; the length of restored coastline will be no less than 400 km; the total area of coastal wetlands will be no less than 20,000 ha; the environment of about 50 bays will be significantly improved.

Agriculture: By 2025, agricultural resources such as farmland and water will be effectively protected and their utilization efficiency will be significantly improved; ecological restoration of degraded agricultural land will have been completed; biodiversity will be effectively protected; farmland ecosystems will become more stable, and their climate resilience will be continuously enhanced; China will have 1.075 billion *mu* of high-standard farmland; 43% of cropland will use chemical fertilizers and pesticides; the recycling rate of agricultural film will reach 85%; the percentage of livestock manure utilized as organic fertilizers or biofuels will reach more than 80%; an additional 14 million *mu* of degraded farmland will have been restored.

Natural disaster prevention and relief: By 2025, China will have made remarkable progress in modernizing its emergency management system and capabilities and built an efficient emergency management system with Chinese characteristics that features unified command, specialized and normalized mechanisms, quick responsiveness, and effective collaboration across all levels, and an efficient, authoritative national emergency response system with unified leadership and clearly defined powers and responsibilities; climate risk management systems and mechanisms will have been continuously improved; emergency rescue capacity will be comprehensively strengthened; legal, scientific, and technological, and other support for emergency management will be significantly improved; significant progress will be made in workplace safety improvement and disaster risk deduction; natural disaster prevention capacity will be significantly improved; and the capacity of the whole society to prevent, respond to and deal with disasters and accidents will be significantly enhanced.

Chapter 4 Climate Change Adaptation Policies and Actions

4.1 Water Resources

China has increased efforts to conserve and protect water resources. Since the start of the 13th FYP period, China has prioritized conservation, spatial balance, and systematic management of water resources, and given full play to the roles of the market and the government. It has attached importance to the control of total water consumption and water use intensity and integrated water conservation into environmental, economic and social aspects of development. The National Development and Reform Commission, the Ministry of Water Resources, the Ministry of Housing and Urban-Rural Development, the Ministry of Industry and Information Technology, the Ministry of Agriculture and Rural Affairs and other relevant departments jointly rolled out a series of policies, including the National Water Saving Action Plan, Citizen Water Saving Action Plan, Measures for Management of Water Efficiency Labels, Implementation Plan for the Energy Efficiency Leader Program, and Total Water Consumption and Water Use Intensity Control Action Plan for the 13th FYP Period, to drive society-wide water conservation actions. China has installed supporting facilities and launched water-saving renovation projects in 434 large-scale irrigation areas. Restored and improved irrigation areas have increased by more than 200 million *mu*. The effective utilization coefficient of farmland irrigation water has climbed to 0.565. These efforts have laid the foundation for continuous harvest and food security across the country.

China has significantly improved water use efficiency. China has adopted a more rigid approach to the management of water resources. It has strictly controlled total water consumption, significantly improved water use efficiency, and ensured that water resources are rationally developed and utilized. During the 13th FYP period, the total water consumption nationwide was controlled within 610 billion cubic meters. Water consumption per 10,000 yuan of GDP dropped by 28.0%, and water consumption per 10,000 yuan of industrial added value dropped by about 39.6%. The average leakage rate of urban public water supply pipe networks was about 10%. Positive progress has been made in the recycling of industrial wastewater. The recycling rate of industrial water of enterprises above the designated size in secondary industries increased from 89% in 2015 to 92.5% in 2020. It has increased the efficiency of water recycling, promoted the application of seawater desalination technology, continuously strengthened the development and management of unconventional water sources, incorporated unconventional water sources into unified water resources allocation, especially in water-scarce areas, and further expanded the scope of unified water resources allocation to include industrial, environmental, urban, agricultural and other uses. In 2020, the country's total annual consumption of unconventional water resources reached 12.81 billion cubic meters, of which recycled water accounted for 85%. China has increased efforts to reclaim and utilize wastewater. About 32.7% of wastewater in water-scarce cities is reclaimed.

China has comprehensively improved water management capacity. To improve the overall resilience of its national water supply system, China has the strictest water resources management system which centers on the “Three Red Lines” (regulations on water resources development and utilization, water use efficiency, and pollutant load control in water function zones). Every year, the utilization of water resources in 31 provinces, autonomous regions and municipalities directly under the central government will be assessed in accordance with the strictest standards. China has launched the South-to-North Water Diversion Project and other water supply rescheduling projects to optimize the pattern of water supply and improve water security. The South-to-North Water Diversion Project has greatly improved China’s water resources management capability. From the completion of the first phase of the east and middle routes of the South-to-North Water Diversion Project to the end of 2020, the project transferred more than 39.4 billion cubic meters of water to the north. China has scientifically planned the distribution of water resources projects. A large number of water control projects, including the Three Gorges Dam on the Yangtze River, the Xiaolangdi Dam on the Yellow River, the Linhuaigang Dam on the Huaihe River, the Nierji Dam on the Nenjiang River, and the Baise Dam in Guangxi, have been completed and put into use, significantly improving the regulatory capacity of major rivers. Efforts have been made to better coordinate water allocation for daily life, production activities, and ecological use in 59 inter-provincial basins, including basins of the Taihu Lake, the mainstream of the Songhua River, the main stream of the Liaohe River, the Xin’an River, and the Wujiang River.

China has effectively improved flood and drought disaster prevention capabilities. It has rolled out the 14th Five-Year Plan for Maintaining Water Security, comprehensively evaluated the implementation outcomes of the 13th Five-Year Plan for Water Resources Reform and Development, systematically analyzed China’s water security status and challenges facing water security, and set out the roadmap, goals, tasks, and measures to maintain water security during the 14th FYP period. The management of major rivers such as the Yangtze River, the Yellow River, and the Huaihe River has been further strengthened. The construction of major water control projects such as the Chushandian Reservoir on the Huaihe River, Dateng Gorge Project on the Xijiang River, and Dongzhuang Project on the Jinghe River has been accelerated. Risk factors of reservoirs have been removed. The country has bolstered the management of small and medium-sized rivers and the prevention and control of flash floods. Its flood control and disaster mitigation capabilities in key river sections and areas have been significantly improved. China has also strengthened flood monitoring, forecasting and early warning. It has taken effective measures to ensure the precise operation of the flood control system and give full play to the role of water control projects in preventing floods and droughts. It has mitigated multiple major and catastrophic floods in the Yangtze River, the Huaihe River, the Songhua River, and the Taihu Lake Basin in a well-conceived manner, successfully handled several barrier lake outbursts, organized successful responses to large-scale droughts, effectively protected the lives and property of citizens, and ensured smooth operation of the national economy.

China has made a continual effort to restore and protect aquatic ecosystems. China has continued to reduce soil erosion in vulnerable areas such as the upper and middle reaches of the Yangtze River, the upper and middle reaches of the Yellow River, the black soil region in Northeast China, and rocky deserts in Southwest China. An additional 300,000 sq km of land has been covered by soil erosion control projects, and both the total area of land affected by and the intensity of soil erosion have declined. The country has stepped up water resources management to ensure that the mainstream of the Yellow River continues to flow for 21 consecutive years. It has taken measures to restore the natural state and functioning of six rivers and five lakes in the Beijing-Tianjin-Hebei region. The Beijing section of the Yongding River has returned to a fully replenished state for the first time in 25 years. China has continued to strengthen the protection and restoration of ecologically fragile rivers such as the Tarim River, the Heihe River, and the Shiyang River. It has reduced groundwater exploitation in North China by increasing water supply from other sources, and groundwater levels in some areas have rebounded. Efforts have been made to improve efficiency, expand capacity and advance reform of small hydropower projects. Water levels of more than 90,000 km of river channels affected by hydropower operations have been restored to their original levels. The power generation capacity of small hydropower projects in China totaled 250 billion kWh in 2020.

4.2 Terrestrial Ecosystems

China has bolstered efforts to protect biodiversity. Its efforts to advance the national park system pilot project, construct nature reserves and protect endangered wild animals and plants have had a positive impact on biodiversity. As of the end of 2018, China had more than 2,700 nature reserves, covering 90% of typical terrestrial ecosystems, 85% of wild animal populations, and 65% of higher plant communities. The populations of endangered wild animals and plants such as giant pandas, crested ibises, Siberian tigers, Amur leopards, Tibetan antelopes, and cycads are on a steady rise. During the 13th FYP period, the number of natural reserves nationwide increased by more than 700, reaching 11,800, and the total area of nature reserves increased by more than 25 million ha, accounting for approximately 18% of China's land area. China's ecological red line areas cover 35 biodiversity hotspots and many habitats of species under special protection by the State.

China has made continual efforts to protect and restore ecosystems. It has rolled out ecological protection and restoration plans such as the National Master Plan for Major Projects to Protect and Restore Important Ecosystems (2021-2035), built large-scale shelterbelts (the Three-North Shelterbelt and the Yangtze River Shelterbelt), strengthened the protection of natural forests, and launched the Returning Farmland to Forest Program (RFFP) and other major ecological protection projects. These efforts have led to the rapid growth of forest resources. As of the end of 2018, China ranked fifth in the world in forest area, sixth in growing stock volume, and first in area of plantation forests. All major greening targets for the 13th FYP period have been achieved. Forest cover has reached 23.04% of China's total land area. Growing stock volume has exceeded 17.5 billion cubic meters. The percentage of land covered by all major grassland types has reached 56%.

China has stepped up its efforts to prevent and control soil erosion and land degradation in vulnerable areas, including Beijing, Tianjin and rocky deserts. It has launched pilot projects such as closed-off protection zones for land affected by desertification. The total area of deserts, including sandy and rocky deserts, in China has continued to decrease. During the 13 FYP period, China restored more than 10 million ha of sandy deserts and 1.3 million ha of rocky deserts, significantly improving soil conditions in areas covered by desert restoration projects. It has delineated aquatic ecosystem protected areas, including wetland nature reserves and wetland parks, to protect ecosystems of rivers, lakes and wetlands. By the end of 2018, China had 57 wetlands of international importance, 156 national wetland nature reserves, and 896 national wetland parks, and 52.2% of the wetlands of the country were protected. During the 13th FYP period, relevant departments of the central government of China, including the Ministry of Finance, the Ministry of Natural Resources, and the Ministry of Ecology and Environment, launched 25 pilot projects to advance ecological protection and restoration of mountains, rivers, forests, farmlands, lakes and grasslands. These projects covered 24 provinces and all national ecological barriers, including the Qinghai-Xizang Plateau Ecological Barrier, the Yellow River Ecological Area, the Yangtze River Ecological Area, the Northeast Forest Belt, the Northern Desertification Control Belt, the Southern Hilly and Mountainous Areas and Coastal Areas. They played an important role in improving the quality and functions of ecosystems in the country.

4.3 Marine and Coastal Ecosystems

China has significantly improved ocean climate observation and monitoring capabilities. It has significantly improved its capabilities to observe sea level changes, marine ecological environment, ocean extremes, signs of ocean disasters, and polar climate; established nearshore, the South China Sea, the Yellow Sea, and the Bohai Sea observation networks and island and coastal hydrometeorological monitoring networks; continuously provided data to support climate change monitoring and research; built the Global Ocean 3D Observation Network and normalized observation of China’s territorial sea, northwest Pacific, northern Indian Ocean, important straits and channels, and the Antarctic and Antarctic regions; actively participated in large-scale international observation programs such as the Tropical Ocean and Global Atmosphere Program, the World Ocean Circulation Experiment, Array for Real-Time Geostrophic Oceanography (ARGO), the Global Tropical Moored Buoy Array, and TPOS 2020, led the implementation of the Northwestern Pacific Ocean Circulation and Climate Experiment (NPOCE) program, and significantly improved its real-time ocean monitoring capability in the Western Pacific.

China has continued to strengthen the protection and restoration of marine ecosystems. It has rolled out the 14th Five-Year Plan for Marine Ecosystem Protection and made an effort to coordinate climate change response, marine environment management, and ecological protection and restoration efforts, promote ocean climate change monitoring and assessment, and enhance the climate resilience of marine ecosystems; launched coastal shelterbelt construction, coastal wetland restoration, and mangrove protection projects; improved the marine environment in some sea areas; curbed the degradation of typical habitats such as mangroves, coral reefs, seagrass beds, and salt marshes; stabilized the overall ecological quality in coastal waters; coordinated the implementation of the Notice on Strengthening Coastal Wetland Protection and Strictly Controlling Land Reclamation (2018); stopped approving new reclamation projects except for major national strategic projects, bolstered the protection of coastal wetlands; provided guidance for local governments over ecological assessment and restoration of coastal ecosystems affected by reclamation, and promoted a nature-based approach to ecological restoration. During the 13th FYP period, China restored 23,000 ha of coastal wetlands, improved their ecosystem services, and enhanced their climate resilience.

China has continued to strengthen coastal zone management. A series of policies, including the Coastline Protection, Utilization and Management Measures, have been issued to guide the restoration, protection, and development of coastal zones. The central government has provided special funds to support the implementation of local sea area, island and coastal zone restoration and protection projects. China has demolished abandoned wharves, cleaned up waste, carried out marine dredging activities, restored beaches, embankments, natural shorelines and geological heritage sites, stepped up artificial shoreline management, and constructed offshore submersible embankments, tidal barrages, and coastal sightseeing corridors. These efforts have significantly improved and stabilized coastal ecosystems. As of the end of 2018, China had completed ecological restoration of about 1,000 km of coastline and 20 islands.

China has gradually improved engineering standards for maritime structures and scientifically planned the distribution of these structures. It has promoted the establishment of a marine engineering standardization system, which will provide effective technical support for the rise of China as a maritime power; developed a blue carbon standards system, launched marine ecosystem carbon sequestration pilot projects, and encouraged Jiangsu, Shandong, Zhejiang and other provinces to engage in blue carbon planning, research, trading and demonstration activities; carried out blue carbon storage surveys and assessment of typical ecosystems such as the Yellow River Estuary Salt Marsh and Changdao Seagrass Bed; issued the National Marine Functional Area Delineation Plan, taken practical measures to ensure the scale of development activities is within the carrying capacity of marine environment, strictly controlled the intensity and scale of offshore development, and promoted moderate development of deep sea; improved integrated in land-sea spatial planning and management, promoted the establishment of an environmental zoning system, and built a marine space management system in parallel with land, river basins, and ocean management systems. The marine space management system coordinates the management of coastal zones, islands, offshore waters, and deep-sea areas.

4.4 Agriculture

China has effectively improved agricultural disaster prevention and mitigation capabilities. It has issued policies such as the National Agricultural Sustainable Development Plan (2015-2030), Agricultural Resources and Environment Protection Plan

(2016-2020), and National Agricultural Modernization Plan (2016-2020) to provide guidance on the adaptation of agriculture to climate change; increased support for the development and protection of agricultural ecosystems; promoted sustainable use of agricultural resources; bolstered agricultural production capacity and disaster prevention and mitigation capabilities; taken measures to ensure the scale of agricultural activities is within the carrying capacity of environment; and increased support for the construction of agricultural infrastructure and improved the climate resilience of agriculture. The central government has provided financial support for the prevention and control of major natural disasters and biological disasters that affect agricultural production, emergency response, and post-disaster recovery at the local level. China has launched smart agricultural projects, promoted the development of smart meteorology, and improved meteorological disaster monitoring, forecasting, and early warning capabilities.

China has increased efforts to conserve biodiversity in agriculture. To protect biodiversity, ensure food security, and strengthen the protection and efficient utilization of germplasm, China has formulated the National Mid- and Long-term Plan for the Protection and Utilization of Crop Germplasm (2015-2030) to provide guidance on the selection of new crop varieties and the development of the modern seed industry. As of 2020, China had more than 520,000 crop germplasm samples, germplasm samples of more than 560 local breeds of livestock, more than 960,000 genetic samples, and more than 100,000 agricultural microbial samples kept in long-term storage. China has surveyed edible and useful wild plants; increased in-situ protection of edible and useful wild plants; bolstered efforts to prevent biological invasions, including investigation, monitoring, early warning, and rapid eradication; carried out surveys on key national, regional and local invasive species; built the China Invasive Species Database; and normalized the prevention and control of biological invasions.

China has made continual efforts to improve cropping systems and livestock management. China has prioritized environmental protection over agricultural development, strengthened soil conservation and ecological protection, and promoted reasonable intercropping systems; advanced spring sowing in the north and the sowing of early rice in the south and postponed the sowing of winter wheat in order to adapt to the phenological shifts brought about by climate change; promoted the use of plastic film to reduce the impact of climate change and extreme cold events; promoted water conservation technology and conservation tillage to mitigate the impacts of drought; encouraged fish farms to use aeration devices to reduce the death of fish caused by rising water temperatures; promoted the return of pastures to grassland, rotational grazing, spell grazing, and cooperation with agricultural areas for cattle fattening to curb the degradation of grasslands caused by global warming and reduction in precipitation. Farmers are suggested to stock enough forage in summer and autumn to support cattle through winter and spring. In recent years, grassland vegetation in China has increased significantly.

China has effectively ensured food security. It has focused on improving land leveling, soil conditions, irrigation, drainage, and water-saving facilities in grain production areas and other important agricultural production zones, promoted the construction of high-standard cropland and cropland water management facilities, and improved comprehensive agricultural production capabilities. During the 13th FYP period, China's high-standard cropland increased by 400 million *mu*, reaching 900 million *mu*. Compared with standard cropland, the average grain production capacity per *mu* of high-standard cropland increased by 10% to 20%, contributing to consecutive years of grain harvests in China. China has established 220 high-standard dry farming and agricultural water conservation demonstration areas in dry farming areas such as North China and Northwest China to demonstrate and promote dry farming and water conservation practices such as soil moisture conservation, construction of irrigation facilities, furrow irrigation, use of soil moisture sensors, fertigation, improvement of stress resistance of crops. The total area of effectively irrigated cropland in China has reached 1.02 billion *mu*, and the agriculture sector has become more drought-resilient. China has effectively ensured food security despite the impacts of climate change.

4.5 Public Health

China has effectively carried out health vulnerability and adaptation assessments in relation to climate change. In 2019, to support scientific and standardized health risk assessments and early warning of health hazards in relation to drinking water, air, soil and climate change, the National Health Commission promoted the establishment of an environmental health risk assessment system. In the same year, it designated five provincial (Hebei, Shandong, Henan, Sichuan, and Jiangsu) and five municipal (Jinan, Qingdao, Hefei, Ningbo, and Shenzhen) CDCs as the first group of participants in the national environmental health risk assessment pilot project. The outcomes of the pilot project have been effectively promoted. Relevant departments of the Chinese government have launched projects, "Research on the Impacts of Climate Change on Human Health and Corresponding Adaptation Mechanisms", a key research project sponsored by the Ministry of Science and Technology, "Research on Climate Change-related Health Risk Assessment, Early Warning, and Response Strategies", a special research project under the national R&D program "Global Change and Response", "Public Health Issues Caused by Climate Change", a research project sponsored by the Ministry of Ecology and Environment, "Climate Change-related Health Risk Assessment Strategies and Technologies", a research project sponsored by the National Health Commission, to evaluate the impacts of climate change on human health and support decision making in relation to adaptation actions in China's health field.

China has gradually improved the infectious disease surveillance and reporting system. In 2009, the National Institute for Communicable Disease Control and Prevention (ICDC) of the Chinese Center for Disease Control and Prevention (China CDC) established the Nationwide Major Disease Vector Monitoring System. The system was officially put into operation in 2014. A system upgrade was completed in February 2022. In 2016, to promote scientific and effective disease vector monitoring and control measures across the country, the National Health Commission issued the National Major Disease Vector Monitoring Plan and the China CDC issued the National Disease Vector Monitoring Implementation Plan to provide guidance on supervision, techniques and training associated with the disease vector monitoring system. In addition, the ICDC has developed a disease vector monitoring data collection and analysis system (Web version) and an Ae. aegypti (dengue vector) monitoring app to harness the power of modern information technology to support risk assessment, prevention and control of vector-borne infectious diseases.

China has established an extreme heat event monitoring and early warning system. Shanghai City has established China's first extreme heat event monitoring and early warning system. The Institute for Environmental Health and Related Product Safety (IEHRPS), China CDC, has implemented the extreme heat event and health risk early warning system in four pilot cities located at different latitudes (Nanjing, Shenzhen, Chongqing, and Harbin), seeking to reduce residents' health risks through early warning, health education and other interventions. The National Health Commission has issued the Notice on Strengthening the Response of the Health Care Sector to Extreme Heat Events, to enhance public health preparedness for extreme heat events and provide guidance on heat stroke monitoring, early warning and treatment and regular reporting of heat stroke cases to the Heat Stroke Case Reporting System of China CDC.

4.6 Urban Adaptation

China has systematically promoted climate-resilient city solutions. In 2016 and 2017, the Chinese government issued the Urban Climate Change Adaptation Action Plan and the Notice on Launching Climate-Resilient City Pilot Projects. It launched climate-resilient city pilot projects in 28 cities and encouraged them to actively explore adaptation options. In 2020, the Ministry of Ecology and Environment and the Ministry of Housing and Urban-Rural Development jointly issued the Notice on Reporting on the Progress of Climate-Resilient City Pilot Projects, providing guidance on the reporting of the progress of the 28 climate-resilient city pilot projects. The pilot cities have taken a series of adaption actions and measures, including establishing an extreme weather and climate event monitoring and early warning system, formulating urban climate change action plans, and strengthening the resilience of vulnerable areas. China has made remarkable progress in improving cities' capability to adapt to climate change, giving full play to the role of urban greening in combating climate change, maintaining water security, and strengthening basic adaption capabilities.

China has integrated climate change adaptation into urban planning. The Ministry of Natural Resources issued the Guidelines for Municipal Land Use Master Planning (Trial), requiring local governments to assess the impacts of climate change and proactively respond to the risks and challenges brought about by climate change. Local governments have integrated adaptation measures designed based on local climate change impact, vulnerability and existing adaptive capability assessments into urban planning. For example, Changde City has formulated the Special Plan for Turning Changde City into a Climate-Resilient City and Changde City Land Use Master Plan; Jinan City has issued Jinan City Climate Change Adaptation Action Plan, setting the goal of building a safe, resilient, livable, and quality modern City of Springs and comprehensively advancing climate change adaptation actions on all fronts, including policies and regulations, institutional mechanisms, planning and coordination, standards and specifications, and construction management; Qingdao City assessed the impacts of climate change and compiled Qingdao City Climate Change Adaptation Plan on the basis of the assessment results to provide guidance for the city's coordination of adaptation actions.

China has continued to strengthen urban lifelines. It has formulated and improved urban infrastructure design and construction standards, strengthened urban emergency preparedness, and enhanced urban resilience; continuously improved the design and construction standards of roads, railways, airports, pipelines, urban rail lines, water buses, and other transport infrastructure, accelerated road reconstruction and rehabilitation, and improved the national highway network's capability to adapt to extreme weather events such as extreme cold events, floods, and typhoons; monitored the status of transport infrastructure across the Qinghai-Xizang Plateau in permafrost areas under the influence of climate change and improved the capability of the transport systems to withstand climate risks; launched old urban community renewal and renovation projects, and required local communities to include the renovation and upgrading of water supply, drainage and other pipe networks into urban community renovation projects.

China has stepped up urban greening and ecological restoration efforts. The Ministry of Housing and Urban-Rural Development has supported ecological restoration and urban repair pilot projects, provided guidance for 58 pilot cities on embarking on the green development path, repairing damaged vegetation on mountains and in river basins and wetlands, improving the urban green space system, optimizing urban spatial forms and patterns, expanding urban ecological space and promoting urban transformation. China has built a comprehensive ecological conservation network, accelerated the construction of urban green spaces such as parks, greenways, and green corridors and the protection and restoration of wetlands, and taken measures to give full play to the role of landscaping in improving urban microclimate. China's urban environment has continued to improve. At the end of 2019, China had 2.2845 million ha of green space in urban built-up areas, 756,000 ha of parkland, and 14.36 square meters of parkland per person; green space accounted for 37.63% of urban built-up areas, and 41.51% of urban built-up areas were covered by vegetation.

China has effectively ensured urban water security. Since 2015, the Ministry of Housing and Urban-Rural Development, the Ministry of Finance, and the Ministry of Water Resources have launched sponge city pilot projects in 30 cities, including Shenzhen, Zhuhai, Pingxiang, Ningbo, Kunshan, and Xixian New District. Sponge cities are a new urban planning model that mimics rainwater absorbing, storing, infiltrating, and discharging processes of the natural water cycle. This helps to reduce flooding within cities. China has prioritized water conservation, comprehensively promoted the transition to a water-saving society in an all-round way, and launched 130 water-saving city projects (10 phases). Their total water consumption accounts for 58.5% of the country's total urban water consumption. These projects have effectively cut China's urban water consumption.

4.7 Disaster Prevention and Relief

China has established climate change monitoring, assessment and early warning systems. It has put in place climate change impact and extreme event monitoring, early warning and response systems. Agriculture, forestry, water resources, marine, emergency management and other climate-sensitive sectors are building adaptation technology systems. China has established collective monitoring and prevention mechanisms at county, township, village, and group levels. A total of 5,700 landslide and debris flow automated monitoring points have been set up across the country. The country's geological disaster and meteorological early warning system has covered 31 provinces, autonomous regions, and municipalities directly under the central government, 323 cities and prefectures, and 1,679 counties. China has successfully responded to major meteorological disasters such as super typhoons, catastrophic floods, and severe droughts, and established a cross-departmental national early warning system.

China has significantly improved its disaster prevention and mitigation capabilities. It has issued policies such as the National Disaster Prevention and Mitigation Plan (2016-2020), and employed technologies to systemically improve accuracy in early warnings, plan implementation, risk management and control, rescue, recovery, and reconstruction on the basis of comprehensive understanding of disaster causes, occurrence and evolution in the context of global climate change. It has established an inter-ministerial joint meeting mechanism for natural disaster prevention and control, launched nine major natural disaster prevention and control projects, conducted the first national natural disaster risk survey, and strengthened the management of large and medium-sized rivers. It has launched national geological disaster prevention and mitigation, mountain torrent prevention and mitigation, fire-prone area management, safe highway, dilapidated rural building renovation, and earthquake-prone area house reinforcement projects. These projects have significantly enhanced urban and rural disaster preparedness and improved China's disaster prevention and mitigation capabilities. Compared with the 12th FYP period (2011-2015), the number of deaths and missing persons, the number of collapsed houses, and direct economic losses (as percentage of GDP) caused by natural disasters decreased by 37.6%, 70.8%, and 38.9%, respectively, during the 13th FYP period.

4.8 Land Use Planning

China has put in place a regional climate resilient land use planning system. Factors that land use planners are required to consider include natural resource distribution, carrying capacity of the environment, climate resilience of different regions, needs of economic and social development, resources required for climate adaptation, climate change impacts and risks, and the Three Red Lines (i.e., arable land and permanent farmland red line, ecological red line, and urban development red line). They have scientifically planned the delineation of agricultural, ecological, urban and other functional zones, enhanced agricultural and ecological security, and comprehensively improved the climate resilience of major functional zones such as agricultural production, ecological, and urban development zones.

China has promoted land use planning for green development. It has rolled out the Outline of the National Land Use Plan (2021-2035), and issued a series of policies and technical standards to guide local governments at all levels in land use planning. Local land use planners are required to proactively respond to the risks and challenges brought about by climate change and prioritize ecological protection, green and low-carbon development, safety, and resilience in land use planning. China has delineated, assessed and adjusted ecological red line areas and optimized the delineated protected areas to further enhance ecological security and stabilize the carbon sequestration effect of ecosystems. China has delineated natural disaster risk zones. Some local governments have delineated flood risk lines based on small-scale (low-resolution) seismic zoning maps and natural disaster risk zoning maps and comprehensively enhanced natural disaster preparedness. Some areas should be maintained as strategically blank in land use plans to cope with the uncertainty in future urban development and enhance urban security and climate resilience.

Part IV Climate Change Mitigation Policies and Actions

As the largest developing country in the world, China has ramped up efforts to address climate change with determination and overfulfilled the goal it announced to the international community that by 2020, its carbon dioxide emissions per unit of GDP will be decreased by 40%-45% from the levels in 2005, bucking its social and economic difficulties. China has contributed greatly to global climate initiatives by effecting a comprehensive green transformation in respect of social and economic development, and rolling out a string of policies and actions to mitigate the effects of greenhouse gases in terms of energy, industry, construction, transport, carbon sink and coordination between pollution control and carbon emissions reduction. On September 22, 2020, Chinese President Xi Jinping pledged at the General Debate of the 75th Session of the United Nations General Assembly that "China will scale up its Intended National Determined Contributions by adopting more vigorous policies and measures. We aim to have CO_2 emissions peak before 2030 and achieve carbon neutrality before 2060." China is now working hard to achieve the goals. Two top-level design documents have been issued, namely the Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy and the Action Plan for Carbon Dioxide Peaking Before 2030, all authorities concerned have formulated implementation plans and policies in different fields and sector, provinces (autonomous regions and municipalities directly under the central government) have all mapped out plans to peak carbon emissions in their territory, and the "1+N" policy framework on carbon dioxide peaking and carbon neutrality has been established.

Chapter 1 GHG Emissions Control Targets and Progress

In 2009, China announced the nationally appropriate mitigation actions to the international community, that is, by 2020, carbon dioxide emissions per unit of GDP will be reduced by 40% to 45% from the levels in 2005, the share of non-fossil energy in primary energy consumption will be increased to around 15%, the forestry area will be increased by 40 million ha on the basis of 2005, and the forest stock volume will be increased by 1.3 billion m^3 from the level in 2005.

In 2016, China released the Outline of the 13th Five-Year Plan, specifying that "the total carbon emissions have been well curbed", and putting forward the goal that by 2020, the carbon dioxide emissions per unit of GDP will be decreased by 18% from the levels in 2015, the total energy consumption will be constrained within 5.0 billion tons of standard coal, the energy consumption per unit of GDP will see a decline of 15% compared with 2015, the share of non-fossil energy will hit 15%, the forest coverage will climb to 23.04%, and the forest stock volume will jump to 16.5 billion m^3. To accelerate green and low-carbon development and ensure the fulfillment of low-carbon development targets and tasks in the above Outline, the Chinese government has specified the related policies and actions in the 13th Five-Year Work Plan for Controlling Greenhouse Gas Emissions (hereinafter referred to as the GHG Control in the 13th FYP).

In the 13th FYP period, China has rolled out numerous policies and actions in terms of industrial restructuring, energy mix optimization, energy conservation and energy efficiency improvement, and synergizing the reduction of pollution and carbon emissions, thus slashing the carbon dioxide emission intensity and curbing GHG emissions. Based on calculations, China has scored the following achievements in controlling GHG emissions.

The carbon emission intensity has weakened dramatically. From 2015 to 2020, the carbon dioxide emissions in energy activities per unit of GDP saw a total decline of about 18.8%, outperforming the target specified in the 13th FYP; levels in 2005 were 48.4% lower than in 2020, exceeding the target of a 40% to 45% increase that China announced in 2009 to the international community.

The energy mix has been improving continuously. The share of non-fossil energy in total energy consumption was 15.9% in 2020, up by 3.9 percentage points from the level in 2015, outperforming both the target in the 13th FYP and the target of around 15% that China announced in 2009.

The forest carbon sink has been on a constant rise. The forest stock volume has exceeded 17.5 billion m^3, outperforming both China’s target in the 13th FYP and the 2020 growth target announced in 2009.

Chapter 2 Energy Mix Adjustment and Optimization

In the 13th FYP period, China has vigorously developed non-fossil energy, promoted clean and high-efficiency utilization of fossil energy and advanced low-carbonization in end-user energy consumption to adjust and optimize its energy structure, striving to establish an energy system that is clean, low-carbon, safe and efficient.

2.1 Prioritizing Non-Fossil Energy

With redoubled efforts in developing non-fossil energy, China's non-fossil energy power has been on a constant rise. In 2020, the installed capacity generated by non-fossil energy amounted to 980 million kW, representing 44.7% of the total, and the output of electricity from non-fossil energy hit 2.6 trillion kWh, accounting for up to 33.3% of the total electricity consumption. The variation in the ratio of non-fossil energy to primary energy consumption in China from 2015 to 2020 is displayed in Figure 4-1.

Figure 4-1 Variation in the Ratio of Non-Fossil Energy to Primary Energy Consumption in China (2015-2020)

2.1.1 Promoting Green Hydropower Development

China has put ecology protection and green development high on its agenda. While well protecting the environment and resettling the affected residents, China advances hydroelectric development in an orderly manner, with the southwestern region being the priority. The National Development and Reform Commission and the National Energy Administration have introduced documents to promote the sound development of hydropower, including the 13th Five-Year Plan on Hydropower Development (2016-2020), the Guidance on Encouraging Social Capital Investment in Hydropower, the Circular on Implementing Environmental Protection Requirements in the Planning and Construction of Pumped Storage Hydropower Stations and the Guide for Benefit Sharing in Hydropower Development. As of the end of 2020, the installed capacity for hydropower amounted to 370 million kW (including 31.49 million kW of pumped storage power) and the hydropower utilization rate in the major river basins reached up to 97%. The variation in China's installed hydropower capacity from 2015 to 2020 is demonstrated in Figure 4-2.

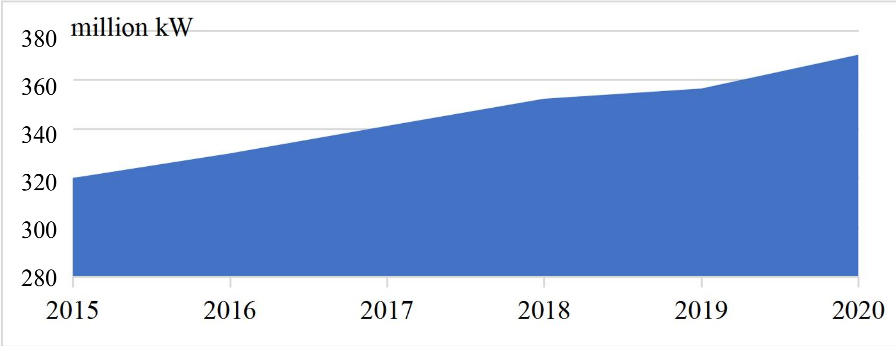


Figure 4-2 Variation in China's Installed Capacity of Hydropower (2015-2020)

2.1.2 Developing Nuclear Power in a Safe and Orderly Manner

To develop nuclear power in a safe, orderly manner, China uses the most advanced technology and the most stringent standards for the development of nuclear power, and strictly manages the entire life cycle of nuclear facilities from siting, design, construction, and operation to decommissioning. Since the start of the 13th FYP period, China has led the world in pivoting from the second generation to the third generation in respect to nuclear power plants and made steady progress in the fourth-generation High Temperature Gas-cooled Reactor (HTGR). The nuclear power units in operation were generally safe, and there have been no incidents or accidents of level 2 or above on the International Nuclear and Radiological Event Scale, and operation incidents trended downwards year by year. As of the end of 2020, China had 66 nuclear power units under operation or construction, of which 48 are under operation; it saw an installed capacity of 70.75 million kW, ranking third in the world. It has 18 approved units under construction and boasts an installed capacity of 20.87 million kW, ranking first in the world. The share of electricity generation from nuclear power in the nationwide output increased to 5% in 2020 from 3% in 2015. The variation in China's installed nuclear power capacity from 2015 to 2020 is indicated in Figure 4-3.

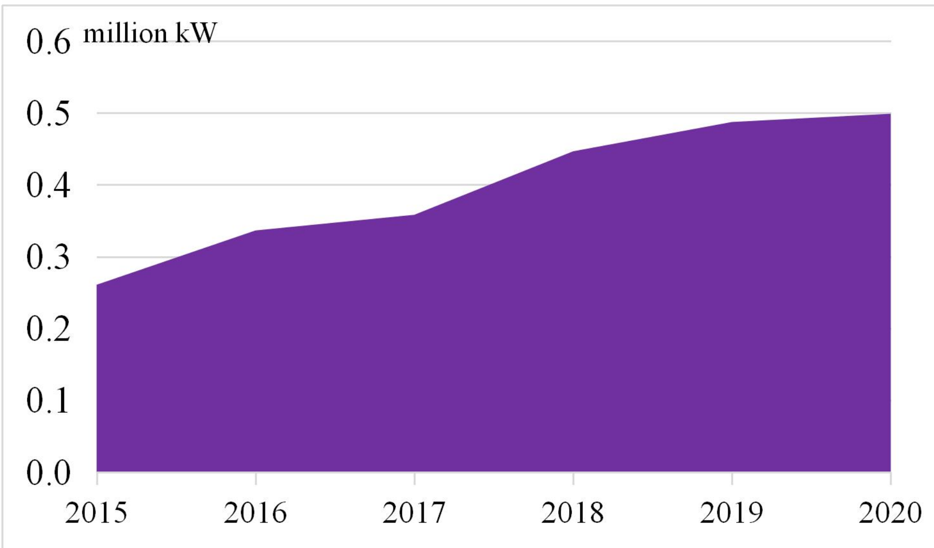


Figure 4-3 Variation in China's Installed Capacity of Nuclear Power (2015-2020)

2.1.3 Coordinating Efforts in Promoting Wind Power and Solar Power Generation

As laid out in its 13th Five-Year Plan on Wind Power Development and the 13th Five-Year Plan on Solar Power Development, China has promoted wind power and photovoltaic base construction on the basis of well-planned distribution and commercialization. It has advanced wind and PV power generation and utilization and the construction of large wind and PV power generation plants, made steady progress in launching demonstration projects on photo-thermal power generation, and vigorously developed distributed wind and PV power generation. China has rolled out a target-oriented management system for the exploitation and utilization of renewable energy, established a system for the full acquisition of renewable power, developed a mechanism for supporting the application of the generated renewable energy, aspired to spearhead photovoltaic development and built bases accordingly, carried forward the project on subsidy-free affordable internet access, boosted in an orderly manner the allocation through market competition, set up a mechanism for Tradable Green Certificate (TGC) trading, and put in place and improved the industry monitoring and prewarning evaluation mechanism. These efforts bring to China a leapfrog development in the sector. As of the end of 2020, the installed capacity of wind power and PV power amounted to 280 million kW and 250 million kW, topping the world for 11 and 6 years in a row, respectively, and the utilization rate of wind power and PV power reached 97% and 98%, respectively. Variations in China's installed capacity of wind power and PV power from 2015 to 2020 are indicated in Figure 4-4 and Figure 4-5, respectively.

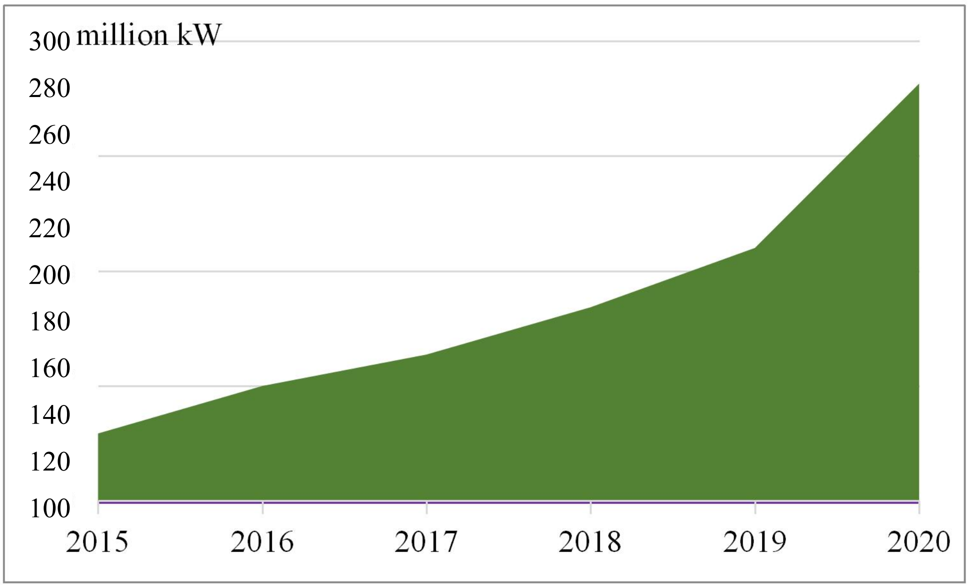


Figure 4-4 Variation in China's Installed Capacity of Wind Power (2015-2020)

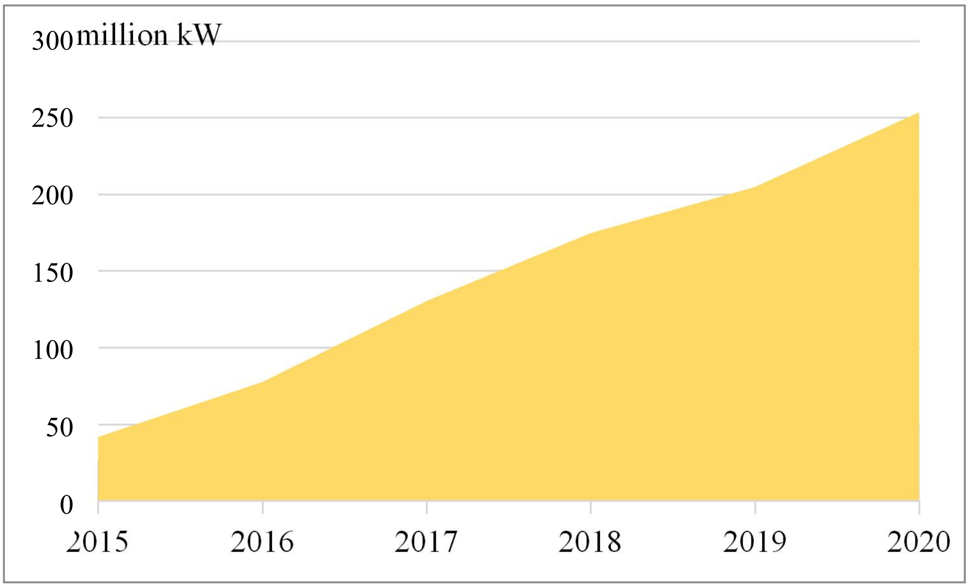


Figure 4-5 Variation in China's Installed Capacity of Solar Power (2015-2020)

2.1.4 Developing Biomass Energy, Geothermal Energy, Ocean Energy and Other Forms of New Energy in Light of Local Conditions

The 13th Five-Year Plan on Biomass Energy Development has been issued, according to which China has promoted biomass power generation in an orderly manner, shifted biomass power generation to co-generation of heat and power, and widened non-electric utilization such as heating with biomass energy and bio-natural gas production to achieve the exploitation and utilization of biomass energy in various ways and on a large scale. China has persisted in avoiding using crops as raw materials and occupying arable land, focused on improving the quality of biodiesel products and advanced the industrialization of non-grain bi-liquid fuels. It developed renewable energy in rural areas, vigorously promoted green energy consumption such as biomass energy and solar power, and accelerated the substitution of renewable energy in terms of heating, cooking and agricultural facilities in rural areas to offset fossil energy emissions in agriculture and rural lives. Power generation using landfill gas was included in the preferential catalog in 2016 to enable resource recycling. As of the end of 2020, the installed capacity of biomass energy of biomass power reached 29.52 million kW; the annual capacity and production of fuel ethanol amounted to approximately 5 million tons and 2.8 million tons, and around 29 million tons of ethanol-added gasoline (contains 10% ethanol, E10) were consumed; there were more than 7,395 large methane and bio-gas plants, annually producing 1.41 billion m^3 of gas for more than 394,500 households; more than 2,664 straw densification briquetting fuel (SDBF) plants and processing sites, with an annual production of close to 12.7965 million tons, were built; and 238 centralized straw bale fired heating boilers were constructed to benefit 106,200 households.

China has promoted geothermal energy utilization technologies, and launched a campaign to tackle technological barriers in geothermal energy utilization across the Beijing-Tianjin-Hebei region. Also, it evaluated the clean geothermal energy surveys as well as its utilization potential in the Xiongan New Area, detected a geothermal water reservoir stratum featuring the highest temperature and the largest capacity in its eastern region, built in the main the demonstration base for multi-cascade comprehensive utilization of geothermal resources in the Beijing-Tianjin-Hebei Region, and launched a new mode to utilize efficiently the underground geothermal reservoir in the Beijing-Tianjin-Hebei Region. In collaboration with the National Energy Administration, the Ministry of Natural Resources released the China Geothermal Energy Development Report (2018).

China is beefing up efforts to boost the ocean energy industry and improve engineering and applications of ocean energy. Firstly, in regard to tidal energy, a large module-based tidal current turbine (TCT) was installed and went into operation in August 2016, followed by the installation of 300 kW and 400 kW power generation modules in 2018. As of June 2020, the module-based TCTs sustained steady operations and generated a total of more than 1.8 million kWh. Secondly, in regard to wave energy, the Sharp Eagle wave energy converter (WEC) has finished its second sea trial in the sea waters of Dawanshan Island, Zhuhai in June 2017, demonstrating world-leading performance in many key indicators. Following a breakthrough made in the MW-level Wave Energy Demonstration Project in 2018, two 500 kW WECs were completed in 2020. In June 2019, the world's first wave energy aquaculture cage "Penghu" was delivered, with a total installed capacity of 120 kW.

2.1.5 Boosting Renewable Energy to Facilitate Low-Carbonization Worldwide

As the world's largest renewable energy consumer and equipment manufacturer, China has formed a complete industry chain for clean energy equipment manufacturing and topped the world for many consecutive years in terms of output of PV modules, output of polycrystalline silicon, newly added installed capacity of PV power and cumulative installed capacity of PV power. China has greatly helped other countries in clean energy development and utilization and supplied global markets with clean and high-quality Chinese products and solutions by spreading its hydropower business in many countries and regions, and manufacturing more than 70% of PV modules consumed globally. Wide applications of renewable energy in China have greatly accelerated the reduction in the cost of renewable energy, thus further driving renewable energy development and utilization across the world and speeding up the global green energy transition. Meanwhile, China has contributed its wisdom and strength to building a green Belt and Road in a high-quality manner by continuing to step up investment in renewable energy projects in countries and regions along the Belt and Road, and assisting underdeveloped countries with the promotion and application of advanced green energy technologies.

2.2 Promoting Clean and Efficient Development and Utilization of Fossil Energy

2.2.1 Advancing the Transition towards Clean and Efficient Coal Power

China is phasing out outdated coal power capacity. In 2017, national authorities jointly issued the Opinions on Advancing Supply-side Structural Reform to Prevent and Address Excess Coal Power Production Capacity. In 2019, the National Development and Reform Commission (NDRC) and the National Energy Administration issued Opinions on Advancing Supply-side Structural Reform to Further Eliminate Outdated Coal Power Capacity to Facilitate Optimization and Upgrades in the Coal Power Sector. Annual targets and tasks for the phase-out of outdated coal power capacity have been issued to guide local authorities and coordinate efforts. Renovations have been made continuously in the coal power sector to achieve ultralow carbon emissions and energy conservation. In the 13th FYP period, a total of more than 45 million kW of outdated coal power capacity has been phased out in China. As of the end of 2020, about 950 million kW of coal-fired power met ultralow emission limits, more than 800 million kW of energy was saved through renovations, and the net coal consumption rate in thermal power plants was reduced to 305 grams of standard coal per kWh. The variation in the ratio of coal consumption to primary energy consumption in China from 2015 to 2020 is shown in Figure 4-6.

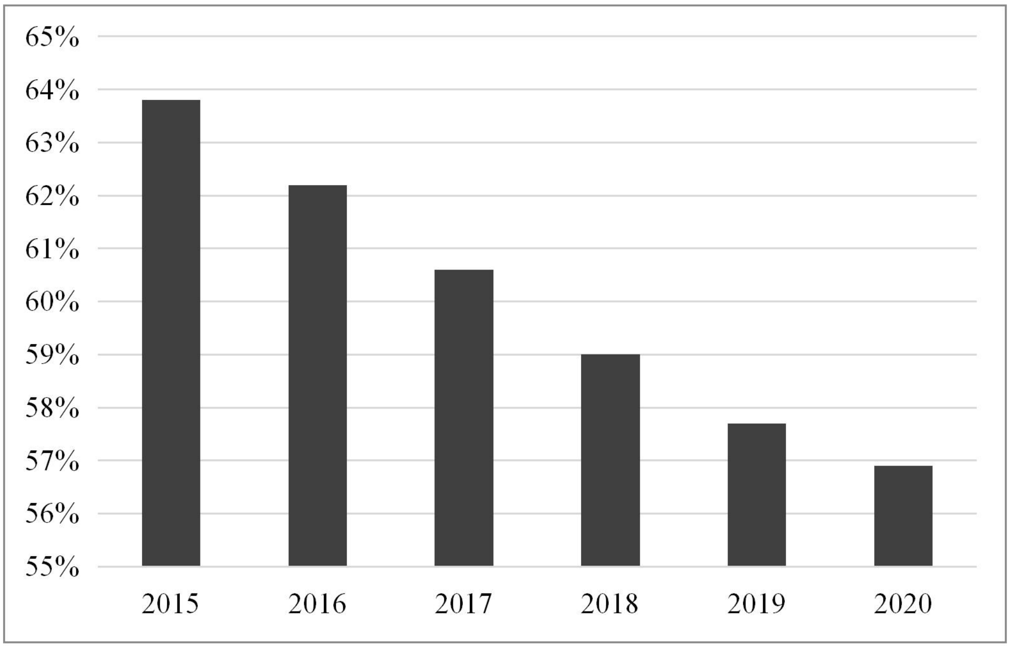


Figure 4-6 Variation in the Ratio of Coal Consumption to Primary Energy Consumption in China (2015-2020)

2.2.2 Promoting High-Quality Development of Natural Gas

The Chinese government has issued Several Opinions on Promoting Coordinated and Steady Development of Natural Gas and the National Development and Reform Commission has issued and implemented the 13th Five-Year Plan on Natural Gas

Development to advance the construction of an integrated production-supply-storage-marketing system for natural gas development. In 2020, the production and consumption of natural gas amounted to 334.0 billion m^3 and 192.5 billion m^3, respectively, and the proportion of natural gas in the energy consumption mix reached 8.4%, 2.6 percentage points up from the level in 2015. As of the end of 2020, a total of 112,000 km-long natural gas pipeline was laid to form a unified national network; coastal LNG receiving stations had a total capacity of 93 million tons per year. The capacity of peak shaving for gas storage has improved remarkably, and a comprehensive peak shaving regulation system for gas storage has been largely established, which is dominated by underground gas storage and storage tanks in coastal LNG receiving stations, and supplemented by other regulating measures.

2.2.3 Intensifying the Development and Utilization of Unconventional Natural Gas

The National Energy Administration has issued and implemented the 13th Five-Year Plan on Coalbed Methane (Coal-mine Gas) Extraction and Utilization to advance the sustained, sound and rapid development of the coalbed methane (CBM) industry, placing ground exploitation of CBM and coal-mine gas extraction on an equal footing, with the construction of CBM industrialization bases and large-scale mining areas for coal-mine gas extraction as the priority. CBM industrial bases in the Qinshui Basin and the Ordos Basin were completed in 2020, leading to constant progress in the extraction and comprehensive utilization of coal-mine gas and producing good results in carbon emission reduction in addition to increasing the supply of clean energy and promoting coal mine safety. As shale gas is being commercialized at a faster pace in the 13th FYP period, China saw a 2 billion m^3 production of shale gas in 2020 and has built demonstration areas for commercial exploitation represented by the Sichuan Basin and its surrounding marine facies. Favorable fiscal and tax policies have been rolled out to incentivize the exploitation and utilization of unconventional natural gas. Since the start of 2019, unconventional natural gas such as shale gas, CBM and tight gas has been included in the scope of subsidy. According to the principle of “more subsidies for larger production, more subsidies for production increase in winter” and based on increment performance and ladder-type rewarding methods, subsidies have been granted to incentivize local governments and businesses to ramp up capacity.

2.2.4 Improving Energy Utilization Efficiency and Promoting Energy Conservation

China is constantly improving energy conservation-related laws and regulations and standard systems. China has revised the Energy Conservation Law of the People's Republic of China, put in place an energy-efficient system in key areas including industry, construction and transport as well as in public institutions, and improved the supporting legal institutions for energy conservation supervision, energy-efficiency labeling, energy-efficient checks on fixed assets investment projects, and energy conservation management of key energy consumers. It has strengthened the role of standards, improved energy-saving standards system, carried out 100 projects to upgrade energy efficiency standards, enacted more than 340 national energy-saving standards, including almost 200 mandatory standards that cover most high energy-consuming industries and final energy consumption products. China has strengthened oversight over energy-saving law enforcement, reinforced operational and post-operational supervision, and exercised strict accountability for law enforcement to ensure the effective implementation of energy conservation laws, regulations, and mandatory standards.

China is doing all it can to optimize the industrial structure, develop advanced manufacturing, high-tech industry and modern services with low energy consumption, and promote the intelligent and clean transformation of traditional industries. Energy efficiency in industry, construction and transport has been improved across the board. A market-oriented system of green technology innovation has been put in place to encourage the R&D, transfer and popularization of green technology. China is promoting national key energy-efficient and low-carbon technologies, particularly for the transport sector, and energy-efficient industrial equipment. The government encourages extensive public involvement in energy conservation, and is raising public awareness of frugality, promoting simple, modest, green and low-carbon lifestyles, and opposing extravagance and excessive consumption.

China is committed to improving energy-efficient and low-carbon incentives and promoting clean final energy consumption. The government is promoting energy performance contracting (EPC) and developing integrated energy services, and encouraging innovations in energy-saving technology and business models. It has strengthened the management of demand-side power use and implemented a market response mechanism to guide the economical, orderly and rational utilization of electricity. Best energy-savers are set as role models to increase the efficiency of final energy consumption products, energy-intensive industries, and public institutions.

A dual control system of total energy consumption and energy intensity is in place. China sets the targets of total energy consumption and energy intensity for different provinces, autonomous regions and municipalities directly under the central government and applies oversight and checks over the performance of local governments at all levels. It has introduced energy-efficient indicators into the performance evaluation system of eco-environmental progress and green development, to guide the transformation of the development philosophy. It breaks down the dual control targets of total energy consumption and energy intensity for key energy consumers, and evaluates their performance accordingly to strengthen energy-efficient management.

Chapter 3 Clean and Low-Carbon Transition in Industry

Since the start of the 13th FYP period, China has pursued industrial transformation and upgrading, scaled up energy-efficient renovations, broadened the application of energy-efficient technologies and exercised stricter control over energy-intensive and high-emission projects to reduce the consumption of resources and energy and curb GHG emissions in the industry. Energy consumption for the added value in China's industrial enterprises above the designated scale has been reduced by 16% in the period, and carbon dioxide emissions per unit of industrial added value in 2020 were about 22% lower than in 2015.

3.1 Industrial Transformation and Upgrading

China continues to address excess production capacity in key sectors to accelerate the green and low-carbon industrial transition. In 2016, the Ministry of Industry and Information Technology (MIIT) issued the Green Development Plan for Industrial Sectors (2016-2020), aiming to advance supply-side structural reform, facilitate steady growth and structure adjustment in industrial sectors, and promote energy conservation and cost reduction. The plan also specified many important tasks relating to the optimization of industrial structure and energy consumption mix, energy efficiency improvement, clean production, comprehensive utilization of resources and cuts in GHG emissions. Such key sectors as the petrochemical industry, electric power, coal and steel are being transformed and upgraded at a faster pace, where outdated production capacity is being phased out according to laws and regulations. In the 13th FYP period, the NDRC and other authorities jointly issued circulars to elaborate on annual targets and tasks in addressing excess capacity in key sectors. The government has released 12 enterprise lists for key industrial fields that were required to shut down outdated production facilities and conducted annual supervision and inspection from 2018 to 2020 to ensure the elimination of outdated production facilities in accordance with laws and regulations. China has largely established long-term mechanisms for phasing out outdated capacity, fulfilled ahead of schedule the goal of reducing 150 million tons of excess capacity in the steel sector, eliminated a capacity of more than 100 million tons of low-quality steel made from scrap metal[32], and basically addressed outdated capacity in electrolytic aluminum and cement sectors. In 2020, up to 380 million tons of renewable resources in ten major categories were recycled, and around 2 billion tons of industrial solid wastes were comprehensively utilized.

China is resolutely curbing the haphazard development of energy-intensive and high-emission projects. China continues to strictly control the haphazard expansion of energy-intensive and high-emission projects. It has implemented strict market access standards for 13 industries including iron & steel, ferroalloy, and coking, tightening requirements on land, environmental protection, energy conservation, technology, and safety, and put in place the national policy on differential electricity prices, raising

[32] Low-quality steel made from scrap metal refers to steel made from scrap iron and steel, melted by induction furnace or other smelters, that cannot be effectively controlled in composition and quality. It also refers to steel rolled with low-quality steel made from scrap metal.

standards for the differential electricity prices for energy-intensive products and expanding the scope of differential electricity prices. It required local governments to clearly identify all energy-intensive and high-emission projects, produce category-based management proposals, carry out special inspections, strictly punish any such projects constructed or operated in contravention of regulations, and implement list management, category-based handling, and dynamic monitoring of energy-intensive and high-emission projects. It has established a sound, complete public reporting, early warning, censorship, and accountability mechanism. The Ministry of Ecology and Environment has issued the Guidelines for Strengthening Source Control over Ecological Environment in Energy-Intensive and High-Emission Projects to curb the blind development of energy-intensive and high-emission projects. List-based management has been practiced to list out all the energy-intensive and high-emission projects to be built, under construction and well completed. Based on the lists, China steps up guidance to make the list of projects that have begun construction prior to approval and the list of projects to be investigated, and urges local authorities to make due arrangements. It is necessary to reinforce examination and approval for environmental impact assessment, guide local governments to tighten examination and approval and limits of examination and approval authority for environmental impact assessment of energy-intensive and high-emission projects, and revise a batch of regulations on environmental access for energy-intensive and high-emission projects. Moreover, it is required to strengthen the review of environmental impact assessment reports for energy-intensive and high-emission projects to tighten source control.

3.2 New and High-Tech Industries and Emerging Industries of Strategic Importance

From 2016 to 2019, emerging industries of strategic importance sustained steady growth in industrial added value at an annual average rate of 10.5%, outperforming industries above the designated scale by 4.4 percentage points; emerging services of strategic importance saw revenue growth at an annual average rate of 15.2%, 3.9 percentage points higher than that in the service sector over the same period. High-tech manufacturing sector and equipment manufacturing sector, which generated 15.1% and 33.7% of the total added value in industries above the designated scale in 2020, increasing by 3.3 percentage points and 1.9 percentage points, respectively, have become important drivers of industrial structural transformation and upgrade, and high-quality economic growth.

3.3 Energy Conservation and Carbon Emission Reduction in Industrial Sectors

China has been working hard to improve modes of energy consumption to enhance energy efficiency in industrial sectors. In 2016, the NDRC and the National Energy Administration jointly issued the Energy Supply and Consumption Revolution Strategy (2016-2030), which proposed launching a special campaign on electric power demand-side management in industrial sectors, drawing up guidelines, and creating and spreading exemplary experience in transport, construction and commerce, among other sectors. The subsequent Special Action Plan for Power Demand-Side Management in Industrial Sectors (2016-2020), issued by the Ministry of Industry and Information Technology has elaborated on systematic guidelines on electric power demand-side management in industrial sectors including industrial enterprises and parks, aiming to pave the way for revolutionizing energy consumption in industrial sectors, and improve across the board energy efficiency and responsiveness by providing better-quality electric energy, scaling up electric equipment renovations and applications of information technology, and promoting substitution of electric energy, utilization of distributed energy, and clean and cyclic utilization of energy. According to the Guidelines on Electric Power Demand-side Management in Industrial Sectors issued in 2019, industrial enterprises or parks have received guidance on optimizing power consumption mix, adjusting modes of power consumption, and better allocating resources to enhance energy efficiency per unit of industrial added value, and more than 400 institutions have been mobilized to provide energy-efficient diagnosis to 14,000 enterprises across the country with energy conservation and made 25,000 proposals on energy efficiency. In the same year, the Ministry of Industry and Information Technology issued the Action Plan on Energy Conservation Diagnosis Services in Industrial Sectors, according to which the energy-efficient diagnosis campaign has been launched nationwide for the first time among enterprises with weaknesses in energy management and key energy-intensive sectors, so as to further enhance energy efficiency and bolster green development in industrial sectors. Meanwhile, special national inspections on energy conservation are carried out annually to instruct enterprises to use energy rationally in accordance with laws and regulations. In the 13th FYP period, a total of 23,470 industrial enterprises have been inspected. The proportion of enterprises violating laws and regulations declined to 2.9% in 2020 from 10.3% in 2016, and 96% of building materials enterprises have met mandatory energy consumption limits.

Giving play to the guiding role of standards on energy efficiency, the Ministry of Industry and Information Technology focuses on green development needs in industrial sectors. China has established a system of green manufacturing standards focusing on green products, green factories, green parks and green supply chains, formulated and revised energy efficiency standards on key general-purpose industrial equipment such as industrial boilers, electrical machinery and transformers to improve the standardization of green development in industrial sectors. It has brought into play the role of enterprises in formulating standards and incentivized them to formulate their own standards that are more stringent than both national and industrial standards to upgrade green development in industrial sectors. Also, it has worked hard to advance mutual recognition of standards, make its standards internationally compatible, and motivated enterprises, scientific research institutes and industrial organizations to participate in or lead the formulation of international standards on energy conservation and environmental protection, new energy, new materials and NEVs. Efforts have been beefed up to supervise and assess the implementation of mandatory standards, evaluate the effects, and put in place statistics, analysis and reporting rules for the implementation of mandatory standards. Furthermore, exemplary energy-saving enterprises are annually selected from key sectors such as steel, electrolytic aluminum and cement so that their peers can better observe standards. The green manufacturing system, consisting of 468 industry standards on energy conservation and green development, 2,121 green factories, 171 green industrial parks, 189 green supply chain enterprises and around 20,000 green products, has underpinned the green transition.

China continues to roll out favorable fiscal and tax policies. In 2017, the Ministry of Finance, the State Taxation Administration, the National Development and Reform Commission, the Ministry of Industry and Information Technology and the Ministry of Environmental Protection[33]jointly issued the catalog of special energy-efficient, water-saving and environmental protection equipment qualified for preferential corporate income tax (2017 version), according to which China has adjusted the above catalog, and rolled out policies on offsetting corporate income tax with a certain proportion[34]of amounts invested in the above equipment.

[33] According to institutional restructuring in 2018, the Ministry of Ecological Environment was founded to replace the Ministry of Environmental Protection.

[34] Preferential treatment: As long as enterprises have indeed purchased and used any energy-efficient and water-saving equipment included in the Catalog of Energy-Efficient, Water-Saving and Environmental Protection Equipment Qualified for Preferential Corporate Income Tax, 10% of the amount for purchasing the special equipment can offset part of the enterprise's tax amount payable in the year; in the case that the creditable tax is not enough, the remaining amount can continue to be offset in the next five taxable years.

Chapter 4 Green and Low-Carbon Development of the Building Sector

In the 13th FYP period, China has made remarkable progress in the low-carbon development of the building sector by vigorously advancing green construction in both urban and rural areas, continuously improving energy efficiency in buildings, promoting clean-energy heating options in northern China and piloting green rural housing construction. As of the end of 2020, China's new green buildings in the urban area have covered an area of more than 6.6 billion m^2, accounting for 77% of all new buildings in the year; with a total of more than 23.8 billion m^2 in area, energy-efficient buildings comprised over 63% of civil buildings in terms of construction area.

4.1 Improving Energy Efficiency in Buildings

Efforts have been made to facilitate energy conservation in new buildings and existing buildings. The Ministry of Housing and Urban-Rural Development has issued the Green Building Action Plan to enhance energy efficiency standards for new buildings in urban and rural areas. Also, it issued national and industrial standards for engineering construction on areas including the acceptance of energy efficient building, energy, energy consumption, nearly zero energy building specifications, design of energy efficient buildings in cold and severe cold regions and design of energy efficient buildings in regions with a moderate climate. Thanks to these efforts, local governments have controlled project survey and design quality more stringently, ensured the implementation of mandatory standards on energy-efficient buildings and improved energy efficiency in the building sector. Energy-efficient reconstruction of existing buildings has been steadily advanced. In the 13th FYP period, a total of 514 million m^2 and 185 million m^2 of existing residential and public buildings have been retrofitted with energy-efficient designs, respectively.

Public institutions have played a guiding role. The National Government Offices Administration has issued documents and standards for public institutions on energy-efficient action plans, best energy-saver evaluation, promotion of energy-saving models, investigation systems for energy consumption, and the setting of energy consumption quota. As of the end of 2020, about 35% of CPC and governmental institutions at the county level and above have finished conservation-oriented transformation, all head offices of central and state authorities have finished conservation-oriented transformation, 5,114 demonstration public institutions for conservation were built, 376 pioneering public institutions in terms of energy efficiency were selected, and 768 exemplary energy and resource-efficient practices in public institutions across the country were chosen and publicized. The energy consumption per unit of construction area and the comprehensive energy consumption per capita for nationwide public institutions in 2020 saw a drop of 10.1% and 11.1% respectively from 2015.

Energy conservation has been integrated into the renovation of dilapidated rural houses. In 2018, the Ministry of Housing and Urban-Rural Development and the Ministry of Finance jointly issued the Three-Year Action Plan for Renovation of Dilapidated Rural Houses, according to which households registered as living under the poverty line were prioritized. From 2019 to 2020, some provinces piloted building energy efficiency in the renovation of dilapidated rural houses to step up guidance on energy-efficient rural housing design and other techniques, and widen applications of new energy-efficient technologies, products and materials in rural housing construction and energy-conserving renovations. As a result, rural building-based energy-efficient demonstration households in northeast, northwest, and north China as well as Xizang have saved at least 0.5 tons of coal from their heating supply every year.

China has stepped up financial support for the building energy conservation drive. From 2011 to 2017, the central government arranged subsidies to fund demonstration energy-efficient rural housing projects for 1.13 million households in northern China in the process of renovating dilapidated rural houses. From 2018 to 2020, the central government had granted a total of 45.2 billion yuan worth of subsidies to fund the renovation of dilapidated rural houses and houses highly vulnerable to earthquake shaking, and encouraged well-off regions to launch energy-efficient renovations in the meantime. Six cities including Shaoxing piloted the use of green materials and pre-fabricated and intelligent construction in public buildings like hospitals and schools, where pilot projects were totally worth 102.5 billion yuan. From 2016 to 2020, more than 14.5 billion yuan of public funds were invested to renovate in an energy-efficient manner an area of about 50.5 million m^2 for air-conditioning ventilation systems in public institutions.

4.2 Promoting Clean-Energy Heating in Northern China

In 2017, ten national authorities including the NDRC jointly issued the Clean Winter Heating Plan in Northern China (2017-2021) to coordinate efforts in achieving clean-energy heating. Since the start of 2017, the Ministry of Finance, the Ministry of Housing and Urban-Rural Development and the Ministry of Environmental Protection[35] have jointly worked to implement experimental policies on clean winter heating in northern China, promote the substitution of clean-energy heating for coal combustion in pilot cities and help rural residents develop green lifestyles. In 2019, the NDRC, the Ministry of Finance, the Ministry of Ecological Environment, the Ministry of Housing and Urban-Rural Development and the National Energy Administration jointly issued the Circular on Further Promoting clean-energy heating to instruct local governments to move forward with the clean-energy heating drive. The NDRC and the National Energy Administration have co-launched the inter-ministerial meeting on clean-energy heating and the scheduling mechanism for coordinated transport of coal and electricity and natural gas guarantee in the heating seasons. The National Energy Administration has carried out a special campaign to supervise clean winter heating in the northern region. The Ministry of Ecological Environment has annually guided the relevant authorities in the Beijing-Tianjin-Hebei region and its surrounding areas as well as cities on the Fenhe-Weihe River Plain by assigning tasks covering the household level based on local

[35] According to institutional restructuring in 2018, the Ministry of Ecological Environment was founded to replace the Ministry of Environmental Protection.

conditions. These arrangements have been made through the action plan for combating air pollution in autumn and winter in key regions. The oversight and assistance campaigns on clean-energy heating are launched annually and the mechanism for verifying and overseeing issues arising from clean-energy heating are put in place. The Ministry of Housing and Urban-Rural Development has guided the way for clean-energy heating in northern China's rural areas where energy-efficient renovations were also underway, instructed local governments to optimize urban heating pipeline planning and ramp up efforts in energy-efficient renovation of heating facilities such as old heating pipelines and heat converting stations. The National Government Offices Administration has helped advance metering and energy-efficient renovations for heating systems in northern China's public institutions, where an area of up to 36 million m^2 has been renovated. Ministries have formed synergy in promoting clean-energy heating, reducing bulk coal consumption and cutting GHG emissions. As of the end of 2020, more than 60% of winter heating has been supplied by clean energy sources including natural gas, electricity, geothermal energy, biomass and solar power in northern China.

4.3 Pilot Green Rural Housing Construction

Green rural housing is constructed. In 2013, the Ministry of Housing and Urban-Rural Development alongside the Ministry of Industry and Information Technology issued circulars on guiding the construction of green rural housing. Since then, a batch of demonstration green rural housing has been built across the country, green building materials have been adopted in rural areas to enhance the energy-efficiency of buildings, so that rural housing is improved in terms of quality, function and attractiveness.

The construction of livable houses is piloted. In 2019, the Ministry of Housing and Urban-Rural Development issued the Circular on Piloting Rural Housing Construction, according to which modern livable rural housing such as pre-fabricated steel structures and passive solar housing has been piloted in many counties of Zhejiang, Hebei, Hainan and Qinghai, and well-off regions and households have been guided to utilize pre-fabricated architecture and passive solar housing and other building technologies to make rural housing increasingly energy-efficient. With the application of new-type building insulation technologies such as thermal insulation-structure integration and the rational use of solar power, biomass energy, geothermal energy and wind energy, among other forms of renewable energy in light of building functions and local climatic features, a number of demonstration livable rural houses, featuring modern functions, structural safety, affordable cost, environmental protection and compatibility with rural environment, have been built.

Chapter 5 A Low-Carbon Transport System

In the 13th FYP period, Chin issued an implementation plan for promoting ecological progress in the transport sector and the railway development plan during the 13^{th} FYP, to further facilitate energy-efficient and low-carbon development of highways, railways, water transport and civil aviation.

5.1 Promoting Energy Conservation in Transport

The Ministry of Transport and other ministries have jointly issued action plans for green travel for the period from 2019 to 2022, laying out the strategy for prioritizing urban public transport, building demonstration cities for public transport, instructing local governments to ramp up efforts on public transport development, stepping up policy support and driving urban development with public transport. The Ministry of Transport and the NDRC have jointly issued the criteria for green travel evaluation to guide local governments in terms of green travel and its demonstration projects on public transport in 87 cities. As of the end of 2019, 190 urban rail transit lines in 41 cities were in operation, covering a mileage of more than 6,100 km. As of the end of 2021, 33 cities were chosen as national demonstration cities for public transport, and more than 100 cities across the country launched campaigns on green travel. The electronic toll collection (ETC) system has been promoted nationwide so that vehicles could pass expressway tollgates quickly. Efforts have been beefed up to verify whether road transport vehicles are up to the latest standards and update timely the types of commercial passenger and cargo vehicles that comply with requirements on safety and energy efficiency, in a bid to drive off-specification vehicles out of the road transport market.

China's railway passenger volume has seen steady growth. In 2019, China's railway passenger volume hit 3.66 billion persons, and passenger turnover amounted to 1,470.66 billion passenger-km, up 55% and 27% from 2014, respectively. China's railway cargo transport volume also increased rapidly, with a cargo volume of 4.77 billion tons and a cargo turnover of 3,323.8 billion ton-km in 2021. The railway sector has seen wide applications of new environment-friendly technologies, equipment and processes as well as new energy, new materials and new products. Efforts have been made to strengthen the examination of energy-efficient, environment-friendly and resource-conserving or sharing technologies, optimize energy-efficient designs for railway engineering and stations, pursue green development throughout the process of railway planning and construction and advocate green consumption and green travel to help weaken the energy consumption intensity at a steady step.

The Civil Aviation Administration of China issued plans on deepening the green development of civil aviation and the three-year action plan to fight air pollution in civil aviation, which clarify targets and requirements in regard to "fuel to electricity (FTE)" and auxiliary power unit (APU) replacement projects. As of the end of 2019, APU replacement was fulfilled as long as conditions permitted, thus reducing carbon dioxide emissions by 760,000 tons annually; approximately 7.5% of ground support vehicles in civil airports were electric, which could help reduce the consumption of gasoline and diesel; airports saw an increasingly improved energy mix, in which electric power, natural gas and outsourced thermal power comprised up to 83%, and clean energy such as solar energy and geothermal energy occupied about 1.4%. In 2019, about 373,000 flights followed provisional air routes, which resulted in a reduction of 15.7 million km in flying distances and 85,000 tons less fuel consumed. In this way, close to 1.3 million tons of carbon dioxide emissions have been cut since 2019.

5.2 Widening Applications of New Energy in Transport

The Ministry of Industry and Information Technology and the Ministry of Finance, along with another 14 ministries, have issued the action plan for promoting the electrification of vehicles in public sectors, which stipulates that Party and government offices and public institutions need to give preference to NEVs, and lists rules on vehicle renewal and use in these institutions, aimed at promoting the application of NEVs. In the 13th FYP period, public institutions across the country have purchased about 261,000 NEVs and built around 187,000 charging facilities; as of the end of 2020, China was home to 466,000 electric buses in urban public transport and 132,400 new energy-powered taxies. China has launched demonstration campaigns on green cargo transport and delivery to widen the use of NEVs for cargo delivery in cities. As of the end of 2019, 46 demonstration cities had 38,000 new energy-powered logistics vehicles, pushing the total ownership to more than 122,000 units and extending the average daily range per vehicle by 10% in favor of remarkable energy conservation and emission reduction in the cargo transport sector. Nearly 100 colleges and universities have put in place the digital energy supervision system, installed charging posts for NEVs and increased the share of NEVs in their shuttle buses.

China has rolled out fiscal policies to promote NEVs, such as grants of financial subsidies. The Ministry of Finance joins hands with other departments to increasingly improve policies for subsidizing NEV purchases, tighten technical thresholds for subsidies, and reduce subsidies gradually in rational magnitude and pace to advance the high-quality development of NEVs. Measures such as differentiated consumption tax rates, and reduction of and exemption from vehicle purchase tax and vehicle and vessel tax have been taken to promote green and low-carbon mobility. Applicable consumption tax rates for passenger vehicles and motorcycles have been set according to the principle that "the larger engine capacity a vehicle has, the more tax the owner has to pay"; NEV purchases have been exempted from tax. Since 2019, the Ministry of Industry and Information Technology and the State Taxation Administration have jointly listed 8,712 energy-efficient NEV models qualified for vehicle and vessel tax reduction and exemption in 38 batches, 14,333 energy-efficient NEV models qualified for purchase tax exemption in 38 batches, and 5,318 NEV models covered by promotion and application campaigns types in 29 batches. As of the end of 2020, China has promoted the sales of more than 4.5 million NEVs, accounting for over half of global sales.

With redoubled efforts in electrification of existing railways and a gradual rise in the share of electrified railways in transport, China has made remarkable progress in the road network electrification rate, which rocketed to 73.3% in 2021 from 60.8% in 2015.

Furthermore, heavy haul railways for cargo transport, including Haolebaoji-Ji'an Railway, Tangshan-Baotou Railway and Watang-Rizhao Railway which have been completed and put into operation, are promoted to greatly improve transport efficiency and reduce carbon emissions in railway cargo transport on a continual basis. The declining energy consumption in railway transport over the years has contributed greatly to the low-carbon development of China's transport sector. For example, the comprehensive energy consumption for transport in the national railway system in 2020 dropped to 4.07 tons of standard coal per kilometer.

To advance the utilization of shore power for ship berthing, the Ministry of Transport has formulated or revised regulations in terms of shore power for ports and ships and port engineering construction as well as mandatory industry standards on the construction and testing of shore power facilities of ports. A policy has been rolled out to prioritize LNG-power ships in passing through ship locks at the Three Gorges Dam, aimed at advancing the application of LNG.

5.3 Accelerating Adjustments in the Transport Structure

China has been continuously replacing highway transport with railway and water transport for commodities, guiding railway transport enterprises to enter into mutual guarantee agreements on transport volume and capacity with large-sized industrial and mining enterprises on coal, ores and steel and port enterprises to increase the share of railway transport, expanding the application of "open top container transport by railway +drayage" for these iron and steel enterprises without dedicated lines to transport more metallic ores, and widely launching demonstration projects on multimodal transport to form green and low-carbon modes of transport and reduce energy consumption, air pollutant and carbon emissions. As of the end of 2020, all coal headed for major coastal ports was transported by either railway or water, rail-water combined transport for port containers saw rapid growth, and 61.3% of ores were evacuated from ports by railway, water and belt conveyors, increasing by nearly 20 percentage points from 2017.

The Ministry of Transport, the Ministry of Public Security and the Ministry of Transport have co-launched the demonstration campaign on green transport and delivery to improve transport efficiency and cut GHG emissions. The candidate demonstration cities have pooled logistics resources, innovated modes of delivery, improved comprehensive public cargo transport hub facilities and rolled out favorable traffic policies for urban delivery vehicles to integrate intercity artery transport and urban terminal delivery, enable an intensive and efficient urban cargo transport and delivery system, and make circulation more efficient and facilitate energy conservation and emission reduction. As an important part of the campaign, the application of new energy logistics vehicles has been widened in the regions where efforts were made to optimize urban delivery networks, roll out subsidy policies, improve traffic conditions and guarantee the right of way for NEVs.

Chapter 6 Effectively Consolidate and Improve Ecosystem Carbon Sinks

During the 13th FYP period, China pursued green development and intensified the efforts to carry out ecological conservation in an all-round way. From the development of territorial spatial planning to the maintenance of ecological conservation red line, and from the implementation of major ecological conservation and restoration projects to the enhancement of forest resources protection, the quality and stability of ecosystems had been improved continuously to achieve carbon sequestration, increase carbon sinks, and avoid losses from carbon pools.

6.1 Strengthened Carbon Sequestration

Since 2019, the Ministry of Natural Resources has initiated the preparation of the Outline of Territorial Spatial Planning (2021-2035). The Ministry has also guided local governments in the formulation of various types of territorial spatial planning at all levels to develop suitability evaluation based on the supporting capacity of resources and environment and the territorial spaces, to take green, low-carbon, safe and resilient development and protection measures, to build ecological safety barriers, to improve biodiversity, to build a new development and protection pattern of territorial spaces, and to enhance the functions of ecosystem services. In addition, the Ministry had been taking the lead in the demarcation (evaluation and adjustment) of the national ecological protection red line, prioritizing protection and trying the best to protect more areas. Areas with extremely important ecological functions, extremely vulnerable ecology and potentially important ecological value had been included in the red line of ecological protection, drawing the “master map” of territorial spatial planning to manage important ecological spaces with a single red line. The ecological protection red line covered most typical terrestrial natural ecosystems such as natural forests, grasslands and wetlands, and typical marine natural ecosystems such as mangroves, coral reefs and seagrass meadows. The terrestrial ecological protection area demarcated by the red line accounted for over 30% of the total land area. The red line further consolidated the national ecological safety pattern and strengthened the carbon sequestration of ecosystems

Climate change had been integrated into the technical specifications for territorial spatial planning. The Ministry of Natural Resources had issued a number of documents, including the Guideline for the Development of Provincial-Level Territorial Spatial Planning (for trial implementation), clearly requesting local authorities to adopt green, low-carbon, safe and resilient development measures, make overall plans to demarcate the red line of ecological protection, control the total energy consumption, use local clean energy and build low-carbon cities through territorial spatial planning. Besides, climate change has also been integrated into the technical specifications for the implementation and supervision of territorial spatial planning. The Rules for Urban Examination and Evaluation of Territorial Spatial Planning issued by the Ministry of Natural Resources requests cities and counties all over the country to carry out regular examinations and evaluations on green, low-carbon production and lifestyle based on low-carbon indicators including the reduction ratio of CO_2 emission per unit GDP, the coverage area of distributed clean energy facilities and the proportion of green transport.

6.2 Improved Carbon Sink Capacities

The National Forestry and Grassland Administration issued several instructive documents, such as Opinions on Actively Promoting Large-scale Territorial Greening Actions and the Work Plan for Further Promoting Afforestation and Greening, and developed and implemented the Outline of National Afforestation and Greening Planning (2016-2020) and two three-year rolling plans of afforestation for 2016-2018 and 2018-2020. Taking greening, quality improvement and efficiency enhancement as the main direction, large-scale territorial greening actions had been implemented to increase the total amount of green resources through various methods and channels. Efforts included increasing the total amount of ecological resources over large areas, further promoting the project of returning farmland to forestland and grassland, strengthening the construction of shelter forest systems such as the Northwest-North-Northeast China (Sanbei) Shelter Forestation Project, accelerating the construction of national reserve forests, greening urban and rural areas steadily, promoting social afforestation and providing more green and ecological products. The National Greening Committee had issued the measures for the management of responsible forms of national voluntary tree-planting (for trial implementation), expanding the scope of responsible forms to eight categories. The pilot project of "Internet + national voluntary tree-planting" had been launched in 15 provincial-level administrative regions across the country, preliminarily integrating online and offline voluntary tree planting. More than 500 million people had been mobilized to participate in voluntary tree-planting through green travel and low-carbon life. The targets were as follows: to greatly improve the quality of ecological resources, to advance the transformation of territorial greening from scale- and speed-oriented to quantity-, quality- and efficiency-oriented, to pursue greening in a well-conceived, ecological and economical manner, to enhance the quality of forest and grass resources precisely, to strengthen the conversion and restoration of natural and degraded forests, and to improve the functions of ecological services and the productivity of forestland and grassland.

During the 13th FYP period, 25 ecological projects are piloted to protect and restore mountains, waters, forests, farmlands and grasslands, coordinating all the natural ecological elements in the pilot areas and implementing overall protection, systematic restoration and comprehensive management. Ecological restoration of mines that were left over from the past in key areas had been resumed, so had marine ecological protection and restoration, including "Blue Gulf" renovation action of coastal cities, the comprehensive renovation and management project of the Bohai Sea and the protection and restoration project of coastal zone. In June 2020, the National Development and Reform Commission and the Ministry of Natural Resources developed and issued the National Master Plan for Major Protection and Restoration Projects of Important Ecosystems (2021-2035), focusing on building national ecological safety barriers in accordance with the idea of a life community of mountains, waters, forests, farmlands, grasslands and deserts. The nine major projects, which were of great significance for continuously improving the capacity of carbon sinks in areas with key ecological functions, can be divided into two categories. The first was seven major projects of ecological protection and restoration in "four areas and three zones," consisting of the Qinghai-Xizang Plateau ecological barrier area, North China sand prevention zone, North-East China forest zone, the Yellow River key ecological area (including the Loess Plateau ecological barrier), the Yangtze River key ecological area (including Sichuan-Yunnan ecological barrier), South China hills and mountains zone as well as the coastal zone. The second was two individual projects, which were nature reserves and wildlife protection and support system of ecological protection and restoration. In September 2020, the Ministry of Natural Resources issued the Notice on Developing Ecological Restoration Planning of Provincial-level Territorial Spaces, requesting provincial-level administrative regions, including provinces, autonomous regions and municipalities directly under the central government, to make overall plans for ecological restoration in local territorial spaces. In 2020, the Special Action Plan for Mangrove Protection and Restoration (2020-2025) was issued to further strengthen the protection and restoration of mangroves and improve the carbon sequestration capacity and level of marine ecosystems.

During the 13th FYP period, China had completed a total of 545 million *mu* of afforestation, 637 million *mu* of forest tending, and 48.05 million *mu* of national reserve forest construction. The forest coverage rate had increased to 23.04%, and the forest stock had exceeded 17.5 billion m^3, maintaining "double growth" for 30 consecutive years and making China the country with the world's largest increase in forest resources. Another 98 new national forest cities had been fostered and the living environment in urban and rural areas had improved significantly. The major project of grassland protection and restoration had gone through in-depth implementation and the pilot project of artificial grass-planting and ecological restoration had been officially launched. The comprehensive vegetation coverage of natural grasslands reached 56.1%, and the total output of fresh grass in natural grasslands exceeded 1.1 billion tons. From 2015 to 2020, 32,747,500 *mu* of grass was artificially planted, 25,996,500 *mu* of grass was replanted and improved and 188,723,200 *mu* of grass was enclosed for tending; in addition, gazing was prohibited on 1.2 billion *mu* of grassland and the balance between grass and livestock was reached for 2.6 billion *mu* of grassland.

6.3 Reduced Losses from Carbon Pools

China has further strengthened the protection of natural resources in every aspect to avoid losses from carbon pools. Measures taken in this regard included strictly protecting and rationally using all types of natural resources, cracking down on all kinds of illegal and criminal acts such as deforestation, grass destruction and wetland destruction, prohibiting unauthorized changes in the uses and natures of forestland, grassland and wetland, and reducing GHG emissions caused by unreasonable land use and destruction. In addition, China had comprehensively enhanced fire prevention in forests and grasslands, implemented disease and pest control, and endeavored to reduce the frequency of fire disasters, so as to reduce the losses from carbon pools in ecosystems. During the 13th FYP period, the number of forest fires, the total burned area and the affected forest area decreased by 44%, 34% and 20% respectively in comparison with the 12th FYP period; to be more specific, compared with 2015, these three figures decreased by 61%, 24% and 34% respectively in 2020. Meanwhile, the control area of forest diseases, pests and rodents, the control area of forest diseases and the control area of forest pests increased by 21%, 68% and 13% respectively; to be more specific, compared with 2015, the three figures increased by 15%, 143% and 1% respectively in 2020.

Chapter 7 Strengthened Control over Non-CO_2 GHG Emissions

The Chinese government attaches great importance to the control of non-carbon dioxide GHG emissions. As early as 2011, the Work Plan on Greenhouse Gas Emission Control for the 12th FYP clearly put forward a series of major targets, one of which was to achieve progress on the control of CO_2 emissions from non-energy-related activities and other greenhouse gas emissions including CH_4, N_2O, HFCs, PFCs and SF_6. The Work Plan on GHG Emission Control for the 13th FYP further proposed that the emission control of non-CO_2 GHG such as HFCs, CH_4, N_2O, PFCs and SF_6 should be further tightened. Non-CO_2 GHG emissions mainly came from energy, industry, agriculture and waste treatment, and the mechanism of non-CO_2 GHG emissions in each field had its own characteristics. Relevant competent governmental departments had adopted a series of incentive policies and actions to control non-CO_2 emissions.

7.1 Energy

The majority of non-CO_2 GHG emissions in the field of energy was methane released or leaked from strata or mining equipment during coal and oil & gas exploitation. Since the 12th FYP period, for the purpose of safe production or resource recycling, China has taken the initiative to carry out activities in relation to methane emission control or methane resource recycling.

Coal. The first action was to eliminate outdated production capacity and control methane emissions in the coal mining industry at the source. The Opinions on Tackling Overcapacity in Coal Industry and Addressing Development Challenges issued in 2016 proposed to withdraw production capacity of about 500 million tons in three to five years, reduce and restructure about 500 million tons, and control methane emissions from coal mining with outdated production capacity. The second action was promoting the procedure of extracting gas before coal mining, researching and developing technologies and equipment that can use low-concentration gas, improving the utilization rate of extracted gas and reducing methane emission. In 2016, the Notice on Subsidy Standards for the Development and Utilization of Coalbed Methane (Gas) for the 13th FYP issued by the Ministry of Finance raised the subsidy standard from 0.2 yuan to 0.3 yuan per m^3.

Oil & Gas. Efforts were made to strengthen the recovery and utilization of venting gas and associated gas in oil fields, innovate the recovery and sales mode of scattered gas, and reduce venting. Also, domestic oil and gas enterprises were encouraged to take the initiative to carry out methane emission reduction or recycling. For example, China National Petroleum Corporation (CNPC) joined the Oil and Gas Climate Initiative (OGCI) in 2015 and participated in the formulation of OGCI-2040 Low Emissions Roadmap. It also developed the Action Plan for Methane Emission Control of CNPC, which committed itself to reduce the methane emission intensity in the upstream of oil and gas supply chain to 0.25% by 2025. And in 2018, Beijing Gas Group joined Methane Guiding Principles (MGP), a partnership of methane emission reduction in the whole value chain of the natural gas industry, and actively participated in the exchange of technologies and experiences about methane reduction in the urban gas industry. In addition, methane and pollutants were treated coordinately in the oil and gas industry. The Ministry of Ecology and Environment issued the Comprehensive Treatment Plan for Volatile Organic Compounds in Key Industries in 2019 to promote the coordinated treatment of methane and volatile organic compounds in the oil and gas industry.

7.2 Industry

Sources of non-carbon dioxide GHG emissions in the field of industry included nitrous oxide emission generated in the production processes for nitric acid, and adipic acid and emission of F-gases such as PFCs, HFCs and SF_6 in the industrial processes including electrolysis of aluminum, manufacturing and operation of power equipment, production of semiconductor and production of monochlorodifluoromethane. The following emission control actions were taken during the 13th FYP period. Firstly, some of the outdated and excess production capacities had been eliminated and prebaked cells with an amperage of less than 160,000 had been eliminated before the end of 2015. As for production capacity with an AC consumption for liquid aluminum electrolysis of over 13,700 kWh and production capacity that failed to meet the standards after the end of 2015, the electricity price increased by 10% on the basis of the standard price. In 2015, the National Development and Reform Commission and the Ministry of Industry and Information Technology jointly issued the notice on printing and distributing opinions on cleaning up illegal projects in the steel, electrolytic aluminum and shipbuilding industries to curb the newly-added production capacity of the electrolytic aluminum industry. In 2018, the Chinese government launched a three-year action plan to clear air pollution, in which it was strictly forbidden to add the production capacity of steel, coking, electrolytic aluminum, casting, cement, and flat glass in key areas such as Beijing-Tianjin-Hebei and surrounding areas, the Yangtze River Delta region and the Fenhe-Weihe River Plain. Efforts were made to strengthen the terminal emission control and follow the emission standard for pollutants in the nitric acid industry to limit the emission of nitrogen oxides in the exhaust of the nitric acid industry. The Ministry of Industry and Information Technology issued the Green Industrial Development Plan (2016-2020) in 2016, proposing to reduce the emissions of N_2O, HFCs, PFCs and SF_6 from industrial processes such as adipic acid, nitric acid and refrigerant production. Enterprises were encouraged to carry out the destruction and disposal of trifluoromethane through financial subsidies. During the 13th FYP period, investment and financial subsidies of the central budget were arranged to support the destruction and disposal of trifluoromethane. As a result, 70,727 tons of trifluoromethane were destroyed and disposed of, equivalent to 828 million tons of carbon dioxide. And the treatment rate of trifluoromethane increased from 55% in 2015 to 95.5% in 2020.

7.3 Agriculture

The emission sources of non-carbon dioxide greenhouse gases in agriculture included methane emission of gastrointestinal fermentation by ruminants in livestock raising; methane and nitrous oxide emission from livestock manure management; methane emission from the anaerobic environment in paddy fields during rice planting; and nitrous oxide emission from nitrogen in agricultural soil through nitrification and denitrification in the presence of microorganisms. The following major control actions had been taken during the 13th FYP period. Efforts were made to demonstrate and popularize the technical model of high yield and low emission for rice-planting. A new rice-planting model with yield increase and methane emission reduction was constructed, which can increase rice yield by 4.1%-8.8%, increase the utilization efficiency of nitrogenous fertilizer by 30.2%-36.0%, increase the "cost reduced + income added" by 8.3%-9.7% and reduce methane emission by 31.5%-71.7%. Water-saving and drought-resistant rice had been cultivated and promoted in Anhui, Hubei, Zhejiang and Hainan among other places, with an annual planting area of more than 3 million *mu*, which led to the reduction of methane emissions. The technologies of soil testing and formula fertilization were promoted and the amount of applied chemical fertilizer was controlled. Since 2005, the Ministry of Agriculture and Rural Affairs had organized the promotion of soil testing and formula fertilization and the implementation of subsidy projects for this technology annually across the country by the scale of county, township and village. In 2015, the Ministry of Agriculture[36] promulgated the Action Plan for Zero Growth of Fertilizer Use by 2020, which put forward the goal of achieving zero growth of fertilizer use for major crops by 2020. During the 13th FYP period, the amount of fertilizer used in China decreased year by year. In 2020, the fertilizer utilization rate of the three major food crops was 40.2%, and the amount of agricultural fertilizer used was 12.8% lower than that in 2015. The total area that adopted soil testing and formula fertilization reached 1.93 billion *mu* times, an increase of 17.7% over 2015. The management and recycling of livestock and poultry waste were strengthened. In 2017, the Chinese government issued the Opinions on Accelerating the Recycling of Livestock and Poultry Waste, which set the national comprehensive utilization rate of livestock and poultry manure at above 75% and the installation rate of manure treatment facilities in large-scale farms at above 95%. County-wide promotion projects for the recycling of livestock manure had been implemented, supporting 819 counties with the breeding of pigs and beef and dairy cattle as their pillar industry, strengthening the construction of manure treatment facilities, and exploring the market-oriented operation mechanism. Other efforts included the treatment of non-point source agricultural pollution, the replacement of chemical fertilizers with organic fertilizers of fruit, vegetable and tea, pilot projects of the cycle of planting and breeding, and promoting the organic connection between livestock and poultry manure treatment and manure utilization. By the end of 2020, the comprehensive utilization rate of livestock and poultry manure in China had reached 76%, the installation rate of manure treatment facilities in large-scale farms had reached 97%, and the annual amount of livestock and poultry manure treated by biogas projects had reached 200 million tons, playing a positive role in controlling greenhouse gas emissions in agriculture.

7.4 Waste Treatment

The main sources of non-CO_2 GHG emissions in the field of waste treatment included methane emissions from urban domestic waste landfill, methane and nitrous oxide emissions from incineration and biological treatment of compost, as well as methane and

[36] In 2018, the Ministry of Agriculture was replaced by the Ministry of Agriculture and Rural Affairs after institutional reform.

nitrous oxide emissions from domestic sewage and industrial wastewater treatment. There were three types of control actions. First, the amount of waste was reduced and the recycling ratio was increased at the source. In 2017, the National Development and Reform Commission and the Ministry of Housing and Urban-Rural Development issued the Implementation Plan of Domestic Waste Sorting System, which requested that by the end of 2020, selected cities should take the lead in implementing compulsory domestic waste sorting in the urban areas, so as to reduce the amount of waste, dispose of waste in a harmless way, recycle over 35% of the waste. By the end of 2020, the coverage rate of domestic waste sorting in residential areas had reached 86.6% in 46 key cities in China, and some cities had introduced local rules or regulations on waste sorting; all cities at the prefecture level and above had formulated and promulgated their own implementation plan on waste sorting, and initiated the classification of domestic waste in an all-round way. Second, the process and scale of waste disposal were upgraded, and technologies of collecting and utilizing landfill gas were developed. In 2016, the Ministry of Housing and Urban-Rural Development and the National Development and Reform Commission issued the Construction of Innocuous Treatment Facilities for National Urban Domestic Waste for the 13th FYP to guide local governments to arrange domestic waste treatment facilities at a faster pace. By the end of 2020, the harmless treatment capacity of urban domestic waste in China was 897,700 tons per day, the innocuous treatment rate was 99.32%, and the incineration treatment accounted for 53.5%. Third, the Action Plan on Water Pollution Prevention was implemented, which requested all counties and key towns in China to develop wastewater collection and treatment capacity, and 85% and 95% of wastewater were required to be disposed of in counties and cities respectively; in addition, the anaerobic digestion process of wastewater and sludge was introduced, and the development of biogas recovery and utilization technologies was promoted. By the end of 2020, the wastewater treatment rates of counties and cities in China had reached 95.05% and 97.53% respectively, both exceeding the expected targets.

Chapter 8 Synergy Between Pollution Abatement and Carbon Reduction

The emission of greenhouse gases, such as carbon dioxide, shares the same sources with conventional pollutants, most of which come from the combustion and utilization of fossil energy. The control of carbon dioxide emissions has a far-reaching impact on the economic structure, energy mix, transport structure and ways of production and living, which is conducive to compelling and promoting the green transformation of the economic structure and boosting high-quality development; it alleviates the adverse effects of climate change and reduces the losses on people’s life and property, economy and the society; it is also conducive to promoting pollution control at the source, achieving coordinated emission reduction of carbon dioxide and pollutants, and improving the quality of ecological environment. China focuses on the integrity of pollution prevention and control and climate governance, stressing structural adjustment and layout optimization and taking the measures of policy coordination and mechanism innovation, so as to enhance the synergy between pollution abatement and carbon reduction with integrated planning, deployment, promotion and assessment. To deliver environmental, climate and economic benefits, China has made coordinated efforts to blaze a path for GHG emission reduction in line with its national conditions.

When China’s economic and social development ushers in green transition, it is an inevitable choice to coordinate and synergize pollution abatement and carbon reduction efforts. The country amended the Law on the Prevention and Control of Atmospheric Pollution in 2015 and added specific provisions, providing a legal basis for the coordinated control of atmospheric pollutants and GHG and pollution abatement and carbon reduction. In order to accelerate the coordination of functions, tasks and mechanisms related to climate change and ecological environment protection, China adjusted the functions of relevant departments in 2018, and the newly-established Ministry of Ecology and Environment addresses climate change, strengthening the coordination of climate change response and ecological environment protection. The Guiding Opinions on Coordinating and Strengthening the Work Related to Climate Change Response and Ecological Environment Protection and the Implementation Plan for Synergy between Pollution Abatement and Carbon Reduction, focusing on the construction of beautiful China and the goals of peaking carbon dioxide emissions and achieving carbon neutrality, were formulated to made systematic arrangements for promoting the synergy between pollution abatement and carbon reduction.

Pursuing the path of green, low-carbon and sustainable development, China has experienced steady economic growth, a sharp decline in carbon emission intensity and remarkable improvement in the quality of the ecological environment. In 2020, China’s GDP quadrupled that of 2005. Meanwhile, the reduction rate of carbon emission intensity exceeded the binding target set in the 13th FYP, which was equivalent to a cumulative reduction of about 5.8 billion tons of carbon dioxide emissions since 2005. The trend for the rapid growth of carbon dioxide emissions was basically reversed and all the binding indicators in relation to the ecological environment determined in the Outline of the 13th

FYP were successfully exceeded. China has been determined to fight the tough battle of pollution prevention and control, defend the blue sky, and build, rebuild and expand coal projects in key areas of air pollution prevention and control such as Beijing-Tianjin-Hebei and surrounding areas, the Yangtze River Delta and the Fenhe-Weihe River Plain, implementing coal reduction and substitution; focusing on Beijing-Tianjin-Hebei and surrounding areas and the Fenhe-Weihe River Plain, the management of scattered coal and the replacement of coal with natural gas, electricity and renewable energy have been promoted. During the 13th FYP period, the size of newly-added electricity substitution was about 820 billion kWh, and public institutions phased out about 67,000 coal-fired boilers.

In addition, according to the estimation by experts, from 1991 to 2020, China actively implemented the Montreal Protocol on Substances that Deplete the Ozone Layer, and had phased out the production and consumption of six types of ozone-depleting substances, including CFCs, halons, carbon tetrachloride, methyl chloroform, methyl bromide and HCFCs, totaling about 504,000 tons. While fulfilling the objectives of each stage, China had avoided greenhouse gas emissions of about 26 billion tons of carbon dioxide equivalent[37].

[37] Source: "Banks, emissions, and environmental impacts of China's ozone depletion substances and hydrofluorocarbon substitutes during 1980–2020" by Wu Jing, et al. published in *Science of the Total Environment*.

Chapter 9 Building of GHG Emission Control Systems and Mechanisms at a Faster Pace

The Chinese government has been fulfilling its international commitments proactively, addressing climate change and intensifying its efforts to mitigate climate change through various measures, such as strengthening the development of laws and regulations, promoting the preparation of plans to deal with climate change, advancing carbon reduction in the field of environmental impact assessment (EIA) with joint efforts, establishing and improving the technical standards for territorial spatial planning, introducing accountability evaluation for the control targets of GHG emissions, guiding local governments to carry out innovative low-carbon development actions independently, and launching low-carbon projects. Departments and sectors, including industry, energy, construction and transport, gave responses to such endeavors through multiple means to reduce energy consumption and GHG emissions.

9.1 Laws and Regulations

China attaches great importance to the legislation on climate change. In 2009, the Resolution on Actively Responding to Climate Change of the Standing Committee of the National People's Congress (NPC) proposed that strengthening the relevant legislation on climate change should be included in the legislative agenda as an important task to form and improve the socialist legal system with Chinese characteristics. In order to fulfill this task, a leading group was set up in 2011, attended by NPC's Environmental Protection and Resources Conservation Committee, NPC's Legislative Affairs Committee, the former Legislative Affairs Office of the State Council, the National Development and Reform Commission and other relevant authorities, to draft laws addressing climate change. In 2016, the legislative project on climate change was included in the list of research projects of the national annual legislative plan for the first time. The competent departments gathered experts to continuously revise and improve the draft law. On the basis of in-depth research and extensive investigation, the framework design and drafting of the draft law were completed, and the legislative opinions of relevant departments, industrial experts and people from all walks of life were widely collected by soliciting opinions in writing, organizing expert forums, and handling suggestions and proposals of the Two Sessions, namely the annual NPC and CPPCC sessions. Qinghai, Shanxi, Nanchang, Shijiazhuang, Shenzhen, Tianjin and other provinces and cities had issued local rules and regulations to promote climate change response or low-carbon development, providing experience for national legislation. China has been actively promoting the legislative process of the Interim Regulations on the Management of Carbon Emission Rights Trading, consolidating the legal basis of carbon emission rights trading, and standardizing all of the key links in the operation and management of the national carbon market. Besides, China has been promoting the revision of the Environmental Impact Assessment Law, and put forward suggestions for the revision of the law to incorporate greenhouse gas emission control and requirements for addressing climate change into environmental impact assessment.

9.2 Accountability Evaluation for the Control Targets of GHG Emissions

According to the requirements set in the Work Plan on GHG Emission Control for the 13th FYP, China comprehensively considered its provinces, autonomous regions and municipalities directly under the central government in terms of development stages, resource endowments, strategic positioning, and ecological environment, and broke down the national control targets of carbon emission intensity into levels, determining the five-grade reduction targets for each provincial-level region during the 13th FYP period: 20.5%, 19.5%, 18%, 17% and 12%. In 2017, China introduced the provincial-level assessment methods of GHG emission control during the 13th FYP period. In light of the relevant requirements set in the Work Plan on GHG Emission Control for the 13th FYP, the assessment indicators were expanded to 27 items in 10 categories, and the assessment rules were continuously improved and adjusted afterwards. Focusing on the completion of targets, the implementation of tasks and measures, the implementation of basic work and capacity building and the initiatives in terms of mechanisms, the Chinese government guided and supervised the GHG control in all regions during the 13th FYP period by making annual supervision and assessment, tracking the completion of related work, analyzing the progress of FYP objectives, and rescheduling tasks for local governments that failed to complete them.

China had included GHG control in the scope of the central inspection of ecological and environmental protection, and urged the regions where GHG control targets and tasks were not fulfilled during the 13th FYP period to speed up industrial restructuring and energy redistribution so as to effectively curb the rising regional carbon emissions.

9.3 Role of Market Mechanism

Efforts were made to continuously promote the launch of pilot projects of local carbon emission rights trading. In 2011, the local pilot projects of carbon emission rights trading (hereinafter referred to as the carbon market) were launched in seven provinces and cities, including Beijing, Tianjin, Shanghai, Chongqing, Guangdong, Hubei and Shenzhen, covering nearly 3,000 key emission units in various industries, such as electricity, iron and steel and cement. These pilot carbon markets continuously deepened the construction of the institutional system, gradually expanded its coverage, explored ways to optimize quota allocation, improved the technical specifications of carbon emission monitoring, accounting, reporting and verification and data quality management, optimized the management process of the carbon market, strengthened market supervision, enhanced compliance management, and innovated business forms such as carbon inclusiveness(*Tan Pu Hui*). The compliance rate of the pilot carbon markets remained at a high level, and it showed an increasing trend year by year. The low-carbon awareness of enterprises was constantly raised, which effectively promoted the reduction of the total amount and intensity of carbon emissions in the pilot area, and played a positive role in achieving the greenhouse gas emission reduction targets in the pilot areas. By the end of 2020, all the pilot carbon markets had organized paid allocation of quotas, with a total of 38 paid auctions and a cumulative trading volume of about 42.299 million tons.

The building of a national market for carbon emission rights trading was accelerated. The competent national departments in charge of addressing climate change issued the Construction Plan on the National Market for Carbon Emission Rights Trading (Electricity Generation), taking the industry of electricity generation as the starting point to establish the national carbon market step by step; they also issued the Measures for the Management of Carbon Emission Rights Trading (for trial implementation), the National Implementation Plan for the Total Quota Setting and Allocation of Carbon Emission Rights Trading in 2019-2020 (Electricity Generation) and the List of Key Emission Units under the National Quota Management of Carbon Emission Rights Trading in 2019-2020. These competent departments required all regions to organize key emission units to monitor, report and verify carbon emission data annually, conduct research on the benchmark value of quota allocation in the industry of electricity generation and organize the trial calculation of quota allocation in the power industry, steadily promote the establishment of the national registration system and trading system of carbon emission rights, and organize large-scale capacity-building / training activities for local teams for climate change response and key emission units in the industry of electricity generation, making preparations for the online trading of carbon emission rights in China.

The voluntary emission reduction trading mechanism was improved. In 2012, China established its voluntary GHG emission reduction trading mechanism. During the 13th FYP period, China continued to improve the voluntary GHG emission reduction trading mechanism and revised the Interim Measures for the Management of Voluntary Greenhouse Gas Emission Reduction Trading. By the end of 2020, the voluntary emission reduction trading showed a steady and rising trend, and the cumulative volume of voluntary greenhouse gas emission reduction certified by the country was about 268 million tons. Some provinces and cities in China had carried out work related to carbon inclusiveness independently. For example, Guangdong Province issued an implementation plan on the pilot projects of carbon inclusiveness, a guide for the construction of pilot projects of carbon inclusiveness, interim measures for the management of certified emission reduction under carbon inclusiveness, and the trading rules for certified emission reduction under carbon inclusiveness. Guangdong had introduced carbon inclusiveness in Guangzhou, Dongguan, Zhongshan, Huizhou, Shaoguan and Heyuan, and established the quantitative methods and trading mechanism of carbon inclusive actions based on carbon coins and Pu Hui Certified Emission Reduction (PHCER). The carbon market in Beijing launched the activity of “I voluntarily drive one day less in a week” to encourage the public to adopt green travel methods with carbon inclusive trading. A platform for the activity was put into operation in 2017. By the end of August 2018, there were 118,000 registered users, and the cumulative carbon emission reduction exceeded 22,000 tons, cutting carbon emissions by about 70 tons per day.

9.4 Provincial- and Municipal-Level Low-Carbon Pilot Projects

On the basis of the pilot projects of low-carbon provinces and cities launched in 2010 and 2012, the third batch of national pilot projects of low-carbon cities was carried out in 45 cities (autonomous regions and counties) including Wuhai City in Inner Mongolia

Autonomous Region in 2017. Hence, a total of 87 provinces and cities, 51 industrial parks, over 400 communities and 8 cities (towns) in China had implemented low-carbon pilot projects, forming an all-round and multi-level low-carbon pilot system preliminarily. These pilot projects actively integrated low-carbon development into the regional planning system, explored the innovation system oriented to targets of peaking carbon dioxide emissions, implemented the responsibility assessment system of carbon emission targets, promoted the establishment of green, low-carbon and circular industrial systems, innovated the low-carbon development system, strengthened the statistics and management system for GHG emissions, advocated the green and low-carbon lifestyle and consumption pattern, actively promoted demonstration of low carbon-related pilot projects, explored new measures for low-carbon development with different characteristics and conduct extensive explorations in improving leadership, policies, market mechanisms, statistical systems, evaluation and assessment, demonstration of pilot projects and cooperation and exchanges. The pilot areas saw a more rapid decline in carbon emission intensity compared with the national average, creating a number of customized and distinctive low-carbon development patterns.

By June 2020, 36 low-carbon development-related plans had been developed by 34 low-carbon pilot projects in different provinces and cities during the 13th FYP period (26 of which had been published), which integrated low-carbon development into the regional development planning system, clarified the main objectives, tasks and safeguard measures of low-carbon development in the region and led the urbanization process and urban spatial optimization with the idea of low-carbon development. 17 provinces and cities with low-carbon pilot projects had researched the targets of peaking carbon dioxide emissions and the implementation roadmap to improve the level of decision support. Other efforts were to organize the research and implementation of experience evaluation and promotion of low-carbon pilot projects, to encourage local authorities to explore and launch demonstration projects with near-zero carbon emission, and to organize relevant provinces and cities to exchange experience concerning low-carbon pilot projects, all of which had achieved positive results.

9.5 Support from Green Finance

China had continuously increased its capital investment to support the response to climate change. In order to strengthen the top-level design of green finance, China set up reform and innovation pilot zones for green finance in nine provinces (regions) including Zhejiang, Jiangxi, Guangdong, Guizhou, Gansu and Xinjiang, which enhanced the function of financial support for green and low-carbon transformation and guided the pilot zones to draw on the experience. China had introduced comprehensive supporting policies for climate investment and financing, promoted the establishment of a standard system for climate investment and financing as a whole, strengthened the market capital guidance mechanism, and promoted the pilot projects of climate investment and financing. It had also developed green credit vigorously, improved the supporting policies for green bonds, and published a catalogue of relevant support projects to effectively guide social capital to support climate change response. By the end of 2020, the outstanding balance of green loans in China was 11.95 trillion yuan, of which the outstanding balance of clean energy loans was 3.2 trillion yuan, and the cumulative issuance of green bonds was about 1.2 trillion yuan, with an outstanding volume of 800 billion yuan, ranking second in the world.

9.6 Low-Carbon Requirements as Part of EIA Systems

The Ministry of Ecology and Environment revised a series of standards in relation to ecology and environment and revised the technical specifications for assessing the environmental impacts for industrial parks, which incorporated carbon emission reduction into all of the assessment chapters and clarified the requirements of pollution abatement and carbon reduction. Efficient and coordinated efforts were made step by step and managed based on classes. The general idea of synergizing pollution and carbon reduction and peaking carbon emission through EIA system was proposed for the formulation of phased targets and work plans in the zoning control of ecological environment, ecological and environmental impact assessment of policies, EIA planning, and EIA of construction projects.

Pilot projects were launched at multiple levels. At the macro level, 16 regions were organized to pilot the projects of “Three Lines and One List”[38] for the coordinated management of pollution abatement and carbon reduction, promoting the integration of targets of peaking carbon dioxide emission with the requirements for zoning control of the ecological environment, and exploring the overall consideration of climate change factors in the ecological and environmental impact analysis of 12 pilot policies. At the meso level, seven industrial parks were selected as the first batch of pilot projects to explore the technical methods for the synergy between pollution abatement and carbon reduction. At the micro level, nine provinces (autonomous regions or municipalities directly under the central government) were organized to focus on “double-high” industries, namely industries with high pollution and high energy consumption, such as electric power, iron and steel, building materials, nonferrous metals, petrochemical industry and coal chemical industry, exploring the carbon emission level and emission reduction potential as well as the coordinated management and control. A total of 336 construction projects were included in the pilot. Under the guidance of the Technical Guidelines for Planning Environmental Impact Assessment: Industrial Parks and the Technical Guidelines for Environmental Impact Assessment of Carbon Emission from Construction Projects in Key Industries (for trial implementation) issued by the Ministry of Ecology and Environment, the pilot areas had actively explored and successively issued 12 technical guidelines for assessment methods that reflected regional and industrial characteristics, including two for environmental impact assessment of industrial parks, four for comprehensive environmental impact assessment of construction projects and six for key industries such as electric power, iron steel, chemical industry and coal chemical industry. Hence, the working path and technology for integrating greenhouse gas control into the management of environmental impact assessment had been set up preliminarily.

[38] Three Lines refers to the enforcement of red lines for ecological conservation, the benchmarks for environmental quality, and the caps on resource utilization, while One List refers to the list for eco-environment access. “Three Lines and One List” is an important program to promote the fine management of eco-environmental protection, strengthen the control of territorial space environment, and foster green and high-quality development.

Chapter 10 Key Objectives and Tasks of the 14th FYP

The objectives and tasks set out in the Outline of the 14th Five-Year Plan, issued in March 2021, include to meet the targets for nationally determined contributions in response to climate change by 2030 and to formulate an action plan for peaking carbon emissions before 2030; to lower carbon emissions steadily after reaching the peak by 2035; and to strive to achieve carbon neutrality before 2060 by adopting stronger policies and measures. Different industries and sectors have set their own objectives and tasks to ensure the successful achievement of peaking carbon emissions in China.

Energy: The energy consumption and CO_2 emission per unit of GDP is reduced by 13.5% and 18% respectively; the proportion of non-fossil energy in the total energy consumption increases to about 20%; the total consumption of renewable energy reaches about 1 billion tons of standard coal, accounting for about 18% of primary energy consumption; the proportion of electricity generation by non-fossil energy reaches about 39% of the total; the annual electricity generation by renewable energy amounts to 3.3 trillion kWh or so.

Industry: For the industrial enterprises above the designated size, the energy consumption per unit of the added value decreases by 13.5; the CO_2 emission per unit of the industrial added value reduces by 18%.

Construction: The area of renovated space for energy efficiency in existing buildings exceeds 350 million m^2; the area of new buildings with ultra-low/near-zero energy consumption exceeds 50 million m^2; the installed solar photovoltaic capacity of new buildings in China exceeds 50 million kW; the application area of geothermal energy in building exceeds 100 million m^2; the substitution rate of renewable energy in urban buildings reaches 8%; the total energy consumption of public institutions is limited to 189 million tons of standard coal and the total CO_2 emission is limited to 400 million tons; during the 14th FYP period, the energy consumption per unit of building area for public institutions decreases by 5%, the comprehensive energy consumption per capita decreases by 6% and the carbon emission per unit of building area decreases by 7%.

Transport: The CO_2 emission intensity of transport decreases by 5%, and the proportion of urban buses using new energy increases to 72%.

Ecosystem carbon sinks: The forest coverage increases to 24.1%.

Control of non-CO_2 GHG emission: On April 22, 2021, President Xi Jinping stressed at the Leaders Summit on Climate that China would continue to strengthen its control over non-CO_2 GHG emission; in June 2021, the Chinese government accepted the Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer, which came into force on September 15, 2021 (not applicable to the Hong Kong SAR for the time being).

Part V Finance, Technology and Capacity-Building Needs

As a developing country with 1.4 billion people and one of the countries affected most by climate change, China is facing multiple challenges in terms of economic development, the improvement of living standards, environmental protection, and climate change tackling. Additionally, China still has acute problems of imbalanced and inadequate development. As one of the non-Annex I Parties to UNFCCC, China has followed the principle of common but differentiated responsibilities to perform its duties stipulated in the UNFCCC. By practicing Xi Jinping Thought on Ecological Civilization, China grounds its work in the new development stage, applies the new development philosophy and fosters a new development dynamic. By applying systematic thinking, China will lay equal stress on climate change mitigation and adaptation. While China has increasingly stepped up financial and policy support, built its strength in science and technology, improved social participation mechanisms and pursued international cooperation, more support is yet to be provided finance, technology and capacity building to fulfill its nationally determined contribution (NDC) goals across the board.

Chapter 1 Financial Needs and Support Received for Addressing Climate Change

1.1 Financial Needs for Addressing Climate Change

As elaborated in Part I "National Circumstances and Institutional Arrangements," although China has fulfilled the arduous task of eliminating absolute poverty, its GDP per capita is slightly lower than the world's average and lags far behind levels in major developed countries, making China still the largest developing country in the world. A continuous, steady and adequate stream of capital inputs is essential for China to push forward climate mitigation and adaptation campaigns. To realize the NDC goals and implement relevant policies, actions and measures, China not only needs to fully mobilize its own public and private investment, but also needs to seek climate financial support from developed countries.

According to the policy objectives and actions of nationally determined contributions submitted in 2015, the Third National Communication on Climate Change reported that from 2016 to 2030, China would need to spend a cumulative amount of approximately 32 trillion yuan (based on the 2015 pricing level) to fulfill the mitigation goals and tasks, equal to an average annual cost of approximately 2.1 trillion yuan; a cumulative amount of approximately 24 trillion yuan to meet the adaptation goals in China's nationally determined contributions, equal to an average annual cost of approximately 1.6 trillion yuan. The total financial spending from 2016 to 2030 adds up to close to 56 trillion yuan, averaging approximately 3.7 trillion yuan annually, and equivalent to 6.3% of China's fixed asset investment in 2016.

In 2020, Chinese President Xi Jinping stated that China will strive to peak carbon dioxide emissions before 2030 and achieve carbon neutrality before 2060; in 2021, China officially submitted China's Achievements, New Goals and New Measures for Nationally Determined Contributions, highlighting its climate mitigation and adaption goals and actions. Based on the new goals and actions, some studies estimated that China's climate mitigation campaign will need to consume a total amount of approximately 19.8 trillion yuan from 2021 to 2030, equal to an average annual cost of approximately 2.0 trillion yuan; a total amount of approximately 260 trillion yuan from 2021 to 2060, equal to an average annual cost of approximately 6.5 trillion yuan. To be specific, China's financial spending for climate mitigation mainly stems from the electric power sector (approximately 9.8 trillion yuan from 2021 to 2030, and approximately 57.6 trillion yuan from 2030 to 2060), the transport sector (approximately 6.3 trillion yuan from 2021 to 2030, and approximately 31.1 trillion from 2030 to 2060), the construction sector (approximately 3.9 trillion yuan from 2021 to 2030, and approximately 18.4 trillion yuan from 2030 to 2060). Few research projects were conducted on China's financial needs in climate adaptation, and no updates are available for the total financial demand for climate adaptation in the updated Nationally Determined Contributions. However, some studies suggested that the mounting climate change risks result in an accelerating growth of China's financial needs for climate adaptation.

Broadly speaking, China needs an enormous amount of money to tackle climate change. China will need to spend far more to reach carbon neutrality than to achieve carbon peaking as the lapse between the two goals is merely three decades. China's climate change and adaptation campaigns will need to consume a combined amount of approximately 35.8 trillion yuan from 2021 to 2030, equal to an average annual cost of approximately 3.6 trillion yuan [39]; approximately 324 trillion yuan from 2021 to 2060, equal to an average annual cost of approximately 8.1 trillion yuan [40].

1.2 Financial Inputs for Addressing Climate Change

The Chinese government has rolled out plenty of investment and mobilizing policy measures to make up for the huge shortfall in addressing climate change. China has arranged future matters of priority concerning financial inputs for tackling climate change by issuing such top-level design documents as the Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy, the Action Plan for Carbon Dioxide Peaking Before 2030 and the National Climate Change Adaptation Strategy 2035.

In the 13th FYP period, the Chinese government stepped up fiscal and tax support to respond to climate change and witnessed rapid progress in green finance. In 2022, the Chinese Ministry of Finance released the Opinions on Financial Support for Peaking

[39] The average annual financial spending for climate change mitigation is an average of figures in a few studies, and the average annual financial spending for climate change adaptation from 2021 to 2030 continues to follow the figure in the third national communication on climate change, i.e., an average annual cost of 1.6 trillion yuan.

[40] Due to the absence of studies of financial spending for climate change adaptation from 2021 to 2060, the average annual financial spending from 2021 to 2060 continues to follow the figure in the third national communication on climate change, i.e., an average annual cost of 1.6 trillion yuan.

Carbon Emissions and Achieving Carbon Neutrality, calling for efforts to facilitate carbon peaking and carbon neutrality from 4 aspects, namely general requirements, priority fields and directions for support, fiscal policy measures and safeguard measures. In regard to fiscal investment, more and more investments from the central budget are being channeled to climate change mitigation and adaptation and sci-tech strength building, as an effort to stabilize the strong development of clean energy; in regard to tax policies, preferential tax reduction and subsidy policies were rolled out in fields relating to new energy vehicles, renewable energy, energy conservation, and energy efficiency improvement; in regard to green finance, China has continued to advance the building of standard systems, improved regulations on supervision and information disclosures by financial institutions, put in place the policy incentive and restraint system, brought forth new green financial products and market systems and reinforced international cooperation on green finance. As of the end of 2020, China had a close to 12 trillion yuan green loan balance, the most in the world, and the world's second largest green bonds inventory valued at 813.2 billion yuan. Green financial assets were good in quality, with the non-performing ratio of green loans lower than the industrial average and no defaults reported in green bonds.

China will plan to prioritize improving investment policies, give full play to the guiding role of government investment, impose strict controls on investment in high-carbon projects on coal power, steel manufacturing, electrolytic aluminum, cement and petrochemical engineering, and step up support for energy conservation and environmental protection, new energy, low-carbon transport equipment and organization forms, and carbon capture, utilization and storage (CCUS), so as to incentivize market players to invest in low-carbon areas and motivate banks, securities, insurance companies and fund managers, among other commercial financial institutions, to channel more money to fund climate change mitigation and adaptation projects. Also, it will vigorously develop green finance, promote the development of green financial products and services in an orderly manner, reinforce studies of transition finance, encourage social capital to set up green and low-carbon industry investment funds, and work hard to launch innovative products such as sustainability linked bond (SLB), catastrophe insurance and climate risk insurance in key fields. It will enable a market-oriented mechanism and accelerate the construction and improvement of the national carbon emissions trading market. Guidance will be given to the use of market resources including venture investment funds, private equity investment funds and trust funds, and international capital as well as loans and grants from bilateral or multilateral organizations will be secured. Fiscal and price policies as well as governmental green purchasing standards will be improved, and more efforts will be made to purchase green and low-carbon products. Climate change adaptation will be better propped up from multiple dimensions by fiscal and financial policies, green finance market and climate investment and financing.

1.3 International Climate Funding Received by China, and Problems and Challenges

From 2016 to 2020, China received international funding including grants and concessional loans through multiple channels including the finance mechanism of the

UNFCCC, multilateral development institutions, and bilateral cooperation mechanisms[41].

1.3.1 Funding Received by China under the Finance Mechanism of the UNFCCC

From 2016 to 2020, China received a total funding of approximately US$220 million. To be specific, grants from the Global Environment Facility (GEF) funded 12 national climate change projects, with a total contract amount of approximately US$116 million (54%); concessional loans for climate change from the Green Climate Fund (GCF) funded one project, with the contract amount of US$100 million (46%). These projects mainly covered energy transition and energy efficiency improvement, and green buildings and transport, the details of which are set forth in the following Table 5-1.

Table 5-1 Funding Received by China from the Finance Mechanism of the UNFCCC (US$)

	Project name	Funding source	Funding nature	Contract amount
1	Upgrading of China small hydro power (SHP) Capacity Project	GEF	Grant	8,925,000
2	Accelerating the Development and Commercialization of Fuel Cell Vehicles in China	GEF	Grant	8,233,560
3	Enabling Solid State Lighting Market Transformation and Promotion of Light Emitting Diode Lighting	GEF	Grant	6,242,694
4	Greening the Logistics Industry in Zhejiang Province	GEF	Grant	2,913,700
5	Integrated Adoption of New Energy Vehicles in China	GEF	Grant	8,930,000
6	GEF China Sustainable Cities Integrated Approach Pilot	GEF	Grant	32,727,523
7	Energy Efficiency Improvement in Public Sector Buildings	GEF	Grant	8,932,420
8	Developing Market-based Energy Efficiency Program in China	GEF	Grant	17,800,000
9	Achieving Efficient and Green Freight Transport Development	GEF	Grant	8,246,095
10	Climate Smart Management of Grassland Ecosystems	GEF	Grant	3,769,083
11	China Distributed Renewable Energy Scale-up Project	GEF	Grant	7,278,600
12	China Capacity Building for Enhanced Transparency Phase I	GEF	Grant	1,650,000
13	Catalyzing Climate Finance (Shandong Green Development Fund)	GCF	Concessional loan	100,000,000

1.3.2 Funding Received from Multilateral Institutions

From 2016 to 2020, China had established close ties with multilateral institutions. Based on available statistics, China had received grants worth US$20.26 million from the Asian Development Bank (ADB), which were mainly used to fund such fields as energy, transport, agriculture, finance and technology. From 2016 to 2020, the World Bank (WB), the ADB, the Asian Infrastructure Investment Bank (AIIB), the New Development Bank

[41] The international climate funding is denominated in US dollars. For projects originally denominated in other currencies, the exchange rates of CNY/USD = 0.1533 and EUR/USD = 1.2217 are used for conversion.

(NDB) and the European Investment Bank (EIB) offered China US$2.5 billion, US$1.449 billion, US$500 million, US$1.995 billion and US$1.688 billion, respectively in sovereign loans for tackling climate change. These fundings were mainly channeled to support energy, forestry, water and health facilities, and urban development, the details of which are set forth in the following Table 5-2 and Table 5-3.

Table 5-2 Grants Received by China from Multilateral Institutions (US$)

	Project name	Funding source	Funding nature	Cumulative disbursement
1	Shandong Spring City Green Modern Trolley Bus Demonstration	ADB[42]	Grant	342,995
2	Qingdao Rural Waste-to-Energy Project	ADB	Grant	240,334
3	National Biomass Heat Supply Development Strategy	ADB	Grant	297,772
4	Guizhou High Efficiency Water Utilization Demonstration in Rocky Desertification Area	ADB	Grant	567,007
5	Heilongjiang Green Urban and Economic Revitalization Project	ADB	Grant	38,055
6	Promoting and Scaling Up Carbon Capture and Storage Demonstration	ADB	Grant	/[43]
7	Study of Clean Energy Supply for the Rural Areas in the Greater Beijing－Tianjin－Hebei Region	ADB	Grant	346,309
8	Green Finance Catalyzing Facility	ADB	Grant	846,519
9	Strategic Policy Study on Collaborative Control of Air Pollution and Carbon Emissions in the Transport Sector	ADB	Grant	301,848
10	Supporting the Application of River Chief System for Ecological Protection in Yangtze River Economic Belt	ADB	Grant	369,831
11	Mainstreaming Urban Climate Change Adaptation in the People's Republic of China	ADB	Grant	335,406
12	Shaanxi Transport and Logistics Port	ADB	Grant	927,946
13	Study on Municipal Solid Waste Regional Integrated Management Model for Beijing－Tianjin－Hebei	ADB	Grant	399,317
14	Policy Research on Ecological Protection and Rural Vitalization for Supporting Green Development in the Yangtze River Economic Belt	ADB	Grant	/
15	Policy Research on Ecological Protection and Rural Vitalization for Supporting Green Development in the Yangtze River Economic Belt - Public－Private Financing Mechanism for Chishui Watershed Protection (Subproject 1)	ADB	Grant	316,150

[42] Data come from the project list on the official website of the ADB. All projects funded by grants listed herein were technical assistance projects. As payment amounts differ considerably from contract amounts in the case of some completed projects, actually paid amounts were used in statistics for all projects (completed or underway).
[43] "/" denotes either a project that comprises sub-projects, the amount of which is split among sub-projects for statistics in order to prevent double counting, or a signed project, the funding of which hasn't materialized; the same below.

	Project name	Funding source	Funding nature	Cumulative disbursement
16	Advanced Renewable Energy Technology Demonstration	ADB	Grant	396,578
17	Improving the Design of the National Carbon Emissions Trading System	ADB	Grant	264,776
18	Piloting Innovative Flash Flood Early Warning Systems in Selected River Basins	ADB	Grant	286,159
19	Hubei Xiangyang Integrated Sustainable Transportation and Logistics Planning and Strategic Study	ADB	Grant	379,980
20	Capacity Development Support to the National and Local Joint Engineering Research Center on Carbon Capture, Utilization, and Sequestration at Northwest University (Subproject 1)	ADB	Grant	780,161
21	Developing a Climate-Friendly Cooling Sector through Market and Financing Innovation	ADB	Grant	452,916
22	Industry Green Growth Indicators and Innovative Mechanisms for Guangdong Province	ADB	Grant	217,035
23	Policy Advice for the Yangtze River Protection Law of the Peoples Republic of China	ADB	Grant	97,287
24	Developing Partnerships for Knowledge Sharing on Natural Capital Investment in the Yangtze River Economic Belt	ADB	Grant	96,878
25	Rural Vitalization - Rural Wastewater Treatment and Environmental Management	ADB	Grant	498,220
26	Agriculture Green Production and Waste Management	ADB	Grant	762,983
27	Preparing Sustainable Development Projects	ADB	Grant	1,072,719
28	Preparing Environmental and Rural Development Projects	ADB	Grant	3,094,820
29	Study on the Municipal Climate Finance Roadmap	ADB	Grant	217,652
30	Promoting and Scaling Up Carbon Capture and Storage Demonstration-Feasibility Assessment of a Large-Scale Carbon Capture and Storage Demonstration Project and Development Support to Yanchang Petroleum Group (Subproject 2)	ADB	Grant	3,584,196
31	Preparing the Silk Road Ecological Protection and Rehabilitation	ADB	Grant	676,999
32	Improving Policies and Planning for Nature-Positive Development in the Huangshui River Source Area	ADB	Grant	65,630
33	Research on Comprehensive Management Planning Policy of Huangshui Basin in Qinghai Province	ADB	Grant	39,847
34	Green Farmland Construction and Agricultural High-Quality Development in the Yellow River Basin	ADB	Grant	164,200
35	Developing Legislative and Planning Mechanisms for Ecological Protection in the Yellow River Basin	ADB	Grant	300,000

	Project name	Funding source	Funding nature	Cumulative disbursement
36	Strategic Research of Promoting Ecological Protection and High-Quality Development in the Yellow River Basin through Economic and Intensive Water Use	ADB	Grant	/
37	Strengthening Capacity, Institutions, and Policies for Enabling High-Quality, Green Development in the Yellow River Ecological Corridor	ADB	Grant	/
38	Yellow River Eco-Compensation Mechanism	ADB	Grant	53,482
39	Ecological Valuation and Compensation Mechanism in the Kubuqi Desert	ADB	Grant	79,028
40	Developing an Eco-compensation Framework for Green Development in the Dabie Mountain	ADB	Grant	171,554
41	Support for National Ecological Compensation Regulation of the People's Republic of China	ADB	Grant	71,243
42	Supporting Sustainable Finance and Regional Cooperation	ADB	Grant	463,279
43	Enhancing the Sustainable Cooperation of Yunnan and Guizhou with the Greater Mekong Subregion	ADB	Grant	68,680
44	Customized Low-Carbon Development Models in Rural and Small and Medium-Sized Towns	ADB	Grant	210,420
45	Green Circular Economy Zero Waste Cities	ADB	Grant	82,809
46	Innovation-Driven Green Economic Diversification for Resource-Exhausted Cities in Heilongjiang	ADB	Grant	50,301
47	Climate Change Financing Acceleration Platform	ADB	Grant	235,862

Table 5-3 Part of Loans Offered to China by Multilateral Institutions (US$)

	Project name	Funding source	Funding nature	Contract amount
1	China Climate Change Framework Loan(CCCFL)-Guizhou Forests	EIB[44]	Loan	30,542,500
2	CCCFL-Hubei Forests	EIB	Loan	30,542,500
3	CCCFL-Jiangxi Forests	EIB	Loan	30,542,500
4	CCCFL-Heilongjiang Forests	EIB	Loan	30,542,500
5	Hohhot Energy Efficiency	EIB	Loan	197,915,400
6	Inner Mongolia Forestry	EIB	Loan	36,651,000
7	Shaanxi Forestry	EIB	Loan	61,085,000
8	Anhui Forestry	EIB	Loan	48,868,000
9	China Climate Eximbank Framework Loan	EIB	Loan	366,510,000

[44] Data come from official websites of the institutions.

	Project name	Funding source	Funding nature	Contract amount
10	Hunan Forestry	EIB	Loan	122,170,000
11	Baotou Energy Efficiency	EIB	Loan	122,170,000
12	Yangtze River Basin Forest Protection	EIB	Loan	244,340,000
13	Imar Tongliao Sand Dunes Shelterbelt Forest	EIB	Loan	366,510,000
14	Beijing-Tianjin-Hebei Low Carbon Energy Transition and Air Quality Improvement Project	AIIB	Loan	500,000,000
15	Hebei Clean Heating Project	WB	Loan	100,000,000
16	Ningbo Sustainable Urbanization Project	WB	Loan	150,000,000
17	Poyang Lake Basin Town Water Environment Management Project	WB	Loan	150,000,000
18	Liaoning Safe and Sustainable Urban Water Supply Project	WB	Loan	250,000,000
19	Jiangxi Integrated Rural and Urban Water Supply and Wastewater Management Project	WB	Loan	200,000,000
20	Zhejiang Qiandao Lake and Xin'an River Basin Water Resources and Ecological Environment Protection Project	WB	Loan	150,000,000
21	Hezhou Urban Water Infrastructure and Environment Improvement Project	WB	Loan	150,000,000
22	Shaanxi Sustainable Towns Development Project	WB	Loan	150,000,000
23	China Renewable Energy and Battery Storage Promotion Project	WB	Loan	300,000,000
24	Forest Ecosystem Improvement in the Upper Reaches of Yangtze River Basin Program	WB	Loan	150,000,000
25	Sichuan Water Supply and Sanitation Public-Private-Partnership Project	WB	Loan	100,000,000
26	Henan Green Agriculture Fund Project	WB	Loan	300,000,000
27	Hubei smart and sustainable agriculture project	WB	Loan	150,000,000
28	Jiangxi Eco-industrial Parks Project	WB	Loan	200,000,000
29	Lingang Distributed Solar Power Project	NDB	Loan	34,115,465
30	Putian Pinghai Bay Offshore Wind Power Project	NDB	Loan	307,692,308
31	Jiangxi Industrial Low Carbon Restructuring and Green Development Pilot Project	NDB	Loan	200,000,000
32	Guangdong Yudean Yangjiang Shapa Offshore Wind Power Project	NDB	Loan	306,518,107
33	Jiangxi Natural Gas Transmission System Development Project	NDB	Loan	400,000,000
34	Guangxi Chongzuo Urban Water System Ecological	NDB	Loan	300,000,000

	Project name	Funding source	Funding nature	Contract amount
	Restoration Project			
35	Zhejiang Green Urban Project-Shengzhou Urban and Rural Integrated Water Supply and Sanitation Project Phase II	NDB	Loan	126,923,077
36	Ningxia Yinchuan Integrated Green Transport Development Project	NDB	Loan	323,076,923
37	Jiangxi Xinyu Kongmu River Watershed Flood Control and Environmental Improvement Project	ADB	Loan	150,000,000
38	Shaanxi Accelerated Energy Efficiency and Environment Improvement Financing Project	ADB	Loan	150,000,000
39	Qinghai Haidong Urban-Rural Eco Development Project	ADB	Loan	150,000,000
40	Henan Hebi Qihe River Environmental Improvement and Ecological Conservation Project	ADB	Loan	150,000,000
41	Shandong Groundwater Protection Project	ADB	Loan	150,000,000
42	Shanxi Urban-Rural Water Source Protection and Environmental Demonstration Project	ADB	Loan	100,000,000
43	Hunan Xiangjiang River Watershed Existing Solid Waste Comprehensive Treatment Project	ADB	Loan	150,000,000
44	Chongqing Longxi River Basin Integrated Flood and Environmental Risk Management Project	ADB	Loan	150,000,000
45	Shandong Green Development Fund Project	ADB	Loan	100,000,000
46	Guizhou Gui'an New District New Urbanization Smart Transport System Development Project	ADB	Loan	199,460,000

1.3.3 Funding from Bilateral Channels

From 2016 to 2020, China pursued international cooperation on climate with the Annex II Parties to the UNFCCC and received a total of US$1.619 billion in funding for tackling climate change from Germany, France, the UK, Norway, Switzerland, the US and Japan, which was split among 213 projects. To be specific, grants and concessional loans amounted to US$140 million (9%) and US$1.479 billion (91%), respectively, and climate change mitigation, adaptation and cross-cutting areas received US$1.01 billion (62%), US$208 million (13%) and US$410 million (25%) in funding, respectively. The key areas targeted for support and funding amounts are specified in the following Table 5-4.

Table 5-4 Funding Received by China from Bilateral Channels (US$)

Funding sourcing	Funding nature	Sectors targeted for support	Contract amount
Austria	Grant	Energy / cross-cutting	32,849
Canada	Grant	Environmental policy and administrative management	548,701
Switzerland	Grant	Cross-cutting / water and sanitation	18,168,445
Germany	Grant	Energy / agriculture / forestry,/ general environmental protection	63,491,844
	Concessional loan	Energy / forestry / water and sanitation/ industry / cross-cutting	919,783,637
Denmark	Grant	Environmental policy administrative management / water / transport / urban development and management	788,157
Spain	Grant	Cross-cutting/ water and sanitation / tourism / general environmental protection	119,954
	Concessional loan	Energy	388,010
France	Concessional loan	Energy / water and sanitation / biodiversity / urban development and management	557,993,236
UK	Grant	Environmental research / cross-cutting	22,520,000
Italy	Grant	Environmental policy and administrative management / agriculture / energy / cross-cutting	1,519,697
	Concessional loan	Agriculture	1,425,502
Japan	Grant	Cross-cutting / water and sanitation / agriculture / energy	5,478,104
Norway	Grant	Energy / fishery / other social infrastructure and service	19,123,082
Sweden	Grant	Environmental policy and administrative management / general environmental protection	555,103
US	Grant	Energy / cross-cutting	7,160,000

1.3.4 Problems and Challenges

First, developed countries are increasingly reluctant to fund China to tackle climate change. After decades of development, China has become the world's second largest economy by GDP and made tremendous progress in economic growth and people's livelihood. On this ground, developed countries cut funding support for tackling climate change to China. Despite a sizable economy, China, as a developing country with a population of 1.4 billion, still lags behind the world's average in terms of the per capita GDP in 2020, which failed to reach 1/3 and 1/6 of the levels in the EU and the US, respectively, and even trailed some small island countries. While working hard to reach carbon peaking and carbon neutrality and implementing the climate change adaptation strategy, China needs to address multiple challenges, including developing its economy, improving livelihood and protecting its ecological environment, to make up an enormous shortfall for tackling climate change.

Second, it is increasingly difficult for developing countries to receive climate change funding support from developed countries. On the one hand, developed countries haven't yet delivered their commitment in the Cancun Agreements that a combined US$100 billion per year would be mobilized by 2020 for climate action in developing countries, which is a statutory obligation specified in the UNFCCC. On the other hand, negotiations on the new collective quantified goal on climate finance for 2025 onwards progress slowly. Furthermore, developed countries underline that the scale of worldwide climate investment and financing had hit US$1 trillion, trying to confound its international obligations to provide climate funding with commercial behaviors in global investment and financing. This can prejudice the lawful rights stipulated in the UNFCCC and the Paris Agreement of developing countries including China.

Third, while China continues to ramp up efforts to tackle climate change, its evaluations of funding needs are at a tentative stage. Scientific forecasts indicate that climate change will increasingly pose risks to the natural ecological environment as well as social and economic development in China and across the globe. Actions addressing climate change are not at others'request but on China's own initiative. China steps up policies to address climate change in accordance with scientific requirements and based on enabling conditions relating to the stage of development, resources and technology. However, the growing expectations worldwide for climate policies coupled with enormous uncertainties in climate impacts, technological advances and resource conditions make it increasingly complicated to evaluate global funding needs for tackling climate change. Likewise, China is still at the stage of tentatively evaluating funding needs for the fulfillment of updated NDC goals and the goal of carbon neutrality.

Chapter 2 Technology Needs and Support Received for Addressing Climate Change

2.1 China's Technology Needs for Addressing Climate Change

China has specified its climate technology needs in the Third National Communication on Climate Change, including mitigation technology needs in 13 sectors or areas and adaptation technology needs in 4 areas. Given the newly-launched technology strategic planning and action programmes for combating climate change, this report updates and highlights carbon neutrality-technologies based on the previous basis. Regarding mitigation technologies, the report sets forth technology needs in key fields including thermal power generation, renewable energy, nuclear energy, smart grid, iron and steel industry, construction materials, transport, waste disposal and utilization, chemical utilization of greenhouse gases, CO_2 storage, carbon sequestration and sink enhancement in ecosystems. In regard to adaptation technologies, this communication elaborates on technology needs in key fields including water conservation in agriculture and breeding for stress tolerance, urban climate-resilient infrastructure and climate adaptation monitoring and disaster warning.

2.1.1 Mitigation Technology Needs

Despite China's mitigation technology accumulations, weak links still exist. China is imposing strict controls over coal consumption growth and has endeavored to promote clean and high-efficiency coal utilization, aiming to increase the share of non-fossil energy such as renewable and nuclear energy, and to motivate new energy consumption to optimize its energy mix. Main core mitigation technology categories for energy sector are: energy storage, hydrogen, advanced solar PV, offshore wind power generation, biomass energy conversion and utilization, next-generation nuclear reactors, carbon capture, utilization and storage (CCUS). Furthermore, iron and steel production, transport, construction materials, nonferrous metal and chemical production are the main industries where technology breakthroughs are desired. To name a few, decarbonization across the entire process of iron and steel production, zero-carbon cement, new and clean energy shipping, new energy vehicles, new energy aero-engines, digital shipping, zero-carbon buildings, municipal solid waste disposal and comprehensive utilization, emission-reduction in petrochemical production, and carbon dioxide enhanced oil recovery (CO_2-EOR).

In addition, enhancing ecosystems' carbon sink capacity is of great significance for China to fulfill its commitment to carbon neutrality, including forests, farmlands, grasslands, costal waters and wetlands carbon sink enhancement. Detailed technology needs are listed below in Table 5-5.

Table 5-5 Part of the Climate Change Mitigation Technology Needs

Technology items	Description	Support areas	Sectors	Sub-sectors	Technology transfer needs	Estimated period	Expected effects
New-type energy storage technology	New-type energy storage technologies can help improve comprehensive efficiency, regulating and safety control capability of power systems, increase the share of renewable energy and cater to needs of different application scenarios.	Mitigation	Energy	Electricity; power grid	Compressed air energy storage (CAES), flywheel energy storage (FES), fuel cells, flow cells, superconducting energy storage, and super-capacitors.	2022–2030	Cost cutting will enable large-scale renewable energy deployment.
Hydrogen	Leveraging hydrogen's large-scale and long duration advantage in energy storage can help to optimize the allocation of heterogeneous energy across regions and seasons, and integrate with electrical and thermal energy in a systematic way, so as to establish a clean energy supply system composed of diversified and complementary	Mitigation	Energy; industry; transport	Electricity; iron and steel industry; power grid; transport	The needs span from hydrogen production, storage and transport, fueling, to fuel cells and system integration. Hydrogen production technology mainly includes water-splitting technologies such as electrolysis and photolysis, and biomass conversion approaches. Storage and transport technology includes tube trailers, liquid hydrogen storage and transport at a low temperature, solid hydrogen storage and transport, pure hydrogen or hydrogen-mixed natural gas pipeline transport. Fueling technology requires key equipment and parts with	2022–2030	Safe and low-cost hydrogen will be applied at a large scale and integrated with electrical, transport and industrial systems.

Technology items	Description	Support areas	Sectors	Sub-sectors	Technology transfer needs	Estimated period	Expected effects
	units. It may also facilitate green development in transport and industry where energy is consumed.				high-reliability and energy efficiency. Fuel cell equipment and system integration technologies mainly include polymer electrolyte membrane fuel cell (PEMFC), solid oxide fuel cell (SOFC) and molten carbonate fuel cell (MCFC).		
Solar PV technology	Low-cost, highly efficient and stable solar PV and solar thermochemical conversion and comprehensive utilization technologies are essential to sustain solar power development with a high quality.	Mitigation	Energy	Renewable energy; electricity; building	Technologies and devices concerning high-efficiency laminated cells, new-type crystalline silicon cells, solar energy thermochemical conversion and other renewable energy complementing each other, medium-temperature solar energy-driven thermochemical fuel conversion and solar thermochemical power generation.	2022–2030	Low-cost solar PV technology will be used more efficiently and better integrate with buildings and other systems.
Offshore wind power generation technology	Develop low-cost and highly efficient wind power in far-out sea areas and ultra-large wind turbine to facilitate the development and utilization of wind power with a high quality.	Mitigation	Energy	Renewable energy; electric power	Technologies mainly include overall design, critical components manufacture and integration for ultra-high-power offshore wind turbine, floating wind turbine in far-out sea areas. Specifically, technologies may include permanent magnet synchronous generators (PMSG), double-fed induction generators (DFIG), direct drive motors, flexible gearboxes for double-fed induction	2022–2030	Offshore wind power generation technology will be utilized in a low-cost, high-efficiency and safe manner.

Technology items	Description	Support areas	Sectors	Sub-sectors	Technology transfer needs	Estimated period	Expected effects
					motors, offshore wind turbine foundations, seabed cable design and laying, typhoon-resistant wind turbine.		
Ocean power generation	Efficient ocean energy capture and conversion technologies to achieve reliable power generation.	Mitigation	Energy	Renewable energy; electric power	Ocean power generation and comprehensive utilization technology include efficient and reliable power generation with wave energy, tidal energy and ocean thermal energy.	2022–2030	Ocean energy will be utilized in a low-cost and high-efficiency manner in light of local conditions.
Biomass conversion and utilization	Efficient and high-value biomass conversion and utilization technologies can help facilitate clean transition in electricity, urban and industrial heating, and transport.	Mitigation	Energy; industry	Renewable energy; electricity industry and building; transport	Efficient biomass conversion technologies to produce aviation and transport biofuels, low carbon energy products and ethanol are included, as well as directional thermal conversion to produce biofuels, thermochemical conversion to produce biodiesel. Technologies across the biogas industrial chain, including raw material pretreatment, stable anaerobic digestion, high-value utilization of by-products are covered.	2022–2030	Biomass energy will be utilized in a low-cost way in the light of local conditions.
Advanced nuclear energy	Combined with passive design concept, promoting innovation of the third- and fourth-generation advanced nuclear power technology can help improve inherent safety continuously.	Mitigation	Energy	Nuclear energy; electric power; industry	New-generation of advanced nuclear energy technologies such as advanced fast reactor, mobile nuclear power sources, and other core technologies including advanced nuclear fuels and high-performance materials.	2022–2030	Enhanced stable, base-load electricity supply, and achieve comprehensive utilization of nuclear energy in a safe, highly efficient manner.

Technology items	Description	Support areas	Sectors	Sub-sectors	Technology transfer needs	Estimated period	Expected effects
Smart grid	Develop new-type smart grid technologies to sustain large scale renewable energy and distributed power integration in a grid-friendly manner.	Mitigation	Energy	Power grid	Loss reduction and efficiency improvement technologies in electric power transmission mainly include ultrahigh-voltage direct-current transmission (UHVDC), flexible AC transmission (FACT), flexible DC transmission, frequency-division transmission, DC power grid, as well as key materials such as superconducting materials and insulation materials. Other smart grid technologies include multi-directional and automatic allocation, energy-borne information, neural network control, predictive control, grid self-healing control and internet remote control technologies.	2022–2030	A smart, stable and flexible power grid will be formed.
Carbon capture, utilization and storage (CCUS)	Application of a new-generation highly efficient and energy-saving CO_2 capture technologies and devices can help facilitate emission control and reduction in the thermal power generation sector.	Mitigation	Energy; industry	Electric power; iron & steel making; cement	High-efficiency, energy-saving and low-cost technology of CCUS prior to and after burning.	2022–2030	CCUS will be applied to promote emission reduction in coal-fired power generation, stall making, cement and other industries.
Energy-saving in coking process	Innovative energy-saving	Mitigation	Industry	Industry; metallurgy	Coking coal humidification, high-temperature and high-pressure	2022–2030	Achieve energy-saving in coking process.

Technology items	Description	Support areas	Sectors	Sub-sectors	Technology transfer needs	Estimated period	Expected effects
	technologies and reformed equipment across coking, iron making, castling and finishing process can help achieve emission reduction in iron and steel industries.				coke dry quenching, thick-bed sintering, small ball sintering, and air leakage reduction in sintering.		
Energy-saving in iron making process		Mitigation	Industry	Iron & steel industry	Blast furnace top gas residual pressure power generation, conventional blast furnace top gas recycling, blast furnace gas CO_2 removal and recycling, blast furnace steam blowing, efficient blast furnace coal injection, and converter dry dust removal.	2022–2030	Achieve energy-saving in iron making process.
Energy-saving in casting and finishing process		Mitigation	Industry	Iron & steel industry	Efficient ladle pre-heating, thin slab/near net shape casting, thick slab continuous casting, direct strip casting, strip integrated continuous casting and rolling, hot pressing process control technologies. Also Energy saving in hot rolling mills, variable-frequency drives on cleaners, and heat recycling for annealed lines.	2022–2030	Achieve energy-saving in casting and finishing process.
Low-carbon iron and steel production	Raw material substitution and process reengineering technologies, including through hydrogen-based direct reduction process.	Mitigation	Industry	Iron & steel industry	Oxygen/oxygen-rich blast furnace, hydrogen-rich blast furnace injection, hydrogen direct reduction, electrochemical iron making, mega-scale electric furnace efficient smelting, co-production of chemicals with carbon-rich waste gases.	2022–2030	Stable and efficient hydrogen smelting process will be achieved.
Industrial waste heat utilization	Recover waste heat from industrial processes and transform into electricity	Mitigation	Industry	Iron & steel industry, metallurgy	Combined heat and power (CHP) and steam turbine technology integration enables cascade utilization of energy.	2022–2030	Achieve energy saving and emissions reduction in the iron and steel

Technology items	Description	Support areas	Sectors	Sub-sectors	Technology transfer needs	Estimated period	Expected effects
	or heat to help achieve energy saving and emission reduction in the iron and steel industry.				Power regeneration technologies such as coke (coke dry quenching) power generation, blast furnace top gas residue pressure power generation, and full-fired blast furnace gas boiler power generation .		industry.
Zero-carbon cement	Reduce carbon emissions in building sector through material substitution, process reengineering and CCUS .	Mitigation	Industry	Construction materials	Emission reduction technologies in cement production mainly include raw material substitution, biomass/refuse derived fuel (RDF) substitution, second-generation dry-process kiln, new-type high-efficiency burners such as multichannel pulverized coal burners, advanced grate cooler such as walking-step coolers, high-efficiency decomposition furnace preheating system, and CCUS in cement industry.	2022–2030	Achieve low carbon emissions in cement production process.

Technology items	Description	Support areas	Sectors	Sub-sectors	Technology transfer needs	Estimated period	Expected effects
Petrochemical emission reduction	Achieve emission reduction in key areas through process optimization and reengineering.	Mitigation	Industry	Chemical	Energy efficiency improvement technologies in the ethylene industry mainly include fired-gas soot blowing, high-temperature resistant materials, high temperature and radiation resistant coating for cracking furnaces. Energy efficiency improvement technologies in the caustic soda industry mainly include the evaporation optimization, falling film evaporation and electrolysis-polar distance ion membrane, membrane filtration, and alkylation-based purification of feed gas.	2022–2030	Facilitate process optimization and emission reduction in the petrochemical industry.
CO_2-EOR technology	Improve extraction efficiency through CO_2 flooding technology and achieve high-value utilization of CO_2.	Mitigation	Energy	Petroleum	Supercritical CO_2 injection technology with the aim to improve oil, natural gas and deep water recovery, strengthen geothermal systems (EGS) and in-situ uranium mining.	2022–2030	Achieve efficient oil recovery and CO_2 storage in a safe manner.
New and clean energy shipping	Achieve green, low-carbon transport through new and clean energy substitution such as liquefied natural gas (LNG), methanol, ammonia, biomass, hydrogen , solar and wind, as well as smart electric vehicles,	Mitigation	Transport	Water transport	LNG, hydrogen, ammonia and methanol fuel, and lithium-ion battery technologies.	2022–2030	Achieve economically competitive, low-carbon and sustainable energy substitution.
New energy vehicles		Mitigation	Transport	Highway transport	Hydrogen fuel cell vehicles, lithium-ion battery vehicles, as well as performance monitoring, transport energy internet, and other infrastructure supporting technologies.	2022–2030	
New energy aero-engine		Mitigation	Transport	Aviation	New energy powered aero-engine technologies, such as by hydrogen	2022–2030	

Technology items	Description	Support areas	Sectors	Sub-sectors	Technology transfer needs	Estimated period	Expected effects
	hydrogen fuel cell vehicles and ships.				energy and biofuel, as well as aerostructure optimization and energy saving technologies, such as wing design optimization.		
Digital technology in transport	Develop digital technology in transport can help achieve energy saving and emission reduction.	Mitigation	Transport	Road, water and air transport	Technologies mainly include innovative transport energy internet, multi-input energy conversion control and management technologies, distributed renewable energy grid integration, charging infrastructure planning, real-time monitoring of energy consumption and emission, information sharing and smart allocation, combined with the new generation of information technologies, including big data, internet of things, cloud computing, artificial intelligence and blockchain.	2022–2030	Improve smartness end efficiency of transport planning and management system to support sustainable development in transport sector.
Zero-carbon building	Develop technologies of energy conservation for buildings, electrification and building integrated PV (BIPV) to help reduce greenhouse gas emissions in the construction sector.	Mitigation; overlapping	Energy, construction	Electricity, power grid, construction	Building energy saving technologies mainly include retrofitting, cook electrification, low-grade access heat usage. Other technologies include renewable energy integration technologies such as BIPV, technologies supporting flexibility such as energy storage, DC distribution and interaction with electric cars.	2022–2030	Reduce energy consumption and promote electricity integration.
Municipal solid waste disposal	Develop municipal solid waste comprehensive	Mitigation	Waste disposal	Municipal administration;	Technologies mainly include gasification and pyrolysis of municipal	2022–2030	Achieve efficient municipal solid waste

Technology items	Description	Support areas	Sectors	Sub-sectors	Technology transfer needs	Estimated period	Expected effects
and comprehensive utilization	disposal technologies to achieve emission reduction and high-value utilization.			electricity	solid waste to produce syngas, tar, and coke. Landfill waste disposal technologies mainly include stabilization process acceleration, carbon sequestration, and landfill gas power generation technologies. Food waste disposal technologies mainly include fermentation and production of methane and organic fertilizer. Other technologies may also include refuse derived fuel (RDF) production with other high calorific value waste.		disposal and fuel substitution.
CO_2 storage	Develop CO_2 storage technology to reduce CO_2 in the air.	Mitigation	Energy; industry	Electric power; geology	Technologies mainly include geomechanical modelling and potential comprehensive evaluation of CO_2 geological storage, integrated with geological exploration, and emerging information technologies such as data mining, artificial intelligence and big data, and also include CO_2 injection-migration-long term storge technologies. Other technologies include storage security monitoring and resource coordination technologies.	2022–2030	Achieve sites selection and evaluation in a more accurate manner, and in a safe, stable and low-cost approach.

Technology items	Description	Support areas	Sectors	Sub-sectors	Technology transfer needs	Estimated period	Expected effects
Ecosystem carbon sink	Improve ecosystems' carbon sequestration capacity through enhanced carbon sink.	Mitigation, overlapping	Agriculture; forestry; ecology	Ecology; afforestation; sustainable forestry	Technologies mainly include carbon sequestration capacity improvement, ecosystem sustainable management such as for forests, grasslands, farmlands, deserts and wetlands, quick recovery of degraded ecosystems, and carbon sink enhancement for certain coastal ecosystems including mangroves, salt marshes and sea grass beds.	2022–2030	Effectively improve the carbon sequestration capacity of ecosystems.

2.1.2 Adaptation Technology Needs

China, as a large agricultural country, is much vulnerable to climate change adverse impacts. China and other developing countries share similar technology needs, of which agriculture and forestry call for the most. For example, agricultural water-saving irrigation, breeding for stress tolerance and pest control in crops are among the most needed. Technology needs in other sectors include vulnerable ecosystem conservation and restoration, comprehensive marine and coastal zone adaptation, climate-resilient urban construction, human health and adaptation, as well as climate monitoring, early warning, prevention and control for natural disasters, especially compound and concurrent catastrophes triggered by climate change. Detailed technology needs are listed below in Table 5-6.

Table 5-6 Part of the Climate Change Adaptation Technology Needs

Technology items	Description	Support areas	Sectors	Sub-sectors	Technology transfer needs	Estimated period	Expected effects
Water-efficient agricultural irrigation	Improve agricultural water efficiency by reducing agricultural irrigation water demand and losses	Adaptation	Agroforestry	Water-efficient irrigation	Technologies reducing agricultural irrigation water demand and losses and improving water use efficiency.	2022–2030	Improve agricultural water efficiency.
Breeding for stress tolerance and pest control	Increase crop resilience to adverse effects of climate change.	Adaptation; cross-cutting	Agroforestry	Agriculture	Technologies mainly include breeding for heat-tolerance in rice; breeding for drought-resistance in wheat and corn; crop pest and disease control. Identification and cultivation for resilient crop strains, such as for extreme high and low temperature, frought waterlogging, salt, and other stress.	2022–2030	Improve crop resilience.
Agricultural catastrophe insurance	Achieve climate transfer and sharing in agriculture.	Adaptation	Agroforestry	Agriculture	Technologies mainly include agricultural catastrophe insurance pricing and loss assessment, combined with the application of agricultural weather index insurance, with the aim to achieve risk transfer and sharing.	2022–2030	Improve agricultural insurance services.
Conservation and restoration of climate-vulnerable ecosystems	Improve the adaptive capacity of climate-vulnerable ecosystems through ecosystem protection and restoration technologies.	Adaptation	Ecosystems	Vulnerable ecosystems	Technologies mainly include biodiversity protection, degraded grasslands restoration and wetlands conservation in warming areas, forest succession, rare animals and plants conservation in areas suffering from dramatic climate change impacts.	2022–2030	Improve resilience of climate vulnerable ecosystems.

Comprehensive adaptation of coastal zones	Develop comprehensive adaptation technologies to achieve marine ecosystem and coastal infrastructure conservation.	Adaptation; cross-cutting	Ecosystems	Oceans and coastal zones	Technologies mainly include sea level and storm surge monitoring, coastal zone protection, mangrove and coral reef conservation, saltwater intrusion and salinization coping, shore revetment greening, costal dam restoration.	2022–2030	Increase resilience in coastal zones.
Climate-resilient infrastructure	Develop urban rainwater-resilient systems to achieve a virtuous urban hydrological cycle, and improve the capacity of rainwater runoff penetration, storage, purification, utilization and discharge.	Adaptation	Urban construction	Urban infrastructure	Achieve risk-resistent construction in urban areas by integrating a variety of comprehensive technologies and concepts of smart and sponge city, with the aim to improve urban climate resilience.	2022–2030	Improve climate-resilience for urban infrastructure.
Comprehensive adaptation of human health	Reduce the adverse effects of climate change on human health through monitoring, early warning and public hygiene.	Adaptation	Health	Human health	Monitoring, early warning and risk assessment for impacts on human health, assessment and prevention for prevalence of vector-borne diseases.	2022–2030	Improve human adaptive capacity to adverse climate effects.

Monitoring and early warning	Reduce risk of natural disasters caused by climate change through monitoring and early warning technologies.	Adaptation	Disaster control and prevention	Climate monitoring and disaster prewarning	Intelligent and precise monitoring of mutual feedback between atmosphere and multi-layers; climate system monitoring and analysis, accurate forecasting, as well as monitoring and early warning of extreme climate events, severe natural disasters, compound and concurrent natural hazards.	2022–2030	Improve climate disaster monitoring and early warning capabilities.
Disaster scenario simulation and replay	Develop disaster scenario simulation and replay technologies to reinforce forecast and intervention of natural disasters triggered by climate change.	Adaptation	Disaster control and prevention	Climate monitoring and disaster prewarning	Disaster scenario simulation and replay technologies, including catastrophe scenario construction, disaster chain analysis and proactive intervention, data analysis and warehouse building, digital-twin technologies.	2022–2030	Improve disaster forcasting capabilities.
Risk assessment and comprehensive precaution	Enhance comprehensive precaution and control through risk assessment and prevention technologies.	Adaptation	Disaster control and prevention	Climate monitoring and disaster prewarning	Climate change impact and risk assessment in vulnerable sectors and key areas, key threshold measurement, adaptation action effect evaluation, and risk prevention, emergency response and comprehensive management. Key equipment for information acquisition, as well as emergency communication, transport, life search and rescue, and epidemic prevention.	2022–2030	Improve risk assessment and comprehensive precaution capabilities.

2.2 China's Technology Inputs on Addressing Climate Change

Based on the Outline of the National Innovation-Driven Development Strategy, and guided by low-carbon development and climate change adaptation goals, China has put in place and continued to improve sci-tech development strategies, planning and policies for combating climate change, and will continue to increase investment in climate technologies and identify future directions.

In the 13th FYP period, China's investment in climate sci-tech research and development has significantly increased, and a market-oriented green technology innovation system has been gradually established. Diverse programmes targeted in climate sci-tech innovation, including the National Key Research and Development Program "Global Climate Change and Response", and the Strategy Priority Research Program "Transformational Technologies for Clean Energy and Demonstration" led by the Chinese Academy of Sciences (CAS). In 2019, China released the Guidance on Building a Market-oriented Green Technology Innovation System, which strengthened the leading role of enterprises in green technology innovation, and required that a market-oriented green technology innovation system be basically established by 2022. By rolling out the List of Energy-saving, Emission Reduction and Low-Carbon Technology Achievements for Transformation and Promotion, and the National Catalog for Key Energy-Saving and Low-Carbon Technologies Promotion, China has accelerated the application and deployment of low-carbon technologies with exemplary demonstration and emission-reduction potential. Basic studies on climate change impact, disaster risk assessment, climate change adaptation mechanisms have been carried out in response to industry and local needs.

Since the 14th FYP, China has launched more than 20 National Key Research and Development Program, including "Earth System and Global Change", "Renewable Energy Technology", "Hydrogen Technology", "Clean and High-efficiency Coal Utilization", with the aim to deploy and support green and low-carbon technology research and development in energy, industry, building, transport, carbon sink and CCUS in a systemic manner, so as to achieve low-carbon development, combat climate change and fulfill its international commitments.

China will take actions and safeguard measures proposed in the Implementation Plan for Carbon Peak and Carbon Neutrality Supported by Science and Technology (2022-2030) to coordinate sci-tech innovation efforts, and fully leverage the key supporting role of scientific and technological innovation in achieving the goal of carbon peaking and carbon neutrality. The Plan specifies actions to promote significant breakthroughs in key low-carbon technologies in key industries and sectors, including energy green and low-carbon transformation, low-carbon and zero-carbon industrial process reengineering, low-carbon and zero-carbon urban and rural construction and transportation, carbon negative and non-CO_2 greenhouse gas emission reduction, cutting-edge disruptive low-carbon technology, low-carbon and zero-carbon technology demonstration, carbon peak and carbon neutrality management and decision making, collaborative enhancement among innovation projects, bases and talent cultivation, green and low-carbon technology enterprise and service cultivation, as well as boosting international technology innovation cooperation.

2.3 Technological Assistance Received by China, and Problems and Challenges in Addressing Climate Change

2.3.1 Technological Assistance Received by China for Addressing Climate Change

A number of climate technology development and transfer activities have been carried out in China, led by international organizations through multilateral cooperation. As indicated in Table 5-7, activities mainly focused on the feasibility study of advanced technologies, capacity building and pilot demonstration, but in general there lacks of substantive transfer targeting key technology needs.

China and Annex II Parties to the UNFCCC have jointly pursued climate technology development and transfer actions under bilateral cooperation mechanisms. As for project purposes, technical activities were mainly intended for capacity building, technology transfer and policy support; from the perspective of fields, cooperation mainly focused on mitigation. Relevant activities were largely concentrated in the energy sector, with the main focus on incentive policies, capacity building and feasibility studies as well. Further steps can be taken in the future to promote climate technology cooperation, based on the technology needs identified above.

Table 5-7 Part of Technological Assistance Provided by International Organizations to China

Project name	Funding institution	Sector	Approval year	Enforcement body	Executive body	Description
Greening the Logistics Industry in Zhejiang Province	GEF	Transport	2016	UNDP	NDRC, local governments	Promote the application and practice of green energy-efficient logistics technology in Zhejiang Province.
Accelerating the Development and Commercialization of Fuel Cell Vehicles in China	GEF	Transport	2016	UNDP	MOST	Promote the commercialized production and application of fuel cell vehicles
Upgrading of China SHP Capacity Project	GEF	Energy	2016	UNIDO	MWR, MOF and International Center on Small Hydro Power	Sustain the transformation and upgrading of small hydro power in rural areas.
Developing Market-based Energy Efficiency Program in China	GEF	Energy	2017	WB	NDRC, local governments , Huaxia Bank	Support the development and implementation of key energy-efficient projects, improve

Project name	Funding institution	Sector	Approval year	Enforcement body	Executive body	Description
						energy conservation metering and verification systems, and promote market-based mechanisms.
Energy Efficiency Improvement in Public Sector Buildings	GEF	Construction	2017	UNDP	MOHURD	Promote energy conservation and efficiency improvement in public buildings.
GEF China Sustainable Cities Integrated Approach Pilot	GEF	Planning	2017	WB	MOF, MOHURD and local governments	Include the public transport-oriented sustainable development strategy in local planning of pilot cities.
Integrated Adoption of New Energy Vehicles in China	GEF	Transport	2017	UNIDO	MOIIT and China Society of Automotive Engineers	Promote the construction and application of the system integrating NEVs, smart grid and renewable energy.
Achieving Efficient and Green Freight Transport Development	GEF	Transport	2018	WB	MOT	Highlight the optimization of multimodal transport and urban freight transport systems, and improve freight transport efficiency and environmental sustainability.
China Distributed Renewable Energy Scale-up Project	GEF	Energy	2019	WB	National Energy Administration	Accelerate the promotion and application of distributed renewable energy and battery energy storage.
Climate Smart Management of Grassland Ecosystems	GEF	Forest grassland	2019	WB	MOA	Launch a pilot project on climate-smart grassland management in

Project name	Funding institution	Sector	Approval year	Enforcement body	Executive body	Description
						Qilian County in Qinghai Province
Catalysing private finance to maximize mitigation and adaptation impacts (Shandong Green Development Fund)	GCF	Comprehensive	2019	ADB	MOF and local governments	Promote financing for climate mitigation in energy and industry, and advanced technologies and climate financing in water resources, agriculture, coastal areas and ecological adaptation.

2.3.2 Problems and Challenges

Firstly, climate technology transfer has been hindered by anti-globalization policies. While the green and low-carbon transition has become an overriding trend internationally under the guidance of the Paris Agreement, the rise of anti-globalism and emergence of national security concepts in recent years has posed more difficulties on climate technology transfer. Developed countries have prioritized ensuring domestic supply chain security and industrial strengths, and their initiative to transfer climate technology to foreign countries has weakened. They have imposed trade restrictions or technology blockades in certain sectors and reinforced so-called security review on foreign investment, therefore posing adverse impacts on climate technology transfer to developing countries.

Secondly, the increasing propensity of multinational companies to monopolize technology has intensified, thus hamper the technology flow. As most advanced climate technologies are in hands of private sectors in developed countries, and enterprises have become increasingly prominent as the main actor of technology innovation and dissemination. With the acceleration of global technology development and the compression of technology products R&D and launch cycles, in order to maximize profits, obtain technology monopoly value, and occupy the market advantage of host countries, the main foreign investment approach of multinational companies has evolved from joint venture towards majority shareholding and sole proprietorship, or confine technology transfers to their overseas branches within the scope of property and control rights, the essence of which is to narrow the relevant technology transfer paths and set up obstacles to climate technology flows.

Chapter 3 Capacity Building Needs and Support Received for Addressing Climate Change

3.1 China's Capacity Building Needs for Addressing Climate Change

Although China has broadly made progress in its capacity to address climate change in terms of systems and mechanisms, policy making and implementation, Measurement, Reporting and Verification (MRV) systems, scientific research, public communication, public awareness, business administration and social action, there is a long way to go before China fulfills its long-term strategy and NDC goals for addressing climate change. Therefore, China still needs to work hard to improve its capacity and working mechanisms to become more capable of addressing climate change. Below are the details.

(1) Reinforce the role of new-generation information technology in climate change monitoring, impact and evaluation to establish a climate change monitoring and evaluation system in a dynamic and holistic manner;

(2) Conduct climate feasibility studies in key projects and national spatial planning for early-warning and risk management in extreme climate incidents;

(3) Deepen the linkage between efforts to address climate change and economic support policies to establish a diversified policy support system including fiscal support, compensation for ecological protection, transfer payment and risk sharing;

(4) Put in place and improve coordination and information sharing mechanisms for addressing climate change to promote cross-cutting cooperation and collaborative innovation; reinforce training for officials, specialized technical training, and public communication and education;

(5) Foster a working mechanism involving the participation and coordination efforts of multiple departments and an action mechanism featuring mass participation.

3.2 China's Input on Capacity Building for Addressing Climate Change

As a populous developing country, China commits itself to fostering an environment where everybody contributes to addressing climate change.

In the 13th FYP period, the whole Chinese society has become increasingly aware of the importance of addressing climate change. China has launched national energy conservation week and low carbon day events on a regular basis to disseminate concepts of energy conservation and low-carbon development. The strengths of traditional media and new media have been stretched to better publicize events or campaigns for addressing climate change. Venues on and off campus have been leveraged to include the knowledge of addressing climate change in teaching courses, practical education, family education and cadre training. The Code of Conduct for Environmental Protection has been rolled out to encourage the public to pursue low-carbon lifestyles through conservation of energy and resources and green consumption, help shift the public attention to food security issues resulting from climate change, and launch the Clear Your Plate campaign nationwide to reduce food waste.

China plans to prioritize the talent education system for carbon peaking and carbon neutrality, reinforce the training of grassroots professionals for climate change adaptation, introduce green and low-carbon development into the national education system, incentivize institutions of higher education to add disciplines related to carbon peaking and carbon neutrality, and compile books to popularize the knowledge of climate change adaptation and publicize climate adaptation efforts. Also, it will build a number of state key laboratories. specializing in product and technology R&D on energy conservation, carbon emissions reduction and new energy, national technological innovation centers and key platforms of sci-tech innovation; put in place and improve the green and low-carbon technology evaluation and transaction system, and the service platform for sci-tech innovation; advocate green and low-carbon lifestyles to adapt to climate change, launch demonstration campaigns on building a green and low-carbon society, and motivate businesses, residential communities, mass organizations and nationals to participate in climate adaptation efforts to make a greater consensus in society and accelerate the participation by all people.

3.3 Assistance Received by China for Capacity Building for Addressing Climate Change

3.3.1 Assistance Received by China for Capacity Building for Addressing Climate Change

From 2016 to 2020, China continued to cooperate on capacity building projects for addressing climate change with the Annex II Parties to the UNFCCC and international organizations.

The assistance received by China in the period for capacity building focused on improvements in contact performance transparency, climate policy making and planning, talent cultivation, and knowledge center construction. With the aid of multilateral mechanisms, China has launched the first phase of the transparency capacity construction project funded by the GEF, and become more capable of compiling the inventory of greenhouse gases, making statistics and evaluations of climate change addressing efforts and drawing out national reports on contract performance. A few developed countries like France, Italy, Japan and Germany have assisted China in carrying out training programs aimed at capacity building for addressing climate change. Joint research centers have also been set up in China through MOUs. The successful experience of developed countries can help China respond better to climate change in terms of theories, practice cases and professional workforce.

3.3.2 Problems and Challenges

When receiving assistance for capacity building, China has noted the absence of a mechanism for supply-demand information sharing and matching across the globe, which caused the phenomenon that numerous China's needs were not timely responded or met. While developing countries including China have figured out their priority sectors for addressing climate change and capacity building needs based on their national conditions by issuing national determined contribution reports, national communications and biennial update reports, there still doesn't exist an effective, comprehensive and transparent supply-demand information platform and a matching mechanism. As a result, it is difficult for developing countries to gain assistance for capacity building for addressing climate change in a timely and efficient manner, including associated climate funding and technology assistance.

Chapter 4 Transparency Needs for Funding, Technology and Capacity Building in Climate Change Response

4.1 Challenges for the Transparency of Funding, Technology and Capacity Building in Climate Change Response

China's efforts in securing funding, technology and capacity building for addressing climate change involve numerous sectors, policies, actions and projects. To be specific, funds come from a variety of channels, technology R&D, application and transference concerns multiple players, and people from all walks of life participate in the capacity building campaigns. In compiling this section, it is found that China still has insufficiency in the statistics and reporting systems of climate funding, technology and capacity building and thus faces enormous challenges in transparency compliance as follows.

(1) Information on international funding, technology transfers and capacity building for addressing climate change has not yet been included in the national statistics system, statistical indicators are not compiled with a unified methodology, and conventional screening, tracking and reporting of such information remains to be done;

(2) In the absence of an authoritative methodology to evaluate climate funding needs, evaluation results based on different methodologies differ considerably and therefore cannot sustain decision making;

(3) It is difficult to establish a stable statistical system and update it timely, as numerous technologies are required for addressing climate change, technological R&D, application and transference needs are changing constantly with global policies concerned, and international cooperation on cutting-edge technologies are subject to disruptions from geopolitics;

(4) The national statistics system and administrative departments cannot get the full picture, attributable to wide social participation and decentralized channels of information on funding, technology and capacity building.

4.2 Transparency Needs for the Funding, Technology and Capacity Building in Climate Change Response

To improve its transparency of funding, technology and capacity building for addressing climate change, China needs to:

(1) Reinforce international exchanges and learn effective statistical and reporting practices from other countries;

(2) Launch studies of statistical methodology, and consider China's features of domestic and international cooperation on climate funding, technology development and transfers, and capacity building to work out a statistical methodology suiting the needs of China's statistical and administrative systems and in line with international practices;

(3) Set up a unified national statistical system for efforts in climate funding, technology development and transfers, and capacity building;

(4) Pairing up with other countries stably with the coordination from the secretariat of the UNFCCC, as a way to enable mutual assistance in climate funding, technology development and transfers, and capacity building.

All the above measures need assistance from the Annex II Parties to the UNFCCC.

Part VI Other Relevant Information for Achieving the UNFCCC Targets

In the 13th FYP period, the Chinese government has earnestly performed its duties under the UNFCCC. China has seen tremendous improvements in climate system observation, the sci-tech capacity for addressing climate change, and the public awareness of climate change response participation; China has pursued international cooperation and exchanges on climate change response, advanced the South-South cooperation in a pragmatic way and helped other developing countries improve their capacity for addressing climate change to promote high-quality social and economic development in China and contribute to safeguarding the global eco-security.

Chapter 1 Climate System Observation

1.1 The Status Quo of China's Climate System Observation

Observation is an essential way to know the status quo of climate systems. In the 13th FYP period, China's comprehensive meteorological observation capacity reached the world-leading level, the comprehensive marine observation capacity has improved remarkably, and the construction of ecological observation systems has been reinforced. These are symbolic of China's substantial progress in climate change information service and supporting capacity.

1.1.1 Atmosphere Observation

Integrated surface-based meteorological observation: China has established a three-sphere system for meteorological observation integrating surface, upper-air and space observation (Table 6-1). By the end of 2020, China's meteorological authorities had built more than 60,000 land- or sea-based stations, which span all rural and urban areas, and realized automatic surface observation. There are a total of 24 national observatories across the country; 224 new-generation meteorological radars that can observe 30% [45] of China's land area. China boasts a total of 10,920 national surface meteorological stations, including 216 reference stations, 626 basic stations and 10,078 conventional stations. Among the national surface observation meteorological stations, 345 are for acid rain observation, 28 are for sandstorm observation, and 7 are atmospheric background stations. China will continue its efforts in building monitoring and evaluation systems for atmospheric background observation, climate systems and ecosystems.

Meteorological satellite observation: By the end of 2020, China had launched a total of 17 meteorological satellites, 7 of which remain in orbit, and built 6 national surface receiving stations.

[45] Calculated at an elevation angle of 0.5 degrees and a distance of 1 kilometer from ground.

Table 6-1 The Quantity of China's Meteorological Stations or Facilities [46]

Station/Facility	Quantity	Station/Facility	Quantity
National surface meteorological stations	10,920	**Satellite data receiving stations**	309
Provincial meteorological stations	53,064	**Automatic soil moisture observation**	2,488
Buoys	40	**Thunder and lightning observation**	499
L-wave upper-air meteorological stations	120	**Wind energy observation stations**	142
National new-generation weather radars	224	**Solar radiation observation**	138
Agricultural meteorological observation	653	**Acid rain observation**	345
Atmospheric background stations	7	**Atmospheric composition observation**	270
Sandstorm observation	28	**Wind profile radars**	156
GNSS/MET observation	1,060	**Space weather observatory**	56
Fengyun meteorological satellite in-orbit	7	**Mobile observation facilities**	1,026

Greenhouse gas observation. In the 13th Five-year Plan period, China continued to maintain and operate 1 global atmospheric background station and 6 regional atmospheric background stations (as elaborated in Figure 6-1), and establish the national GHG observation network to carry forward high-precision CO_2 concentration observation, atmosphere background observation of total elements of GHG, and satellite remote sensing observation for GHG. China's first GHG monitoring interferometer, carried by the Fengyun-3D satellite, can provide data of global GHG emission and support studies of the relationship between GHG and climate change; the GHG monitoring Instrument (GMI) on Gaofen-5, China's first hyperspectral observation satellite, monitors the atmospheric environment through retrieving GHG by employing Spatial Heterodyne Spectroscopy (SHS) to split hyperspectral beams. These will provide database for China's studies on climate change.

[46] Statistics by the end of 2020.

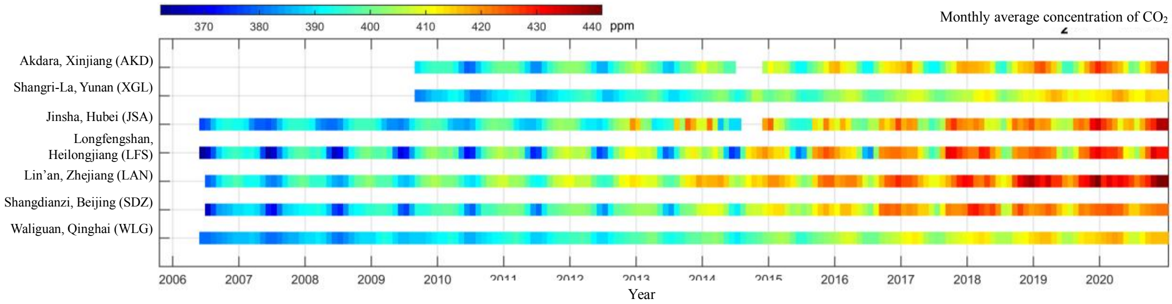


Figure 6-1 Monthly Atmospheric CO_2 Average Concentration Statistics of 7 Atmospheric Background Stations in China, 2006-2020

China has been publishing the Climate Change Bulletin annually (renamed the Blue Book on Climate Change in China in 2016), which elaborates on the conditions of the atmosphere, hydrosphere, cryosphere and biosphere, as well as drivers of climate change. Since 2012, China has been publishing the Greenhouse Gas Bulletin annually to introduce China's background observation of GHG. China's risk management capacity on meteorological disaster and hazard has been improved across the board, and the risk management systems have been expanded from the national level to provincial level. Also, China's capabilities in early warning of meteorological hazards and information dissemination have been further enhanced. For example, the accuracy rate for rainstorm warning has reached 90%; the severe convection weather warning can be advanced to 40 minutes; the dissemination time of hazard warning information can be shortened from 30 minutes to 3-10 minutes; and the public coverage of early warning information can reach 95%. These represent China's capability of methodological disaster prevention and relief, and fully played the role of the first line of defense for meteorological hazards prevention and mitigation. .

1.1.2 Marine Observation

Integrated marine observation network. In 2008, China initiated the air-sea CO_2 flux monitoring campaign, in which 29 ship-based cruise monitoring sections, six shore- or island-based base stations and 5 buoy stations have been planned and designed to establish a stereoscopic monitoring system integrating cruise observation and long-sequence time-series fixed point observation. The marine observation layout has been improved. In the 13th FYP period, China has established 47 new national basic marine observation stations and installed 84 sets of anchored and drifting buoys, making the national basic marine observation stations and buoys of all kinds reach 155 and 143 in total, respectively. The first two 3,000-tonnage professional buoy operation ships independently designed and built by China officially entered service. The marine observation system has been improved through establishing a comprehensive marine monitoring system. Fixed point observation stations have been deployed on a long-term basis in typical bays, estuaries and special habitats. An offshore and oceangoing observation network, mainly composed of arrays of surface buoys and subsurface buoys, has also been established to monitor global climate change, evolution in marine ecosystems and transformation of biological resource.

Oceanography **satellite observation.** In the 13th FYP period, China launched 6 oceanography satellites, namely HaiYang-1C, HaiYang-2B, CFOSAT, HaiYang-1D, HaiYang-2C and Gaofen-3. By the end of the 13th FYP Period, seven oceanography satellites remained operating in orbit. A national global stereoscopic marine observation network has been established, composed of oceanographic stations, radars, buoys, seabed observations, volunteer ships, section surveying, satellite remote sensing and flexible observation, covering shore-, sea-, air-, and space-based ocean observation systems. China's oceanography satellites have basically pivoted from a single model to multiple models, and from pilot applications to operational services, providing global integrated environmental information on sea surface wind fields, waves, flow fields, sea surface temperatures, red tides and green tides.

Marine monitoring and disaster early warning. The First Scientific Assessment Report on the Ocean and Climate Change, published in 2019, elaborated on the changes of oceans and climate change, and its impacts and adaptation measures. Since 2018, China has been publishing the Blue Book on Marine Climate Change annually to analyze marine climate conditions and trends. The warning and forecasting capacity for ocean hazards has been further improved. For example, the forecast validity period has extended from 3 days to 5-7 days and the forecast accuracy has improved by 5%; the time frame for tsunami warning has shortened from 15-20 minutes to 8 minutes. The annual monitoring on sea surface change and assessment on its impacts, alongside the annually released China Sea Level Bulletin, can provide a reference for national territorial and spatial planning and marine disaster prevention and reduction.

1.1.3 Ecosystem Observation

Terrestrial ecosystem observation network. By the end of 2020, the National Ecosystem Research Network of China (CNERN) had put in place 18 national farmland ecosystem research stations, 17 national forest ecosystem research stations, 9 national grassland and desert ecosystem research stations and 7 national water and wetland ecosystem research stations. The Chinese Ecosystem Research Network (CERN) has built 44 ecosystem research stations across ecological zones in the country, including 48 comprehensive observation fields, 120 auxiliary observation fields, 1,100 locating observation points and 15,000 fixed survey spots, where observations of ecological elements such as biology, hydrology, soil and meteorology in farmlands, forests, grasslands and deserts, wetlands and cities and other ecosystems, can be made; the ChinaFLUX has accumulated raw data through continuous observations of carbon, nitrogen, water, and energy flux since its inception in 2002, putting in place 79 observation stations and becoming a national-level ecosystems observation and research network system for carbon, nitrogen, water, and energy flux. Up to 100 terabytes of annual flux and meteorological data, covering more than 400 sites and 50 indicators, has been collected.

Marine ecosystem observation network. Early warning and monitoring for marine ecosystems has been launched nationwide by putting in place more than 1,100 stations and making standard section investigations in 12 coastal waters. A total of 31 red tides have been swiftly responded by conducting early warning and monitoring in 36 high risk areas of red tides across the country. In 2020, a total of 409 monitoring points were set up in coastal provinces (autonomous regions or municipalities directly under the central government) to establish linkages with national sea water quality control points. The health conditions of 24 typical marine ecosystems covering estuaries, bays, coastal wetlands, mangroves, coral reefs, and seaweed beds were monitored using five categories of indicators comprising water quality, sediment quality, biological quality, habitat conditions and biocoenosis. The relevant results were published in the Bulletin of Marine Ecology and Environment Status of China.

Phenological observation. The Chinese Phenological Observation Network (CPON) has established 44 observation stations, comprising 39 manual observation stations (34 conventional stations and 5 phenological observation stations for ornamental flowers and trees) and 9 camera observation stations. Chengdu of Sichuan Province, Xinyang of Henan Province, and Danzhou of Hainan Province are making phenological observations through both approaches. These stations are observing 35 species of common plants, 127 species of endemic plants, 12 species of animals, 4 species of crops and 12 species of meteorological and hydrological phenomena.

1.1.4 Water Resources Observation

Surface water observation. China's hydrological stations network has made rapid progress and a sound hydrological monitoring system has taken shape. The number of hydrological stations has increased significantly, covering almost all major rivers and tributaries in the country, and effectively monitoring the hydrological situation of major rivers. By the end of 2020, there were 3,265 national basic hydrological stations, 4,492 special hydrological stations, 16,068 gauging stations, 53,392 precipitation stations, eight evaporation stations, 4,218 soil moisture monitoring stations, 61 experimental stations and 2,608 forecasting stations.

Groundwater observation. China has completed and put into operation its national groundwater monitoring project, and the capacity of water resources management and security guarantee has been improved. By the end of 2020, 27,448 groundwater stations and 10,962 water quality stations had been built. The national hierarchical and automatic groundwater monitoring network were established, carrying out 29 shallow groundwater and 23 deep groundwater monitoring in major plains and basins, involving a monitoring area of 3.50 million km^2 and enabling information sharing at more than 20,000 monitoring stations. As a result, China's major plains, basins and karst aquifers have been effectively monitored to offer a general idea of groundwater levels and quality changes nationwide.

1.1.5 Cryosphere Observation

High-cold region Observation and Research Network for Land surface processes & Environment of China (HORN). A total of 17 field stations under the CAS, combined with others from outside the CAS, formed the HORN, which is the long-term monitoring network for and surface processes and environmental changes in high-cold regions, thus bolstering studies such as the integrated study of the earth system, impact of changes in key regions and the responses to the global change, and quantitative attribution of the role of human activities in global change.

Observations in the polar regions. Annual scientific expeditions in the polar regions are carried out on a regular basis. Cruising observations in the Arctic and Antarctic regions rely on “Xue Long” and “Xue Long 2” icebreakers, which are equipped with atmospheric, hydrological, biological and computer data processing centers and meteorological analysis and forecast centers, as well as scientific research labs on marine physics, marine chemistry, biology, geology, meteorology and contamination control. Meteorological observations in the polar regions have comprised cruising observations as well as continuous observations based on automatic weather stations. A total of 4 automatic weather stations in Antarctica and 1 automatic weather station in the Arctic have been built, all of which have the ability to carry out continuous automatic meteorological observations in ultra-cold regions. An inland scientific expedition on Antarctic ice sheet has been made to observe the ice sheets’ mass balance, and the conditions of ice and snow.

1.2 Document Management and Data

Observations of the different components of climate system in China are separately collected and managed by the respective operating authorities and research institutions such as the CAS. The China Digital Ocean Information Basic Framework has been established and strict quality control has been carried out in the production process of data products; Under framework of the WMO’s Global Atmosphere Watch (GAW) Programme, China has been geared to international practices in regard to GHG observation methods, standards and procedures; scientific data on ecosystems that are closely associated with climate change stem from long-term accumulation of observation and research data, and are accessible in different ways including opening to the public, protocol-based sharing or restricted sharing; accumulation of scientific data on the cryosphere have gradually shifted from single component observation to systemic observations of multiple components. In addition, certain observation standards or specifications for all components of the cryosphere have been formulated, and related standards or specifications were also followed when producing data.

After many years of constant effort, China has accumulated scientific data on climate change for a prolonged period of time. The spatial coverage and accuracy of data have been continuously improved, and most of the data are publicly accessible or registered for access. China has regulated the management of national sci-tech resources and stepped up the construction of national science data centers (Table 6-2).

Table 6-2 China's National Scientific Data Centers on Climatic System Observation

National platforms	Founders	Competent authorities
National Earth Observation Data Center	Institute of Remote Sensing and Digital Earth, CAS	CAS
National Polar Data Center	Polar Research Institute of China	MONR
National Tibetan Plateau Data Center	Institute of Tibetan Plateau Research, CAS	CAS
National Ecosystem Science Data Center	Institute of Geographic Sciences and Natural Resources, CAS	CAS
National Cryosphere Desert Data Center	Northwest Institute of Eco-Environment and Resources, CAS	CAS
National Earth System Science Data Center	Institute of Geographic Sciences and Natural Resources, CAS	CAS
National Agricultural Science Data Center	Agricultural Information Institute of CAAS	MOA
National Forestry and Grassland Science Data Center	Resources Information Institute of CAF	National Forestry and Grassland Administration
National Meteorological Science Data Center	National Meteorological Information Center	China Meteorological Administration
National Marine Data Center	National Marine Data Information Center	MONR

Chapter 2 Basic Research of Climate Change

China has always attached great importance to its sci-tech innovation capacity for addressing climate change. The MOST, among other authorities, released the National 13th Five-Year Plan for Sci-tech Innovation for Addressing Climate Change, which made an overall planning for sci-tech efforts for addressing climate change. The MOST, the National Natural Science Foundation of China, the CAS, the Chinese Academy of Social Sciences, institutions of higher learning and local governments have set up a range of climate change research projects. More than 10 key technology R&D projects on climate change response have been launched under the National Key Research and Development Program of China. A total of 143 technologies of GHG emission reduction and recycling have been vigorously promoted and applied. China has made a big step forward in scientific research and technological development for addressing climate change and improved its related scientific and technological capacity.

2.1 The Status Quo and Main Achievements of Climate Change Research

2.1.1 Basic Science

A slew of original achievements have been scored in the basic science of climate change, and the cross-disciplinary research capacity has improved remarkably. A collection of internationally influential data sets or bases for climate change research have been created, including the satellite retrieval of global vegetation chlorophyll fluorescence, gridded data of global ocean temperature and salinity, and multi-source meteorological data fusion and reanalysis data. New understandings and discoveries have been made on many aspects, such as the dynamics of the Earth system in the monsoon Asia-western Pacific-Indian Ocean region, Earth system process and mechanisms, subseason-season-interannual prediction by integrated climate model attribution of major climate events, marine biogeochemical cycles of carbon and nitrogen in the context of climate change, the mechanism of interdacadal changes in sea surface temperature of the tropical western Pacific, the impact of interaction between paleomonsoons and west winds on the spatial-temporal pattern of dry and wet paleoclimate, and the impact of large-scale wind and solar power generation facilities on regional climate and ecological environment. China has also developed its own integrated assessment models and policy simulation platforms for addressing climate change. China has quantitatively evaluated the vulnerability of agricultural production, established an assessment framework of urban adaptation ability to climate change based on the exposure-sensitivities-resilience pattern, worked out methods to assess quantitatively climate change risks, and carried out theoretical exposition and cases analysis for emergencies and transition events. The MOST worked with 16 authorities including the China Meteorological Administration, the Chinese Academy of Sciences and the Chinese Academy of Engineering to compile the Fourth National Assessment Report on Climate Change. Eight climate system models or Earth system models participated in the Coupled Model Intercomparison Project Phase 6 (CMIP6). The results were included in the sixth assessment report of the

Intergovernmental Panel on Climate Change (IPCC) and applied in China's climate simulation research and short-range climate prediction operations.

2.1.2 Mitigation Technologies

R&D of cutting-edge energy technologies has moved towards a new stage. Technology R&D of high precision seismic prospecting and exploitation for oil gas, shale gas, coalbed methane and deep-sea oil and gas resources under complicated geological conditions in Western China has been launched. The key technology design for "Hualong No. 1" nuclear power plant with independent intellectual property rights in China has been completed, and construction of the world's first demonstration project for commercial purpose—No.5 generating set in Fuqing Nuclear Power Plant—has begun; key technologies of high temperature gas-cooled reactors (HTGR) have been tackled, and the demonstration project of HTGR nuclear power plant in Shidao Bay with a capacity of 200,000 kW has begun construction. The R&D of core key technologies including green coal development, high-efficiency coal power generation, clean carbon transformation and CCUS has been accelerated, and a batch of advanced and applicable technologies have been demonstrated and promoted. Coal-fired power generation and ultra-low emission technologies have achieved an overall leadership, and modern coal chemical industry and poly-generation technologies have achieved major breakthroughs. Large-scale grid-connected scheduling and control for renewable energy, flexible grid interconnection, supply and demand interaction-based power consumption among diversified users and basic support technologies for smart grids have been also developed. The technology R&D of UHV power transmission and flexible power transmission between Zhangjiakou and Beijing has been fulfilled. The first off-shore floating wind turbine as well as high-quality electroslag molded blades for the world's first 1,000-megawatt water turbine in Baihetan Hydropower Station have been developed. Systemic studies of engineering applications have been launched on green and intelligent inland ships, hydrogen fuel batteries, and battery power and hybrid power for ships.

China has been advancing the technological research of carbon dioxide geological storage. The Roadmap for Carbon Capture, Utilization and Storage Technology Development in China (2019) was released. The potential of carbon dioxide geological utilization and storage in Qitai area, eastern Junggar Basin, Xinjiang, was evaluated, and the methods for evaluation of basin-scale carbon dioxide geological storage potential and storage engineering site selection in basins were optimized; the evaluation of carbon dioxide storage potential of the Junggar Basin and its suitability, as well as the atlas compilation, had been completed, making clear the matching conditions of carbon source and sink for carbon storage in the basin. A pioneering field test of CO_2-EWR, which involved a filling of 1,010 tons of carbon dioxide was launched in Zhundong, Xinjiang, andverified that CO_2-EWR is technologically feasible and geologically safe; a technique for tracing and monitoring carbon dioxide diffusion and transport in deep underground reservoirs was developed.

2.1.3 Adaptation Technologies

China has developed climate risk evaluation technologies to improve its capacity of disaster prevention. The second round of evaluations of climate change has been made in China's eight climatic regions. A relatively comprehensive seamless meteorological forecast and prediction operation system has been basically established for China and globally from zero time to monthly, seasonal, and annual scale, covering elementary meteorological elements, severe weather and climate events and their impacts, climate risk early warning, and so on. The space-air-ground integrated detection methods and catalysis technologies suitable for the landform in Northwest China have been worked out. The technologies of nationwide natural disaster risk investigation, assessment and zoning have been studied and developed, and both the single disaster risks and integrated risks of 9 categories of meteorological disasters at national, provincial, municipal and county levels has been assessed and zoning. In July 2020, China launched its first national general survey of integrated risks of natural disasters, covering damages caused by 22 kinds of disasters in six broad categories, namely earthquake disasters, geological disasters, meteorological disasters, floods and droughts, marine disasters, and forest and grassland fire disasters. A technical and methodological system for drawing the red lines for ecological conservation has been put in place, which has supported the establishment of a management system for the protected natural area with national parks as the main body.

Adaptation technologies for all sectors have advanced. With the integrated applications of new water-efficient winter wheat species and supporting techniques, a package of solutions ranging from pest control to special combined harvesting machinery has been worked out. A total of 220 high-standard demonstration areas for water-efficient agriculture have been built in dry farming regions in North China and Northwest China, where water-deficient dry farming techniques, such as water storage and moisture preservation, rainwater harvesting for irrigation, ridge tillage and furrow irrigation, supplemental irrigation based on soil moisture measurement, water and fertilizer integration, drought and stress resistance, and etc., were demonstrated and promoted to improve the efficiency of water utilization. A unique theoretical and technological system for early round-grain non-glutinous rice breeding in cold regions has been created. Research of the key technologies of water pollution control in river basins, prevention and control of lake eutrophication, and restoration of water environment and ecology has been launched; technological breakthroughs have been made in drinking water source protection and advanced treatment and transportation of drinking water. Integrated technologies for ensuring the safety of drinking water and technologies of water quality improvement and water quantity allocation have been developed. Studies have been made on the impacts of extreme weather and climate events on human health and the role of climate change in the spread of parasitic diseases. Adaptation technologies targeting typical coastal areas and sectors like bumper grain harvests have been demonstrated, promoted and applied in an integrated manner.

2.1.4 International Cooperation in Science and Technology

Project cooperation and technical discussions have been conducted with the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), the Asian Development Bank (ADB), the Global Environment Facility (GEF), the World Meteorological Organization (WMO), the International Union of Conservation of Nature (IUCN), the Intergovernmental Panel on Climate Change (IPCC), the Global Climate Observation System (GCOS) and the Future Earth, among other international institutions. The Global Center on Adaptation (GCA) China Office has been set up, and the report named Adapt Now: A Global Call for Leadership on Climate Resilience has been released. The Technology Transfer South-South Cooperation Centre has been founded to pursue cooperation on studies of technology transfer and capacity building for addressing climate change in developing countries. Studies have been made on "ecosystem-based adaptation" and "nature-based solutions." Documents including Overview of Environmental Risk Analysis by Financial Institutions, Case Studies of Environmental Risk Analysis Methodologies, UK-China Co-operation on Climate Change Risk Assessment: Developing Indicators of Climate Risk have been published, and Chinese experts on climate change held dialogues with their peers from the US, India and Germany respectively. China has further promoted the use of meteorological satellites for "Belt and Road" projects and provided gratuitously international users with carbon satellite data. Technological exchanges and cooperation with other developing countries have been strengthened on satellite monitoring, marine monitoring, and fields such as agriculture, water resources and clean energy development and utilization. Since the start of 2011, China has trained approximately 2,000 officials and technicians from nearly 120 developing countries on climate change policies, mitigation and adaptation technologies and measures, thereby making them more capable of tackling climate change.

2.2 Inadequacy in Research of Climate Change and Future Research Direction

The overall level of China's scientific and technological research for addressing climate change needs to be improved. It still lacks research on such mechanisms as interactions between multiple spheres, multiple dimensions and multiple factors of the Earth system, and mutual feedback between the Earth and its regions; the originality for basic data development and R&D on high-resolution Earth system models is yet to be improved; capacity in quantitative evaluation of climate change impacts and risks is weak, and adaptation technologies in key regions and sectors are insufficient; capacity and standards of greenhouse gas calculation and monitoring are to be improved, and new methods for technological substitution in the low-carbon energy system are lacking. Therefore, China desperately needs new data, theories, methods, models and technologies as follows.

(1) **Research of multi-source data fusion and climate change regularities.** China needs to prioritize integrated, unified and intelligent global climate system observation technologies, improve the high-resolution observation and monitoring system, combine sea-land-space observation and monitoring systems and basic data, develop global and key regional data products with proprietary intellectual property rights and find out the inpacts

of climate change on key species and ecosystems.

(2) **R&D on Earth system simulators and regional climate change models.** China needs to study the mechanism of interactions between multiple spheres of the climate system at seasonal to interdecadal scales, launch R&D on couplers to couple in climate system models more human activities, such as atmospheric chemistry and aerosol, and processes of other Earth system component, build regional climate models with kilometer-level resolution that is suitable for China's complex terrain, and develop detection and attribution technologies for climate change and extreme events.

(3) **R&D on key technologies of climate change impacts, vulnerability and risk evaluation, and adaptation.** China needs to develop an indicator system and quantitative analysis technologies for multidimensional impacts of climate change, reinforce studies of varied strategies for adaptation to climate change in different regions, improve capacity of quantitative assessment of climate change adaptation and resilience of key industries and different regions, such as coastal areas, agricultural areas, poverty-stricken areas, ecologically fragile areas, the Qinghai-Xizang Plateau and biodiversity hotspots, and prioritize technology R&D on effect monitoring and evaluation, cost and benefit evaluation, recognition of technological limitations and adverse effects, and planning and zoning for climate change adaptation in key sectors and regions.

(4) **R&D and promotion of key and applicable technologies for climate change mitigation.** China needs to develop the monitoring, calculation, data storage, processing and utilization for GHG and other anthropogenic emissions, key technologies for energy conservation and energy efficiency improvement and for zero carbon and negative emissions, technologies for carbon sink management (ecological restoration, afforestation, etc.) and evaluation of its contribution to global emissions reduction. The future energy system will be characterized by diversity, low carbonization and volatility. From the system level, the safety, efficiency and interaction of energy supply and demand sides will require new technologies such as multi-energy integration, intelligent source-network-load-storage coordination optimization, supply and demand balance. It is necessary to evaluate, select and establish the most feasible and operable climate change mitigation technologies for different sectors and regions, and seek effective integration of technologies, so as to form a Chinese technique system of climate change mitigation that can be popularized.

Chapter 3 Education, Public Communication and Public Awareness Raising

3.1 Education and Training

3.1.1 Strengthened Education on Climate Change Response

China has continued to reinforce eco-civilization education in elementary and middle schools and clearly requires that students should be taught the basic knowledge of climate change, ecological environment, as well as the hazards and implications in such courses as sciences and comprehensive practices and activities. In addition, China has ramped up efforts to promote climate change-related majors in institutions of higher learning.

Ecological education is strengthened in elementary and middle schools. A guideline on moral education in elementary and middle schools has been rolled out to make ecological education an important part of moral education in elementary and middle schools. The guidelines call for reinforcing education on resource saving and environmental protection, launching activities of saving grain, water and electricity, promoting waste sorting, advocating green consumption, and instructing students to develop habits of frugality, low-carbon living and environmental protection. Campus activities themed on ecological civilization have been held across the country, and educational activities on environmental protection have been implemented on Tree-Planting Day, Earth Day and World Environment Day. Activities are also held outside the campus to encourage eco-environmental protection. For example, 622 national research and practice education bases for elementary and middle school students have been selected and named in the 13th FYP period. Schools have been encouraged to develop courses on ecological education in the light of their local conditions including features of physical geography and traditional culture. Schools and families have joined hands to make elementary and middle school students aware of the importance of ecological progress, and the role of families as an education front has been leveraged.

Efforts are ramped up to develop climate change-related majors in universities and colleges. By the end of 2020, over 10 climate change-related programs in three categories, namely atmospheric sciences, energy and power engineering, and natural conservation and environmental ecology had been set up nationwide, involving more than 300 colleges and universities, and more than 10 undergraduate programs had been newly launched including meteorological technology and engineering, energy storage sciences and engineering, energy service engineering, hydro energy sciences and engineering, sustainable energy, wetland conservation and restoration. The cultivation of top-notch personnel in atmospheric sciences has been innovated, the Double Ten Thousand Plan has been launched to build first-class programs, and 113 climate change-related programs have been included in the national construction campaign for first-class undergraduate programs. A number of second-level disciplines related to climate change response have been set up under first-level disciplines. To be specific, more than 50 second-level disciplines closely associated with climate change response, including climate change economics, Earth meteorology and environment, and agricultural ecology and climate change have been set up under such first-level disciplines as applied economics, geology and agricultural resources and environment. A total of 12 new doctoral programs, 61 new master programs and 21 new professional master programs have been established in first-level disciplines related to climate change response. Following the adjustment and optimization for professional degrees of engineering, 73 professional doctoral programs and 736 professional master programs have been set up nationwide on materials and chemical engineering, resources and environment, energy and power engineering, civil and hydraulic engineering, to improve the landscape of training of professionals. Cross-disciplinary integration has been vigorously promoted. In December 2020, the Academic Degree Committee of the State Council introduced the “cross disciplinary” category, marking the 14th discipline category, paving the way for developing cross-discipline subjects for addressing climate change.

3.1.2 Training on Climate Change Response

Chinese governmental authorities have launched capacity-building courses for addressing climate change. Since 2018, the Chinese Ministry of Ecology and Environment has hosted six capacity building sessions on addressing climate change for eco-environmental-related officials and one China-Italy capacity building session on climate change response, sustainable development and environmental management. The above training sessions have been provided to 356 eco-environmental-related officials nationwide, including 100 and 214 from department level and division level, respectively. Targeted and multilayered training sessions on different fields have helped local governments better respond to climate change. Since 2019, the National Forestry and Grassland Administration has opened “Tackling Climate Change in Forestry and Grassland Systems” courses in the regular training for civil servants. Furthermore, the Ministry of Education, the Ministry of Civil Affairs, the Ministry of Water Resources, the National Health Commission, the Ministry of Emergency Management, the National Government Offices Administration and the China Meteorological Administration have all organized training sessions of different scales for capacity building in climate change related sectors across the board.

Local governments have vigorously held training sessions on climate change response. After actively attending national-level capacity building activities, local governments have ramped up efforts to train their personnel. Close to 50,000 training sessions and lectures were held merely during the Disaster Prevention and Mitigation Week of 2019. From October 22 to December 8, 2019, the training courses on carbon emission quota allocation and management, sponsored by the Ministry of Ecology and Environment, have been held in many Chinese cities. These courses have enhanced knowledge and raised awareness of carbon emission reduction and its management for enterprises from across the country.

3.2 Public Communication and Popularization

3.2.1 Conference Communication

Chinese governmental authorities have held many meetings to address climate change. In recent years, national authorities have held meetings on low-carbon and green development, urban low-carbon transition, climate change adaptation and carbon market building to communicate China's latest achievements in climate change response. The China Meteorological Administration has advanced science popularization of and educational training on climate change response, launched the 16th International Seminar on Climate System and Climate Change, and sponsored the 15th Session of the Forum on Regional Climate Monitoring-Assessment-Prediction for Asia (FOCRAII). The China Council for International Cooperation on Enthronement and Cooperation sponsored the Round Table on Cooperative Governance of Climate Change and the UN 2030 Sustainable Development Agenda in New York, the US.

Local governments have actively hosted international events on climate change. In 2016, Beijing hosted the second U.S.-China Climate-Smart/Low-Carbon Cities Summit, where the two countries strengthened pragmatic cooperation on the construction of low-carbon cities. In the 13th FYP period, Shenzhen Municipality has successively sponsored the Shenzhen International Low-Carbon City Forum, participated by senior government officials, famous experts on green and low-carbon development, prestigious entrepreneurs and representatives of international organizations across the world via both online and offline channels.

China has enabled public communication and exchanges through international platforms. During the Conference of the Parties to the UN Convention on Climate Change, the Chinese delegation launched several public communication events including the "China Pavilion." Eight universities from across the world jointly declared the founding of the Global Alliance of Universities on Climate (GAUC) at the World Economic Forum Annual Meeting 2019 in Davos, Switzerland; in the same year, the first GAUC Postgraduate Forum was held in Tsinghua University, attended by students from 55 universities in six continents.

3.2.2 Media Public Communication

Major news media both online and offline from *People's Daily*, Xinhua News Agency, China Media Group, *China Daily* and China News Service, have shown keen interest in and given full coverage to important climate change related news such as the UN Climate Change Conference and the NDC goals established by China with pictures, texts and videos, and swiftly reported on and made in-depth interpretations of strategic planning on low-carbon development and climate change policy documents, including carbon emissions trading market and the development of a green BRI, drawing attention from the public.

Under the guidance of the Ministry of Ecology and Environment and the China Meteorological Administration, the Handle Climate Change Film Festival (HCCFE), founded in 2015, has been launching green activities based on films and committing itself to communicating climate change knowledge and visions through the solicitation and appraisal of film and TV works, industrial and professional forums, lectures on science popularization, public-benefit showing and workshops. Low-Carbon Day has been covered by both traditional and new media such as TV interviews, livestreaming, solicitation of articles or essays on climate change, picture posters, and public information texts. The China Meteorological Administration in collaboration with top media reported on the "Record of China's Response to Climate Change" series of climate change-related field investigations and science popularization events, in which climate change is interpreted and communicated to the public through scientific approaches. In 2020, the new media for the administration of the Ministry of Ecology and Environment launched the program "Response to Climate Change," and Sichuan Province's ecological and environmental authorities produced the first provincial promotional video on climate change named Sichuan Contributing to Addressing Global Issues.

3.2.3 Thematic Public Communication

A total of 16 authorities including the National Development and Reform Commission (NDRC), the Ministry of Education, the Ministry of Science and Technology and the Ministry of Industry and Information Technology have annually launched National Energy Conservation Publicity Week, during which National Low-Carbon Day took place. From 2016 to 2020, the week-long campaign to promote energy conservation was themed "Pacemaker in Energy Conservation, Green Development," "Contribute to Energy Conservation, Share Good Environment," "Energy Conservation and Cost Reduction, Make the Skies Blue," and "Lucid Waters and Lush Mountains, Energy Conservation and Efficiency Improvement," respectively; Low-Carbon Day themes included "Green Development, Low-Carbon Innovation," "Low-Carbon Industry Development," "Enhance Climate Change Awareness, Strengthen Low-Carbon Campaigns," "Low-Carbon Campaigns, Make the Skies Blue," and "Green and Low-Carbon, Moderate Prosperity in All Respects." In 2020, the Ministry of Education and the NDRC jointly issued a circular on the green campus construction plan, according to which public communication and educational activities on energy conservation and emissions reduction close to teachers and students' lives have been widely launched across schools of all levels and kinds, and events as National Energy Conservation Publicity Week and National Low-Carbon Day have been utilized to spread related laws and regulations, the common knowledge of waste sorting, and energy conservation cases.

China launches thematic public communication events every year. Since 2012, China has been advancing the Clear Your Plate campaign, which set off a wave of food conservation across the country. The National Government Offices Administration, among other authorities, has advocated energy and resources conservation and promoted green and low-carbon development in "Public Sector Energy Conservation Promotion Week." The Ministry of Ecology and Environment has taken advantage of World Environment Day, National Low-Carbon Day and other campaigns to carry out public activities themed on climate change response annually. In collaboration with many other authorities, the Ministry of Transport has launched and organized Green Travel Promotion Month and Bus Travel Publicity Week annually to guide the public to opt for green travel such as public transport means. The Ministry of Natural Resources has launched a publicity event on World Oceans Day to popularize the sciences of ocean and climate change. In 2019, the Ministry of Water Resources sponsored the first national water conservation knowledge contest, aimed at promoting the knowledge of water saving across the society and raising the public awareness and competence of water conservation. In 2020, the Ministry of Education issued the Circular of the Action Plan on Curbing Food Waste and Developing the Habit of Frugality in the Education Sector.

3.3 Mass Participation

The Chinese public has become increasingly active in events on climate change response in different ways. A number of internet influencers, who focus on climate change topics, have emerged on we-media platforms. For example, Wang Xiangjun, known as "Bin Chuan Ge" (Brother Glacier) on the internet, was committed to showing the melting of ice glaciers in the Xizang region to call on the public to give concern to global climate issues from an ordinary person's perspective. In the Climate Action Summit held in California in September 2018, representatives of some Chinese nongovernmental organizations co-launched the "Global Climate Action" initiative. At COP 25 2019 Climate Summit in Madrid, the "panda girl" Li Zilin introduced what she did to combat climate change. New media channels including "Internet+," micro blogs, WeChat public accounts and short videos have been employed to send popular science knowledge to the public. New media platforms play an increasingly important role in disseminating policy information and news reports on climate change responses. Surveys indicate that the Chinese people are increasingly willing to spend on environment-friendly products and to engage in climate change response.

Chapter 4 International Exchanges and Cooperation

4.1 Bilateral and Multilateral Exchanges and Cooperation

4.1.1 Multilateral Exchanges and Cooperation with Major Developed Countries in Europe and America

Cooperation on climate change is a priority and highlight of China-Europe relations. During the 13th FYP period, China and Europe had pursued candid dialogue and pragmatic cooperation on carbon markets, EU-China urbanization partnership, green and low-carbon investment and financing. In April 2019, China and the EU signed the Joint Statement on the Implementation of the EU-China Cooperation on Energy, following a joint statement on climate change and clean energy made by heads from the two sides in July 2018. In September 2020, heads from the two sides announced the launching of the EU-China High-Level Environment and Climate Dialogue. The inter-governmental cooperation projects have covered energy training cooperation, energy environment, and clean energy centers. China has also conducted exchanges and cooperation with EU member states on climate change and low-carbon development. Below are the details.

China-Germany exchanges and cooperation. In 2019, China and Germany exchanged opinions on the status quo and strategic trends of electric vehicles (EVs) and fuel cell vehicles (FCVs) and decided to expand cooperation to facilitate the sustainable development of NEVs on two sides. The two counties signed the Terms of Reference for Sino-German Working Group on Environment and Climate Change in the 6th Sino-German Environment Forum in Beijing sponsored by the Chinese Ministry of Ecology and Environment in October 2019, and the second and third phases of the climate partnership projects have been launched under the mechanisms of the Sino-German working group on environment and climate change; the Sino-German Track-2 Dialogue (T2D) on Climate Change and Sustainable Development has been launched to reinforce communication and exchanges between think tanks or experts in the two countries. The Ministry of Natural Resources has implemented the integrated spatial planning for low-carbon and resilient cities (China part), a project in cooperation with Germany, to strengthen cooperation with Europe on ocean and coastal zone conservation and disaster mitigation, ecosystem restoration and territorial spatial planning.

China-France exchanges and cooperation. China and France made a joint statement to launch the China-France Year of the Enthronement when the French president visited China in January 2018. The activities of the China-France Year of Environment have been launched in Beijing in November 2018. President Xi Jinping and his French counterpart Emmanuel Macron exchanged congratulatory messages, and cooperation on combating climate change has been listed as an important part of the Year of Environment. When President Xi Jinping visited France in March 2019, the two countries reiterated bilateral efforts to tackle climate change and a full observance of the Paris Agreement in a joint statement. When President Emmanuel Macron visited China in November 2019, the two countries jointly announced the Beijing Call for Biodiversity Conservation and Climate

Change, indicating positive signs of bilateral cooperation on biodiversity conservation and climate change tackling for the fulfillment of the 2030 Sustainable Development Goals.

China-Netherlands exchanges and cooperation. In October 2018, China co-launched the Global Commission on Adaptation (GCA) with the Netherlands and other countries. With bilateral efforts, the GCA located its first regional office in China in June 2019, and held a launching ceremony participated by then Chinese Premier Li Keqiang, the Netherlands' Prime Minister Mark Rutte and GCA Chairman Ban Ki-moon, in which the Chinese Ministry of Ecology and Environment and the Netherlands' Ministry of Infrastructure and Water Management signed the joint statement on strengthening adaptation panning. The Ministry of Ecology and Environment has actively attended board meetings and senior dialogues of the GCA. In 2019, the Ministry of Transport selected experts to serve as members of the PIARC Technical Committee to learn updated information on climate change in the international highway sector and to include China's experience and technology in the committee's achievement report.

China-US cooperation on climate change in many fields. In March 2016, heads from the two sides made a joint statement on climate change, and proposed continuing to deepen and expand bilateral cooperation through the China-US Climate Change Working Group (CCWG). The two countries worked together on green ports and ships under the CCWG and the China-US Ten-Year Framework for Cooperation on Energy and Environment and officially launched the Race to Zero Emissions (R2ZE) in the US-China Transportation Forum, where successful practices in electric buses and other kinds of zero emissions buses were promoted. The NDRC and the US Department of Energy have co-sponsored a CCUS seminar in China and made field investigations to improve petroleum recovery efficiency. The National Forestry and Grassland Administration has cooperated with the US Department of State and the US Forest Service on research, investigation and training in regard to "technologies of measurement, reporting and verification for forestry-related greenhouse gases" and "technologies of and policies on coordinated efforts in forestry-related climate change mitigation and adaptation." In the 2016 U.S.-China Smart/Low-Carbon Cities Summit, 11 Chinese provinces/cities and 18 states/cities from the US signed the U.S.-China Climate Leaders Declaration. In regard to think tank cooperation, Chinese think tanks like the Counsellors' Office of the State Council and their US counterpart such as the World Resources Institute have co-sponsored the U.S.-China High-End Think Tank Symposium on Energy and Climate Change and other exchange events, and University of California, Berkeley and Tsinghua University have co-founded the California-China Climate Institute.

China and Canada have continued to intensify cooperation on climate change. In December 2017, then Chinese Premier Li Keqiang and Prime Minister Justin Trudeau made the Canada-China Joint Statement on Climate Change and Clean Growth. The two countries have launched ministerial dialogues on climate change and clean growth to achieve all-round cooperation on climate change policies.

China and New Zealand have maintained exchanges and cooperation on climate change. The two governments signed the Climate Change Cooperation Arrangement when President Xi Jinping visited New Zealand in 2014, and the Implementation Arrangement on Reinforcing Cooperation on Climate Change when the Chinese premier visited New Zealand in 2017. The two countries co-announced the China-New Zealand Leaders' Statement on Climate Change when New Zealand's prime minister visited China in 2019. China and New Zealand have regularly launched ministerial dialogues to exchange opinions on climate issues of common concern.

China, the EU and Canada have co-sponsored related meetings. In 2017, China, the EU and Canada co-sponsored the first Ministerial on Climate Action in Montreal, Canada. In December 2019, the Chinese Ministry of Commerce and the Norwegian Ministry of Foreign Affairs signed the China-Norway Carbon Emission Trading System scheme to help China establish and implement its carbon emission trading system. By the end of 2020, the Ministerial on Climate Action had been held for four consecutive times.

4.1.2 Mechanisms for Cooperation with the UN Institutions and Other International Organizations

By signing MOUs and co-sponsoring major international conferences, China and UN institutions as well as other international organizations have fostered fruitful cooperation, marking strengthened ties between China and the international community.

In 2018, China and the International Energy Agency (IEA) signed the Memorandum of Understanding on Cooperation on Climate Change Response. In 2019, China and New Zealand were invited to co-chair the dialogue on "nature-based solutions" in the UN Climate Action Summit, unveiled the "nature-based solutions to climate change," etc., which call for reinforcing international and regional cooperation, stepping up funding support, and enhancing pragmatic action in priority areas including forestry and other terrestrial ecosystems, ocean and water resources, agriculture and grain and the systemic role of nature in sustainable development. In the same year, China hosted such conferences as World Forestry Congress (WFC), the UN Forestry Forum and the International Forum on Tiger and Leopard Transboundary Conservation. In 2020, China attended the 40th OECD Round Table on Sustainable Development and engaged in discussions on climate change issues under IPCC and other channels. China and the International Union on Conservation of Nature (IUCN) signed an MOU, drew out the cooperation plan, co-released the Chinese version of the IUCN Global Standard for Nature-Based Solutions and typical practice cases in China, and worked to co-build the nature-based solutions Asian hub.

4.1.3 Regional International Cooperation Mechanisms

In recent years, China has increasingly pursued regional cooperation with other governments through important regional environmental and climatic cooperation platforms and mechanisms like those with Japan and the ROK, the ASEAN, and Africa as well as the Lancang-Mekong cooperation and cooperation with countries along the Belt and Road.

Cooperation under the Tripartite Environment Ministers Meeting among China, Japan and the ROK. In 2018, the first China-Japan-ROK seminar on low-carbon cities was held in Beijing. In December, the China National Center for Climate Change Strategy and International Cooperation (NCSC), the Institute for Global Environmental Strategies (IGES) from Japan and the Korea Environment Institute (KEI) held trilateral meetings on the sidelines of COP 24 in Katowice, Poland. In 2019, the second China-Japan-ROK seminar on low-carbon cities was held in Yokohama, Japan, where trilateral research institutes jointly released a report on local law-carbon campaigns and best practices of low-carbon cities in China, Japan and the ROK.

China has continued to ramp up communication and coordination with other BASIC countries and "developing countries with similar standpoints." China has hosted or attended the BASIC Ministerial Meeting on Climate Change, sponsored the Beijing meeting for "developing countries with similar standpoints" and attended all coordination meetings for "developing countries with similar standpoints."

China has pursued dialogue with Africa, Pacific island countries and the least developed countries. President Xi Jinping noted in the opening ceremony of the 2018 Beijing Summit of the Forum on China-Africa Cooperation that China would reinforce exchanges and cooperation with Africa on ecology and environmental protection including climate change response. China and South Africa have signed the MOU on Intergovernmental Cooperation on Climate Change and maintained communication on the progress in cooperation. In 2020, the China-Africa Environmental Cooperation: Youth Roundtable on Climate Change and Biodiversity was held in Beijing, where youths from China and Africa had in-depth discussions with representatives of international organizations, institutions of higher learning and businesses on youth contribution to addressing climate change, climate change response and biodiversity protection, innovations for climate action and biodiversity protection and other topics. When meeting leaders of Pacific island countries, which have established diplomatic relations with China, in Papua New Guinea in 2018, President Xi Jinping said that China would offer assistance within its reach. In 2019, the China-Pacific Island Countries Economic Development Cooperation Forum and its sub-forum on environmental protection and climate change were held to strengthen policy exchanges and cooperation on the environment with Pacific island countries.

China has cooperated with the countries and regions involved in the Belt and Road Initiative (BRI) to jointly combat climate change. President Xi Jinping attended the 2019 Second Belt and Road Forum for International Cooperation, in which the Chinese Ministry of Ecology and Environment initiated and co-launched the Belt and Road Initiative International Green Development Coalition (BRIGC), joined by more than 150 partners from 43 countries, including environment authorities of 26 countries and regions along the Belt and Road. Ten special partnerships such as "Global Climate Change Governance and Green Transition" and the BRI International Green Development Research Institute have been established under the coalition. Furthermore, research reports including the Report on Cases of BRI Green Development and the Guidance for Green

Development for BRI Projects have been released to promote outstanding practices in response to climate change. The coalition has sponsored a few events on green and low-carbon development, including the BRI Green Development Roundtable Meeting, the BRI Green Innovation Conference, the BRIGC policy release and the BRI Forum on Green Finance and Low-Carbon Development.

Chapter 5 South-South Climate Cooperation

While China is not obliged to assist other developing countries in regard to funding, technology and capacity building as it is a non-Annex I Party to the UNFCCC and a developing country party under the Paris Agreement, China has upheld the philosophy of building a global community of shared future to vigorously pursue South-South climate cooperation with other developing countries.

At the 2015 Paris Climate Conference, President Xi Jinping launched the "10-100-1,000" Initiative for south-south cooperation on climate change, which refers to supporting other developing countries to tackle climate change by developing 10 low-carbon demonstration zones, 100 climate mitigation and adaptation projects and 1,000 climate trainees from developing countries. In the Second Belt and Road Forum for International Cooperation held in April 2019, President Xi Jinping proposed that China would work together with relevant countries to jointly implement the Belt and Road South-South Cooperation Initiative on Climate Change. For the past few years, China has been helping other developing countries, particularly the least developed ones, African countries and small island countries, to make progress in combating climate change by pursuing cooperation on the building of low-carbon demonstration zones and donating green and low-carbon materials and technological products including clean stoves, solar photovoltaic power generation systems, electric buses, remote sensing satellites, mobile weather stations and environmental monitoring equipment. By the end of 2020, China had signed close to 40 South-South climate cooperation agreements with around 30 developing countries, engaged extensively in climate capacity building and held more than 40 training sessions and South-South climate cooperation, in which approximately 2,000 climate-related officials and technicians in over 120 countries and regions received training.

China will continue to faithfully implement the "10-100-1,000" initiative for the South-South climate cooperation and the BRI South-South climate cooperation plan, step up support to African countries, small island countries, the least developed countries, and other developing countries, in tackling climate change based on their needs and within China's capacity. It will continuously help other developing countries in their climate action by launching innovative climate mitigation and adaptation projects, promoting the building of low-carbon demonstration zones and diversifying capacity building training in forms and content.

Figure 6-2 The Signing Ceremony for China and the Laos Cooperation on Building the Vientiane Saysettha Low-Carbon Demonstration Zone

In 2019, China held the China-ASEAN climate policies and action seminars in Beijing and Shenzhen to deepen consensus among the ASEAN member states on climate change and help the ASEAN countries improve their capacity for addressing climate change. In the Lancang-Mekong Low-Carbon Industrial Park Launching Ceremony and the Forum on Climate Change Response and Sustainable Development virtually held in 2021, representatives of national environmental authorities, international organizations, industrial associations and financial institutions in the Lancang-Mekong River Basin exchanged opinions on the boosting role of renewable energy for low-carbon parks, climate cooperation progress and outlook, climate security and sustainable development and governance in the Lancang-Mekong River Basin and the promotion of low-carbon development by sustainable finance. In the “Lancang-Mekong Roundtable Dialogue on Regional and Global Environmental Governance: Action on Climate Change and Sustainable Infrastructure” held in the same year, intensive discussions have been made on regional climate action and practices in renewable energy, among other topics.

Part VII Basic Information of Hong Kong SAR on Addressing Climate Change

Hong Kong SAR (hereinafter referred to as Hong Kong) is a special administrative region of the People's Republic of China. It is a vibrant city with a mild climate, limited natural and land resources, high population density and a highly-developed service industries. It is also an eminent international financial, trading and shipping hub.

Chapter 1 Regional Circumstances

1.1 Natural Conditions and Resources

Hong Kong is located in the southern part of China, bordering Shenzhen City of Guangdong Province in the north and surrounded by sea on three sides. By 2020, Hong Kong has a land area of 1,106.81 km^2 comprising Hong Kong Island, Kowloon, the New Territories and the Islands. With hilly terrain, less than 300 km^2 of land has been developed for living and economic activities. More than 500 km^2 of land has been designated for nature conservation, including country parks and other conservation-related areas. Hong Kong is located within the sub-tropical region with a mild climate. The annual mean temperature was 23.5°C and the average yearly rainfall was about 2,430 mm for the past 30 years (1991-2020). Extreme weather conditions that occur in Hong Kong include tropical cyclone, strong monsoon, monsoon troughs and strong convective weather. Sub-tropical evergreen broadleaf forest is the main vegetation of Hong Kong. Hong Kong has a rich biodiversity of marine species such as fish and crustaceans. However, fresh water resource is relatively scarce. Rainwater collected from local catchment accounts for about 20% to 30% of the fresh water supply, and the remaining 70% to 80% of fresh water supply relies on import from the Dongjiang River in Guangdong Province.

1.2 Population and Society

Hong Kong had a population of around 7.48 million in 2020. The average annual population growth rate was 6% from 2010 to 2020. The labor force was around 3.89 million in 2020, of which 49.9% were males and 50.1% were females. In 2020, there were some 310,000 primary students and 300,000 secondary students studying in public or subsidised schools. The total expenditure on education amounted to HK$125.3 billion in the 2019–2020 financial year, which accounted for 20.6% of the total government expenditure.

1.3 Economic Development

Hong Kong is a highly urbanised economy. The Gross Domestic Product (GDP) of Hong Kong at current prices in 2020 was approximately HK$2.68 trillion, or about HK$357,600 per capita. The annual rates of change of GDP in 2019 and 2020 were +0.3% and -6.0% respectively. In 2020, the ratio between the primary, secondary and tertiary industries[47]

[47] The primary industry includes agriculture, fishing, mining and quarrying; the secondary industry includes manufacturing, electricity, gas and water supply, waste management and construction; the tertiary industry includes service sector.

was 0.1 : 6.4 : 93.5. Both the added value of the primary industry and the percentage of the workforce engaged in the primary industry were low. Since the early 1980s, the manufacturing industry has substantially relocated to the Mainland China, resulting in a gradual shrinkage in its contribution to the added value of Hong Kong's economy. On the other hand, the contribution of the tertiary industry (the service sector) has been increasing progressively. Of the tertiary industry, financial services, tourism, trading and logistics, professional services and other producer services have become the pillar industries of Hong Kong. In 2020, the total value of external merchandise trade amounted to HK$8.2 trillion; the value added of the financing and insurance industry was HK$598.0 billion. Affected by the COVID-19 epidemic in 2019, the number of visitor arrivals greatly reduced from 55.91 million, including 43.77 million from the Mainland China, in 2019 to 3.57 million in 2020, of which 2.71 million were from the Mainland China.

There is no primary energy production in Hong Kong. Hong Kong's electricity consumption is mainly from local thermal power, with nuclear power imported from Guangdong Province as a main supplement. In the overall fuel mix for electricity generation in Hong Kong in 2020, coal accounted for around 24%, natural gas accounted for around 48%, renewable energy and nuclear power accounted for around 28%.

Hong Kong has a well-developed public transport system, comprising railways, tramways, buses, taxis, and ferries. The public transport system on average carried 8.93 million passenger trips daily in 2020. This represented nearly 90% of the daily number of passenger trips. As at the end of 2020, there were around 803,000 licensed motor vehicles in Hong Kong, with around 573,000 of them being private cars. The motor vehicle and private car ownership were 122 and 87 per 1,000 people respectively.

The statistics on the summary of Hong Kong's circumstances in 2020 are set out in Table 7-1.

Table 7-1 Summary of Hong Kong's Circumstances in 2020

Indicators	Description
Population (million)	7.481
Land area (square kilometer)	1,106.81
GDP (HK$ billion, at current market prices)	2675.31
Per capita GDP (HK$, at current market prices) (based on mid-year population)	357,600
Percentage share of industry in GDP[48]	6.4
Percentage share of service sector in GDP	93.5
Percentage share of agriculture, fishing, mining and quarrying in GDP	0.1
Land area for agriculture purposes (sq km)[49]	49
Cattle	1,140
Horse	1,951
Pig	64,883
Woodland area (square kilometer)	289
Life expectancy (year)	Male: 83.4; Female: 87.7

1.4 Institutional Arrangements for the Preparation of Climate Change Information

The Government of the Hong Kong SAR (hereinafter referred to as the HKSAR Government) proactively implements relevant provisions of the United Nations Framework Convention on Climate Change (UNFCCC). It strives to coordinate present and future work and activities to address climate change, enhance capacity to mitigate and adapt to climate change and promote public awareness and understanding of climate change through co-operating closely among relevant bureaus and departments and other bodies concerned.

The Paris Agreement, which came into force in November 2016, applies to Hong Kong as well. In this connection, the HKSAR Government set up the Steering Committee on Climate Change in 2016. Chaired by the Chief Secretary for Administration and with members comprising various Policy Secretaries, the Steering Committee has been making reference to the experiences outside Hong Kong in combating climate change and considering ways to enhance the mitigation, adaptation and resilience actions in Hong Kong to combat climate change.

Hong Kong's GHG emissions reached its peak in 2014. To fulfill the goals set in China's NDC and align with its commitment to achieve carbon neutrality by 2060, the HKSAR Government would strive to achieve carbon neutrality before 2050 and reduce the total

[48] Industry includes manufacturing, electricity, gas and water supply, waste management and construction.
[49] Area used for cultivation.

carbon emissions from the 2005 level by half before 2035. In October 2021, the HKSAR Government announced the *Hong Kong's Climate Action Plan 2050*, which set its target on the three major sources of GHG emissions (i.e. electricity generation, transport and waste) and put forward the four major decarbonisation strategies (i.e. "net-zero electricity generation", "energy saving and green buildings", "green transport" and "waste reduction"), to lead Hong Kong towards the goal of carbon neutrality. To this end, the Government set up the new Steering Committee on Climate Change and Carbon Neutrality under the chairmanship of the Chief Executive of the Hong Kong SAR. It replaced the Steering Committee on Climate Change chaired by the Chief Secretary for Administration. The new Steering Committee is responsible for formulating the overall strategies, and overseeing the co-ordination of various actions, and will bring them to the highest level for deliberating and decision-making. The Environment and Ecology Bureau (EEB) [50] of Hong Kong will also set up a new Office of Climate Change and Carbon Neutrality to strengthen co-ordination and promote deep decarbonisation, and to encourage different sectors in the community, especially young people, to participate actively in climate change. In addition, the EEB / Environmental Protection Department (EPD) is responsible for compiling and publishing yearly the inventory and annual trends of Hong Kong's GHG emissions[51].

[50] Formerly the Environment Bureau. The HKSAR Government has been re-organised with effective from 1 July 2022. The newly set up EEB has enlarged the policy functions of the former Environment Bureau to consolidate the polices and work related to environmental protection, conservation of natural ecology, environmental hygiene, food safety, agriculture, fisheries, animal welfare, etc. so as to achieve synergy in enhancing the overall environment of Hong Kong and maintaining environmental hygiene, as well as the work related to driving climate action, promoting biodiversity, etc.

[51] The statistics of GHG in Hong Kong is available at: https://cnsd.gov.hk/en/climate-ready/ghg-emissions-and-trends/.

Chapter 2 Hong Kong's Greenhouse Gas Inventory in 2017

In the process of compiling Hong Kong's GHG inventory, references have been made to the GPG 2000 and the 2006 IPCC Guidelines. The reporting year was 2017, and the scope covered sectors including energy, industrial processes, agriculture, land-use change and forestry (LUCF) as well as waste management. The reported GHGs cover carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6).

2.1 Overview of the 2017 GHG Inventory

In 2017, Hong Kong's net total GHG emissions (including LUCF) amounted to about 39 624.0 kilo tonnes of carbon dioxide equivalent (kt CO_2 eq), amongst which the removal by carbon sink from LUCF amounted to about 463.9 kt CO_2. Therefore, when excluding LUCF, Hong Kong's total GHG emissions stood at about 40 087.8 kt CO_2 eq, among which CO_2 accounted for about 35 770.2 kt, or 89.23%; CH_4 about 2 662.7 kt CO_2 eq, or 6.64%; N_2O about 560.1 kt CO_2 eq, or 1.40% (see Table 7-2, Table 7-3); fluorinated gases[52] about 1 094.8 kt CO_2 eq, or 2.73% (see Table 7-4). Table 7-3 sets out Hong Kong's emissions inventory of CO_2, CH_4 and N_2O in 2017 by sector. Table 7-4 sets out the emissions inventory of fluorinated gas in Hong Kong in 2017.

Table 7-2 Hong Kong's GHG Emissions in 2017 (kt CO_2 eq)

	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Total
Energy Sector	35 131.9	81.9	346.2				35 559.9
Industrial Processes	606.8	NO	NO	1 027.7	NO	67.1	1 701.6
Agriculture		11.3	16.7				28.0
LUCF	-463.9	NE	NE				-463.9
Waste Disposal	31.6	2 569.4	197.3				2 798.3
Total (without LUCF)	35 770.2	2 662.7	560.1	1 027.7	NO	67.1	40 087.8
Total (with LUCF)	35 306.4	2 662.7	560.1	1 027.7	NO	67.1	39 624.0

Notes: 1.Shaded cells do not require entries. Due to rounding, a slight discrepancy may exist between table breakdowns and the total figures; the values that are displayed as "0.0" are not actually zero, but are very small numbers that round to zero;
2. NO (Not Occurring) refers to activities or processes that do not occur for a particular gas or source/sink category within Hong Kong;
3. NE (Not Estimated) indicates that existing emissions and removals have not been estimated.

[52] Fluorinated-gases include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6).

Table 7-3 Hong Kong's Emissions of Carbon Dioxide, Methane, and Nitrous Oxide in 2017 (kt)

GHG Source/Sink categories	CO_2	CH_4	N_2O
Total (without LUCF)	35 770.2	126.8	1.8
Total (with LUCF)	35 306.4	126.8	1.8
1. Energy Sector	35 131.9	3.9	1.1
- Fuel combustion	35 131.9	2.6	1.1
♦Energy industry	26 497.2	0.7	0.6
♦Manufacturing industries and construction	721.2	0.1	0.0
♦Transport	6 719.6	1.8	0.5
♦Other sectors	1 194.0	0.0	0.0
- Fugitive emission		1.3	
♦Solid fuel		NO	
♦Oil and natural gas system		1.3	
2. Industrial Processes	606.8	NO	NO
- Cement production	606.8		
- Production of halocarbons and SF_6			
- Consumption of halocarbons and SF_6			
3. Agriculture		0.5	0.0
- Enteric fermentation		0.2	
- Manure management		0.4	0.0
- Rice cultivation		NO	
- Farmland		NO	NO
- Agricultural Soils		0.0	0.0
- Prescribed burning of savannas		0.0	0.0
4. Land-use change and forestry (LUCF)	-463.9	NE	NE
- Changes in forest and other woody biomass stocks	-463.9		
- Forest conversion	0.0	NE	NE
5. Waste	31.6	122.4	0.6
- Solid waste disposal	31.6	116.7	0.0
- Wastewater handling		5.6	0.6
Memo Items			
- Special regional aviation	1 726.2	0.1	0.1
- Special regional marine	14 091.9	1.3	0.4
- International aviation	14 760.6	0.1	0.5
- International marine	20 136.2	1.9	0.5

Notes: 1. Shaded cells do not require entries. Due to rounding, a slight discrepancy may exist between table breakdowns and the total figures. The values that are displayed as "0.0" are not actually zero, but are very small numbers that round to zero;
2. NO (Not Occurring) refers to activities or processes that do not occur for a particular gas or source/sink category within Hong Kong;
3. NE (Not Estimated) indicates that existing emissions and removals have not been estimated;
4. Values given in "Memo Items" are not counted in the total emission;
5. Special regional aviation and special regional marine represent aviation and marine transport between Hong Kong and other parts of China (including Macao SAR and Taiwan area).

Table 7-4 Emissions of Fluorinated Gas in Hong Kong in 2017 (hundred tons)

GHG source	HFCs					PFCs	SF_6
	HFC-32	HFC-125	HFC-134a	HFC-143a	HFC-227ea		
Total	0.04	0.07	7.21	0.04	0.19	NO	0.03
Energy Sector							
Industrial Processes	0.04	0.07	7.21	0.04	0.19	NO	0.03
- Mineral products							
♦Chemical industry							
♦Metal production						NO	
- Production of halocarbons and SF_6	NO	NO	NO	NO	NO	NO	NO
- Consumption of halocarbons and SF_6	0.04	0.07	7.21	0.04	0.19	NO	0.03
Agriculture							
LUCF							
Waste Disposal							

Notes: 1. Shaded cells do not require entries. Due to rounding, a slight discrepancy may exist between table breakdowns and the total figures. The values that are displayed as "0.0" are not actually zero, but are very small numbers that round to zero;
2. NO (Not Occurring) refers to activities or processes that do not occur for a particular gas or source/sink category within Hong Kong.

Energy activities are the primary source of GHG emissions in Hong Kong. In 2017, GHG emissions from energy accounted for 88.71% of the total GHG emissions (without LUCF), while GHG emissions from waste, industrial processes and agriculture accounted for 6.98%, 4.24% and 0.07% of the total emissions respectively (See Figure 7-1).

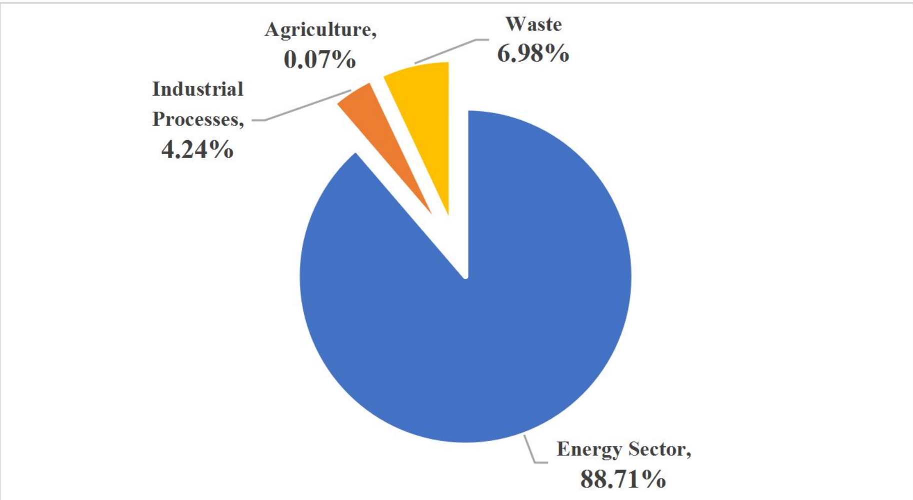


Figure 7-1 Hong Kong's GHG Emissions (without LUCF) by Source in 2017

The GHG emissions in Hong Kong are primarily CO_2. In 2017, CO_2 accounted for 89.23% of the total emissions, while CH_4, fluorinated gases and N_2O accounted for 6.64%, 2.73% and 1.40% of the total emissions respectively (See Figure 7-2).

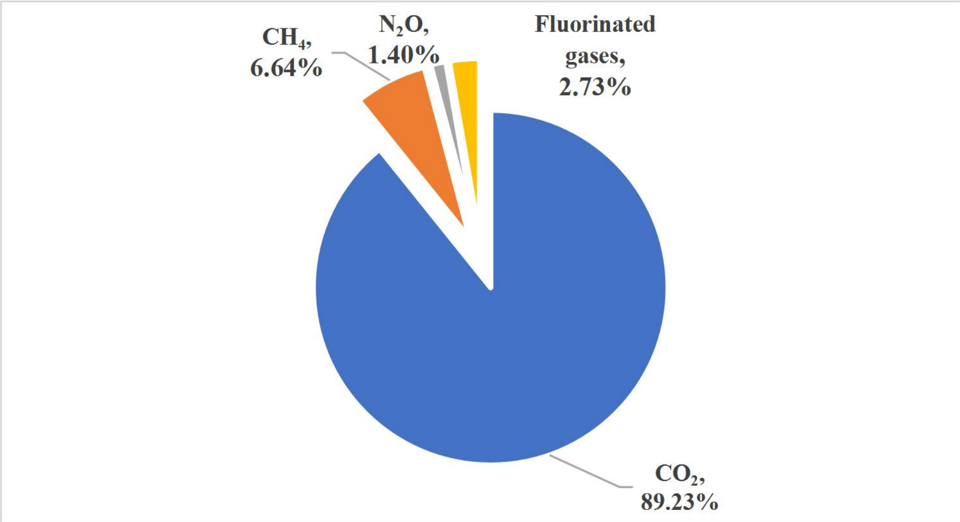


Figure 7-2 Hong Kong's GHG Emissions by Gas in 2017

In 2017, the GHG emission from special regions routes and international bunker fuel amounted to about 51.227 million tonnes (Mt) CO_2 eq, which included 15.979 Mt CO_2 eq from special regional marine and aviation emissions, and 35.248 Mt CO_2 eq from international marine and aviation. While the aforesaid emissions were deemed as memo items and not counted in Hong Kong's total GHG emissions, the emissions from special regional aviation and marine have been counted into total emissions of China's inventory as domestic aviation and navigation.

2.2 Energy Sector

2.2.1 Scope

The report on energy activities mainly covers emissions of CO_2, CH_4 and N_2O from fossil fuel burning in the energy industry, manufacturing industry, construction industry, transport sector and other sectors; and fugitive CH_4 emissions of oil and gas systems.

2.2.1 Methodologies

The estimation of emissions from energy activities in Hong Kong is mainly based on the 2006 IPCC Guidelines. Tier 3 methods were adopted to calculate emissions of CO_2, CH_4 and N_2O in electricity production. Tier 2 methods were adopted to calculate CO_2 emissions while Tier 1 methods were adopted to calculate CH_4 and N_2O emissions in gas production. Tier 2 methods were adopted to calculate CO_2 emissions while Tier 1 methods were adopted to calculate CH_4 and N_2O emissions in utilising landfill gas for energy purposes. As for the manufacturing and construction industries and other sectors, Tier 2 methods were adopted to calculate CO_2 emissions while Tier 1 methods were adopted to calculate CH_4 and N_2O emissions.

Tier 1 and 2 methods were adopted to calculate emissions of CO_2, CH_4 and N_2O from local aviation and marine, rail, non-road transport and road transport sources.

Special regional transport refers to aviation and marine transport activities departing from Hong Kong with destinations in of the Mainland China (including Macao SAR and Taiwan area) while international transport denotes aviation and marine transport activities departing from Hong Kong with destinations other than the Mainland China (including Macao SAR and Taiwan area). Tier 3(a) methods were adopted for the calculation of emissions of CO_2, CH_4 and N_2O from special regional and international aviation transport activities. Tier 1 methods were adopted to calculate emissions of CO_2, CH_4 and N_2O from special regional and international marine transport activities.

Tier 1 methods were adopted to calculate fugitive methane emissions of CH_4 from gas transmission while Tier 3 methods were adopted to calculate other fugitive CH_4 emissions.

2.2.3 Emissions Inventory

In 2017, GHG emissions from energy activities in Hong Kong amounted to 35 559.9 kt CO_2 eq, of which CO_2 emissions amounted to 35 131.9 kt, CH_4 and N_2O emissions amounted to 81.9 kt CO_2 eq and 346.2 kt CO_2 eq, respectively. CO_2 emissions from energy activities accounted for 98.22% of the total of such emissions.

Among the 2017 GHG emissions from energy activities, 26 707.7 kt CO_2 eq, or 75.11% were from the energy industry (electricity and town gas production); 6 903.8 kt CO_2 eq, or 19.41% were from transportation; 1 195.9 kt CO_2 eq, or 3.36% were from other sectors (including commercial and residential sectors); 724.9 kt CO_2 eq, or 2.04% were from manufacturing and construction industries; 27.6 kt CO_2 eq, or about 0.08% were from CH_4 fugitive emissions.

2.3 Industrial Processes

2.3.1 Scope

The report on industrial processes mainly covers the emissions of CO_2 from the production of cement; the emissions of hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) from refrigeration, air conditioning and fire-fighting equipment; and the emissions of sulfur hexafluoride (SF_6) from electrical equipment.

2.3.2 Methodologies

Based on cement clinker production and related data, Tier 2 methods of the 2006 IPCC Guidelines were adopted to calculate CO_2 emissions from cement production. Tier 2 methods of the 2006 IPCC Guidelines were adopted to calculate HFCs emissions from refrigeration and air conditioning sub-sectors. Tier 1 methods of the 2006 IPCC Guidelines were adopted to calculate PFCs emissions from solvents. Tier 1 methods of the 2006 IPCC Guidelines were adopted to calculate emissions of HFCs and PFCs from fire-fighting equipment. And Tier 3 methods of the 2006 IPCC Guidelines were adopted to calculate emissions of SF_6 used in electrical equipment.

2.3.3 Emissions Inventory

In 2017, GHG emissions from industrial processes in Hong Kong were around 1 701.6 kt CO_2 eq, accounting for 4.24% of Hong Kong's total emissions, of which 606.8 kt were emitted from cement production. HFCs and SF_6 emissions from refrigeration, air conditioning, fire-fighting and electrical equipment were 1 027.7 kt CO_2 eq and 67.1 kt CO_2 eq respectively.

2.4 Agriculture

2.4.1 Scope

The report on agriculture mainly covers emissions of CH_4 and N_2O from livestock fermentation and manure management; emissions of N_2O from agricultural soils; and emissions of CO_2, CH_4 and N_2O from grassland burning.

2.4.2 Methodologies

Tier 1 methods of the 2006 IPCC Guidelines were adopted to estimate CH_4 emissions from enteric fermentation, the direct and indirect emissions of N_2O from agricultural soils, and the emissions of CH_4 and N_2O from prescribed grassland burning.

2.4.3 Emissions Inventory

In 2017, GHG emissions from agricultural activities amounted to 28.0 kt CO_2 eq, or 0.07% of Hong Kong's total emission. CH_4 and N_2O emissions from livestock enteric fermentation and manure management amounted to 15.4 kt CO_2 eq while N_2O emissions from agricultural soils were 12.4 kt CO_2 eq.

2.5 Land-Use Change and Forestry

2.5.1 Scope

The report on land-use change and forestry (LUCF) mainly covers the changes in biomass carbon stock caused by the conversion of forestland, cropland and grassland.

2.5.2 Methodologies

Tier 1 methods of the 2006 IPCC Guidelines were adopted and reference was made to relevant emission factors in calculating the CO_2 emissions caused by the conversion of forestland, cropland and grassland. Tier 1 methods of the 2006 IPCC Guidelines were also adopted to calculate the emissions and removals of CO_2 caused by the changes in the biomass carbon stock of forests and other woody plants.

2.5.3 Emissions Inventory

In 2018, as carbon sinks, land-use change and forestry had a net removal of approximately 463.9 kt CO_2 eq in total. All of the carbon removals were caused by changes in the carbon stock of forests and other woody biomass resulting from the conversion of forestland and grassland.

2.6 Waste

2.6.1 Scope

The report on waste treatment mainly covers CH_4 emissions from solid waste landfills, CH_4 and N_2O emissions from the treatment of domestic sewage and industrial wastewater, and CO_2 emissions from waste incineration.

2.6.2 Methodologies

The calculation of emissions from waste treatment was mainly based on the 2006 IPCC Guidelines. Tier 2 methods were adopted to estimate CH_4 emissions from landfilling of solid waste. Tier 1 methods were adopted to estimate the emissions of CH_4 and N_2O from wastewater treatment. And Tier 1 methods were also adopted to calculate the emissions of CO_2 from chemical waste treatment.

2.6.3 Emissions Inventory

In 2017, GHG emissions from waste treatment in Hong Kong amounted to 2 798.3 kt CO_2 eq, or 6.98% of Hong Kong's total emission. Most of such emissions were CH_4 which amounted to 2 569.4 kt CO_2 eq, or 96.50% of the total CH_4 emissions in Hong Kong.

2.7 Quality Assurance and Quality Control

2.7.1 Quality Assurance and Quality Control

To improve the quality of the inventory compilation, the institutions concerned made efforts to enhance quality assurance and control. The efforts mainly include:

1. In compiling the guidelines, those provided by IPCC were strictly followed to ensure the compilation work was well-planned, comparable and transparent;

2. In selecting the methodologies for compilation, based on data availability, higher-tier methods were used where appropriate to calculate the emissions for the inventory to ensure the accuracy of the results in the inventory;

3. In the process of collecting and analysing the activity data, the institutions worked closely with the relevant authorities to acquire first-hand rational official information, which was then managed, verified and examined by specialised personnel, so as to ensure the reliability and rationality of the data used;

4. In determining the emission factors, emission factors suitable to Hong Kong's actual circumstances were adopted as far as possible. If such emission factors cannot be found, reference would be made to the default emission factors provided by the IPCC Guidelines to ensure the accuracy of the results in the inventory.

Two-pronged approach were implemented to reduce the uncertainties. Firstly, the data collection process was improved; Official statistics, locally measured emission factors and parameters were adopted and the latest parameters of the 2006 IPCC Guidelines were used as reference. Secondly, appropriate methodologies were selected; Based on data availability, higher-tier methods were used to calculate the emissions for the inventory.

2.7.2 Uncertainty Analysis

Based on the analysis conducted in accordance with the propagation of error stated in the 2006 IPCC Guidelines, the uncertainty of Hong Kong's 2017 GHG inventory was around 4.33%. Emissions produced in the process of coal-fired electricity generation were the major reason for the uncertainty mainly due to the limitation in statistical data such as the type and quantity of coal consumption by power plants.

Chapter 3 Impacts of and Adaptation to Climate Change

According to existing observations and assessments, the warming trend in Hong Kong has been accelerating. The sea level is rising and extreme weather events are becoming more frequent. The HKSAR Government has implemented various measures such as strengthening its infrastructure developments and setting up relevant working mechanisms to enhance its adaptability to climate change.

3.1 Characteristics of and Trends in Climate Change

3.1.1 Climatic Characteristics

Generally speaking, the trends in climate change in Hong Kong basically align with the overall global trends. The Hong Kong Observatory (HKO) began to make systematic observations of meteorological parameters in the 1880s (Figure 7-3). As shown by the temperature trend, the annual mean temperature increased at an average rate of 0.13°C per decade during 1885-2020. The rate of increase became higher during 1991-2020, reaching 0.24°C per decade.

Regarding the rising trend in sea level, there was an obvious rise of sea level at Victoria Harbour during 1954-2020, and the average rate was 3.1 mm per year. As for extreme weather events, the annual number of heavy rain days (days with hourly rainfall exceeding 30 mm) in Hong Kong increased at an average rate of 0.3 days per decade during 1947-2020, and the annual number of thunderstorm days increased at an average rate of 2.1 days per decade during the same period.

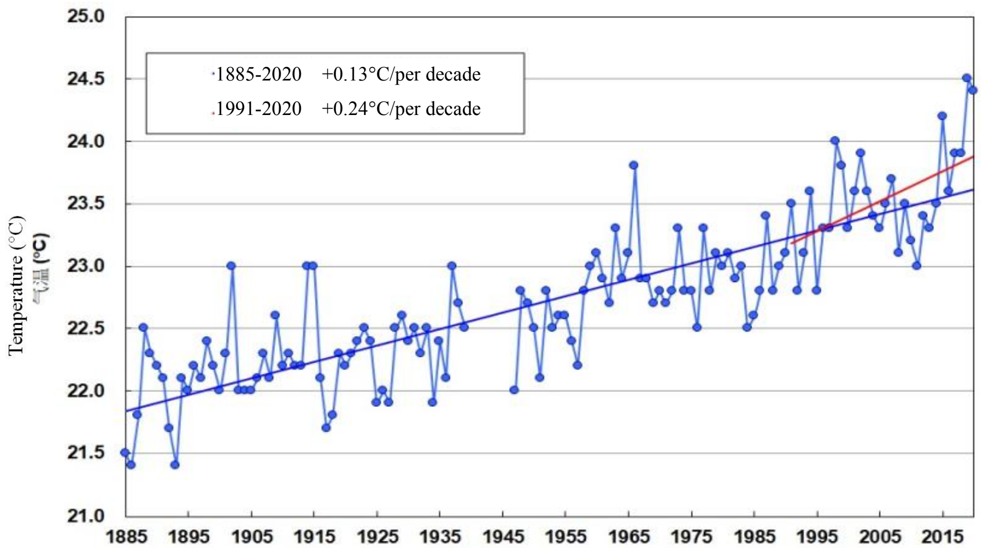


Figure 7-3 Annual Mean Temperature Recorded at the Hong Kong Observatory Headquarters (1885-2020)

3.1.2 Future Trends in Climate Change

HKO updated the climate projections for Hong Kong based on global climate model data of the Sixth Assessment Report of IPCC. The projections are as follows: Firstly, under the low, intermediate and very high GHG emission scenarios[53], the annual average temperature in 2081-2100 is expected to rise by 1.2°C, 2.0°C and 3.6°C respectively, when compared with the average temperature of 23.4°C during 1995-2014, while the average annual maximum temperature in 2081-2100 is expected to rise by 1.2°C, 1.9°C and 4.1°C respectively, when compared with the average figure of 34.4°C during 1995-2014. Secondly, under the low, intermediate and very high GHG emissions scenarios, the average annual rainfall in 2081-2100 is expected to rise by 8%, 7% and 9% when compared to the average annual rainfall of 2,456 mm during 1995-2014, while the average annual maximum daily rainfall in 2081-2100 is expected to rise by 9%, 16% and 28% respectively[54] when compared to the average figure of 203 mm during 1995-2014. Thirdly, under the low, intermediate and very high GHG emissions scenarios, the annual mean sea level in 2100 is expected to rise by about 0.42 m, 0.56 m and 0.78 m respectively (in terms of median), compared to the average value during 1995-2014 (1.45 m above Hong Kong Chart Datum); extreme sea levels caused by the rising of sea level is also expected to increase significantly.

3.2 Major Vulnerable Areas and Climate Change Adaptation Actions

The areas that are most vulnerable to climate change impacts in Hong Kong include: biodiversity, water resources, hygiene and health as well as infrastructure.

To address the potential impacts of climate change, the HKSAR Government has been taking action proactively to adapt climate change. Currently, progress has been made in multiple areas.

3.2.1 Biodiversity

Enhancing the vegetation diversity in urban areas is a priority in the HKSAR Government's formulation and promotion of urban forestry strategies. Through promoting diversification of planting, the resistance of our urban forests to pests and diseases can be enhanced, large-scale tree die-offs can be prevented, and long-term maintenance efforts can be reduced. The planting of native species in urban areas not only benefits biodiversity, but also enhances the ecological linkages between urban areas and the surrounding protected areas. Besides, the stratification of vegetation can capture more dust and pollutants, further reduce the urban heat island effect, provide a more sustainable urban landscape, and improve the liveability of the surrounding places.

3.2.2 Water Resources

Hong Kong lacks fresh water resources. There are no natural lakes, rivers or substantial underground water sources. Besides rainwater collected from local catchment, Hong Kong needs to import Dongjiang water from Guangdong Province with annual supply capped at 820 million m^3 according to the current Agreement for the supply of Dongjiang water to Hong Kong . In 2020, the total water consumption of Hong Kong was about 1 345 million

[53] For projections under other GHG emission scenarios, please refer to: https://www.hko.gov.hk/sc/climate_change/future_climate.htm.

[54] Since rainfalls exhibits significant variability, rainfall deficits in individual years cannot be ruled out in spite of an overall upward trend in rainfall projection.

m^3, of which around 59% was imported Dongjiang water from Guangdong Province, 17% was locally collected rainwater, and the remaining 24% was seawater for toilet flushing. In faces of the challenges of climate change, increasing water demand due to population and economic growth, as well as the keen demand for water resources in the Pearl River Delta, the HKSAR Government has included climate change adaptation into its water resources management policy since 2008 to ensure water security and support for sustainable development in Hong Kong. Besides taking forward some measures on the hardware front (such as using flow controllers, etc.), the Water Supplies Department (WSD) has launched publicity and promotion of water conservation and implemented initiatives to reduce water loss in supply networks. It is also implementing measures to increase the supply of potable water through seawater desalination as well as the use of reclaimed water, treated grey water[55] and harvested rainwater for non-potable purposes, and has been exploring ways to utilise local water resources efficiently.

3.2.3 Healthcare

In prevent vector-borne diseases and heat-related diseases related to climate change, the Department of Health (DH) has been disseminating related information through various channels. In addition to enhancing public awareness of mosquito-borne diseases and promoting protective measures against mosquito bites, the DH also collaborates with the HKO to timely issue press releases to remind the public to take appropriate measures against heatstroke and ultraviolet radiation during very hot weather.

The Centre for Food Safety (CFS) under Food and Environmental Hygiene Department has formulated a risk-based Food Surveillance Programme to collect food samples at import, wholesale and retail levels for microbiological, chemical and radiological tests. Considering the possible impacts brought about by climate change, the CFS will assesses the Food Surveillance Programme regularly to ensure that the food sold on the market is fit for consumption.

3.2.4 Infrastructure

Since its establishment in 2016, the Climate Change Working Group on Infrastructure (CCWGI) of the HKSAR Government has been co-ordinating climate change adaptation measures in infrastructural aspect as well as relevant researches to strengthen the resilience of infrastructure. The CCWGI is convened by the Civil Engineering and Development Department (CEDD) with representatives from the Development Bureau, the Architectural Services Department (ArchSD), the Buildings Department, the Drainage Services Department (DSD), the Electrical and Mechanical Services Department (EMSD), the Highways Department (HyD), HKO and the Water Supplies Department (WSD). The above-mentioned government departments have taken various measures to cope with climate change:

(1) CEDD updated the Port Works Design Manual in 2018 by making reference to the IPCC Fifth Assessment Report (AR5) . It has also conducted a number of studies, such as the strategic study and assessment on the resilience of government key infrastructure in

[55] Grey water refers to water collected from baths, wash basins, kitchen sinks, laundry machines, etc.

2017 to formulate the scopes of enhancement works. The study was completed in 2020 and relevant government departments will formulate measures and implementation plans to enhance the resilience of key infrastructure with reference to the recommendations of the study. The CCWGI also shares relevant experience and findings with public organisations and public utility undertakers through relevant government departments, thereby facilitating the enhancement of the overall infrastructure resilience of the society. Besides, CEDD has the Landslip Prevention and Mitigation Programme in place to deal with landslide risks arising from both man-made slopes and natural hillsides.

(2) Over the years, the Drainage Services Department (DSD) has continuously reviewed the Drainage Master Plan of various districts in Hong Kong to assess the drainage performance of the existing stormwater drainage systems and the flood risk and allocate resources for implementing drainage improvement works. DSD has also been actively promoting the introduction of more "Blue-Green Infrastructure" in New Development Areas, such as stormwater storage tank, flood lakes, floodable area[56], river revitalisation, rainwater harvesting and other sustainable drainage systems, with the aim of reducing the burden on drainage facilities.

(3) The WSD has been applying technologies to implement various measures to improve water supply network management, including progressively implementation of the Water Intelligent Network (WIN) by establishing District Metering Areas (DMAs) in the potable water distribution network, with a view to determining priorities and the most cost-effective measures for management of DMAs, which include:

(i) Water pressure management;

(ii) Active leakage detection and control;

(iii) Quality and speedy repair of water pipe burst and leak;

(iv) Replacement and rehabilitation of water pipes that are not cost-effective for maintenance.

Under WIN, the potable water distribution network of Hong Kong will be divided into about 2,400 DMAs. As of the end of 2020, WSD has set up about 1,440 DMAs and the remaining DMAs are expected to be established by 2024.

(4) The Hongkong Electric Co., Ltd has installed anti-flood systems and enhanced the flood walls at Lamma Power Plant; adopted higher ground-level design standards for new generating units and substations; and installed flood alarms, bund walls and sump pumps at substations subject to flooding risk from storm surge to reduce the impacts. The CLP Power Hong Kong Limited has also deployed suitable anti-flooding measures, including ground-level drainage systems, sea walls along power station shorelines, flood gates and flood barriers. Besides, the CLP Power Hong Kong Limited has been conducting flooding assessments and implementing mitigation measures for new and existing substations, as

[56] Generally speaking, the idea of "floodable area" is to allow a certain degree of flooding in a specific and controllable area under severe extreme weather conditions, so as to reduce the damage caused by floods to large areas or areas with important urban facilities, reduce the pressure on traditional drainage systems and the degree of socio-economic losses, and improve the flood resilience of cities.

well as reinforcing the overhead line structures.

3.2.5 Emergency Response

Extreme weather conditions have become more frequent due to climate change. The HKSAR Government continues to strengthen preparation for and response to natural disasters, and to enhance capabilities in post-disaster recovery. Relevant government departments will enhance the arrangements on information dissemination so that the public can be well prepared with contingency and aftercare plans, with a view to mitigating the impacts of natural disasters.

The Security Bureau has formulated the Contingency Plan for Natural Disasters (CPND). To cope with natural disasters, the HKSAR Government evaluates the situation in advance, makes contingency plans, and allocates resources and manpower in a timely manner at all stages of preparation, response and recovery. In case of a large-scale natural disaster that calls for all-round emergency response from the Government, the Emergency Monitoring and Support Centre will give immediate response across the board. Besides, financial regulators have made contingency plans to ensure that important financial infrastructures, the settlement system and the securities and futures trading markets function in an orderly manner, minimising the impacts arising from emergencies including extreme climate events. As for the electricity systems, solutions have been developed to resist extreme weather events, including improving the structure of high-risk buildings and electric towers, installing intelligent switches, setting up flood forecasting and prevention mechanisms, as well as advancing equipment specifications to withstand the higher operating temperature. The emergency procedures and manpower deployment plans have also been formulated, complemented by regular drills, to make Hong Kong well-prepared for emergency incidents.

After the Super Typhoon Mangkhut hitting Hong Kong in September 2018, the HKSAR Government conducted an inter-departmental review to improve the mechanism for the preparation, response and recovery from super typhoons or other large-scale natural disasters in the future. One of the measures requires that in the event of a super typhoon or other large-scale natural disaster, the HKSAR Government will set up a high-level inter-departmental steering committee according to specific circumstances when necessary. The steering committee will be chaired by the Chief Secretary for Administration to supervise the work of relevant bureau and departments and set priorities in a coordination manner. If a super typhoon or other large-scale natural disaster paralyzes the city and seriously prevents employees from resumption of work, the Chief Secretary for Administration, having regard to the views of the steering committee, may make a territory-wide “Extreme Condition” announcement to extend the time of resumption work, so as to minimise possible injuries to the public. Relevant bureaux and government departments would conduct various forms of drills regularly to enable better preparation and coordination for natural disasters in order to safeguard the life and property of the public.

Relevant government departments have set up ongoing surveillance systems to combat extreme weather conditions and natural disasters such that early warnings can be issued to the public as soon as possible when coping with disasters. The HKO closely monitors the weather situation, and will issue weather warnings and bulletins for severe weather where necessary to remind the public, particularly those in vulnerable areas, to seek shelter in a safe places and take corresponding precautionary measures to minimise losses. Owning to the complex coastline of Hong Kong, the degree of impacts from storm surges associated with tropical cyclones can vary significantly across different locations.. HKO, in collaboration with District Offices and the DSD, has establish an early alert mechanism. When the HKO predicts that the water level will reach a certain warning level during the tropical cyclone, it will issue alert short message to the relevant government departments. District Offices will inform the local residents and the property management offices concerned to take appropriate preparatory and precautionary measures. DSD will mobilise manpower to provide assistance to the residents in the areas that are more vulnerable to flood risk. Besides, DSD has set up an "Emergency Control Center" equipped with a Flood Monitoring and Reporting System to monitor rainfall and the water levels of major rivers and channels in real-time. The DSD has installed telemetry systems in more than 140 locations to collect data such as tide level and water level at the sites and send them to the monitoring center. This can facilitate speedy analysis of the flooding situation and timely notification of other departments as and when necessary, so that the departments can be well prepared for rescue, evacuation and opening of temporary shelter. The Office of the Communications Authority has engaged local mobile network operators to set up an emergency alert system for dissemination of time-critical public announcements and messages by the Government via mobile network to mobile service users during emergency situations, such as extreme weather, so that the public can adopt contingency measures quickly.

3.3 Future Adaptation Measures Against Climate Change

The HKSAR Government has taken the following measures to adapt to climate change.

Strengthening infrastructure facilities: The CCWGI updates the design standards for various types of infrastructure in a timely manner pursuant to relevant climate change parameters, coordinates studies relating to the potential impact of climate change on infrastructure, and formulates measures and implementation plans to enhance the resilience of infrastructure;

Combating sea level rise and protecting shorelines: The HKSAR Government implements suitable improvement works and formulates management measures for some of the low-lying coastal or windy locations in order of priority, and conducts a strategic study on shoreline management with a view to formulate suitable long-term strategies and protection measures;

Combating extreme rainstorms and tropical cyclones: The HKSAR Government has adopted a "three-pronged flood prevention strategy" (i.e. stormwater interception at upstream, flood storage at midstream, and drainage improvement at downstream) to formulate appropriate flood prevention and drainage management measures, and to eliminate flooding blackspots. To address landslide risk, the HKSAR Government will continue to implement the Landslip Prevention and Mitigation Programme to upgrade government man-made slopes, mitigate natural terrain landslide risk, and strengthen the resilience of the slopes against extreme rainstorms;

Combating extreme drought and safeguarding water supply: The Total Water Management Strategy is implemented to contain potable water demand growth. Smart technologies will be adopted to enhance the implementation of various water demand management initiatives. The use of lower grade water for non-potable purposes will be expanded, and desalination plants are being constructed to enhance resilience in the fresh water supply;

Combating extreme heat: Green building design and sustainable building environment have been advocated, along with the promotion of urban forestry, with the aim of alleviating and coping with temperature rise;

Enhancing response to natural disasters: Pursuant to the Contingency Plan for Natural Disasters, the HKSAR Government will take early actions in the stages of preparedness, response and recovery to guard against natural disasters by enhancing situation assessment, devising the response strategy and plan, as well as redeploying resources and manpower in a timely manner. When extensive government emergency response operations are required, the Emergency Monitoring and Support Centre will be activated immediately. The emergency alert system will be used for disseminating time-critical public announcements via mobile networks in emergency situations, such as extreme weather.

Chapter 4 Policies and Actions for Climate Change Mitigation

Being an international city of China, Hong Kong has all along been involved in the work on combating climate change. It has spared no efforts in controlling the GHG emission effectively by targeting the three major GHG contributing sources (i.e. electricity generation, transport and waste) in Hong Kong and , and formulating policies and actions on alleviating climate change.

4.1 Policies and Targets

The HKSAR Government endeavors to implement policies and measures to mitigate GHG emissions. Following the publication of *Hong Kong's Climate Change Strategy and Action Plan* in 2014 and *Hong Kong's Climate Action Plan 2030+* in 2017, the HKSAR Government announced in 2020 and 2021 respectively the target to strive to achieve carbon neutrality before 2050 and the medium-term target to reduce GHG emissions from the 2005 level by half before 2035. In October 2021, the HKSAR Government issued *Hong Kong's Climate Action Plan 2050* (the Plan). Targeting the three major GHG emission sources in Hong Kong, i.e. electricity generation, transport and waste, the Plan put forward four decarbonisation strategies: net-zero electricity generation; energy-saving and green buildings; green transport; and waste reduction. It was estimated that the per capita carbon emission would drop to 2 to 3 tonnes by 2035, with a view to achieving the goal of carbon neutrality by 2050.

4.2 Energy Industry

Phasing down of coal-fired electricity generation. As electricity generation accounts for around two thirds of Hong Kong's carbon emissions, the most effective way of cutting the emissions is to change the fuel composition of electricity generation. The existing two power companies have installed new gas-fired generating units to replace coal-fired ones over the past few years. In order to further reduce carbon emissions and achieve the 2035 carbon reduction target, Hong Kong will further reduce coal-fired electricity generation and phase it out by 2035, replacing it with lower-carbon electricity generation processes.

Promotion of Renewable Energy. Apart from taking the lead in installing renewable energy systems in buildings and facilities and developing more advanced waste-to-energy facilities, the HKSAR Government has also taken a number of measures to support the development of renewable energy in the private sector, including introducing the Feed-in Tariff Scheme to encourage various sectors to install renewable energy systems, installing solar energy generation systems for schools and non-governmental organisations free of charge, and introducing facilitation measures to assist the installation of solar energy generation systems in open car parks by the private sector. The HKSAR Government will strive to increase the share of renewable energy in the fuel mix to 7.5% to 10% by 2035, and further increase it to 15% in the future.

Developing zero-carbon energy. The HKSAR Government will try out the use of new energy and strengthen cooperation with neighboring regions, thereby striving to increase the share of zero-carbon energy to 60% to 70% of electricity generation before 2035 and achieving the goal of net-zero-electricity generation before 2050 in the long run.

4.3 Building Industry

Enhancing buildings' energy efficiency. The amendments to the Code of Practice for Energy Efficiency of Building Services Installation was completed in 2018 and took effect in 2019. Upon the implementation of the new standards, there would be an estimated accumulative energy saving of 27 billion kilowatt hours (kWh) of electricity in all new and existing buildings in Hong Kong by 2028, equivalent to a reduction in carbon dioxide emissions of about 19 million tons. The Buildings Energy Efficiency Ordinance also requires owners of commercial buildings to carry out energy audits for central building services installations in accordance with the Code of Practice for Building Energy Audit (Energy Audit Code or EAC) once every decade. The EAC is reviewed once every three years. Taking the lead in setting specific electricity reduction targets for government buildings, the HKSAR Government planned to work towards the target of achieving 5% savings in the electricity consumption of government buildings in the five financial years from 2015/16 to 2019/20, under comparable operating conditions in 2013/14. The HKSAR Government ultimately achieved its goal of saving electricity by 7.8% in 2019/20. At present, the HKSAR Government has completed energy audits for about 340 major government buildings. To assist the relevant bureaux and departments in implementing the energy saving measures identified in the energy audits, the Government has earmarked at least HK$900 million to take forward the relevant measures progressively, such as the installation of energy-efficient air-conditioning and control systems, energy-efficient lighting and control systems, light-emitting diodes and floodlights. The HKSAR Government also encourages the relevant bureaux and departments to strengthen energy saving efforts by appointing green managers and energy wardens, adopting better housekeeping measures and implementing electricity saving projects.

Enhancing energy efficiency of appliances. The HKSAR Government has implemented the Mandatory Energy Efficiency Labelling Scheme (MEELS), which requires that all prescribed products[57] sold on the market must be labeled with energy information, so that consumers can know their energy efficiency performance. The scheme is implemented in phases. By the end of 2020, it has covered eight categories of prescribed products. The third phase has been fully implemented since December 1, 2019. After the full implementation of the third phase, it is estimated that the whole scheme can help consumers save about 625 million kWh per year, which is equivalent to reducing about 440,000 tons of carbon dioxide emissions per year. The HKSAR Government will continue to include more appliances in the MEELS and tighten the energy efficiency grading standards in phases.

Conducting GHG emission audits on buildings. The HKSAR Government is committed to promoting carbon audit and published the Guidelines to Account for and Report on Greenhouse Gas Emissions and Removals for Buildings (Commercial, Residential or Institutional Purposes) in 2008. Since 2017-2018, the HKSAR Government has taken the lead in conducting carbon audit on major government buildings on a regular basis and

[57] Prescribed products are those specified in the Energy Efficiency (Labelling of Products) Ordinance.

disclosing the results afterwards. The carbon auditing work involves more than 300 major government buildings of different sizes and uses.

Improving energy efficiency in district development. To support low-carbon development in the Kai Tak Development District, the HKSAR Government has established a district cooling system (DCS), providing chilled water to buildings in the area for air conditioning purposes. The system went into operation in early 2013. In addition, in order to cope with the expected increase in the demand for cooling capacity of various development projects in the Kai Tak Development District, the construction of the additional cooling system started in 2020. The DCS consumes 35% and 20% less electricity as compared with traditional air-cooled systems and individual water-cooled systems using cooling towers respectively. With higher energy efficiency, it is estimated that the whole system will save 138 million kWh of electricity and reduce 96,500 tons of carbon dioxide emissions. At the same time, the HKSAR Government will explore the feasibility of establishing district cooling systems in more New Development Areas, so as to promote energy efficiency and low-carbon development.

Generally speaking, the HKSAR Government reduces the energy demand of buildings by promoting green buildings, improving energy efficiency and implementing a low-carbon lifestyle. The goal is to reduce the electricity consumption of commercial buildings by 30% to 40% and that of residential buildings by 20% to 30% by 2050 compared with 2015, and to achieve half of the above targets by 2035.

4.4 Transport

Expanding the railway network. Hong Kong uses railways as the backbone of the passenger transport system, integrating transport and land-use planning. Hong Kong's railway development has progressed rapidly over the past few years, with the successive commissioning of the West Island Line, the Kwun Tong Line Extension, the South Island Line (East), the Hong Kong section of the Guangzhou-Shenzhen-Hong Kong Express Rail Link, the Tuen Ma Line and the Cross-Harbour Extension of the East Rail Line. At present, the total length of Hong Kong's railways has increased to more than 270 km, bringing more than 70% of the local population into the railway catchment. Taking into account transport demand, cost-effectiveness and the development needs of New Development Areas and other new development projects, as well as considering the potential housing supply that may be brought about by railway development, the HKSAR Government is implementing the new railway projects recommended in the Railway Development Strategy 2014 in an orderly manner. The target is for the railway network to serve around 75% of the inhibited areas in Hong Kong and around 85% of job opportunities. In the long run, the HKSAR Government is conducting the "Strategic Studies on Railways and Major Roads Beyond 2030" with a view to exploring the layout of railways and major road infrastructure in Hong Kong, such that the relevant planning can facilitate or even reserve capacity to meet, the overall long-term development needs of Hong Kong, including those laid out in the Northern Metropolis Development Strategy.

Promoting the wider use of electric vehicles (EVs). In response to global climate change, full electrification of transportation system has become a global trend. In order to improve air quality and achieve the long-term goal of zero vehicular emission, the HKSAR Government is determined to promote the use of EVs and has implemented the following major measures.

(a) The HKSAR Government has exempted electric commercial motor vehicles from the first registration tax since 1994 (until March 31, 2024). Since February 2018, the "One-for-One Replacement" scheme for electric private vehicles has been implemented, and the first registration tax relief has been provided to owners who replace old private vehicles. In 2020, the upper limit of the relief was HK$250,000, while the upper limit of the general purchase of new EVs was HK$97,500. In 2021, the upper limit of the tax relief for the "One-for-One Replacement" scheme increased to HK$287,500 (until March 31, 2024);

(b) Businesses which have purchased eligible environment-friendly vehicles, including EVs, may deduct the capital expenditure incurred under profits tax[58] in the first year after the purchase;

(c) The HK$300 million Pilot Green Transport Fund (PGTF) was established in March 2011 to encourage the public transport sector, goods vehicle operators and non-profit organisations to try out green, innovative and low-carbon transport technologies including commercial EVs. In order to further encourage the trial and wider use of green innovative transport technologies, the HKSAR Government injected an additional HK$800 million in 2020 to expand the funding scope of the Fund. The Fund was renamed the "New Energy Transport Fund" in September of the same year;

(d) The HKSAR Government subsidised the franchised bus companies in full to purchase 36 single-deck electric buses and related charging facilities for trial on a number of routes to assess their operational performance in local conditions;

(e) The HKSAR Government granted concessions on gross floor area for car parks in new private buildings with EV charging-enabling infrastructure, so as to encourage developers to install necessary EV charging-enabling infrastructure for car parks in new buildings, including sufficient power supply, cablings and conduits, to facilitate future installation of EV chargers as needed;

(f) In October 2020, the HKSAR Government launched the HK$2.0 billion "EV–charging at Home Subsidy Scheme" to subsidise the installation of EV charging infrastructure in parking lots of existing private residential buildings. After installing the charging infrastructure, EV owners can install appropriate chargers according to their personal needs and easily get their vehicles charged at home. The scheme is initially expected to cover more than 60,000 parking spaces in existing private residential buildings within three years.

(g) The HKSAR Government had installed more than 1,000 medium-speed (7 kW) EV chargers at 70 public parking lots by the end of 2022;

(h) The HKSAR Government established a dedicated team and a hotline to provide

[58] Profits from operating a trade, profession or business in Hong Kong are subject to profits tax at the profits tax rate. (https://www.ird.gov.hk/eng/tax/bus_pft.htm).

information and technical support to those who would like to install charging facilities. Moreover, the HKSAR Government has also issued guidelines on the arrangements and technical requirements for installing charging facilities.

(i) In 2021, the HKSAR Government launched the first Hong Kong Roadmap on Popularisation of Electric Vehicles[59], which set a clear direction for the all-round electrification of road traffic in the future.

Taking forward other related measures. The HKSAR Government continues to take appropriate measures to control the number of private vehicles, and improve coordination of different modes of public transport to alleviate traffic congestion and better meet passenger demand. The HKSAR Government will continue promoting "Walk in Hong Kong" to foster a pedestrian-friendly environment, and create a "bicycle-friendly" environment in new towns and New Development Areas to facilitate the public to ride bicycles for short-distance commuting or leisure purposes.

To achieve carbon neutrality by 2050, the HKSAR Government strive to promote the electrification of vehicles and ferries, develop new-energy transport and implement measures to improve traffic management. In 2021, the HKSAR Government announced that new registration of fuel-propelled and hybrid private cars will cease in 2035 or earlier. The HKSAR Government will also collaborate with the franchised bus companies in future to test out hydrogen fuel cells buses and plans to collaborate with other relevant institutions to test out heavy goods vehicles powered by hydrogen fuel cells.

4.5 Waste Treatment

Promoting waste reduction. The HKSAR Government continues to promote waste sorting at the source and clean recycling. Apart from setting up waste separation facilities at source, it encourages waste reduction, clean recycling and resource recycling through territory-wide publicity, education campaigns and outreach services of individual communities. In 2020, 28% of municipal solid waste generated in Hong Kong was recovered.

Enhancing recycling and reuse of resources. All operating landfills have been utilising landfill gas to generate power for use in on-site infrastructures and provide heat energy for the leachate treatment facilities. In addition, the surplus landfill gas after treatment will be exported to the gas supply network of the Towngas company or used to generate electricity for connection to the public grid. Currently, there are four large-scale secondary sewage treatment plants in Hong Kong. Biogas released by anaerobic digestion of sludge is used for electricity generation and heat supply for facilities in the plants. The digested sludge will be transported to sludge incineration facilities for treatment and energy recovered from the treatment process was converted into electricity. There is also an organic resource recycling centre in Hong Kong, which uses anaerobic digestion technology to convert kitchen waste into biogas. The two facilities mentioned above can turn waste into energy, and the surplus electricity can be transmitted to the public grid.

[59] The Hong Kong Roadmap on Popularisation of Electric Vehicles is available at: https://www.eeb.gov.hk/sites/default/files/pdf/EV_roadmap_eng.pdf.

To achieve carbon neutrality by 2050, the HKSAR Government is committed to developing abundant waste-to-energy facilities by 2035 or before, so as to avoid relying on landfills to treat municipal solid waste and support the development of the circular economy. By implementing the municipal solid waste charging scheme and adopting other waste reduction and recovery measures, the HKSAR Government aims to gradually reduce the amount of daily municipal solid waste per capita by 40% to 45%, and increase the recovery rate to about 55%. It also plans to implement the first-stage control of disposable plastic tableware earlier than the previously proposed year of 2025.

4.6 Tree-Planting and Urban Greening

From 2010 to 2020, about 74 million trees and shrubs were planted in Hong Kong, among which about 7 million of them were trees. In recent years, the HKSAR Government has adopted a comprehensive and sustainable approach in taking forward quality urban landscape designs and tree management initiatives, including tailoring the Greening Master Plans based on district characteristics and the “Right Tree, Right Place” principle on species selection and introducing green infrastructure measures such as the use of vertical landscape, rooftop landscape, rain gardens, permeable paving materials and rainwater harvesting. In 2020, Hong Kong has 24 country parks and 22 special areas, taking up a total area of about 443 km^2, accounting for about 40% of the land in Hong Kong. Apart from fostering a rich biodiversity in Hong Kong, such protected areas conserve the effectiveness of natural “carbon sink” to enhance Hong Kong’s carbon dioxide removal capacity and contribute to Hong Kong’s effort in alleviating climate change in a sustainable manner.

Chapter 5 Other Relevant Information

Hong Kong has kicked off a series of activities in strengthening monitoring of and research on climate systems; enhancing public education, public communication and capacity building on climate change; encouraging public engagement; raising public awareness on climate change; and developing cooperation and exchanges with counterparts across the world.

5.1 Monitoring of and Research on Climate Systems

The HKO is responsible for climate observation and climate change research in Hong Kong. It has been operating since the end of the 19th century, and has accumulated more than 130 years of climate data, which is helpful to analyse climate trends in Hong Kong. In addition, the HKO has updated future projections of temperature, rainfall and mean sea level in Hong Kong based on the Sixth Assessment Report of IPCC. HKO's studies provides scientific support to the mitigation, adaptation and contingency measures as well as work carried out by relevant bureaus/departments.

5.2 Education, Publicity and Public Awareness

The HKO organises school talks, produces short educational videos and publishes articles and the latest research results on global climate change on its website to raise public awareness of climate change. With regard to public education, HKO in 2019-20 launched the "Climate Change Impacts" webpage to present different types of climate change impacts to the public, joined hands with Ho Koon Nature Education cum Astronomical Centre to compile the "Geography E-learning Package about Climate Change" to enhance geography teachers and students' understanding of climate change and its impacts, collaborated with the Agriculture, Fisheries and Conservation Department to publish the book "Climate Change and Biodiversity in Hong Kong" presenting climate change and its impacts on biodiversity.

In raise public awareness of addressing climate change, and highlight the key measures that the HKSAR Government will introduce, the EEB produces publicity leaflets, disseminates TV and radio publicity messages, makes short videos and posters, creates websites on climate change and develops a "LowCarbon Living Calculator"[60]. In addition, the Environment and Conservation Fund Committee subsidises non-profit-making organisations to launch educational activities and projects theme of climate change.

The Education Bureau (EDB), in collaboration with the Environment and Ecology Bureau and the Council for Sustainable Development, established the "Long-term Decarbonisation E-Learning Platform" in the 2020/21 school year to enhance the learning and teaching effectiveness of the topic of sustainable development under the Senior Secondary Liberal Studies curriculum, and planned to expand the platform to support environmental education at the junior secondary level in the 2022/23 school year. The EDB also invites government departments, conservation groups and schools to organise seminars on climate change for primary and secondary school teachers in Hong Kong, as

[60] The website "low-carbon life calculator" is available at https://www.carboncalculator.gov.hk/en.

well as provides schools with learning and teaching resources on climate change, so as to enhance students' awareness of environmental conservation and develop their positive values, attitudes and behaviors related to climate change mitigation. In April 2017, the EDB issued a circular on the "Environmental Policy and Energy Saving Measures in Schools" to all schools to remind them of the importance of formulating school-based environmental protection policies and implementing energy saving measures, and provided the latest information and resources. In September 2019, it issued a circular memorandum on "Participation of Schools in Feed-in Tariff Scheme" to encourage schools to install renewable energy systems in their buildings in line with their environmental protection policies, actively demonstrating the implementation results to communities and stakeholders, and further promoting environmental education.

The EEB and the EMSD launched the campaign of "Energy Saving for All" campaign in 2015. In 2020, they continued to carry out activities such as "Energy-saving Charter" and "Energy Saving Championship Scheme"[61] under the campaign. To support the World Environment Day, the Environmental Campaign Committee set up by the HKSAR Government held the "Plastic-free Fun Fair"[62] in June 2019 under the theme "Go Plastic-free" [63]. Citizens were encouraged to reduce the use of plastics by asking restaurants not to provide disposable tableware when ordering takeaway meals, thus developing into the habit of "plastic-and-disposable-free"[64]. The event brought together nearly 30 government departments, non-governmental organisations, green groups, colleges and universities and residential communities, and made the public pay attention to and reduce the use of disposable plastic products through booths, environmental protection workshops and music performances. In addition, the government provided funding for non-profit making organisations to carry out public education activities and projects with the theme of climate change through the Environment and Conservation Fund, and funded 23 projects with specific themes of climate change from 2017 to the end of 2020.

5.3 Strengthening Regional Cooperation

The HKSAR Government supports the research on development strategies for regional clean energy and renewable energy, promotes research & development and application. Enterprises are encouraged to save energy and reduce emission. At the same time, exchanges and collaboration on scientific research, technology development and

[61] The "Energy Saving Championship Scheme" aims to encourage the trades to improve the energy efficiency of buildings with the application of retro-commissioning and innovation and technology, and to inspire the creativity and imagination of young people to be creative and stimulate their imagination in energy conservation and the development of renewable energy, so as to make their contributions to achieving carbon neutrality. Winners will be invited as role models to share the operation mode of energy-saving and/or renewable energy technologies during visits or seminars.
[62] "Plastic-free Fun Fair" is an integrated activity that includes environmental protection booths, expert sharing, upgraded environmental protection workshops and music performances and aims to promote the habit of reducing the use of plastic products to the public. Participants include government departments, non-governmental organisations, green groups, colleges and universities and residential communities.
[63] The slogan of "Go Plastic-free" encourages citizens to reduce the use of plastic products and foster environmentally-friendly living habits.
[64] "Plastic-and-disposable-free" focuses on encouraging citizens not to use disposable tableware when buying takeout meals, so as to promote waste reduction at the source. At the same time, all sectors of society are encouraged to support the use of reusable tableware and reduce the manufacturing of disposable plastic items.

application, publicity and education and infrastructure construction, etc. related to climate change are enhanced.

Due to environmental and geographical factors of Hong Kong, the potential for developing large-scale renewable energy in Hong Kong is relatively limited; therefore, strengthening regional cooperation is the key to achieving low-carbon electricity generation in Hong Kong. The HKSAR Government, together with power companies, would explore ways to enhance regional cooperation on zero-carbon energy supply, including seeking joint investment and joint development opportunities for participating in and operating zero-carbon energy projects near Hong Kong.

Hong Kong has become a member of the C40 Cities Climate Leadership Group Steering Committee since 2011, promoting collaboration amongst cities in the world to address climate change. Guangdong and Hong Kong continue to conduct exchange activities on mitigation, adaptation and response to climate change, and jointly promote the implementation of various relevant tasks, including the exchange of research progress on strategies and paths to achieve the peaking of carbon dioxide emissions and carbon neutrality, technologies and projects using renewable energy, technologies of existing building re-calibration devices and technologies and development of new energy vehicles etc.

5.4 Finance, Technology and Capacity Building Needs

5.4.1 Needs for Funding

Low-carbon transformation requires a lot of resources. In the past 10 years or so, the HKSAR Government has allocated more than HK$47.0 billion to implement various measures for energy saving and renewable energy, promote electric vehicles, and introduce innovative waste-to-energy and waste-to-material facilities, contributing to the reduction of waste and carbon. In the next 15 to 20 years, the HKSAR Government will invest another HK$240.0 billion to implement various measures to mitigate and adapt to climate change, including renewable energy, energy-saving green construction, green transport and waste management.

In addition, the HKSAR Government needs to provide funding for compilation of GHG inventories, organisation of seminars and workshops on capacity building, implementation of mitigation and adaptation measures, and participation in international conferences and training.

Innovative technology plays a pivotal role in achieving carbon neutrality. In 2020, the HKSAR Government allocated HK$200 million to set up the "Green Tech Fund" to provide better and more focused funding support for the research and development (R&D) and application of decarbonisation and green technologies, with a view to expediting deep decarbonisation in Hong Kong and enhance environmental protection. In 2022, the Government injected an additional HK$200 million into the fund.

5.4.2 Needs for Technologies

Major needs for technologies for mitigating climate change include those on zero-carbon energy, energy-saving products in buildings, new wall materials, electric vehicles, high-efficiency fast recharging and changing facilities for electric vehicles, high-efficiency batteries and materials, renewable energy (in particular building-integrated photovoltaics system), and waste-to-energy. The “Green Tech Fund” helps to promote the R&D and application of decarbonisation technologies that cater for the specific needs of Hong Kong’s environment, meet the environmental needs of Hong Kong, and support projects in priority areas such as net-zero electricity generation, energy saving and green buildings, green transport and waste reduction. Moreover, when setting the energy efficiency standards of buildings, reference will be made to the relevant technical and international standards to harness innovative and intelligent technologies to ensure the energy efficiency standards of building services installations are up to date with continuous improvement.

Major needs for technologies for adaptation to climate change include those for the protection of environment and ecosystems, climate risk assessment for building environment and infrastructure developments, forecast of energy demand and supply changes, and analysis of the impacts on food chain, food hazards and water resources.

5.4.3 Capacity Building

Major needs for capacity building include strengthening the team building and relevant training for the enhancement of information communication and compilation of GHG inventories, enhancing the current legislation and management, formulating new legislation; stepping up monitoring; enhancing the government’s and enterprises’ capability; updating the disaster management and contingency plans; conducting researches and studies to raise the awareness of the government and public about climate change and strengthen their resilience to climate change.

The HKSAR Government will enhance teachers’ knowledge of climate change at the school level. Schools can strengthen relevant learning contents in different subjects and arrange diversified learning experiences to enhance students’ understanding of climate change and its impact, and encourage them to practice what they have learned and promote low-carbon transformation. In order to cultivate professional talents, the universities and post-secondary institutions [65] need to enrich the learning contents related to climate change, low-carbon technology and green finance in relevant courses in a timely manner, and strengthen cooperation and exchanges between the universities and post-secondary institutions, so that teachers and students can keep abreast of the times and equip themselves with relevant professional knowledge and skills.

[65] Post-secondary institutions refer to higher education institutions, professional education colleges and institutions that provide professional education apart from the universities.

Part VIII Basic Information of Macao SAR on Addressing Climate Change

Macao is a Special Administrative Region (SAR) of the People's Republic of China. It is a city with a mild climate, limited natural resources, high population density and a well-developed gambling industry. Being full of vibrancy, it is also a world-famous center for tourism and leisure activities.

Chapter 1 Regional Circumstances

1.1 Natural Conditions and Resources

The Macao Special Administrative Region (hereinafter referred to as Macao) is situated on the west side of the estuary of the Pearl River Delta on the South China coast, bordering the City of Zhuhai of Guangdong Province in the north, facing the South China Sea to the south, having the Hong Kong SAR on the eastern side of the Pearl River's estuary, and being separated by seawater from Wanzai District and Hengqin Island of Zhuhai to the west. With its three sides being engulfed by sea, Macao mainly consists of the Macao Peninsula, Taipa Island and Coloane Island.

Under the subtropical marine climate, Macao is significantly influenced by monsoon. Macao has a mild climate. According to statistics from 1991 to 2020, the annual mean temperature of Macao was 22.8°C. January was the coldest month with a monthly mean temperature of 15.2°C, and July was the warmest month with a monthly mean temperature of 28.4°C. Its annual average precipitation is 1,966.6 mm with significant seasonal differences. Macao's wet season lasts from April to September, accounting for more than 84% of its total annual precipitation, during which extreme heavy precipitation events may lead to a maximum daily rainfall above 300 mm. The extreme weather and climate events that influence Macao the most include tropical cyclones and associated storm surges, rainstorms, thunderstorms and strong monsoons. Each year, about five to six tropical cyclones affect Macao on average, of which one to two may bring about winds up to Force 8 or even beyond in Beaufort wind scale to Macao.

Macao's land resources are extremely limited, and traditionally its land area has been increased through reclamations from sea. In 2009, the central government approved a proposal for land reclamation, which added a total of 3.6 sq km to the new urban zone. As of 2020, the land area of Section A of the new urban zone and the Macao Port Management Area of the Hong Kong-Zhuhai-Macao (HKZM) Bridge has reached 32.9 sq km, an increase of about 7.9% compared with 2016.

The local water storage facilities in Macao are insufficient, and over 98% of its drinking water needs to be supplied by Zhuhai, Guangdong Province. In 2020, Macao's total water consumption was up to 85.52 million m^3, of which 50% was used by households, 43% by industry and commerce, and the remaining 7% by governmental departments and other facilities.

1.2 Population and Society

Macao is among the most densely populated regions in the world. In 2020, Macao's total population was 683,000, an increase of 5.9% compared to 2016, and its density was approximately 21,000 persons per square kilometer. The labor force in Macao was about 405,000, of which 395,000 were employed. Of all the employed persons in Macao, 0.23% worked in the primary industry, 11.43% in the secondary industry and 88.34% in the tertiary industry.

Based on the educational statistics for school year from 2020 to 2021, the total number of schools under formal education [66] in Macao was 75, with 82,900 students enrolled. There were ten higher education institutions with about 39,000 students, of whom the locals accounted for 40.8%, and the non-locals for 59.2%.

In 2020, there were 1,789 doctors, 2,568 nurses and 1,715 hospital beds in Macao. The spending on healthcare totaled MOP$10.4 billion, accounting for 10.5% of the total expenditure of the Macao SAR government, which was equivalent to 5.1% of Macao's GDP.

1.3 Economic Development

Due to COVID-19, Macao's GDP (calculated by expenditure approach at current prices, the same below) in 2020 was about MOP$204.4 billion, and its GDP per capita was about MOP$300,000, both of which were down more than 50% compared with 2019. In Macao's GDP (calculated by production approach), the contribution from the primary industry was barely null, while that from the secondary and tertiary industries accounted for 8.7% and 91.3% respectively. Pillar industries such as gambling, real estate, banking and public administration accounted for 21.3%, 17.6%, 13.0% and 10.0% of Macao's GDP respectively. In 2020, the number of visitors to Macao significantly decreased to 5.897 million, most of whom were from the Chinese mainland, accounting for 80.6% of the total.

In 2020, Macao's total primary energy consumption was 457,000 tons of standard coal equivalent, of which light diesel, gasoline, natural gas, petroleum gas, kerosene and heavy oil accounted for 23.9%, 22.5%, 21.5%, 11.7%, 10.8% and 9.6% of the total energy consumption respectively. From the perspective of sectors, road transport accounted for 34.4% of the total, energy processing and transformation 26.9%, business, catering and hotel 11%, aviation 10.4%, industry and construction 9.6%, living of residents 5.8%, waterway transport 1.2%, and others 0.7%.

Macao's electricity consumption is primarily supported by Guangdong Province, which is supplemented by local power generation. Since 2007, the local power generation has been continuously decreased with increasing electricity import. In 2020, Macao's total electricity import was 4.85 billion kWh, while the local power generation was only 560

[66] The education system of Macao, excluding the tertiary stage, consists of formal education and further education. Formal education is divided into three phases: preschool, primary and secondary (junior and senior). Further education refers to any educational activity other than formal education, including family education, community education, and vocational education.

million kWh.

The transport system in Macao consists of three components: highways, waterways and aviation. In 2020, Macao's highway spanned 453.4 km in total. There were 240,000 automobiles and 20,000 passenger ferry trips. The number of commercial flights reached 7,000 with the Macao International Airport either as the point of arrival or the point of departure.

The summary of Macao's circumstances in 2020 is set out in Table 8-1.

Table 8-1 Summary of Macao's Circumstances

Indicators	Description
Population (in 10,000 at the year end)	68.3
Area (square kilometer)	32.9
GDP (in US$100 million by expenditure approach, US$1 = 7.9888 Patacas)	255.9
GDP per capita (in US$ by expenditure approach)	37553
Proportion of industrial value added to GDP (by production approach) (%) 1)	8.7
Proportion of service value added to GDP (by production approach) (%)	91.3
Proportion of agricultural value added to GDP (by production approach) (%)	0
Farmland area (square kilometer)	0
Proportion of urban population to total (%)	100
Cattle	6
Horse	375
Pig	3
Sheep	1
Forest area (square kilometer)	5.12
Number of households receiving regular financial aid	3,364
Life expectancy at birth (year)	Male: 81.1; Female:86.9
Literacy rate (%)2)	96.5

Notes: 1. The industrial sectors here include mining, manufacturing, water, and electricity and gas production and supply;
2. The data are based on the literacy rate of population aged over 15 shown in the population census of Macao in mid-2016.

1.4 Institutional Arrangements for Addressing Climate Change

The Government of the Macao Special Administrative Region (hereinafter referred to as the Macao SAR government) has always attached great importance to climate change issues. In order to effectively manage and coordinate the efforts in response to climate change, Macao SAR has established an Inter-departmental Working Group on Climate Change, which is responsible for coordinating the arrangements concerning the implementation of the UNFCCC, including the development of “measurable, reportable and verifiable” actions for emission reduction, and the introduction of mitigation and adaptation efforts to the private sectors and the general public for mobilizing the public to involve in efforts addressing climate change.

The Inter-departmental Working Group on Climate Change, led by the Secretariat for Transport and Public Works (STOP), has organized relevant governmental departments to take measures to address climate change. In recent year, in line with the optimization of administrative structure of the Macao SAR government, the number of relevant departments has been adjusted from 14 to 12, which are Municipal Affairs Bureau (IAM), Economic and Technological Development Bureau (DSEDT), Macao Government Tourism Office (DST), Statistics and Census Service (DSEC), Education and Youth Development Bureau (DSEDJ), Health Bureau (SS), Marine and Water Bureau (DSAMA), Environmental Protection Bureau (DSPA), Transport Bureau (DSAT), Civil Aviation Authority (AACM), Housing Bureau (IH) and Meteorological and Geophysical Bureau (SMG). Among them, the Meteorological and Geophysical Bureau coordinates the preparation of the basic information of Macao on addressing climate change for the National Communications and Biennial Update Reports.

Chapter 2 Macao's Greenhouse Gas Inventory of 2017

In the process of compiling Macao's GHG inventory of 2017, references had been made to the 2006 IPCC Guidelines and 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories; default values in 1996 IPCC Guidelines were used as reference for certain parameters and emission factors. According to the actual circumstances of Macao and the availability of relevant data, the reporting scope of Macao's GHG Inventory of 2017 mainly covers GHG emissions from energy and municipal waste treatment, including carbon dioxide, methane and nitrous oxide.

2.1 Overview

In 2017, Macao's total GHG emissions were 174.6 × 10^4 t CO_2 eq (see Table 8-2 and 8-3), of which the emission from energy accounted for 95.9%, and the emission from waste 4.1% (see Figure 8-1). In 2017, the total emissions of carbon dioxide, methane and nitrous oxide were 164.9 × 10^4, 1.4 × 10^4 and 8.3 × 10^4 tons of CO_2 equivalent, accounting for 94.5%, 0.8% and 4.7% of the total GHG emission respectively (see Figure 8-2).

Table 8-2 Macao's GHG Emissions in 2017 (10,000 t CO_2 eq)

	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Total
Energy	164.6	0.6	2.3				167.5
Industrial processes	NE	NE	NE	NE	NE	NE	NE
Agriculture		NO	NO				NO
LUCF	NE	NE	NE				NE
Waste	0.4	0.8	6.0				7.1
Total (without LUCF)	164.9	1.4	8.3	NE	NO	NO	174.6
Total (with LUCF)	164.9	1.4	8.3	NE	NO	NO	174.6

Notes: 1. Being rounded to the nearest whole numbers, the sums of all sub-items may slightly differ from the total;
2. NO (Not Occurring) refers to activities or processes that do not occur for a particular gas or source/sink category within Macao; NE (Not Estimated) indicates that existing emissions and removals have not been estimated.

Table 8-3 Macao's Greenhouse Gas Inventory of 2017 (100 t)

Categories of GHG sources and sinks	**CO_2**	**CH_4**	**N_2O**
Total (without LUCF)	16,491.8	6.7	2.7
Energy	16,455.4	3.1	0.7
- Fuel combustion	16,455.4	3.1	0.7
♦Energy industry	9,296.1	1.9	0.4
♦ Manufacturing and construction industries	1,111.0	0.0	0.0
♦Transport	4,073.0	1.0	0.4
♦Other sectors	1,975.4	0.0	0.0
- Fugitive emission	NE	NE	NE
Industrial processes	NE	NE	NE
Agriculture		NO	NO
LUCF	NE	NE	NE
Waste	36.4	3.6	1.9
- Treatment of solid waste	36.4	0.0	0.0
- Treatment of wastewater		3.6	1.9
Memo Items			
- Special regional aviation	3,808.4	0.0	0.1
- Special regional marine	2,082.2	0.2	0.1
- International aviation	2,541.6	0.0	0.1
- International marine	NO	NO	NO
- Biomass burning	2,762.7		

Notes: 1. Being rounded to the nearest whole number, the sum of sub-items may slightly differ from the total;
2. NO (Not Occurring) refers to activities or processes that do not occur for a particular gas or source/sink category within Macao; NE (Not Estimated) indicates that existing emissions and removals have not been estimated;
3. The data of HFCs, PFCS and SF_6 related activities that are not collected and estimated in the industrial processes are presented as NE in total;
4. Fugitive emissions from fuels and LUCF cannot be estimated due to the in-progress statistics system;
5. Values given in 'Memo Items' are not counted in the total emission, and CO_2 emissions from biomass combustion only include those from biogenic waste incineration;
6. Special regional aviation and special regional marine represent aviation and marine transport between Macao and other parts of China (including Hong Kong SAR and Taiwan area);
7. 0.0 indicates calculation results that is less than 0.05.

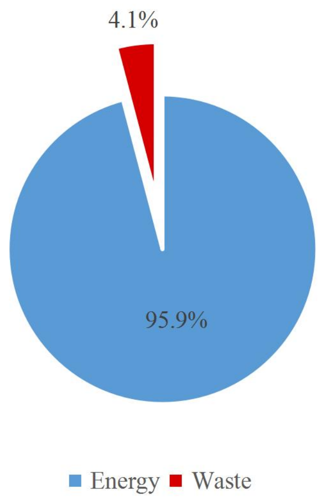


Figure 8-1 Macao's GHG Emissions by Sector in 2017

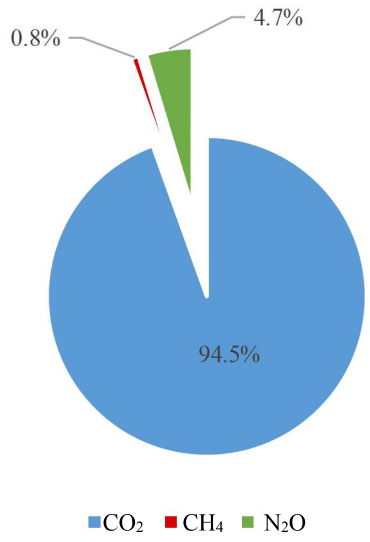


Figure 8-2 Macao's GHG Emissions by Gas in 2017

In 2017, the total emission from international aviation and special regional aviation in Macao was 64.1×10^4 t CO_2 eq, that from special regional marine transport was 21.0×10^4 t CO_2 eq, and carbon dioxide emission from biomass burning of urban waste was 27.6×10^4 t CO_2 eq, all of which were listed separately as Memo Items. The total GHG emissions from above-mentioned activities were about 112.7×10^4 t CO_2 eq and not counted into the total emissions of Macao.

2.2 Energy Sector

2.2.1 Scope

For Energy, the reporting scope of Macao's GHG Inventory mainly covers the CO_2, CH_4 and N_2O emissions from fossil fuel combustion in energy, manufacturing and construction, road transport and other sectors. Considering the fact that incineration is the major approach for waste treatment in Macao, and the heat generated in the incineration process is retrieved to generate electricity and transmitted to Macao's power grid, the GHG emissions from incineration of fossil-derived waste (such as clothing and plastics) are counted in the source category of Energy. While CO_2 emissions from biomass combustion of urban waste are not included in the total emissions but are only listed as a Memo Item.

2.2.2 Methodologies

For the GHG inventory concerning Energy, Tier 1 methods by sector approach in 2006 IPCC Guidelines were applied for the estimation of CO_2, CH_4 and N_2O emissions caused by fossil fuel combustion from energy processing and conversion, manufacturing and construction, road transport and other sectors as well as special regional marine transport. While Tier 2 methods in the 2006 IPCC Guidelines were used for CO_2, CH_4 and N_2O emissions from international and special regional aviation.

The data of activity levels were from Macao's official statistics and related industrial data, and the classification of sectors and fuel types were basically the same as those given in the 2006 IPCC Guidelines.

The emission factors mainly referred to the 2006 IPCC Guidelines and the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The default values provided in the 1996 IPCC Guidelines were adopted for the emission factors that were not included in the two guidelines mentioned above.

2.2.3 Emissions Inventory

Macao's GHG emissions from Energy in 2017 were about 167.5×10^4 t CO_2 eq (164.6×10^4 t CO_2 eq for CO_2, 0.6×10^4 t CO_2 eq for CH_4 and 2.3×10^4 t CO_2 eq for N_2O), accounting for 95.9% of the total GHG emissions. CO_2 emissions from energy activities accounted for 99.8% of the total CO_2 emissions of Macao.

In 2017, among Macao's total GHG emissions from Energy, 94.5×10^4 t CO_2 eq, or 56.4%, was from energy processing and conversion; 42.1×10^4 t CO_2 eq, or 25.1%, was from road transport; 19.8×10^4 t CO_2 eq, or 11.8%, was from other sectors, including business, catering, hotels and residential buildings; and 11.1×10^4 t CO_2 eq, or 6.7%, was from manufacturing and construction.

2.3 Waste Disposal

2.3.1 Scope

The reporting scope of Macao's GHG inventory for waste treatment mainly covers CH_4 and N_2O emissions from urban wastewater treatment, and CO_2, CH_4 and N_2O emissions from solid waste incineration.

2.3.2 Methodologies

The compilation of GHG inventory for emissions from waste treatment in Macao adopted Tier 1 methods provided by the 2006 IPCC Guidelines and 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Activity data of N_2O emissions from wastewater treatment were based on the total population provided by the Statistics and Census Service (DSEC) and Macao's per capita annual protein consumption in 2017 from the Food and Agriculture Organization of the

United Nations, and the emission factors adopted IPCC default values. The activity data provided by DSEC and Environmental Protection Bureau (DSPA) and the default values of emission factors recommended by IPCC were simply adopted for CO_2, CH_4 and N_2O emissions from solid waste incineration.

2.3.3 Emissions Inventory

In 2017, Macao's total GHG emission from waste treatment was 7.1×10^4 t CO_2 eq, accounting for 4.1% of the total GHG emissions in Macao, of which emissions from wastewater treatment and solid waste incineration were 6.7×10^4 t CO_2 eq and 0.4×10^4 t CO_2 eq, accounting for 94.8% and 5.2% of the total respectively.

2.4 Quality Assurance and Quality Control

2.4.1 Quality Assurance and Quality Control in Compiling the Inventory

To reduce uncertainties of the inventory, in terms of methodologies, those from the 2006 IPCC Guidelines and the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories have been followed to ensure the compilation work was well-planned, comparable and consistent. In accordance with the available activity data, the institutions engaged in the preparation of the inventory in Macao have selected the higher-tier methods where possible. For instance, Tier 2 methods have been used for international aviation and special regional aviation. As for activity data, the institutions have used the data verified by governmental departments of Macao SAR, such as the Statistics and Census Bureau, the Civil Aviation Authority, the Environmental Protection Bureau and the Transport Bureau, as much as possible to ensure the authoritativeness of such data. The national inventory compilation team was invited to review Macao's GHG Inventory during the preparation process as an independent third-party expert.

2.4.2 Uncertainty Analysis

In the process of preparing the GHG Inventory of Macao in 2017, although the institutions engaged in inventory preparation had put considerable efforts in terms of its scope, methodologies and quality, there remain uncertainties in Macao's GHG Inventory.

Institutions engaged in the compilation of Macao's inventory adopted Tier 1 methods of the 2006 IPCC Guidelines for the calculation of uncertainties, and made reference to the uncertainty of emission factors in the 2006 IPCC Guidelines and 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The overall uncertainty of Macao's GHG inventory in 2017 was about 9.9%, and 7.8% and 158.7% for energy activities and waste treatment respectively as shown in Table 8-4.

Table 8-4 Results of Uncertainty Analysis of Macao's GHG Inventory of 2017

	Emissions (t CO_2 eq)	Uncertainty
Energy	1,675,000	7.8%
Waste	71,000	158.7%
Total uncertainty		9.9%

Chapter 3 Impacts of and Adaptation to Climate Change

Macao SAR government has organized relevant departments and research institutions to monitor and assess the impacts of climate change on water resources and terrestrial ecosystems, making preparations for the development of mitigation and adaptation policies on climate change. Moreover, on the basis of Macao's historical climatological observation data and global climate model simulation data, study has been carried out to assess and predict the climate change in Macao.

3.1 Assessment Method and Model

To assess the impacts of climate change in Macao, Macao has conducted time series analysis on climate change using its relatively complete climatological observation data from 1901 to 2020, and has predicted future climate change in Macao with the multi-model ensemble assessment methods using the GHG emission scenarios and global climate model simulation data adopted in the IPCC Fifth Assessment Report (AR5).

3.2 Analysis and Prediction of Climate Change in Macao

3.2.1 Characteristics of Climate Change

Based on the analysis of the daily average temperature and precipitation data from 1901 to 2020, the characteristics of climate change in Macao are as follows:

The trend of temperature changes in Macao in the past 120 years was basically consistent with that of the global average. The linear warming trend in 100 years was 0.88℃, and the warming rate after the 1970s increased. Of the ten warmest years in the past 120 years, eight were in the 21st century. The temperatures of different seasons in Macao all increased, of which spring saw the biggest rise, which was about 0.10℃ per 10 years, followed by winter (about 0.096℃ per 10 years) and autumn (about 0.095℃ per 10 years), while summer had the smallest rise of about 0.061℃ per 10 years. Both the daily maximum temperature and the daily minimum temperature in Macao showed a rising trend, and the former showed clear interdecadal variations. There were clear interdecadal variations in the number of summer days with daily maximum temperature over 33℃, but there's no significant increase in the number of summer days. Regarding the cold nights (with a minimum temperature of 12℃ or below) and tropical nights (with a minimum temperature of 27℃ or above), there was a significant and continuous changing trend. The number of cold nights decreased by about 1.4 days per 10 years, while that of tropical nights increased by about 1.9 days per 10 years. Moreover, the frequencies of heavy rain (over 50 mm per day) and rainstorms (over 100 mm per day) also increased. The linear trends of the two in 100 years were 3.6 days and 1.4 days, respectively.

The precipitation in Macao showed clear interdecadal variations. In the 20th century, the precipitation was on the rise in general. Precipitation increment in every 10 years was about 37.9 mm. Summer saw the most significant precipitation increase, while other seasons showed no clear changes. According to the definitions of the Expert Team on Climate Change Detection and Indices (ETCCDI), the Macao Meteorological and

Geophysical Bureau (SMG) has calculated climate change indices (see Table 8-5). The overall changes have reflected the warming trend. Meanwhile, precipitation intensity and maximum consecutive precipitation of 5 days also showed a clear rising trend.

Table 8-5 Index Table on Macao's Climate Change (Based on information between 1901 and 2020)

Index	Definition	Change per ten years
ID12	**Cold days**	-0.138 days
CD12	**Cold nights**	-1.44 nights
SU33	**Hot days**	0.30 days
TR27	**Hot nights**	1.91 nights
TXx	**Annual maximum value of daily maximum temperature**	0.058℃
TNx	**Annual maximum value of daily minimum temperature**	0.051℃
TXn	**Annual minimum value of daily maximum temperature**	0.072℃
TNn	**Annual minimum value of daily minimum temperature**	0.087℃
SDII	**Daily simple precipitation intensity index**	0.42mm/day
RX5day	**Maximum consecutive 5-day precipitation**	7.72mm

3.2.2 Future Climate Change Trends

Based on the past climatic data of Macao and the GHG emission scenarios and climate model simulation results in IPCC AR5, Macao has assessed its future climate change.

The key conclusions are as follows. The average temperature in Macao will continue to rise. Research shows that in all scenarios, by the middle of the 21st century (2050-2059), the temperature will be 1.4-2.2℃ higher than the average temperature in 1956-2005; by the end of the 21st century (2090-2099), the temperature will increase 1.4-3.9℃ (Table 8-6); and by the end of the 21st century, the temperature of all seasons will also be on the rise (Table 8-7). In addition, the precipitation intensity of the wet season in Macao by the middle and the end of this century tends to increase, and the highest precipitation intensity may reach 14%.

Table 8-6 Multi-model Evaluation of Future Temperature Change of Macao (Compared with 1956-2005)

Temperature (℃)		
GHG Emission Scenarios	**2050-2059**	**2090-2099**
RCP2.6	1.4	1.4
RCP4.5	1.6	2.1
RCP6.0	1.3	2.5
RCP8.5	2.2	3.9

Table 8-7 Future Temperature Change in Different Seasons of Macao (Compared with 1956-2005)

Temperature (℃) (2090-2099)				
GHG Emission Scenarios	**Spring**	**Summer**	**Autumn**	**Winter**
RCP2.6	1.3	1.3	1.4	1.5
RCP4.5	2.1	2.0	2.3	2.3
RCP6.0	2.2	2.4	2.6	2.7
RCP8.5	3.8	3.8	4.1	4.1

3.3 Main Vulnerable Areas of Macao

3.3.1 Water Resources

Over 98% of the water supply in Macao was from the Xijiang River, a tributary of the Pearl River. The changes in its future water resources mainly depend on the precipitation changes of the Pearl River basin, the utilization of upstream water resources and the sea level changes of the South China Sea. According to the results of national analysis, the runoff of southern rivers has not changed much in the last 30 years. However, due to the rapid economic development of Macao, its water consumption had increased to more than 1.7 times during 2001-2020. Due to the rising sea level in the South China Sea, seawater intrusion into the Pearl River basin in the dry season became more serious, and the phenomenon of salt tide became more common, directly threatening the water supply safety of Macao.

It has been difficult for the runoff in the Pearl River basin to meet the increasing demand for water resources as a result of rapid urbanization and population growth in the region. In addition, precipitation in South China is likely to concentrate in summer and autumn in the future; while precipitation in winter and spring will continue to decrease. Against the backdrop of global warming and sea level rise, the possibility of the occurrence of salt tides during winter and spring dry seasons will increase in the future. It is thus particularly important to store and utilize the precipitation in summer and autumn with frequent rainfall.

3.3.2 Terrestrial Ecosystem

Over the past decades, the tropical liana of the forest vegetation in Macao has grown faster. Its large coverage has made the trees continue to weaken to death because of the inability to perform photosynthesis, and the growth of seedlings underneath has also been affected because they cannot get enough sunlight. Therefore, the forest area cannot be regenerated naturally. In addition, the increase in invasive alien plants has affected the stand structure and the normal growth of other plants. In the meantime, the number of individual cases of plant diseases and insect pests in forests has been on the rise. Preliminary assessment indicated that it might have something to do with the growth of CO_2 concentration and temperature. However, it is still quite difficult to tell whether the impacts are caused by climate change or the human factor of urbanization.

To know more about the impacts of climate change on Macao's ecology, apart from the establishment of special natural conservation areas, the Macao SAR government, together with domestic scientific research institutes, has continuously conducted basic surveys of animals and periodical monitoring and study of plants and animals sensitive to meteorological conditions since 2011, so as to produce more comprehensive data to make preparations for assessment of future climate change.

3.3.3 Sea Level Change and Coastal Ecosystem

Macao is a coastal city. The west coast of the Macao Peninsula, the lowest location in terrain, is the area affected the most by sea level rise. When a relatively strong tropical cyclone approaches or lands the coast along the Pearl River Estuary, it might lead to a storm surge. If there is an astronomical tide, it might cause serious inwelling and extensive flooding. According to the analysis of tide station data in Macao from 1925 to 2020, the sea level of Macao rose at a rate of 1.7 mm per year, and the rise rate had increased in the past 20 years, which was about 2.5 mm per year. Since the 1970s, Macao has been seriously affected by 14 storm surges, of which nine occurred in the past 20 years. It is projected that the degree and frequency of the impacts of inwelling and flooding in Macao will increase, so will the probability of being affected by strong storm surges.

3.4 Adaptation Measure Already Adopted

Macao addresses the impacts brought out by climate change actively and has been developing adaptation measures. Some of the measures and actions that Macao has adopted to adapt to climate change in recent years have shown positive effects.

3.4.1 Water Resources

To stabilize the water resource supply and reduce salt tides in Macao, water resource adaptation measures are mainly designed to strengthen water resource management and build a water saving society. The measures and actions that Macao has taken in recent years are as follows: In 2008, Macao established the Working Group on Promoting the Building of a Water saving Society to plan as a whole and coordinate salt tide countermeasures, promote knowledge of water conservation and management and plan overall water resources; In 2009, Macao allocated 800 million yuan to support the resettlement of inhabitants, water and soil conservation and environmental governance of the Guangxi Dateng Gorge Water Conservancy project; in 2009 Macao trusted a research institution to develop the Overall Water-saving Plan Research Report of Macao; In 2010, Macao prepared the Outline of Water-saving Plan of Macao, determining the development direction of Macao's water-saving efforts in the next 15 years; Through the cooperation between Guangdong and Macao, the construction of Zhuyin Reservoir in Zhuhai, Guangdong Province was completed in 2011, and Macao obtained a total operating water volume of about 16 million m^3; In 2015, the project of Macao Dashuitang Water Plant was completed, increasing the daily water supply capacity of Macao from 330,000 m^3 to 390,000 m^3; The construction of the Seac Pai Van Water Treatment Plant began in 2018; In 2019, the fourth raw water pipeline from Zhuhai to Macao was put into operation, which improved the efficiency of the water supply system; In 2020, the Pinggang-Guangchang raw water support project completed and went into operation, which greatly increased the stability and risk resistance of water supply from Zhuhai to Macao.

3.4.2 Terrestrial Ecosystem

In 2001, the Macao SAR government established the first ecological protection zone in the wetland located in the west of the Cotai Reclamation Zone. Covering a total area of about 55 ha, it protects over 100 species of plant and animal. During the non-bird season in 2019 and 2020, optimization of tidal-flat area in ecological zone I was carried out to improve the living environment of waterfowl, benthic animals and fish, so that the number of migratory birds returning to Macao remained basically stable in recent years. In addition, in order to prevent lianas from continuing to affect the ecological functions of forest areas, the Macao SAR government has continuously carried out the liana caring and clearing work for the forests in various districts, and implemented the transformation of stand structure.

3.4.3 Seal Level and Coastal Zone

In order to reduce the damages to economic development and urban operation due to flooding caused by storm surges and astronomical tides, the Macao SAR government has taken a number of measures. For example, research was carried out in 2017 for the construction of a tidal sluice in Wan Chai Waterway to reduce flooding in low-lying areas caused by storm surges and astronomical tides. In 2018, the Technical Specification for Power Installations of New Buildings in Low-lying Areas was finalized, according to which the newly-equipped power facilities such as transformer rooms, branch boxes and meters have to be set above the "flooding-proof elevation" so as to improve the flood control standards of urban infrastructure. In the same year, the storm surge warning system was optimized to strengthen the ability of governmental departments and the citizens regarding prevention and response. In addition, regular monitoring and protection have been carried out to improve the environment of mangroves along the coastal beaches and ensure the species diversity of the ecosystem.

3.5 Adaptation Measures to be Adopted in the Future

In 2019, the Macao SAR government announced the Ten-year Plan for Disaster Prevention and Mitigation of the Macao SAR (2019-2028), which assessed the main risks and challenges faced by Macao in the fields of natural disasters, accidents, public health incidents and social security incidents, established the priority areas of Macao's emergency capacity building in the future, determined the primary planning tasks in nine aspects, and used 37 indicators to comprehensively reflect the effectiveness of Macao's disaster prevention and mitigation as well as emergency capacity building in the next 10 years. Among them, strengthening infrastructure disaster prevention and mitigation capabilities, improving emergency management system, strengthening risk management and monitoring and early warning capabilities, and improving social coordinated response are included to cope with extreme and severe weather events and water shortage problems that may be aggravated by climate change and to enhance the overall ability of the city to address climate change.

Chapter 4 Policies and Actions for Climate Change Mitigation

Macao SAR government has always attached great importance to climate change mitigation, and has been dedicated to building a green and low-carbon economy and society by implementing policies and measures on the optimization of energy structure, energy conservation, energy efficiency improvement as well as urban greening and preference to public transport, so as to effectively reduce GHG emissions effectively.

4.1 Policies and Targets for GHG Emission Control

Macao prepared the Five-Year Development Plan of Macao SAR (2016-2020) in 2016, clarifying its efforts to actively support the national green development strategy and vigorously promote a civilized and healthy mode of life that pursues green, low carbon and emission reduction. In 2021, the Second Five-Year Plan for the Economic and Social Development of the Macao Special Administrative Region (2021-2025) was released, which further set the goal of controlling greenhouse gases: reducing greenhouse gas emissions per unit of GDP by 55% relative to the 2005 level by 2025, and striving to reach carbon dioxide peak before 2030.

To protect Macao's environment in a systemic manner and achieve the targets in relation to GHG emission control, the Environmental Protection Plan of Macao (2010-2020) was formulated in 2010. With "sustainable development, low carbon development, public participation and regional cooperation" as the four core concepts, the plan is designed to improve the living environment and protect people's life through three states, namely near-term (2010-2012), medium-term (2013-2015) and long-term (2016-2020). To supervise its implementation, Macao SAR government evaluated its effectiveness in 2014 and 2016 and issued the Implementation and Effectiveness Evaluation of the Environmental Protection Plan of Macao (2010-2020) in 2022, which comprehensively summarized the implementation, evaluated the changes in environmental quality, resource utilization and the completion of environmental protection work during the period, and provided reference and suggestions for the formulation of environmental protection plan in the next stage. In 2022, the Environmental Protection Plan of Macao (2021-2025) was released, which formulated a number of measures and action plans to deal with climate change and promote low-carbon development from the aspects of promoting the use of electric vehicles, energy conservation and emission reduction, green city construction, green life and consumption, and corporate environmental protection.

4.2 GHG Emission Mitigation Actions

4.2.1 Energy Industry

Optimizing the energy supply structure. In terms of power supply, Macao continues to import electricity through China Southern Power Grid to meet its main power demand. According to the supplementary agreement of the Framework Agreement on Power Cooperation (2010-2020), clean electricity (including electricity generated by hydropower, nuclear power, wind power and solar power) accounts for more than 40% of the total power import from 2017, and the proportion will be gradually increased in line with the optimization of power supply structure in the southern region in the future. Natural gas is the major source for local power generation, and the existing oil-fired generating units will be used as emergency backup. In the future, carbon capture technology will be adopted when the gas-fired generating units are updated. In addition, Macao continues to make full use of the electricity generated by biomass energy, including waste incineration and kitchen waste.

Promoting the use of clean energy. In order to promote the use of clean energy, Macao has introduced a large amount of natural gas to replace heavy oil; and in 2008, it officially realized power generation from natural gas. In 2020, the proportion of natural gas power generation in Macao increased from 52.9% in 2017 to 57.1%, and the greenhouse gas emissions related to power generation decreased. In the future, Macao will further increase the proportion of natural gas power generation. In addition, the Macao SAR government has started the construction of a public natural gas pipeline network in 2012. The construction of the main natural gas pipeline network in Cotai was basically finished in 2017. The construction of the cross-sea gas supply pipeline connecting Taipa and the Macao Peninsula began in 2021. After its completion, the gas supply network will extend to the southern part of the Macao Peninsula. In the same year, the Technical Regulations of Gas Pipeline Supply Facilities in Buildings was revised, requiring that new buildings should be compatible with natural gas facilities. In the future, priority will be given to the use of natural gas in public projects where possible. At the same time, hotels and tourist facilities will be stimulated to switch to or expand the use of natural gas.

Expanding the use of renewable energy. In order to promote solar photovoltaic power generation, the Macao SAR government has developed incentives in terms of feed-in tariffs and photovoltaic power purchase contracts, and encouraged the installation of related systems to gradually expand the use of clean energy. Between 2015 and 2021, five departments or institutions have connected to the grid to sell electricity after installing solar photovoltaic systems. According to the Second Five-Year Plan for the Economic and Social Development of the Macao Special Administrative Region (2021-2025), the photovoltaic power generation system or vegetation area on the roof of newly-built public buildings shall not be less than 30% of the open-air surface. In the future, Macao will continue to put efforts to promote the application of solar photovoltaic power generation, encourage private installation of solar photovoltaic systems, and give priority to the installation of solar photovoltaic systems on the roofs of newly-built public buildings when permitted.

4.2.2 Transport

Prioritizing Public Transport. In 2010, the Macao SAR government promulgated the Overall Land Transport Policy for Macao (2010–2020). In 2019, the 9.3-kilometer light-rail Taipa Line was officially put into use, with 11 stations covering the main residential areas, old urban areas and tourist areas in downtown Taipa, with a passenger capacity of more than 820,000 in the first month of operation.

Promoting electric vehicles. According to the Five-Year Development Plan of Macao SAR (2016-2020), in order to improve the supporting facilities for charging electric vehicles, the target for the first five years of planning was achieved in 2020, installing 200 charging slots for light vehicles and 2 for motorcycles in 42 public parking lots and 7 public roads in Macao by stages. The Policy Address 2022 and the Second Five-Year Plan for the Economic and Social Development of the Macao Special Administrative Region (2021-2025) have put forward the application direction of electric vehicles in Macao. The Macao SAR government will continue to take the lead in promoting the use of electric vehicles, appropriate installation of charging equipment at existing public parking lots, and the reservation of charging capacity and infrastructure for all parking spaces in new public parking lots and public buildings in the future. Similar requirements will apply to all parking spaces in new private buildings when it is legal to do so.

Involving in "Airport Carbon Accreditation Program". In 2014, Macao International Airport became accredited at the "Reduction" level (or Level II) of Airport Carbon Accreditation, a program launched by Airports Council International, and continued to implement various measures from 2017 to 2020, including gradually upgrading the lighting system with energy-saving light bulbs, replacing vehicles in the airport convoy with environmentally-friendly ones, and adjusting the air-conditioning temperature and lighting time according to the plan. As the Macao International Airport maintained its daily operation with the basic energy consumption even though its number of fights decreased significantly after 2019, the carbon emission per take-off/landing at the airport in 2020 increased compared with that in 2012.

4.2.3 Energy Conservation and Efficiency Improvement

Energy conservation and efficiency improvement in public sectors and institutions. In 2016, public sectors and institutions began implementing the energy efficiency evaluation plan. While continuing to implement the energy management mechanism, the standard of energy consumption limit suitable for Macao was formulated with reference to that of neighboring regions (For each sector, the per capita annual electricity consumption is 3,000 kWh, or the annual electricity consumption per square is 150 kWh.), so that all sectors can determine more specific energy-saving targets and continuously improve and optimize energy management. Relevant plans have been implemented till now, and "Workshop on Basics of Energy Management" has been held regularly, where new members of the energy management team will introduce the mechanism of energy management, relevant knowledge and energy-saving methods.

Energy conservation of lighting systems in outdoor public spaces. In 2008, the Guide to the Design of Public Outdoor Lighting in Macao was formulated to promote the application of LED lamps. After the installation of LED lamps in the public housing area in Seac Pai Van and Zona Nova de Aterros do Porto Exterior, the street lamp replacement project started in June 2017. The plan was to gradually replace about 14,000 standard-pole high-pressure sodium lamps with LED street lamps so that the lamp arrangement is energy-saving, pleasing-to-the-eye, and safe. By the end of 2021, the replacement project had basically been completed, and the LED street lamps in Macao will account for about 54% of the total number of street lamps.

4.2.4 Hotels and Tourism

Promoting emission reduction in the hospitality industry. Since 2007, Macao has held the "Macao Green Hotel Award" every year to encourage hotels and related industries to achieve the goals concerning environmental protection and low-carbon clean development. Since the establishment of this award, the review criteria have been optimized and perfected, with an increasing number of hotels participating in the appraisal. As of 2020, the number of environmentally-friendly hotels has increased from 8 to 57, accounting for about 50% of the total number of hotels in Macao. All the award-winning hotels installed energy-saving LED lamps; some of them even set up solar facilities to generate renewable energy for the hotels to use. Compared with last year, the number of electric vehicle charging slots at award-winning hotels increased by more than 70%, and the number of award-winning hotels using electric vehicles as shuttle buses also increased by more than 30%. In addition, the Macao SAR government continues to promote the carbon audit of the hospitality sector, thus encouraging hotel enterprises to participate in energy conservation and emission reduction.

4.2.5 Urban Greening

Increasing green coverage. Macao continued planting new trees, actively increased its green coverage, and planted trees in parks, recreational areas and pavements every year. Between 2017 and 2020, more than 10,000 mangrove saplings were planted along the Leisure Area on Taipa Waterfront, and more than 6,000 trees were planted for the reconstruction of forest area in Coloane. In 2017, after Macao was hit by a super typhoon, the forests and trees were damaged to varying degrees. In 2018, the Macao SAR government started the restoration project of forests and trees, and built an ecological corridor with high ecological benefits and characteristic landscapes through reseeding and replanting, comprehensively boosting the high-quality development of forests. In addition, the government has been organizing the annual event of "Macao Green Week" with various forms of publicity activities to encourage all citizens to take part in the greening of Macao.

Greening more spaces. To reach the green city targets and get more spaces green, the Macao SAR government expanded the greening scope to cover public garbage chambers, piers of overpasses, the roofs and facades of stations in 2011. Between 2017 and 2020, pergolas were set up for plazas and streets, road slopes and medians were made greener, and overhead green corridors were planned so as to strengthen road greening, develop multi-dimensional greening and carry out roof greening, creating more green spaces in Macao. The construction of a coastal green corridor in the south of the Macao Peninsula started in 2020 and the project was designed to be completed in stages. By adjusting the layout of green belts, more trees and other plants would be planted to build recreational and comfortable avenues for the citizens.

Chapter 5 Other Relevant Information

Macao has initiated a series of activities to enhance climate system observation and relevant research, conduct education, public communication and training on climate change, encourage public participation, and raise awareness of climate change.

5.1 Climate System Observation

Despite its small size, Macao has a rather dense atmospheric and ocean observation network, including 16 automatic weather stations, one climate observation station, one atmospheric radiation monitoring station, six air quality monitoring stations, and two tide monitoring stations. Also, to address seawater inwelling caused by storm surges and astronomical tides, Macao has built 20 automatic water level monitoring stations in the low-lying areas along the western coast to monitor coastal water level changes and flooding in Macao by 2020.

5.2 Climate Change Research

Macao's long history of meteorological observation has left it with systematic and detailed records. By compiling these data, the Macao Meteorological and Geophysical Bureau has created a 100-year data set (1901-2000), provided a solid foundation for climate change and related research and produced high-level research results. Besides continuing to strengthen routine monitoring, analysis and research on meteorological conditions and sea level, Macao also caught up on ecological monitoring in areas that have relatively fewer data and smaller monitoring windows, and implemented monitoring of migratory birds and in-depth baseline survey of various plants.

Macao studied and compiled relevant action plans for addressing climate change. To this end, multiple fundamental and special research is needed to support policy-making. Major research projects include organizing meteorological materials accumulated since 1901; introducing multiple global climate change models, and assessing climate change impacts on Macao with downscaling analysis, particularly its impacts on water resources; studying climate change impacts on extreme weather events including typhoon and heavy rainfall, and assess the risks of disastrous weather events, particularly the possible damages to Macao's society and economy due to storm surges caused by typhoon.

5.3 Education, Public Communication and Public Awareness

The Macao SAR government attaches great importance to the publicity and education on climate change so as to raise public awareness in this regard and advocate the protection of global climate and environment with joint efforts. Since 2008, the Macao SAR government has held the well-received Macao International Environmental Co-operation Forum and Exhibition (MIECF) annually, which provides an efficient platform for environmental cooperation between different sectors.

In terms of climate change education, the Macao SAR government pays special attention to the good ideas and actions during the publicity and education. In the field of formal education, the government has implemented the Curriculum Framework for Formal

Education in Local Academic System in an orderly manner since the 2014/2015 school year. Since the 2015/2016 school year, the relevant provision of the Basic Academic Attainment Requirements for Formal Education in Local Academic System has been implemented in an orderly manner, so as to ensure that according to the learning characteristics of students at different educational stages, schools standardize and guide the integration of environmental education-related contents into subjects, including caring about climate change, environmental protection, resources conservation, and pursuing the philosophy of sustainable development, and to guarantee the cultivation of knowledge, skills, abilities, emotions, attitudes and values in relation to environmental education. Thus, students may gradually understand the significance and influence of environmental protection education from the early childhood stage, and establish the consciousness and social responsibility of caring for the environment and avoid wasting resources. In 2013, the Macao Youth Policy (2012-2020) was published, which aims to enable all youth affairs to be effectively implemented. What's emphasized in it includes the enhancement of youth's environmental awareness, the gradual cultivation of youth's habit of participating in environmental protection, fostering the idea of green and low-carbon development, and advocating green, simple life with focus on energy conservation and emission reduction.

In terms of climate change publicity, relevant authorities and organizations in Macao not only spread the ideas of energy conservation, emission reduction and green and low-carbon living through various media such as television, internet and newspapers, but also compile and publish various publicity materials related to climate change, such as "Energy Stories: The Journey of Clean Coal", "Nightwalking of Energy Conservation" and "Discovery of Baby Spoonbill".

Besides, the Macao SAR government is also committed to delivering water conservation information to the public. To raise water-saving awareness among students, relevant departments initiated the campaign of "Save Water on Campus". Since 2015, the school play "Weishui Superman" for the publicity of water conservation has been staged, along with the publication of storybooks about "Weishui Superman" and materials such as "Knowledge of Water Resources in Macao". In 2019, the "Campus Water Saving Program" was launched to encourage students to cherish water resources. In order to spread knowledge of water saving, a community tour with the theme of "Safe Sea & Quality Water" was held for the public to learn about the water resources in Macao and the significance of protecting them through various forms such as workshops and plays. For hotels and shops, the "Water Saving Plan for Hotels" and "Water Saving Plan for Business Buildings" have been launched to arouse the public's awareness of water conservation.

5.4 Technology and Capacity Building Needs

Macao highly values the technologies and capacity-building in regard to climate change. The "Environmental Protection and Energy Conservation Fund" (Fundo para a Protecção Ambiental e a Conservação Energética, FPACE) has been established to support medium- and small-sized businesses, social communities and other organizations and institutions to boost their participation in environmental protection and energy conservation, broaden the space for the development of environmental protection and energy conservation, and promote diversified development in these industries. In the meantime, all governmental departments have made necessary financial arrangements in their own budgets to conduct research and implement activities in relation to climate change. Despite all the policies and actions taken to address climate change by Macao, insufficient technological capacity has been holding back progress in many sectors.

For climate change mitigation, Macao has been actively increasing energy efficiency and utilization of renewable energies and decreasing local carbon emissions. In this regard, the key technologies in demand include: building energy conservation technologies, efficient solar energy utilization technologies, waste recycling and reuse technologies, hydrogen power generation technologies, carbon capture and sequestration technologies, and quick charge technologies for electric vehicles.

For climate change adaptation, Macao is in urgent need of strengthening prevention and protection along coastal areas, so the main technologies in demand include technologies for utilizing reclaimed water, technologies for forecasting and assessing sea-level rise, highly effective flood prevention technologies, ecosystem restoration and reconstruction technologies, as well as methods and measures in assessing disastrous weather events caused by climate change.

For capacity building, Macao needs to establish a nonlinear dynamic model of coupling “Energy-Economy-Environment-Population” for assessing future energy demands in Macao. It also needs to enhance the executive capabilities of governmental authorities to promote education and publicity on climate change, so as to raise public awareness in this regard with the aim of accelerating the building of low-carbon society and economy.

It is Macao’s hope to advance technological development through broad cooperation and capacity building, so as to address climate change by joint efforts.