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The People's Republic of China Third National Communication on Climate Change

December 2018

Foreword

Global climate change, which has profound impacts on human survival and development, poses a major challenge to all nations. Recalling Articles 4 and 12 of the United Nations Framework Convention on Climate Change (hereinafter referred to as the Convention), each Party shall submit its national communication. As a non-Annex I party to *the Convention*, the People's Republic of China (hereinafter referred to as China) has attached great importance to its international obligations. China submitted its *Initial National Communications on Climate Change* and *Second National Communications on Climate Change* in 2004 and 2012 respectively, in which policies and actions in response to climate change were comprehensively elaborated, and the 1994 National Greenhouse Gas (GHG) Inventory and 2005 National GHG Inventory were reported.

Upon receiving the grants from the Global Environment Facility (GEF) in 2015, the Chinese government launched the preparation of its third national communication by organizing the departments and research institutions concerned and by following the guidelines for the preparation of national communications from Parties not included in Annex I to *the Convention*, which was adopted by COP 8. After three years of efforts, China has completed *The People's Republic of China Third National Communication on Climate Change*. In 2018, in accordance with the arrangements for the institutional reform of Chinese government, the functions of addressing climate change were allocated from China's National Development and Reform Commission to the newly established Ministry of Ecology and Environment. This report was approved by the State Council after multiple and repeated revisions based on broad comments and submitted by the Ministry of Ecology and Environment.

The People's Republic of China Third National Communication on Climate Change, approved by the Chinese government, is divided into eight Parts: National Circumstances and Institutional Arrangements, National Greenhouse Gas Inventory, Impacts of Climate Change and Adaptation, Policies and Actions for Climate Change Mitigation, Finance, Technology and Capacity-Building Needs and Support Received, Other Information on Achieving Target of the Convention, Basic Information of the Hong Kong Special Administrative Region (SAR) on Climate Change, and Basic Information of the Macao SAR on Climate Change, presenting a full picture of China's national efforts on climate change. According to the relevant decisions of *the*

Convention, and in light of China's national circumstances and the information reported by *the Second National Communication on Climate Change*, the National GHG Inventory presented herein is based on the data of 2010, while the description about relevant conditions given in other chapters is generally updated to 2015. In accordance with the relevant principles set down in 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.

Addressing climate change is a shared mission of mankind. Considering its basic national circumstances and the characteristics of its development stage, China is vigorously promoting eco-civilization, and executing a national strategy for actively addressing climate change by integrating climate change into its medium- and long-term national socio-economic development planning and by attaching equal importance to mitigation of and adaptation to climate change, and trying to accelerate green and low-carbon development by actively controlling GHG emissions and enhancing climate change adaptation capability. 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, and to fulfill the international commitments actively. China will implement its Nationally Appropriate Mitigation Actions (NAMAs) and Nationally Determined Contributions (NDC) comprehensively, participate in negotiations on global climate change actively, promote the establishment of an equitable, rational, cooperative and win-win global climate governance, deepen multi-lateral and bilateral dialogs and pragmatic cooperation on climate change, support other developing countries to enhance their capacity building in response to climate change, and promote to build a community with a shared future for mankind.

Contents

Part I National Circumstances and Institutional Arrangements

China is a country with a huge population, complex climate and vulnerable eco-environment, and 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 coordinative 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, sets up national, local or relevant organizations and institutions to address climate change, creates stable technical support institutions and organizes core expert teams as an 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

China is situated in East Asia, on the west coast of the Pacific, with a total land area of about 9.6 million square kilometers (Mkm^2), the coastline along its east and south runs for over 18,000 kilometers; sea area under its governance is about 3 Mkm^2, and there are more than 11,000 islands. China borders 14 countries on land, and is adjacent to 8 countries on sea. Its administrative divisions at the provincial level constitute 23 provinces (including Taiwan), 5 autonomous regions, 4 municipalities directly under the central government and 2 special administrative regions (Figure 1-1).

1.1 Natural Conditions

1.1.1 Topography

China's terrains vary significantly. The five basic 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 like a terrace from west to east. The Tibetan Plateau at an average altitude of 4,000-5,000 meters constitutes the highest step. From the Tibetan Plateau to the north and the east, such plateaus as the Yunnan-Guizhou Plateau, the Loess Plateau, and the Inner Mongolian Plateau, and the basins in between, such as Sichuan

Basin, the Tarim Basin and the Junggar Basin, which are all at an altitude of 1,000-2,000 meters, constitute the second step. From the east of the Greater Khingan Range, the Taihang Mountain, the Wu Mountains and the Xuefeng Mountains, to the west of the ocean, the hills of Liaodong, Shandong, Zhejiang-Fujian and Guangdong-Guangxi, and the plains, such as the Northeast China Plain, the North China Plain, the Plain of the Middle and Lower Reaches of Yangtze River, and the Pearl River Delta Plain lying in between, most of which are at an altitude of up to 500-1,000 meters, constitute the third step. To the east of China's land, there are 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).

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Figure 1-1 Administrative Division Map of China

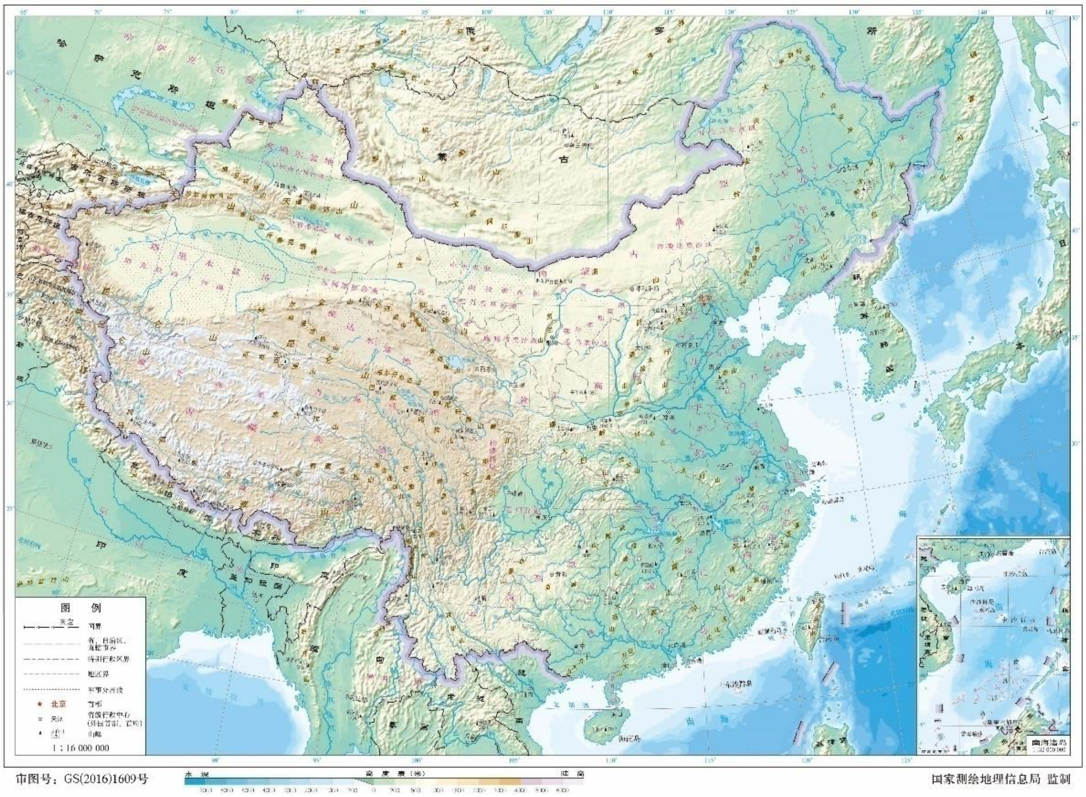

Figure 1-2 Topography Map of China

1.1.2 Climate and Climatic Disasters

China's climate features complexity and diversity. The Eastern China has a monsoon climate, the northwestern region is of a temperate continental climate, and the Tibetan Plateau falls into an alpine climate category. China's climate is characterized by hot and rainy summer, cold winter with little rain, and the coincidence of high-temperature period and rainy period. In 2016, China's total annual precipitation amounted to 6,888.8 billion cubic meters (m^3), the year is an exceptional high flow year, with an average precipitation of 730 millimeters, higher than the annual average. In 2016, China's average temperature was 10.36°C, 0.81°C higher than that in previous years. Its average temperature in summer was a new high in history. There were many hot days with wide influence. China suffered 4 long-lasting regional hot weather conditions, and the daily maximum high temperatures of many regions exceeded extremes in local history.

China is subject to frequent disastrous weather, with droughts, floods, cold waves and typhoons being major disastrous weather having considerable influence for China. Northern China is mainly subject to droughts, while both floods and droughts affect Southern China. In summer and fall, the southeast coastal region of China is often stricken by tropical storms, between June and September in particular. In fall and winter, the cold air from Mongolia and Siberia moves southward, resulting in cold wave and causing such disaster as low temperature, gale, sand storm, and frost. In the wake of global warming, such meteorological disasters as rainstorms, floods, typhoons and severe convection stroke frequently in 2016. Waterlogging occurred in the cities of 26 provinces (autonomous regions, municipalities) and typhoons hit China frequently and heavily; over 2,000 counties (or cities) were struck by hail or tornadoes.

1.2 Natural Resources

1.2.1 Land Resources

China's land resources are characterized by complexity and diversity in types, 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, North China Plain, Middle- and Lower-reach Yangtze Plain, Pearl River Delta and Sichuan Basin are the areas where croplands mostly concentrate, while grasslands are mainly distributed in the northern and western China, and forests mainly concentrate in the Northeast, Southwest and South China.

Up to the end of 2016, China had 135 million (M) hectares (ha) of arable land (the per capita arable land was 0.098 ha), 14.30 million ha of parkland, 253 million ha of forest land, 219 million ha of rangeland and 39.10 million ha of construction land.

1.2.2 Water Resources

China is one of the countries with the most rivers and lakes in the world, there are over 1,500 rivers having a drainage area exceeding 1,000 square kilometers, and over 2,800 natural lakes having an area exceeding 1 square kilometer. 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 the western and northern regions. China's per capita water resources are only a quarter of the global average. In 2016, China's total stock of water resources was 3,246.64 billion m^3, which included 3,127.39 billion m^3 of surface water sources, and 885.48 billion m^3 of groundwater resources (between the two, there was an overlap of 766.23 billion m^3); the per capita water resources were 2,354.9 m^3; the total water supply was 604.02 billion m^3, 18.6% of the total stock of water resources of the year. With respect to seawater utilization, Guangdong, Zhejiang, Fujian, Liaoning, Shandong and Jiangsu rank high in China; in 2016, 88.71 billion m^3 of seawater were directly utilized, and most of them were used as the cooling water for thermal or nuclear power plants.

China’s potential hydropower resources rank top in the world. Most of the exploitable hydropower technology is concentrated in the Yangtze River Basin, the Yarlung Tsangpo River Basin, and the Yellow River Basin; Sichuan, Yunnan, and Tibet located in Southwestern China are the provinces having the richest hydropower resources in China.

1.2.3 Forest and Grassland Resources

According to the 8th forest resource census’s results, from 2009-2013, China’s forestry land was 208 million ha, with its forest coverage rate at 21.63% and its plantation at 69.3338 million ha; its total growing stock volume was 16.433 billion m^3, with 15.137 billion m^3 being forest growing stock volume and accounting for 92.11% of the total growing stock volume. In 2016, China's forest area was 214 million ha, forest coverage as 22.3% and forest stock volume as 16.372 billion m^3.

In 2016, China has around 400 million ha of natural grassland, national total production of fresh grass from natural grasslands reached 1.039 billion tons, and comprehensive vegetation coverage reached 54.6%; China implemented grazing prohibitions on grasslands of 80 million ha, achieved balance between forage and animal on 170 million ha, built fences for restoring grazing to grassland on 2.28 million ha, spread good grass seeds on 170,000 ha, and established artificial grassland of 70,000 ha.

1.2.4 Marine Resources

China abounds with marine resources. In 2016, China’s gross marine production was 7,050.7 billion Renminbi yuan (yuan), accounting for 9.5% of its GDP. This included 4,328.3 billion yuan of the value added of the marine industry and 2,722.4 billion yuan of the value added of marine-related industries. From the perspective of regions, the gross marine production of the Bohai Rim, the Yangtze River Delta and the Pearl River Delta were 2,432.3 billion yuan, 1,991.2 billion yuan and 1,589.5 billion yuan respectively, which accounted for 34.5%, 28.2% and 22.5% of national gross marine production respectively. By the end of 2016, the total employed population in the ocean-related industry was 36.225 million.

China maintained a stable marine ecological environment. In the spring and summer of 2016, most sea areas under China’s jurisdiction complied with the Class 1

Seawater Quality Standards (SQS). By the end of 2016, China has established some 250 marine protection areas (marine parks) of different levels, with a total area of about 124,000 square kilometers. In 2016, 16 national marine parks are newly approved of being established. In 2016, China's sea level was 82 millimeters higher than the annual average elevation, and this was the highest elevation since1980, which meant that marine resources and marine ecosystem faced increased risk.

1.2.5 Biodiversity

In 2016, China had many categories of terrestrial ecosystems, including 212 categories of forests, 36 categories of bamboo forests, 113 categories of shrubs, 77 categories of meadows and 52 categories of deserts. The freshwater ecosystem was complex; natural wetland had 5 categories, namely offshore and inshore wetland (coastal wetland), riverside wetland, lake wetland, marsh wetland, and artificial wetland. The offshore area had 4 marine ecosystems, namely the catchments of the Yellow Sea, the East China Sea, the South China Sea and the Kuroshio, where coastal wetland, mangrove, coral reef, estuary, gulf, lagoon, island, upwelling, and seagrass bed are distributed, and there are also natural landscape and natural relics, such as sea-bottom ancient forest, marine abrasion and marine deposition landforms. In addition, China had farmland ecosystems, man-made forest ecosystems, artificial wetland ecosystems, artificial grassland ecosystems and urban ecosystems.

In terms of diversity of species, there were 34,792 higher plants in China in 2014, including 2,572 bryophyte species, 2,273 pteridophyte species, 244 gymnosperm species, and 29,703 angiosperm species. There are approximately 7,516 vertebrates in China, including 562 mammals, 1,269 birds, 403 reptiles, 346 Amphibians and 4,936 fishes. There were total 420 endangered, precious, and rare species of wild animals included in the lists of wildlife under special state protection; several hundred animal species such as giant panda, crested ibis, snub-nosed monkey, South China tiger, and Chinese alligator are unique to China. In terms of diversity of genetic resources, there were 1,339 cultispecies in 528 categories, over 1,000 economic tree species, 7,000 ornamental plant species indigenous to China, and 576 domestic animal species.

Up to the end of 2016, China had created 2,750 nature reserves of different levels and in different categories, and their total area was 147.33 million ha, with the nature reserves' land area being 142.88 million ha and accounting for 14.88% of China's land area; China had 446 state-level nature reserves, and their total area was around 96.95 million ha.

Chapter 2 Social and Economic Development

Since the 21st century, China's social and economic development has experienced fundamental changes. With the economic development, China has become the world's second largest economy since 2010, and has risen to the largest goods trading nation since 2013. After 2012, it gradually transformed from the high-speed growth stage to the high-quality development stage, and has achieved notable results in promoting employment, eliminating poverty, improving people's livelihoods, protecting environment and so on.

2.1 Social Development

2.1.1 Population

By the end of 2016, the Chinese mainland had a total population of 1.383 billion, accounting for 18.58% of the world's population. The eastern China with a high population density bear 41.54% of national population with only 10.30% of national territorial area; the western part with a low population density bears 27.11% of national population with 73.51% of national territorial area.

Since the 1970s, China has begun implementing the one-child policy, which effectively controlled the momentum of population growth, and reduced the population natural growth rate from 25.83‰ in 1970 to 4.96‰ in 2015, a number significantly lower than the global average 11.86‰ over the same period. To prevent and respond to the aging of Chinese population, China has begun implementing the two-child fertility policy for couples where either the husband or the wife is from a single-child family since 2013, and begun the universal two-child policy since 2015. In 2016, China's population natural growth rate rebounded up slightly to 5.86‰ (as shown in Figure 1-3).

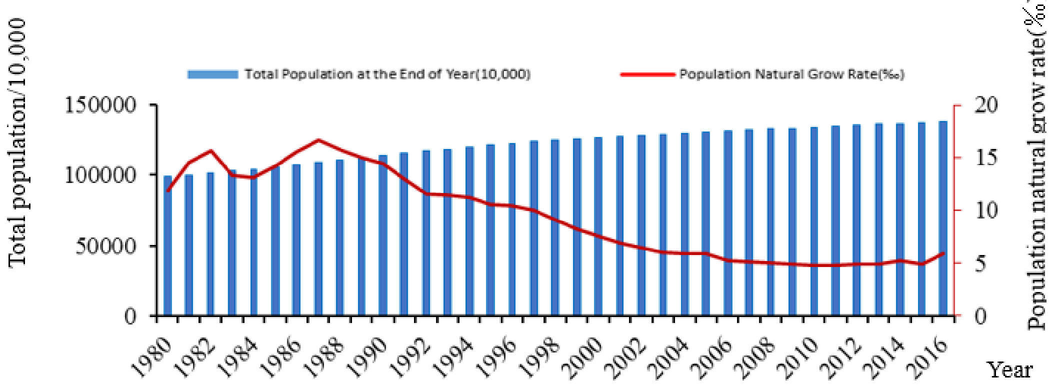

Figure 1-3 Changes in China's Total Population and Natural Growth Rate 1980-2016

With the improvements of people's living standard and the education and medical conditions, the average life expectancy of Chinese people was expected to be 76.5 years old in 2016 (as shown in Table 1-1), which is higher than the world average. The proportion of aging population is growing gradually. In 2016, the people aged over 65 took up 10.85% of the Chinese population. China's urbanization level grows gradually and has reached 57.35% in 2016, which was 14.35% up than 2005 and higher than the world's average of 54.30%.

Table 1-1 Population Indicators of China and the World in 2016

Population indicators	China	World
Population natural growth rate (‰)	5.86	11.24
Birth rate (‰)	12.95	18.89
Mortality rate (‰)	7.09	7.65
Average life expectancy (years)	76.5	71.9

Source: China Health Statistical Yearbook 2018, the China Statistical Yearbook (CSY)-2018, and the statistical database from the World Bank.

2.1.2 Education and Medical Care

In 2016, China had 1.981 million postgraduate students, 26.958 million undergraduate and junior college students, 15.991 million secondary vocational education students, 23.666 million regular high school students, 43.294 million junior middle school students, and 99.13 million regular primary school students. In per 100,000 people, 2,530 ones were undergraduate students, 2,887 were high school students, 3,150 were junior middle school students, and 7,211 were primary school students. In addition, there were 492,000 students in special education schools and 44.139 million children at the pre-school education stage and in kindergartens. The rate of nine-year compulsory education was 93.4% and the gross enrollment rate of high school education[1] was 87.5%.

By the end of 2016, China has totally established 983,000 medical and health organizations, with 7.41 million sickbeds. It also had 3.19 million medical practitioners and assistant medical practitioners and 3.51 million registered nurses. The total number of annual visits was 7.93 billion and that of discharged patients was 230 million.

[1] The gross enrollment rate refers to the proportion of internal students in an academic year or a grade to the total population of the corresponding school age.

2.1.3 Employment

In 2016, the total number of employed population in China was 776.03 million, in which 214.96 million ones engaged in the primary industry, 223.5 million in the secondary industry, and 337.57 million in the tertiary industry, respectively taking up 27.70%, 28.80%, and 43.50% of the gross employed population. The urban and rural employed populations reached 414.28 million and 361.75 million respectively, being in the ratio of 53.38:46.62 (Table 1-2).

Since 2005, China averagely has had about 17 million new births and about 7 million net population growth in each year. The number of yearly new labor force on urban area was over 10 million in average, in which 8 to 9 million people were from rural area.

Table 1-2 Change in the Composition of Employees in China (2005-2016)(%)

Employment structure	2005	2010	2016
Proportion of employees in first industry	44.80	36.70	27.70
Proportion of employees in secondary industry	23.80	28.70	28.80
Proportion of employees in tertiary industry	31.40	34.60	43.50

Source: China Statistical Yearbook-2018.

2.1.4 Poverty Elimination

Since 1986, the Chinese government has taken a series of important measures to strengthen poverty reduction, and organized and implemented the medium-term and long-term plans of *Seven-Year Priority Poverty Alleviation Program*, *National Program for Rural Poverty Alleviation (2001-2010)* and so on. In November 2015, the Chinese government issued the *Decisions on Wining the Fight of Poverty Elimination*, which highlighted the strategy of accurate poverty alleviation and promoted poverty elimination among poverty population. From 2010 to 2016, according to the poverty standard set by the Chinese government, the rural poverty population mired in absolute poverty has reduced from 166 million to 43.35 million, down by 73.9% subsequently. At present, the poverty population is mainly distributed in the areas lacking in resources and with poor natural conditions. In such a case, it is still difficult to eradicate poverty.

2.1.5 Environmental Protection

The average percent of attainment days on air quality of the 338 above prefecture level (APL) cities was 78.8%, with an increase of 2.1 percentage points (pps) compared with that of 2015. The average ratio of low-quality days was 21.2%. Precipitation monitoring was carried out in 474 cities (districts and counties), of which 19.8% were acid rain-plagued cities, mainly in the category of sulfuric acid rain. Acid rain pollution was mainly spread in the areas south of the Yangtze River and east of the Yunnan-Guizhou plateau.

China's annual Wastewater Handling Volume (WHV) was 71.1 billion tons, 10.47 million tons (Mt) of which were Chemical Oxygen Demand (COD) volume. The urban sewage treatment plants could dispose 148.23 million m^3 of wastewater in each day, with the sewage treatment rate up to 92.4%.

In 2016, the annual output of industrial solid wastes in China was 3.092 billion tons, and the comprehensive utilization of industrial solid wastes was 1.841 billion tons, with the rate of comprehensive utilization being 59.54%. The clearance amount of household refuse was 204 Mt. The number of garbage innocuity disposal plants was 940, with the harmless treatment capacity to 621,400 tons per day, the sanitary landfill capacity to 350,100 tons per day, the incineration capacity to 255,900 tons, and the capacity of other disposal modes to 15,400 tons. The rate of harmless disposal of household refuse was 96.6%.

2.2 Economic Development

2.2.1 Economic Growth

The year of 2016 produced a GDP of 74.3586 trillion yuan, achieving a growth rate of 6.7%, in which the value added of the primary industry was 6.3673 trillion yuan, that of the secondary industry was 29.6548 trillion yuan, and that of the tertiary industry was 38.3365 trillion yuan. The per capita GDP is 53,935 yuan. The structure of the three industries was optimized continuously from 11.6:47.0:41.3 in 2005 to 8.6:39.9: 51.6 in 2016 (Table 1-3). The proportion of agriculture and industry were decreased constantly, while that of the service industry was increased by 10.3 pps from 2005 to 2016. In 2013, the value added of Chinese tertiary industry surpassed that of the secondary industry for the first time; "mass entrepreneurship and innovation" became a new momentum of economic growth in China, the new industrial mode of "Internet plus e-commerce" became a new engine for promoting the development of China's economy. In 2016, the sales of enterprise e-commerce were 10.73 trillion yuan, and the online retail sales were 5.15 trillion yuan.

Table 1-3 China's GDP and Industrial Structure (2005-2016)

Industry	2005	2010	2016
GDP (billion yuan)	18,731.89	41,303.03	74,358.55
First industry (billion yuan)	2,180.7	3,936.3	6,367.3
Secondary industry (billion yuan)	8,808.4	19,163.0	29,654.8
Tertiary industry (billion yuan)	7,742.8	18,203.8	38,336.5
Industrial structure（%）	11.6:47.0:41.3	9.5:46.4:44.1	8.6:39.9:51.6
The per capita GDP (yuan)	14,368	30,876	53,935

Source: China Statistical Yearbook-2018.

2.2.2 Industrial Development

1) Agriculture, Forestry, Animal Husbandry and Fishery

In 2016, the gross output of agriculture, forestry, animal husbandry and fishery industries was 10.6479 trillion yuan, of which 52.3% was from agriculture, 4.4% from forestry, 28.6% from animal husbandry and 10.2% from fishery. The total planting area of crop was 166.939 million ha, in which 119.23 million ha were used for growing of grains, accounting 71.4% of the total planting area. The planting area of wheat was 24.694 million ha, that of rice was 30.746 million ha, that of corn was 44.178 million ha, that of cotton was 3.198 million ha, that of oil plants was 13.191 million ha, and that of sugar crop was 1.555 million ha. The year of 2016 yielded a total of 660.435 Mt of grain, including 211.094 Mt of rice, 133.271 Mt of wheat, and 263.613 Mt of corn. The output of cotton was 5.34 Mt, that of oil plants was 34 Mt, that of sugar crop was 111.76 Mt, and that of tea was 2.313 Mt. The gross output of meat was 86.283 Mt, that of aquatic products was 63.795 Mt, and that of timber was 77.759 million $m^{3.}$

In 2016, China possessed a total of 972.456 GW agricultural machinery power, and had 23.17 million agrimotors and 9.408 million agricultural drainage and irrigation diesel engines. The consumption of chemical fertilizers was 59.841 Mt, including 23.105 Mt of nitrogenous fertilizer, accounting for 38.6% of the total consumption.

2) Industry and Construction

In 2016, China achieved the industrial value added of 24.7878 trillion yuan, accounting for 33.3% of the GDP, with 8.3 pps lower than that of 2005. By implementing a series of policies, China actively promoted adjustment of the industry structure, and significant progress was made in the transformation and upgrading of the industrial structure. Among the industrial enterprises above designated size, the value added of strategic emerging industries increased by 10.5%. The value added of high-tech manufacturing industry grew by 10.8%, taking up 12.4% of that created by the industrial value added. The value added of equipment manufacturing industry grew by 9.5%, taking up 32.9% of that created by the industrial value added. The value added of the six high energy-consuming industries grew by 5.2%, taking up 28.1% of that created by the industrial value added.

In 2016, the installed capacity of power generation of China was 1,650.51 GW, including 1,060.94 GW installed capacity of thermal power, 332.07 GW installed capacity of hydroelectricity, 33.64 GW installed capacity of nuclear power, 147.47 GW installed capacity of grid combination wind power, and 76.31 GW installed capacity of grid combination solar power generation.

In 2016, the value added of overall construction industry in China was 4.9703 trillion yuan. The general and professional contracting construction enterprises qualified in China realized the profit of 698.6 billion yuan.

3) Development of the Tertiary Industry

The industries of wholesale and retail sales, finance, real estate and transportation are the major sectors of the tertiary industry. In 2016, the proportion of transportation, storage and post industries in the tertiary industry were obviously lower than that in 2005; and the proportion of finance in the tertiary has increased significantly (as shown in Table 1-4).

Table 1-4 Structure of the Tertiary Industry in China (2005-2016) (%)

Sector	2005	2010	2016
Wholesale and retail	18.0	19.7	18.6
Transportation, storage and post	13.8	10.3	8.6
Accommodation and catering	5.4	4.2	3.5
Finance	9.6	14.1	15.9
Real estate	11.0	12.9	12.6
Other sectors	41.0	37.6	39.9

Source: China Statistical Yearbook-2018.

In 2016, total retail sales of consumer goods in China was 33.2316 trillion yuan. The urban retail sales of consumer goods was 28.5814 trillion yuan, and the rural retail sales of consumer goods was 4.6503 trillion yuan. The total retail sales was 29.6518 trillion yuan, the income of catering was 3.5799 trillion yuan, the online retail sales was 4.1944 trillion yuan, accounting for 12.6% of the total retail sales of the country.

In 2016, the increase of China's social financing was 17.8 trillion yuan, the saving deposits in Renminbi and foreign currencies in all financial institutions were 155.5 trillion yuan, in which the saving deposits in Renminbi were 150.6 trillion yuan. The loan balances in Renminbi and foreign currencies in all financial institutions were 112.1 trillion yuan, in which the loan balances in Renminbi were 106.6 trillion yuan. The balances of domestic household consumption loans in Renminbi in all financial institutions were 25.0472 trillion yuan. The accumulated financing amount of listed countries through domestic markets were 2.3342 trillion yuan. The amount of credit bonds from issuing companies was 8.22 trillion yuan. The original insurance premium income of insurance companies was 3.0959 trillion yuan.

China has constructed a comprehensive transportation network mainly integrating highway, railway, air and waterway transportation. From 2005 to 2016, the increase of mileages by transportation modes varied (as shown in Table 1-5). In particular, China's high-speed rail construction made remarkable achievements. In 2016, the length of Chinese high-speed railway was 23,000 km, which ranked first in the world. In 2016, China's passenger capacity was over 19 billion people, in which the passenger capacity of highway was 15.43 billion people, taking up 81.2% of the total. The total freight was 43.86 billion tons, in which the freight through highways accounted for 76.2%; secondly the freights through waterways and railways respectively accounted for 14.5% and 7.6%; and the freights through pipelines and air aviation accounted for below 2%. The goods transport turnover was 18.6629 trillion ton-kilometers. The cargo handling capacity of ports above designated size was 11.889 billion tons, and the container throughput of such ports was 217.98 million standard containers.

Table 1-5 Lengths of Transportation Lines in China (2005-2016) (10,000 km)

Program	2005	2010	2016
Railway	7.5	9.1	12.4
Including: High speed railway	-	0.5	2.3
Highway	334.5	400.8	469.6
Including: Express	4.1	7.4	13.1
Inland waterway	12.3	12.4	12.7
Regular flight route	199.9	276.5	634.8
Oil (gas) pipeline	4.4	7.9	11.3

Source: China Statistical Yearbook -2006, China Statistical Yearbook-2011, China Statistical Yearbook-2018.

2.2.3 Income and Consumption Levels

In 2016, the per capita disposable income of residents was 23,821 yuan, while that of urban residents was 33,616 yuan, and that of rural residents was 12,363 yuan. The per capita consumption expenditure of residents nationwide was 17,111 yuan, and that of urban and rural residents were 23,079 yuan and 10,130 yuan respectively. In the household consumption expenditure, food took a high proportion, for which the Engel coefficient was 0.301, and in urban and rural areas was respectively 0.293 and 0.322. With the improvement of people's living standard, the holding quantity of durable consumer goods went up dramatically in contrast to 2005 and 2010 (as shown in Table 1-6), especially the home computers, mobile phones and household cars.

Due to the imbalance of Chinese economic and social development, income distribution is uneven in the country. The income of the eastern coastal area is apparently higher than those of the central and western regions. In 2016, the per capita disposable income of the eastern coastal area was 30,654.7 yuan, that of the northeast area was 22,351.5 yuan, that of the central area was 20,006.2 yuan, and that of the west area was 18,406.8 yuan.

Table 1-6 Number of Durable Consumer Goods Owned per 100 Urban Households in China (2005-2016)

Program	2005	2010	2016
Refrigerator	90.7	96.6	96.4
Color TV (set)	134.8	137.4	122.3
Air conditioner (set)	80.7	112.1	123.7
Home computer (set)	41.5	71.2	80.0
Mobile phone (set)	137	188.9	231.4
Private car (set)	3.4	13.1	35.5

Source: China Statistical Yearbook -2006, China Statistical Yearbook-2011, China Statistical Yearbook-2018.

2.2.4 Foreign Trade

In 2016, China's exports and imports of goods totaled 24.3386 trillion yuan, in which the amount of exports was 13.8419 trillion yuan and that of imports was 10.4967 trillion yuan, producing the trade surplus of 3.3452 trillion yuan. China's imports and exports with "Belt and Road" countries totaled 6.2517 trillion yuan. In 2016, China's service exports and imports totaled 5.3484 trillion yuan, in which the amount of service imports was 1.8193 trillion yuan, and that of service exports was 3.5291 trillion yuan, resulting in the trade deficit of 1.7097 trillion yuan. EU, the USA, ASEAN and Hong Kong were the main export destination countries and regions of China, and EU, ASEAN, Korea and Japan were the main import countries and regions of China (as shown in Table 1-7).

In 2016, 27,900 enterprises were newly established based on foreign direct investments (excluding banking, securities and insurance) in China. The actual use of foreign direct investments was 813.2 billion yuan, including the direct investments in China from "Belt and Road" countries used to set up 2,905 enterprises, and the amount of direct investments in China of 45.4 billion yuan. The amount of outward foreign direct investment was 1.3029 trillion yuan (equivalent to US $196.15 billion), in which the amount of direct investments in "Belt and Road" countries was US $15.34 billion. The accomplished turnover of China's foreign contracted projects throughout the year was 1.0589 trillion yuan (equivalent to US $159.4 billion), in which the accomplished turnover for "Belt and Road" countries was US $76 billion, accounting for 47.7% of the accomplished turnover of foreign contracted projects. A total of 490 thousand contract workers of various types were dispatched for foreign labor cooperation.

Table 1-7 Major Importers & Exporters for China and their Proportions in 2016

Countries and regions	Export value (100 million yuan)	Proportion in the total export value of China (%)	Export value (100 million yuan)	Proportion in the total import value of China (%)
European Union	22,369	16.2	13,747	13.1
USA	25,415	18.4	8,887	8.5
ASEAN	16,894	12.2	12,978	12.4
Hong Kong, China	19,009	13.7	1,107	1.1
Japan	8,529	6.2	9,626	9.2
Republic of Korea	6,185	4.5	10,496	10.0
Chinese Taiwan	2,665	1.9	9,203	8.8
India	3,850	2.8	777	0.7
Russia	2,466	1.8	2,128	2.0

Data source: Statistical Communique of the People's Republic of China on the 2016 National Economic and Social Development.

Chapter 3 National Development Strategies and Targets

The 13th five-year plan (FYP) period is the decisive stage for China to build a moderately prosperous society in all respects. The Chinese government will, according to the planning and deployment of national development strategies and targets and based on the profound changes in the world economic situation and the domestic development characteristics, actively adapt to, seize and lead the new normal of economic development and advance the innovation-oriented, coordinated, green, opening and sharing development ideas on all sides to ensure the building a moderately prosperous society in all respects.

3.1 National Development Strategy

After rapid development in nearly four decades of reform and opening up, national food and clothing problems have been basically solved, people's living standards have improved significantly and social development has progressed. On that basis, the Chinese government has further put forward the "three-step" strategic targets by the middle of the century and has made the following strategic arrangement for national development:

——The time period from now to 2020 is the decisive stage to build a moderately prosperous society in all respects. According to the requirements on building a moderately prosperous society in all respects, focus on the main contradiction changes in Chinese society, plan as a whole and advance economic construction, political construction, cultural construction, social construction and ecological civilization construction, and stick to the implementation of the strategy of rejuvenating the country through science and education, the strategy of reinvigorating China through human resource development, the innovation-driven development strategy, the rural vitalization strategy, the regional coordinated development strategy, the sustainable development strategy and the military-civilian integration strategy.

——From 2020 to 2035, on the basis of the moderately prosperous society in all aspects, we will work hard for another 15 years and spare no efforts to basically realize modernization. National economic strength and science and technology strength improve significantly, and China rises among innovative countries; the people's equal participation rights and equal development rights are fully guaranteed, the building of a country, a government and a society under the rule of law is basically completed, systems in all aspects are further improved, and the modernization of the national governance system and governance capability is basically realized; the degree of social civilization reaches a new height, and national cultural soft power improves significantly; the people are better-off, the proportion of the middle-income group increases significantly, the development gap between urban and rural areas and the living standard gap between urban and rural residents reduce significantly, the equalization of basic public services is basically realized, and a solid step is made in achieving common prosperity of all people; modern social governance is basically formed, and the society is full of vitality, harmonious and orderly; the ecological environment takes a fundamental turn for the better, and the goal of building a beautiful China is basically realized

——From 2035 to the mid-term of the century, on the basis of basic modernization, we will work hard for another 15 years to build China into a prosperous, democratic, civilized, harmonious and beautiful modern socialist country. China's material, political, cultural and ideological, social and ecological civilization improves in all aspects, the modernization of the national governance system and governance capability is realized, common prosperity of all people is basically realized, and the people enjoy a happier and healthier life.

3.2 Future Economic and Social Development Goals

According to the new target requirements of building a moderately prosperous society in all respects, the main economic and social development targets of China during the 13th FYP period are as follows (Table 1-8):

——Medium-high rate of economic growth. Based on improved balance, inclusiveness and sustainability of economic development, China will double its GDP and per capita income of urban and rural residents by 2020 relative to 2010. While the key economic indicators will be balanced and coordinated, and the development quality and efficiency will be significantly increased. 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 innovation-driven development strategy is implemented in depth, 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 talents.

——Significant enhancement of development coordination. China continues to improve the contribution of consumption to the economic growth for the sake of a significant increase in 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. The depth and breadth of opening up increase, global resource allocation capability is further enhanced, the import & export structure is further optimized, and international payments are basically balanced.

——Generally improve people's well-being. More adequate public service systems in the fields of employment, education, culture, social security, health care and housing have been established, ensuring a higher rate of full employment and the stable improvement of equal access to basic public services. Important progress is made in education modernization and the education years of working-age population increase significantly. Employment is relatively sufficient, income gap is narrowed and the proportion of middle-income population increases. The rural poverty population under the current Chinese standard overcomes poverty, all poverty-stricken counties get rid of their poverty title, and regional overall poverty is solved.

——Notable improvement of the quality of people and the degree of social civilization. The Chinese dream and core socialist values enjoy greater popularity, patriotism, collectivism and socialist ideology are widely spread, the social morals of making progress, striving for better, being honest and helping each other become more popular, national ideological and ethical standards, scientific and cultural qualities and healthy quality increase significantly, and the awareness of rule of law of the whole society is enhanced. The public cultural service system is basically completed, and the cultural industry becomes the pillar industry of national economy.

——Improve eco-environmental quality. People tend to adopt environmental friendly production mode and green lifestyle, thus furthering ensuring the low carbon development. Energy resource development and utilization efficiency increases significantly, energy and water resource consumption, construction land and total carbon emission are effectively controlled, and the total emission of major pollutants decreases significantly. The layout of main functional areas and ecological safety barriers are basically formed.

——Systems in all aspects are improved. The modernization of the country's governance systems and capabilities have achieved great progress, and the basic institutional system has been formed. People's democracy is further improved, a government ruled by law is basically established, and public credibility of the judiciary 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. The institutionalization level of Party building improves significantly.

Table 1-8 Main Socio-economic Indicators in the 13th FYP Period[1]

Indicators		2015	2020	Annual average growth rate	Attribute
Economic development					
(1)GDP (trillion yuan)		67.7	>92.7	>6.5%	Anticipatory
(2)Overall labor productivity (10,000 yuan per employed person)		8.7	>12	>6.6%	Anticipatory
(3)Urbanization Level	Permanent household urbanization rate (%)	56.1	60	[3.9]	Anticipatory
	Registered household urbanization rate (%)	39.9	45	[5.1]	
(4)Proportion of Service Industrial Added Value (%)		50.5	56	[5.5]	Anticipatory
Innovation-driven					
(5)Research and experiment development expenditure strength (%)		2.1	2.5	[0.4]	Anticipatory
(6)Patents per 10,000 people (patents)		6.3	12	[5.7]	Anticipatory
(7)Contribution of scientific and technological advances to economic growth (%)		55.3	60	[4.7]	Anticipatory
(8)Internet access	Households with fixed broadband（%）	40	70	[30]	Anticipatory
	Mobile broadband users（%）	57	85	[28]	
People's wellbeing					
(9)Per capita net income of rural residents（%）		-	-	>6.5	Anticipatory
(10)Average length of education received by the working-age population (years)		10.23	10.8	[0.57]	Obligatory
(11)New urban employment (10,000 people)		-	-	[>5000]	Anticipatory
(12)Rural population lifted out of poverty (10,000 people)		-	-	[5575]	Obligatory
(13)Basic old-age insurance coverage（%）		82	90	[8]	Anticipatory
(14)Rebuilt housing in rundown urban areas (10,000 units)		-	-	[2000]	Obligatory
(15)Average life expectancy (years)		-	-	[1]	Anticipatory
Resource environment					
(16)Arable land(100 million mu)		18.65	18.65	[0]	Obligatory
(17)Increase in land newly designated for construction (100 million mu)		-	-	[<3256]	Obligatory
(18)Water use reduction per 10,000 yuan of GDP（%）		-	-	[23]	Obligatory

[1] The table is an extract from *the 13th Five-Year Plan for Economic and Social Development of the People's Republic of China*; those indicated with "-" are those not provided with the values in 2015 and 2020, while the annual average growth rates or the 5-year cumulative totals are used to show the targets.

Indicators		2015	2020	Annual average growth rate	Attribute
(19)Reduction rate of energy consumption per unit of GDP（%）		-	-	[15]	Obligatory
(20)Proportion of non-fossil energy in primary energy consumption（%）		12	15	[3]	Obligatory
(21)Carbon emission per unit of GDP is reduced（%）		-	-	[18]	Obligatory
(22)Forest growth	Forest coverage（%）	21.66	23.04	[1.38]	Obligatory
	Forest growing stock (100 million m^3)	151	165	[14]	
(23)Air quality	Percent of attainment days of the APL cities (%)	76.7	>80	-	Obligatory
	Reduction in PM 2.5 concentration for non-attainment APL cities (%)	-	-	[18]	Obligatory
(24)Surface water quality	Water reaching Grade III or better (%)	66	>70	-	Obligatory
	Worse than Grade V（%）	9.7	<5	-	
(25)Aggregate major pollutant emissions reduction（%）	Chemical oxygen demand			[10]	Obligatory
	Ammonia nitrogen			[10]	
	SO_2			[15]	
	Nitric oxide			[15]	

Note: 1. GDP and overall labor productivity growths were calculated based on comparable prices, and the absolute values based on the constant prices in 2015;

2. The numbers in [ ] are cumulative numbers of 5 years;

3. PM2.5 falling short of standard means the annual average value is over 35 micrograms per cubic meter.

3.3 NDCs Targets and Actions

In accordance with relevant decisions of the Conference of the Parties to *the Convention*, in June 2015, the Chinese government officially submitted NDC target documents, presenting China's enhanced actions and measures on climate change as its nationally determined contributions that are made to achieve the objective set out in Article 2 of *the Convention* and represent its utmost efforts in addressing climate change.

3.3.1 NDCs Targets

According to its own national circumstances, characteristics of development phases, the strategic goal of sustainable development and the basic spirit and relevant principles of *the Convention,* China has set NDCs targets for 2030: to achieve the peaking of carbon dioxide emissions around 2030 and making best efforts to peak early; to lower carbon dioxide emissions per unit of GDP by 60% to 65% from the 2005 level; to increase the share of non-fossil fuels in primary energy consumption to around 20%; and to increase the forest stock volume by around 4.5 billion m^3 on the 2005 level. China will continue to proactively adapt to climate change by enhancing mechanisms and capabilities to effectively defend against climate change risks in key areas such as agriculture, forestry and water sources, as well as in cities, coastal and ecologically vulnerable areas and to progressively strengthen early warning and emergency response systems and disaster prevention and reduction mechanisms.

3.3.2 Policies and Measures to Implement Climate Change Mitigation Actions

—Implement national strategy that actively addresses climate change. Strengthen the building of legal system addressing climate change, include the targets and actions on climate change in the planning on national economy and social development, and develop long-term low carbon development strategy and roadmap.

—Improve regional strategy on climate change. Implement region-specific policies on climate change, and determine differentiated climate change mitigation and adaptation targets, tasks and realization paths for different main functional areas.

—Build low carbon energy system. Control total coal consumption, improve the ratio of centralized, efficient coal power generation, expand natural gas utilization scale, actively promote hydroelectricity development while ensuring protection of ecological environment and resettlement of affected residents, develop nuclear power safely and efficiently, vigorously develop wind power, accelerate the development of solar power generation, and actively develop geothermal energy, bioenergy and ocean energy. Strengthen the recycling of vent natural gas and oilfield associated gas. Vigorously develop distributed energy resources and strengthen the construction of intelligent grid.

—Form energy-saving, low carbon industry systems. Stick to the path of new industrialization, vigorously develop circular economy and optimize industrial structure. Control emissions in building and transportation sectors. Stick to the path of new urbanization, optimize urban system and urban space layout, and include the idea of low carbon development in the urban planning, building and management process.

—Increasing Carbon Sinks. Vigorously carry out afforestation, promote national voluntary tree-planting in depth, continue to implement natural forest protection, grain for green and comprehensive treatment of stony desertification, focus on strengthening forest tending operation, and increase forest carbon-sink.

3.3.3 Enhance Overall Climate Change Resilience

—Improve the safe operation capability of infrastructure such as water conservancy, transport and energy against climate change. Properly develop and optimize the allocation of water resources, implementing the strictest water management regulation, building a water-saving society in all aspects, and intensifying the development and utilization of unconventional water resources, including recycled water, desalinated seawater and rain and flood water.

—Improve the construction of water conservation facilities for farmland, vigorously develop water-saving agricultural irrigation and cultivate heat-resistant and drought-resistant crops. Enhance resistance to marine disasters capacity building and management of coastal zones, and improve the resilience of coastal areas against climatic disasters. Track, monitor and assess the impact of climate change on biodiversity. Strengthen Infrastructure Construction in Forestry Industry

—Properly lay out functional zones in cities, make overall arrangements in developing infrastructure and effectively safeguard city lifeline system. Develop contingency plans for public health under the impacts of climate change and improve the capacity of public medical services to adapt to climate change. Strengthen comprehensive assessment and risk management of climate change and improve the national monitoring, early warning and communication system on climate change. Take full account of climate change in the planning, design and construction of distribution of productive forces, infrastructure and major projects. Improve the emergency response mechanism for extreme weather and climatic events. Strengthen the building of disaster reduction and relief management systems.

3.3.4 Further Strengthen the Building of Systems and Mechanisms to address Climate Change

—Propose low-carbon lifestyle. Enhance education for all citizens on low carbon lifestyle and consumption, advocate green, low carbon, healthy and civilized lifestyle and consumption patterns, and promote low carbon consumption throughout society. Encourage public institutions to take the lead and set an example.

—Innovate low carbon development patterns. Advance low-carbon city pilots in provinces and cities, conduct pilot low carbon cities (towns), as well as low carbon industry parks, low carbon communities, low carbon business and low carbon transport pilots, and explore diversified patterns of low carbon development.

—Enhance science and technology support. Improve the fundamental research into climate change and conduct research on climate change. Increase financial and policy support. Further increase budgetary support, actively innovate the utilization of finance, and explore new investment and financial mechanisms for low carbon development, such as public-private partnerships.

—Promote carbon emission trading market. Give full play to the decisive role of market in resource allocation, and on the basis of carbon emission trading pilots, steadily promote the building of a nationwide carbon emission trading system and gradually establish a carbon emission trading mechanism. Develop mechanisms for carbon emission reporting, verification and certification, and improve the rules for carbon emission trading to ensure openness, fairness and justice of the carbon emission trading market.

—Improve GHG statistical accounting system. Further strengthen the work on statistics of climate change, and improve the statistical indicator system on climate change.

—Improve social participation mechanisms. Enhance the responsibility of enterprises for low carbon development, and encourage enterprises to explore low carbon development patterns that are resource-saving and environment-friendly. Strengthen the role of public supervision and participation in low carbon development.

—Actively promote international cooperation. As a responsible developing country, China will stand for the common interests of all humanity and actively engage in international cooperation to build an equitable global climate governance regime that is cooperative and beneficial to all.

Chapter 4 National Institutional Arrangements

The Chinese government attaches great importance to the institutional arrangements for addressing climate change. After persistent efforts, China has built institutional frameworks for addressing climate change on national, local and relevant departmental levels, and is constantly improving them based on needs from daily work. For National Communications and Biennial Update Reports, China has set up a relatively stable technical support institution and organized core teams of experts, providing organizational support for the preparation and submission 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, in June 2007, the Chinese government decided to set up the National Leading Group on Climate Change, Energy Conservation and Emissions Reduction (hereinafter referred to as the Leading Group), as a cross-department coordination organization of China for climate change, energy conservation and emissions reduction. 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 national authority department. According to the requirements of organizational structuring and personnel changes as well as work needs, the State Council has adjusted the units or personnel of the Leadership Group[1] (Figure 1-4).

[1] Data Source: *Notice of the General Office of the State Council on Personnel Adjustments of the Leadership Group* (State Council [2013] No. 72).

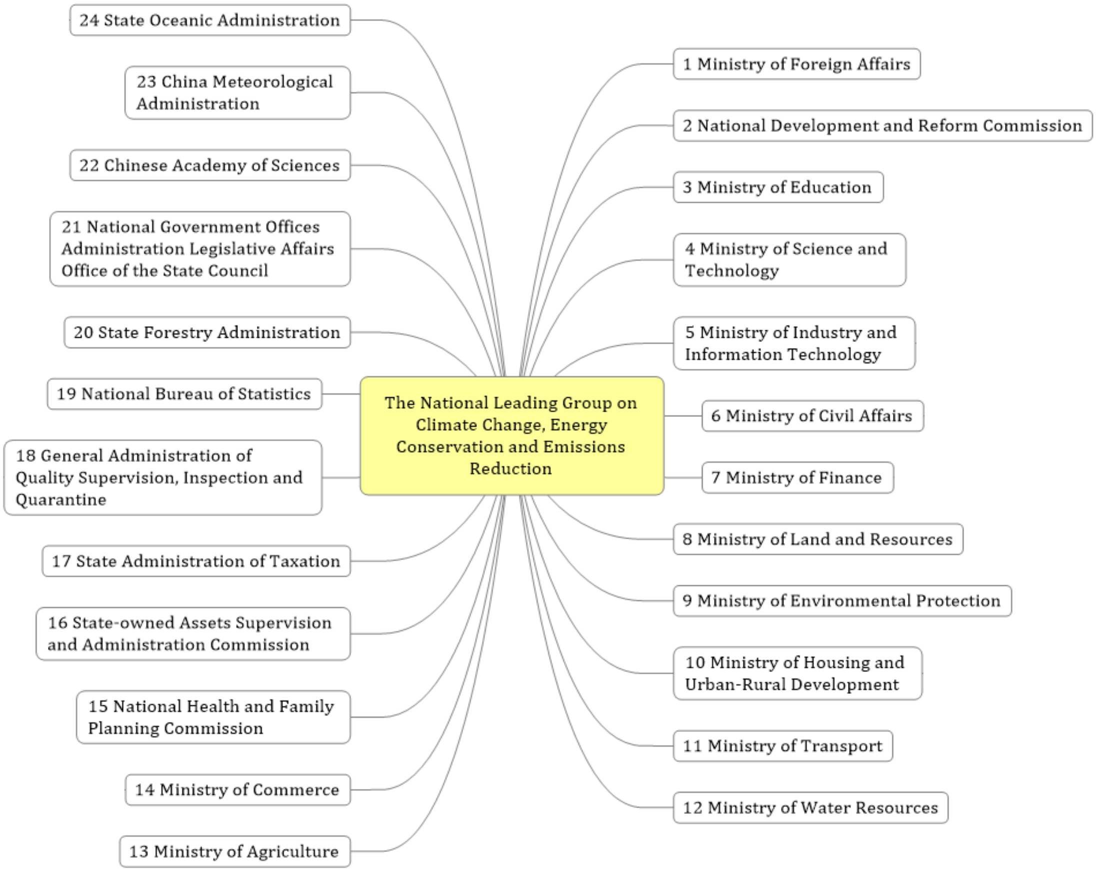

Figure 1-4 National Leading Group on Climate Change

4.2 Local and Departmental (industry) Institutions

In recent years the Chinese government has further strengthened the building of institutional frameworks to conduct the work on climate change. In 2008 the National Development and Reform Commission (NDRC) set up the Department of Climate Change. In 2012, National Center for Climate Change Strategy and International Cooperation (NCSC) was established.

All units of the Leadership Group, as governmental authorities in respective industries, have appointed leaders and major responsible units for addressing climate change, meanwhile strengthened 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, with the establishment of the Department of Climate Change under the NDRC, many provinces, municipalities and autonomous regions have started to set up departments of addressing climate change in their local development and reform commissions as the administrative body of the 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

Preparing and submitting National Communications and Biennial Update Reports, including National Greenhouse Gas Inventories, is a continuous, deepening task requirement. Therefore, since the Initial National Communication on Climate Change, the Chinese government has preliminarily established a national system for the preparation and reporting of National Communications on Climate Change and formed a relatively stable team for the preparation of National Greenhouse Gas Inventories, National Communications on Climate Change and Biennial Update Reports (Table 1-9). According to the responsibilities of the departments engaging in the work on climate change, the national competent department is responsible for the preparation of National Greenhouse Gas Inventories, while the National Bureau of Statistics organizes relevant departments to provide basic statistical data, coordinates relevant industry associations and typical enterprises to provide relevant data and establishes national greenhouse gas inventory database to support the preparation of the National GHG Inventory database and data management. Upon completion, National Communications on Climate Change and Biennial Update Reports are approved by National Authority Responding to Climate Change and officially submitted to the secretariat of the Convention.

Table 1-9 Main Organizations Involved in Preparation of the National Communication (NCs), Biennial Update Reports (BURs) and National GHG Inventories

Tasks	Organizations
In charge of the national communications, biennial update reports and national GHG inventories	National authority addressing climate change
GHG inventory for energy	NCSC, Energy Research Institute of National Development and Reform Commission (ERI), Fudan University, China Special Equipment Inspection and Research Institute (CSEI)
GHG inventory for industrial processes	Tsinghua University, Foreign Economic Cooperation Office of the Ministry of Ecology and Environment (MEE)
GHG inventory for agriculture (livestock)	Institute of Environment and Sustainable Development in Agriculture, Chinese Academy of Agricultural Sciences
GHG inventory for agriculture (croplands)	Institute of Atmospheric Physics, Chinese Academy of Sciences
GHG inventory for LULUCF	Institute of Forest Ecology, Environment and Protection of the Chinese Academy of Forestry; Research, Planning and Design institute of the National Forestry and Grassland Administration; Research Institute of Forestry New Technology of the Chinese Academy of Forestry; Institute of Environment and Sustainable Development in Agriculture, Chinese Academy of Agricultural Sciences; Institute of Atmospheric Physics of Chinese Academy of Sciences
GHG inventory for waste	Chinese Research Academy of Environmental Sciences
National greenhouse gas inventory database	NCSC

Table 1-10 Basic Information of China in 2010

Indicators	2010
Population (ten thousand persons)	134,091
Land area (10,000 square km)	960
Per capita GDP (yuan, of current year)	413,030.3
Per capita GDP (yuan, of current year)	30,876
Percentage share of industry in GDP (%)	40.0
Percentage share of agriculture in GDP (%)	9.5
Area (10,000 ha)[1]	12,172
Forest area (10,000 ha)[1]	30,590
Total energy consumption (Mtce)	360,648
Final cattle amount (ten thousand) [2]	9,120
Final horse amount (ten thousand)	530
Final pig amount (ten thousand)	46,765
Final sheep amount (ten thousand)	28,730
Poverty population (ten thousand persons)[3]	16,567
Life expectancy(years)	72.38 (Male); 77.37(Female)

[1] Source: 2nd National Land Survey and Annual National Land Use Change Survey conducted by the Ministry of Natural Resources (formerly Ministry of Land and Resources).

[2] Livestock data are from the 3rd agriculture economic census results, and other data are from *China Statistics Yearbook-2018* unless specified.

[3] 2010 poverty standards for rural populations provides: 2300 yuan per capita per year (at 2010 constant price).

Part II National Greenhouse Gas Inventory

The eighth Conference of the Parties (COP) of the Convention passed Decision 17/CP.8, the guidelines for the preparation of National Communications on Climate Change from non-Annex I Parties. According to relevant requirements of the Decision, and considering China's specific-national circumstances, the China National GHG Inventory of 2010 contained in China's Third National Communication on Climate Change covers six gases, namely carbon dioxide (CO_2), methane (CH_4), Nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF6) from energy, industrial processes and product use (IPPU), agriculture, land-use, land-use change and forestry (LULUCF) and waste sector. The preparation of the GHG Inventories mainly followed *Revised 1996 IPCC Guidelines on National Greenhouse Gas Inventories* (hereinafter referred to as *Revised 1996 IPCC Guidelines*), *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (hereinafter referred to as *IPCC GPG 2000*) and *IPCC Good Practice Guidance for Land-Use, Land-Use Change and Forestry* (hereinafter referred to *IPCC Good Practice for Forestry*), and referred to *2006 IPCC Guidelines for National GHG Inventories* (hereinafter referred to as *2006 IPCC Guidelines*) as reference.

Chapter 1 National Greenhouse Gas Inventory of 2010

1.1 Overview of Greenhouse Gas Inventory

In 2010, total GHG emissions in China (with LULUCF) were about 9,551 Mt CO_2 eq (Table 2-1), of which CO_2, CH_4, N_2O and fluorinated gases accounted for 80.4%, 12.2%, 5.7% and 1.7% respectively (Table 2-2). The total GHG removals in LULUCF sector were about 993 Mt CO_2 eq. China's total GHG emissions (without LULUCF) in 2010 were around 10,544 Mt CO_2 eq, of which CO_2, CH_4, N_2O and fluorinated gases accounted for 82.6%, 10.7%, 5.2% and 1.5% respectively. Global warming potential (GWP) values (Table 2-3) are from IPCC SAR for 100-year time horizon.

Table 2-1 GHG Emissions and Removals of China in 2010 (Mt CO_2 eq)

	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Total
Total (with LULUCF)	7,678	1,163	547	132	10	21	9,551
1. Energy	7,624	564	96				8,283
2. Industrial processes	1,075	0	62	132	10	21	1,301
3. Agriculture		471	358				828
4. LULUCF	-1,030	37	0				-993
5. Waste	8	92	31				132
Total (without LULUCF)	8,707	1,127	547	132	10	21	10,544

Note: 1. Shaded cells do not require entries;
2. 0 indicates that the value is less than 0.5;
3. Due to rounding, the aggregation of various items may have slight difference with the total.

Table 2-2 China's GHG Emissions by Gas in 2010

GHGs	With LULUCF		Without LULUCF	
	Emissions (Mt CO_2 eq)	Proportion (%)	Emissions (Mt CO_2 eq)	Proportion (%)
CO_2	7,678	80.4	8,707	82.6
CH_4	1,163	12.2	1,127	10.7
N_2O	547	5.7	547	5.2
Fluorinated gas	163	1.7	163	1.5
Total	9,551	100.0	10,544	100.0

Note: Due to rounding, the aggregation of various items may have slight difference with the total.

Table 2-3 GWP Used in the Inventory (100-year time horizon)

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

Note: GWP value for 100-year of HFC-245fa is from the IPCC AR4.

In regard of different sectors involved in the Inventory, in 2010, GHG emissions from energy, industrial processes, agriculture and waste were 8,283 Mt, 1,301 Mt, 828 Mt and 132 Mt CO_2 eq respectively. The above mentioned four sectors accounted for 78.6%, 12.3%, 7.9%

and 1.2% of the total emissions (without LULUCF) respectively, as shown in Figure 2-1.

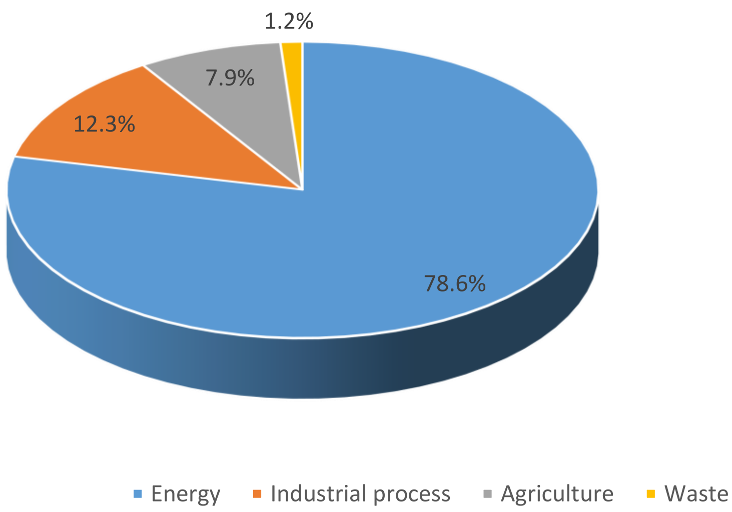

Figure 2-1 GHG Emissions by Sectors in China in 2010 (without LULUCF)

Also, in 2010, China's GHG emissions from international bunker fuels (international aviation and marine) were about 48.387 Mt CO_2 eq (Table 2-4).

Table 2-4 CO_2, CH_4 and N_2O Emissions and Removals in 2010 (kt)

GHG Source/Sink categories	CO_2	CH_4	N_2O
Total (with LULUCF)	7,677,656	55,394	1,764
1. Energy	7,623,859	26,834	308
—Fuel combustion	7,623,859	3,000	308
♦Energy industry	3,425,185	42	165
♦Manufacturing industries and construction	2,914,516	284	53
♦Transport	653,135	73	20
♦Other sectors	567,776	803	7
♦Others	63,247	1,797	63
—Fugitive emission		23,834	
♦Solid fuels		22,870	
♦Oil and gas system		964	
2. Industrial processes	1,075,072	5	200
—Mineral products	755,370		
—Chemical industry	118,413	NE	200
—Metal production	201,288	5	NA
—Production of halocarbons and SF_6			
—Consumption of halocarbons and SF_6			
3. Agriculture		22,414	1,154
—Enteric fermentation		10,329	

GHG Source/Sink categories	CO_2	CH_4	N_2O
—Manure management		3,048	236
—Rice cultivation		8,729	
—Agricultural soils		NA	911
—Prescribed burning of savannahs on tropical grassland		NO	NO
—Field burning of agricultural residues		307	7
4. LULUCF	-1,029,720	1,740	IE, NE
—Forest land	-779,230		
—Cropland	-66,040	IE	IE
—Grassland	-45,130	IE	IE
—Wetlands	-45,080	1,740	NE
—Settlements	1,620		
—Other land	0		
—Harvested wood products	-95,860		
5. Waste	8,446	4,401	101
—Solid waste	8,446	2,207	5
—Wastewater treatment		2,194	96
Memo items			
—International aviation	21,488	0	1
—International marine	26,436	2	1
—CO_2 emissions from biomass	898,255		

Note: 1. Shaded cells do not require entries;

2. 0 indicates that the value is less than 0.5;

3. NE (not estimated) stands for existing emissions and removals which have not been estimated; IE (included elsewhere) stands for sources which have been calculated and reported under other sub-categories; NO (not occurred) stands for emission sources which do not exist in the territory;

4. Due to rounding, the aggregation of various items may have slight difference 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 2010, China's CO_2 emissions (without LULUCF) were 8,707 Mt, of which 7,624 Mt were from energy, accounting for 87.6%; 1,075 Mt were from industrial processes, accounting for 12.3%; 8.446 Mt were from waste of fossil origin incineration, accounting for 0.1%. CO_2 net removal from LULUCF were 1,030 Mt. In 2010, net emission of CO_2 (with LULUCF) in China were 7,678 Mt.

1.3 Methane

Energy and agriculture were main sources of CH_4 emissions in China. CH_4 emissions in China in 2010 were 55.394 Mt, i.e. 1163 Mt CO_2 eq, of which 26.834 Mt were from energy, accounting for 48.4%; 22.414 Mt were from agriculture, accounting for 40.5%; 4.401 Mt were from waste, accounting for 7.9%; 1.74 Mt were from LULUCF, accounting for 3.1%.

1.4 Nitrous Oxide

Agriculture and energy were main sources of N_2O emissions in China. In 2010, N_2O emissions were 1.764 Mt, an equivalent of 547 Mt CO_2 eq, of which 1.154 Mt were from agriculture, accounting for 65.4%; 0.308 Mt were from energy, accounting for 17.5%; 0.2 Mt were from industrial processes, accounting for 11.4%; 0.101 Mt were from waste, accounting for 5.7%.

1.5 Fluorinated Gas

Industrial processes were main sources of fluorinated gases emission. In 2010, total emissions of fluorinated gases including HFCs, PFCs and SF_6 were about 163 Mt CO_2 eq (Table 2-5).

Chapter 2 GHG Emissions by Sectors

2.1 Energy

2.1.1 Scope

National GHG Inventory for Energy sector contains fossil fuel combustion and fugitive emissions. Fossil fuel combustion emissions cover CO_2, CH_4 and N_2O emissions from energy industries, manufacturing industries and construction, transport, other sectors and other categories. "Other" includes CH_4 and N_2O emissions from biomass, CO_2 emissions from non-energy use. Fugitive emissions cover CH_4 emissions from solid fuels, and oil and natural gas systems. GHG Inventory for Energy sector also includes memo items which reported CO_2, CH_4 and N_2O emissions from international bunker fuels and CO_2 emissions from biomass.

Table 2-5 China's Emissions of HFCs, PFCs and SF_6 in 2010 (kt)

Sources	HFCs									PFCs		SF_6
	HFC-23	HFC-32	HFC-125	HFC-134a	HFC-143a	HFC-152a	HFC-227ea	HFC-236fa	HFC-245fa	CF_4	C_2F_6	
Total emission	8.6	1.7	1.9	18.9	0.1	0.2	0.0	0.0	0.1	1.3	0.1	0.9
1. Energy												
2. Industrial processes	8.6	1.7	1.9	18.9	0.1	0.2	0.0	0.0	0.1	1.3	0.1	0.9
—Mineral products												
—Chemical industry												
—Metal production										1.1	0.1	NO
—Production of halocarbons and SF_6	8.6	0.1	0.2	0.4	0.1	0.2	0.0	0.0	0.0	0.0	0.0	NE
—Consumption of halocarbons and SF_6	NO	1.6	1.7	18.5	0.1	NO	NO	NO	0.1	0.1	0.0	0.9
3. Agriculture												
4. LULUCF												
5. Waste												

Note: 1. Shaded cells do not require entries;

2. 0.0 indicates that the value is less than 0.05;

3. NO (Not Occurred) stands for that this emission source does not exist, NE (Not Estimated) for existing emissions and removals which have not been estimated;

4. Due to rounding, the aggregation of various items may have slight difference with the total.

2.1.2 Methodologies

The preparation of 2010 GHG Inventory for Energy sector mainly followed *Revised 1996 IPCC Guidelines* and *IPCC GPG 2000*. When necessary, to further improve the accuracy and completeness of the inventory, *2006 IPCC Guidelines* were also referred in light of China's specific national circumstances.

CO_2, CH_4 and N_2O emissions from fossil fuel combustion were calculated by sectoral approach. CO_2 emissions were calculated by Tier 2 method and reference approach were adopted for the purpose of verifying the results achieved by Tier 2 method. Public electricity departments, thermal department and aviation adopted Tier 1 method. Road transportation adopted Tier 3 method (the COPERT mode). CH_4 and N_2O emissions in all other fields adopted Tier 1 method.

For fugitive emissions of CH_4 from solid fuels, emissions from underground mining activities were calculated by Tier 2 method, surface coal mining Tier 1 method, post-mining activities Tier 2 method, and abandoned coal mines Tier 1 method in *2006 IPCC Guidelines*. Emissions from natural gas exploration and transportation and crude oil exploration were calculated by Tier 3 method. Fugitive emissions of CH_4 from other sub-sectors of oil and gas system were calculated by Tier 1 method.

CH_4 emissions from biomass burning in residential sector were calculated by Tier 2 method, and other sectors Tier 1 method.

Emissions from international aviation were calculated by Tier 2 method and international marine Tier 1 method.

2.1.3 Activity Data and Emission Factors

The activity data on the 2010 Chinese fossil fuel combustion were mainly from energy statistics and other relevant statistics provided by NBS. In 2015, as a routine practice and according to the third economy general survey, the National Bureau of Statistics revised China's energy consumption statistics of 2010 and published *China Energy Statistical Yearbook 2014*. In this inventory, activity data of fossil fuel combustions adopted the newly revised statistics. The activity data sources of biomass burning included the *China Agriculture Economic Yearbook 2011*. The activity data of fugitive emissions from coal mining were mainly from the *China Energy Statistical Yearbook 2014*. Activity data of fugitive emissions from oil and gas system were mainly quoted from *CNPC Annual Statistical Report* 2011 and *Sinopec Group Annual Statistical Report* 2011. Major activity data of energy activities in 2010 can be seen in Table 2-6.

Table 2-6 Major Activity Data on Energy Activities in 2010

	Activity Data		Activity Data
Coal consumption (Mtce)	2,496	Underground coal mining production (Mt)	2,864
Oil consumption (Mtce)	628	Coal production from surface mining (Mt)	564
Natural gas consumption (Mtce)	144	Straw consumption (Mtce)	167

Net calorific value (NCV) and carbon contents of coal and carbon oxidation factors of some solid fuel boilers were country-specific obtained by investigation. For liquid fuels and gas fuels, NCV were adopted from the National Bureau of Statistics and default values in *2006 IPCC Guidelines*, carbon contents were default values in 2006 IPCC Guidelines and carbon oxidation factor were taken from research data in 2005 inventory of the Second National Communications on Climate Change. Emission factors of CH_4 and N_2O emissions from stationary fuel combustion sources were default values in *2006 IPCC Guidelines*.

The mine gas identification results of national coal mines were used as the basis of calculating national average emission factors of CH_4 of underground mining. Emission factors of surface mining adopted the emission factors in *Revised 1996 IPCC Guidelines*.

The calculation of newly added emission sources, fuel types and gases of biomass burning adopted the default values in *2006 IPCC Guidelines*. Emission factors of manure burning were the default values in *2006 IPCC Guidelines*, as well as the emission factors of agricultural waste, biogas and waste (biogenic).

2.1.4 Results

In 2010, China's total GHG emissions from energy sector were 8,283 Mt CO_2 eq. Of which, the emissions from fuel combustion were 7,782 Mt CO_2 eq, accounting for 94.0%; fugitive emissions were 501 Mt CO_2 eq, accounting for 6.0%. In terms of gas composition, CO_2 emissions were 7,624 Mt, which accounted for 92.0% of total GHG emissions from energy sector. CH_4 emissions were 564 Mt CO_2 eq and accounted for 6.8%; N_2O emissions 96 Mt CO_2 eq and accounted for 1.2%, as shown in Figure 2-2.

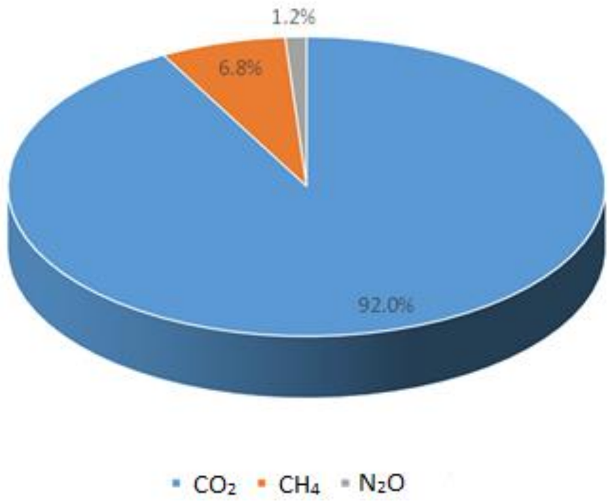

Figure 2-2 GHG Emission from Energy by Gas in 2010

2.2 Industrial Processes

2.2.1 Scope

The 2010 GHG Inventory for Industrial Processes includes the emissions from mineral products, chemical industry, metal production, and production and consumption of halocarbons and SF_6. Manufacturing of mineral products included CO_2 emissions from production processes of cement, lime and glass. Chemical production included CO_2 and N_2O emissions from production processes of ammonia, calcium carbide, sodium carbonate, nitric acid and adipic acid. Metal products included CO_2, CH_4 and PFCs emissions from production processes of iron and steel, ferroalloy, aluminu, magnesium, lead and zinc. Production of halocarbons and SF_6 included HFCs and PFCs emissions from HCFC-22 production processes, and other HFCs and PFCs productions. Consumption of halocarbons and SF_6 included HFCs, PFCs and SF_6 emissions from utilization processes.

2.2.2 Methodologies

According to practical situations and data basis, different versions of Guidance and methods were adopted in calculating GHG emissions from different industrial processes.

—CO_2 emissions from cement and lime production processes were calculated according to *Revised 1996 IPCC Guidelines*;

—CO_2 emissions from glass production processes were calculated by Tier 1 method of *2006 IPCC Guidelines*;

—CO_2 emissions from synthetic ammonia and sodium carbonate production processes were calculated by Tier 2 method of *2006 IPCC Guidelines*;

—CO_2 emissions from calcium carbide production processes were calculated according to *Revised 1996 IPCC Guidelines*;

—N_2O emissions from nitric acid and adipic acid production processes were calculated according to *IPCC GPG 2000*;

—CO_2 emissions from flux material used in iron and steel production processes were calculated by Tier 1 method of *Revised 1996 IPCC Guidelines*;

—CO_2 emissions from steel-making were calculated by Tier 2 method of *IPCC GPG 2000*;

—CO_2 emissions from ferroalloy, zinc and lead production processes were calculated by Tier 1 method of *2006 IPCC Guidelines*;

—CO_2 emissions from aluminum production processes were calculated by Tier 2 method of *2006 IPCC Guidelines*;

—PFCs emissions from aluminum production processes were calculated by Tier 2 method of Revised 1996 IPCC Guidelines;

—CO_2 emissions from magnesium production processes were calculated by Tier 2 method of *2006 IPCC Guidelines*;

—HFC-23 emissions from HCFC-22 production processes were calculated by Tier 2 method of *Revised 1996 IPCC Guidelines*;

—HFCs and PFCs emissions from other production processes were calculated by Tier 1 method of *Revised 1996 IPCC Guidelines*;

—HFCs emissions from utilization of sub-sectors of refrigeration and air conditioning and SF_6 emissions from electric equipment production processes were calculated by Tier 2 method of *Revised 1996 IPCC Guidelines*;

—HFCs, PFCs and SF_6 emissions from other utilizations were calculated by Tier 1 method of *Revised 1996 IPCC Guidelines*.

2.2.3 Activity Data and Emission Factors

The production amount of cement clinker, crude steel and primary aluminum of China in 2010 were quoted from statistical materials released by the National Bureau of Statistics. The production amount of synthetic ammonia were mainly from *China Chemical Industry Yearbook 2011/2012*. The production amount of lime were from the estimated data of China Lime Association. The production amount of nitric acid were from research data of National Chemical Industrial Nitric Acid and Nitrate Technological Coordination Network. The production amount of adipic acid, ferrosilicon and HCFC-22 were from company researches. Activity data of major industrial processes in 2010 can be seen in Table 2-7.

The emission factors of production of cement clinker, ammonia, adipic acid and HCFC-22 are country-specific data in 2010 received through typical enterprise survey. The emission factors of other sources are adopted from the second National Communication on Climate Change.

Table 2-7 Activity Data of Major Industrial Processes in 2010

	Production (Mt)		Production (Mt)
Cement clinker	1,188.75	Ferrosilicon	5.05
Crude steel	637.23	Primary aluminum	15.77
Ammonia	49.65	HCFC-22	0.55

2.2.4 Results

In 2010, GHG emissions from industrial processes were 1,301 Mt CO_2 eq, of which emissions from mineral products accounted for 58.1%, chemical industries 13.9%, metal production 16.2%, production of halocarbons and SF_6 7.8%, and consumption of halocarbons and SF_6 4.0%. Of total emissions, CO_2 accounted for 82.7%, N_2O, HFCs, PFCs and SF_6 accounted for 4.8%, 10.2%, 0.7% and 1.6% respectively; and CH_4 emissions accounted for less than 0.1%, as shown in Figure 2-3.

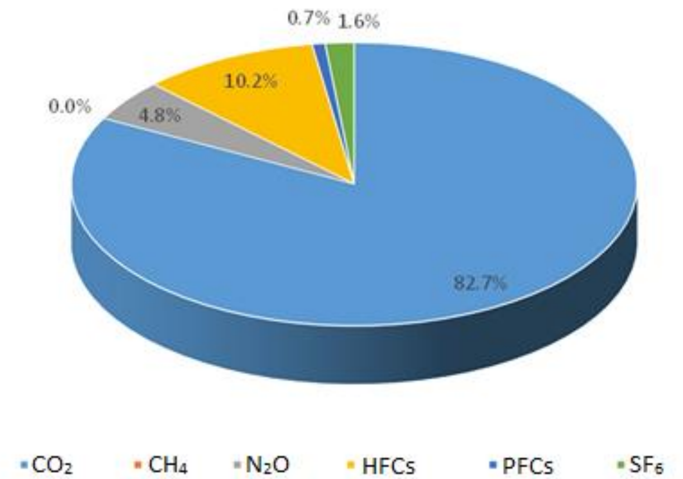

Figure 2-3 GHG Emissions by Gas in China in 2010

2.3 Agriculture

2.3.1 Scope

The 2010 inventory for agriculture includes CH_4 emissions from livestock 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. The inventory of enteric fermentation reports the CH_4 emissions from 12 kinds of livestock, including beef cattle, dairy cow, goat and sheep, etc. The inventory of manure management reports the CH_4 and N_2O emissions from 14 kinds of livestock, including dairy cow, beef cattle, goat and pig, etc. The inventory of rice cultivation reports the CH_4 emissions from the rice paddies of different planting modes, different irrigation and management modes and different fertilization patterns. The inventory of agriculture soils reports the direct N_2O emissions from nitrogen conversion in agriculture soils (containing grazing), and the indirect N_2O emissions caused by nitrogen deposition, leaching and runoff.

2.3.2 Methodologies

—In the part of enteric fermentation, the CH_4 emissions from the sources of beef cattle, dairy cow, buffalo, yak, other kinds of cattle, sheep, goat and pig were calculated by Tier 2 method of *Revised 1996 IPCC Guidelines*; and those from other sources were calculated by Tier 1 method.

—In the part of manure management, the CH_4 emissions from the sources of pig, beef cattle, dairy cow, poultry, buffalo and goat were calculated by using a Tier 2 method of *Revised 1996 IPCC Guidelines* and those from other sources were calculated by using a Tier 1 method.

—The CH_4 emissions from of rice paddies were estimated by China's rice paddy methane model (CH4MOD) again, which was developed based on the methods of *Revised 1996 IPCC Guidelines* and the characteristics of Chinese statistical data. The model was rated as a Tier 3 method of *Revised 1996 IPCC Guidelines*. The model is used to calculate the CH_4 emissions of each county and add them up based on the essential data of county-level rice paddies. The N_2O emissions from farmland were calculated by summing up the emissions from various provincial and regional farmland through the regional nitrogen-cycling model (IAP-N), which was rated as a Tier 2 method of *2006 IPCC Guidelines*.

—The CH_4 and N_2O emissions from field burning of agricultural residues were calculated by Tier 1 method of *Revised 1996 IPCC Guidelines*.

2.3.3 Activity Data and Emission Factors

The activity data of enteric fermentation, manure management, rice paddies and farmland were mainly from China Statistical Yearbook-2011, China Animal Husbandry Yearbook 2011 and 3rd agricultural census results and the

Department of Animal Husbandry, Ministry of Agriculture (MOA), in which the data of large-scale feeding, of farmer-household feeding, and of age structure of various animals were from the statistical data on the animal husbandry industry offered by the Department of Animal Husbandry, MOA. Main activity data of agricultural inventories in 2010 were shown in Table 2-8.

The production-related data involved in the calculation of emission factors of CH_4 from enteric fermentation, including body weight of animal, daily gain, feed intake, feed quality, milk yield, butter-fat content, wool yield and so on were from the typical data received through the survey carried out over 79 counties in 2015.

The use proportion of fecal management mode required to calculate the factors of CH_4 emissions from fecal management comes from the survey data on the 79 counties. The default values of methane conversion factors (MCF) used in different fecal management modes of *Revised 1996 IPCC Guidelines* were chosen based on the annual average temperatures of various provinces. The volatile solids in daily excreta of various animals at different age stages and indifferent regions were calculated according to the animal food intakes that were received through the method recommended in *Revised 1996 IPCC Guidelines* and the typical surveys. The methane production potential (Bo) was the default value offered by *Revised 1996 IPCC Guidelines*. The annual nitrogen excretions of the pig, dairy cow, cattle beef and livestock used to calculate the N_2O emission factors from fecal management were derived from the *Manual of Discharge Coefficients of Livestock and Poultry Production from the National First Pollution Source General Survey*; and those of other animals were the default values of *Revised 1996 IPCC Guidelines.*

The factors of CH_4 emissions from rice paddies were calculated by using the CH4MOD. The factors of CH_4 emissions from flooded paddy field in non-rice growing season were calculated by using the empirical formula.

The emission factors of direct N_2O emissions from farmland were calculated through statistical analysis on the nearly 30-year observational data about different categories of farmland. The emission factors of N_2O emissions from grazing were the default values of *Revised 1996 IPCC Guidelines.* The emission factors of direct N_2O emissions from atmospheric nitrogen deposition into farmland were the direct emission factors of farmland. The factors of direct N_2O emissions that were caused when atmospheric nitrogen deposited outside farmland and by nitrogen leaching and runoff were all the default values of *2006*

IPCC Guidelines.

Table 2-8 Major Activity Data on Agricultural Activities in 2010

	Activity data		Activity data
Dairy herd stock (million)	12.11	Sheep stock (million)	145.35
Beef cattle stock (million)	62.37	Pig stock (million)	467.65
Buffalo stock (million)	23.72	Nitrogen fertilizer consumed (Mt)	23.54
Goat stock (million)	141.95	Compound fertilizer net consumed (Mt)	17.98

2.3.4 Results

In 2010, the total GHG emission from agriculture sector was around 828 Mt CO_2 eq, of which the emissions from enteric fermentation were 217 Mt CO_2 eq, accounting for 26.2%; the emissions from manure management were 137 Mt CO_2 eq, accounting for 16.6%; the emissions from rice cultivation were 183 Mt CO_2 eq, accounting for 22.1%; the emissions from agriculture soils were 283 Mt CO_2 eq, accounting for 34.1%; and the emissions from field burning of agricultural residues were 9 Mt CO_2 eq, accounting for 1.0%, as shown in Figure 2-4. In the total emissions, CH_4 accounted for 56.8%, and that of N_2O accounted for 43.2%.

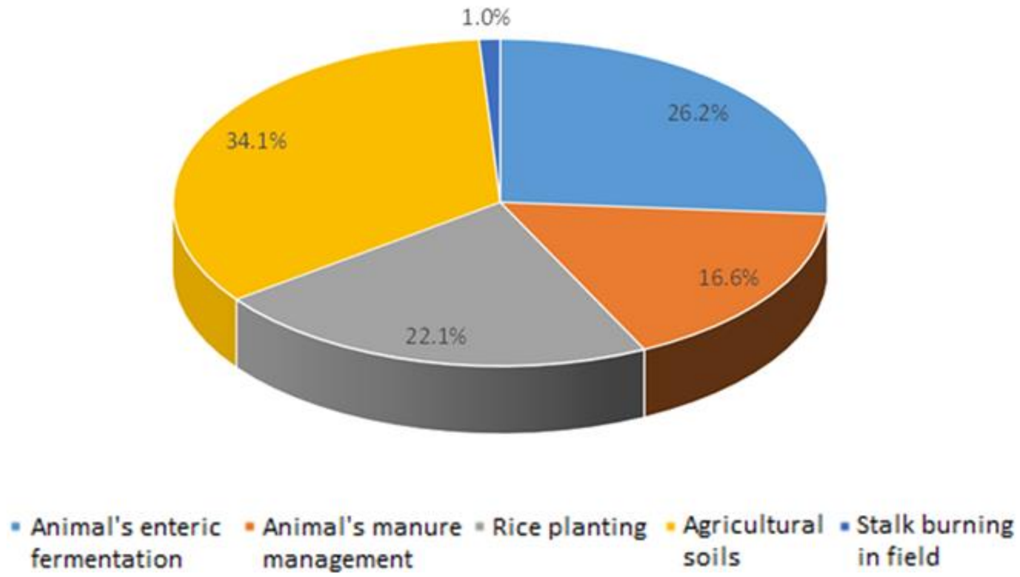

Figure 2-4 GHG Emissions from Agriculture by Sector in China in 2010

2.4 Land-Use, Land-Use Change and Forestry

2.4.1 Scope

The inventory of China's land use, land-use change and forestry GHG in 2010 contains CO_2 emissions and CH_4 emissions from six land-use categories: forest land, cropland, grassland, wetlands, settlements and other land. For each land-use categories, two kinds of land-use changes including "unchanged land-use type" and "transformation into another category of land" between 1990 and 2010 were considered. The changes of carbon reserves in aboveground biomass, underground biomass, litters, dead and dying trees and soil organic carbon based on actual situations, as well as those in other woods other than forests and in wood products were estimated. The removal or emission amount of CO_2 and CH_4 were evaluated.

2.4.2 Methodologies

The inventory of China's land-use change and forestry GHGs in 2010 was prepared by referring to *IPCC GPG 2000, IPCC Good Practice for Forestry*, 2006 *IPCC Guidelines*, and *2013 Supplement to the IPCC 2006 Guidelines for National GHGs Inventories: Wetland*.

The CO_2 emission and removal from forest land was estimated by using the stock-change approach (Tier 2). The forest land was divided into high forest land, bamboo land, economic land, shrub land, open forest land and immature wood land. The carbon pool contained the aboveground biomass, underground biomass, litters, dead and dying trees, and soil organic carbon.

The change of organic carbon reserves in agricultural soils was calculated by using the Tier 3 method (Agro-C model), which can be used to stimulate the process in which stalks, root system and organic fertilizers enter into the soil and are broken down to leave the soil, thus to calculate the change of soil carbon pool.

The changes of reserves of soil organic carbon, the volume of CO_2 emission and removal from wetland, CH_4 emissions, and CO_2 emissions from building land were all calculated by using Tier 2 methods.

The changes of carbon reserves in forestry products were estimated by using the "production method" (Method 2).

2.4.3 Activity Data and Emission Factors

Classification of forest land referred to *Technical Code for Continuous Check of National Forest Resources*. The areas of lands for various lands are published by the Ministry of Natural Resources, while data on standing timber are from the national continuous check of forest resources. The subdivision of grassland management areas and wetland subtype areas are determined in light of the remote sensing data. Data on the major activity data in land use, land-use change and forestry in 2010 Inventory is shown in Table 2-9.

Table 2-9 Major Activity Data on LULUCF in 2010

	Area (M ha)		Area (M ha)
High forest	163.52	Cropland	135.27
Bamboo forest	5.91	Grassland	287.17
Open forest	4.13	Wetlands	40.02
Shrub land	71.65	Settlements	34.52

Main emission factors and related parameters were derived from the national industrial standards, published relevant literatures and some test data. The model and parameters were verified by using the data in terms of meteorology, soil and vegetation published by the country.

2.4.4 Results

In 2010, China's LULUCF absorbed 1,030 Mt CO_2 eq. CH_4 emissions were 1.74 Mt, and the net absorption amounted to 993 Mt CO_2 eq. The forest land, agricultural soils, grassland and wetland respectively absorbed 779 Mt, 66 Mt, 45 Mt and 45 Mt of CO_2; the construction land emitted 2 Mt of CO_2; the harvested forestry products absorbed 96 Mt of CO_2. The CH_4 emissions from the wetland were 1.74 Mt.

2.5 Waste

2.5.1 Scope

The inventory of Chinese GHGs from waste sector in 2010 contains the emissions of CO_2, CH_4 and N_2O from the municipal solid waste (MSW) treatment as well as the CH_4 and N_2O emissions from domestic and commercial wastewater treatment and industry wastewater treatment.

The inventory of solid waste sector reports the emissions of GHGs from the landfill, incineration, and biological treatment of municipal solid wastes. The inventory of wastes incineration incudes the emissions of CO_2, CH_4 and N_2O. The CO_2 emissions from waste incineration derived from fossil CO_2 emissions, which was included in national inventory and biogenic CO_2 emissions which was reported as a memo item in national inventory.

The inventory of wastewater treatment reports the CH_4 emissions from treatment of domestic and commercial wastewater and industrial wastewater, and the N_2O emissions from wastewater treatment.

2.5.2 Methodologies

The GHGs emissions from municipal solid waste landfill were calculated by using the first order decay (FOD) model of 2006 IPCC Guidelines (Tier 2), and those from incineration and biological treatment were calculated by using *Revised 1996 Guidelines* and *IPCC GPG 2000*.

The GHG emissions from wastewater treatment were calculated by using the methods of *Revised 1996 Guidelines, IPCC GPG 2000* and by referring to *2006 IPCC Guidelines.*

2.5.3 Activity Data and Emission Factors

The activity data (AD) of MSW landfill were from *China Urban-Rural Construction Statistical Yearbook* and *China Population & Employment Statistical Yearbook*.

The activity data of domestic and commercial wastewater treatment and industrial wastewater were from *China Environment Statistical Yearbook 2010*, *Annual Statistic Report on Environment in 2010*, and *Collections of Chinese Urban Wastewater Treatment Plants*. The number of populations was from *China Statistical Yearbook -2011*; the per capita protein consumption was from the United Nations Food and Agriculture Organization (FAO). The amount of composted waste was from *China Urban Construction Statistical Yearbook 2010*.

The activity data of waste incinerated was from *China Urban Construction Statistical Yearbook 2010*; the hazardous waste and clinical wastes were from *China Environment Statistical Yearbook 2010*; the data of sludge landfilled was from *China Environment Statistical Yearbook 2010* and *Annual Statistic Report on Environment in 2010*. The activity data of waste sector in 2010 were listed in Table 2-10.

Table 2-10 Activity-related Data of Waste Sector in 2010

Main waste disposal activities	Activity data (Mt)
Landfill of municipal solid waste (MSW)	95.98
Incineration amount of MSW	23.17
Biological treatment amount of MSW	1.81
COD discharged from wastewater	12.38

The emission factors (EFs) of CH_4 emissions from municipal solid waste landfills were country specific values. The content of degradable organic carbon (DOC) in municipal solid waste was determined based on the real situation of MSW collection and treatment present and MSW historical trends, with analyzing typical landfills sampling analysis. Based on the MSW and its treatment developing trend and historical record materials, referring to the expert judgements, the CH_4 correction factor (MCF) that can reflect China's real situations was determined the country specific eigenvalue in the half-time of municipal solid waste was verified through field sampling and survey in the northern and southern areas of China.

The emission factors of CH_4 and N_2O emissions from industrial and domestic and commercial wastewater treatment were the country specific values used in inventory year. The emission factors of CH_4 and N_2O emissions from biological treatment of wastes were the default values from *IPCC GPG 2000*.

The emission factors of CO_2, CH_4 and N_2O emissions from waste incineration were determined based on the scope of default values in *IPCC GPG 2000* and *2006 IPCC Guidelines* to choose the emission factors which to meet the real circumstances of China.

2.5.4 Results

In 2010, the total GHG emissions from waste sector were 132 Mt CO_2 eq, of which 56 Mt were from municipal solid waste landfills, accounting for 42.7%; 76 Mt were from wastewater handling, accounting for 57.3%. The proportions of CO_2, CH_4 and N_2O emissions were respectively 6.4%, 69.9% and 23.7%, which were shown in Figure 2-5.

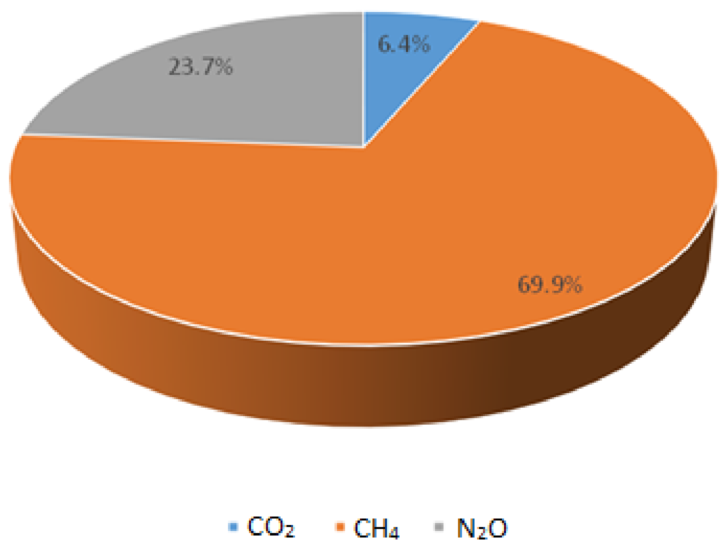

Figure 2-5 GHG Emissions by Sector in China in 2010

Chapter 3 Data Quality and Uncertainty Assessment

3.1 Data Quality Control

3.1.1 Data Collection and Verification

Since 2012, National Bureau of Statistics has joined hands with departments and units involved in the national GHG inventory preparation to carry out basic statistical system and capacity building activities targeting GHG emission, so as to improve the statistical data of major concerned sectors and guarantee the data quality of activity data in national GHG inventory preparation.

The inventory preparation team has, guided by the data-first collection principle under *IPCC GPG 2000*, collected several categories of data including statistical data, important parameters and emission factors (see Table 2-11).

The team has controlled the quality of inventory data through data review which mainly includes the following efforts:

1）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.

2）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.

3）Verification of the consistency of data from different inventory sector. For example, checking the consistency of data in various 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 inventory and energy inventory. 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 2-11 Principle for the Collection of Authoritative Data and Overview of the Data Collection from Various Fields

Data category	Principle of authoritativeness	Overview of the data collection from various fields
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 on energy, industrial processes, the agriculture, land-use change and forestry and those involved in waste inventories are from the National Bureau of Statistics and relevant departments (such as the Ministry of Agriculture and Rural Affairs, the National Forestry and Grassland Administration, the Ministry of Natural Resources and the MEE); ♦ Some data are received from corresponding industry associations, such as the energy y consumption by the transportation industry, the number of the animals grazed in pastoral areas, and the data on their dung as fuel, soil data and vegetation data, which are not available from the statistics authority. ; ♦ The areas of forest lands and the cumulative data on standing timber are from the data on the national continuous check of forest resources; ♦ The subdivision of grassland management areas and wetland subtype areas are determined in light of the remote sensing data.
Important parameters/ emission factor	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 are the second order; expert judgment and IPCC data are the third order, and their uncertainty shall be within IPCC data range.	♦ The calorific value of solid fuel, the carbon content and carbon oxidation rate for unit calorific value are mainly from the measurement by the research and test of special research and major research projects (such as the carbon research project by the Chinese Academy of Sciences and relevant achievements of the "973 Program"); ♦ Such data as the residues/straws return-to-field rate and the annual average nitrogen excretion per animal of species, et al., are from the data on National First Pollution Sources Census as conducted by the Ministry of Agriculture and Rural Affairs and the MEE; the fractions for different animal manure management system in different regions are from the survey results of typical sample counties; ♦ Such data as the constituents of resident refuse and waste disposal modes are from the results of the CDM project.

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

Principle	General improvements
Completeness	♦ Energy: different from the 2nd National Communication on Climate Change,, the energy inventories issued this time take the lead to calculate the CH_4 and N_2O emissions from all stationary sources, and additionally calculate the carbon emissions from those fossil-fuel in the "other energy sources" category of the energy balance sheet, fugitive emissions of CH_4 in the course of oil and natural gas prospecting, the CH_4 emissions arising out of biogas burning in rural living and biomass power generation, and the CO_2 emissions from biomass burning (information item); ♦ Industrial processes: the inventories increase five new emission sources and extend the sub-emission sources of fluorinated gas; ♦ Agriculture: the inventories increase the calculation on the CH_4 and N_2O emissions from straw field burning; ♦ Land use, land-use change and forestry: except for woodland, the inventories extend the scope of carbon pool, and increase the estimates on the changes of soil carbon pool in different land-use patterns (including farmland, grassland and wetland) and also increase the estimation of wetland CH_4 emissions; ♦ Waste: the inventories increase the estimates on CH_4 and N_2O emissions derived from biological treatment.
Accuracy	♦ Energy: for the emissions from coal burning, the inventories strengthen the investigation on carbon content in net calorific value and unit heat value of different coal classes and of different uses in main coal-consuming industries, and study the development situation and the input and output of Chinese coal chemistry industry, thus gaining more reliable carbon sequestration rate parameters; use the COPERT model method to calculate the CH_4 and N_2O emissions from road traffic instead of calculation based on emission factors, and upgrade the calculation method in terms of civil aviation from Tier 1 to Tier 2. ♦ Agriculture: due to the improvement of N_2O analysis method and monitoring flux conversion method, they generally rectify the N_2O emission factors in the past 30-year field observation data of China, forming a set of N_2O direct emission factors with sub-area sub-field type , and increasing the accuracy of estimates on direct emissions of N_2O from cropland. The investigation on the straws returning-to-field rate before rice planting and on the composition of animal feed and fractions of animal manure management system can improve the accuracy of agricultural GHGs inventories and reduce their uncertainty.
Consistency	♦ Compared to the 2nd National Communication, the source/sink categories of the 2010 National Greenhouse Gas Inventory of China are consistent with the IPCC Guidelines. ♦ To avoid double counting and omission, we have put together and checked inventory boundaries in cross areas and the basic data adopted, for example: — the boundary between the non-energy utilization in energy and the industrial processes, and sources of data; — the data on animal manure and animal feeding between energy and agriculture, the data on wood as fuel between energy and the LULUCF

Principle	General improvements
Scientificity and comparability of inventory preparation methods	Subject to the methods of *Revised 1996 IPCC Guidelines* and *2006 IPCC Guidelines*, *IPCC GPG 2000*, and *IPCC Good Practice Guidance for Forestry*. ♦ Main emission sources: the level 2 or Tier 3 method is adopted in consideration of the real situations of China; ♦ Secondary emission sources: the Tier 1 method is employed, for example: — The energy inventory is in strict compliance with the comparison table of the *Revised 1996 IPCC Guidelines*, which is about the types of emission sources and ISIC classes; corrects the mapping relationship between the types of fossil fuel emission sources in previous energy activity inventories and the industrial subsectors in national industries classification, making the classification of emission sources more consistent with *Revised 1996 IPCC Guidelines* and ensuring the comparability of inventories; — Industrial processes: for half of the emission sources, the Tier 2 method provided in *2006 IPCC Guidelines* is used. In the respect of fluorinated gas, the level-1 emission calculation method of *2006 IPCC Guidelines* is more scientific and accurate than that of *Revised 1996 IPCC Guidelines* because the former takes into account the real emission reductions and emission lagging.

3.1.2 Archive of Information

Complying with the *IPCC GPG 2010*, the GHG emission inventory preparation units of various sectors have created databases targeting activity data, emission factors and related parameters and databases on the management of information sources and references.

Various sectors have recorded the methodology selection basis and its process of improvement in the form of technical report, and archived after the review of peer experts.

3.2 Data Quality Assurance

For the inventory report, the member units of National Climate Change Response Leadership Group and concerned industry associations have been asked for advice and suggestions to guarantee the accuracy of inventory activity data and the rationality of parameters, emission factors and methodology selection. The inventory estimates have been compared with related estimates published by domestic and international peer organizations to ensure reliable data, scientific methodologies and comparable results of this national GHG inventory.

3.3 Uncertainty Assessment

3.3.1 Measures to Reduce the Uncertainty of Inventories

As China’s GHG statistical system is established and improved gradually, the uncertainty of activity data of each emission source is also decreasing. In this national GHG inventory, local emission factors are preferred for each emission source, which has greatly reduced the uncertainty of the inventory. For specific measures taken by each sector to reduce the uncertainty of the inventory, see 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	♦ The CO_2 emissions from fossil fuel combustion are estimated by specific sector approach and verified based on reference approach; ♦ The COPERT model method is used to calculate the CH_4 and N_2O emissions from road traffic instead of the calculation based on emission factors; and the calculation method in terms of civil aviation is upgraded from Tier1 to Tier2. ♦ An investigation is strengthened on the carbon content and carbon oxidation in net calorific value and unit heat value of different coal classes and of different uses in main coal-consuming industries; ♦ A systematic analysis is made on the information of carbon content and carbon oxidation in unit heat value in the existing inventories and research results, such as the carbon-specific project data from Chinese Academy of Sciences; ♦ In contrast to previous national energy inventories, this one significantly improves the typicality, coverage and data quality of samples, and reduces the uncertainty of emissions from fossil fuel combustion.
Industrial processes	♦ Due to the differences in statistical standards, the data (such as cement clinker, synthesis ammonia) from analysis and statistics departments and industrial associations should be used after being checked; ♦ The cement clinker emission factors are received by integrating various provincial-level GHG inventories, and for major industries (such as synthesis ammonia and adipic acid), such factors are locally received through field investigation among enterprises.
Agriculture	♦ An investigation is carried out on the straw return-to-field rate before rice planting in typical rice planting regions; ♦ The direct emission factors of N_2O from farmland is corrected by using improved the N_2O analysis method and monitoring flux conversion method, thus increasing the accuracy of estimates on direct emission factors of N_2O from farmland; ♦ Cattle is further divided into five types (cow, beef cattle, buffalo, yak and other cattle) from the three ones in the 2nd National Communication. This improves the quality of the data used to estimate the emission factors and related parameters of CH_4 derived from enteric fermentation; ♦ An investigation is carried out on the composition of animal feed and the fractions of animal manure management system in typical counties of different regions, and the CH_4 and N_2O emissions generated under the waste management mode of piggery are determined; ♦ The investigation adopts the proportion of field straw burning in different provinces and the annual nitrogen excretions of cattle, sheep and pig individuals received from the database of the National First Pollution Source Census.

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

LULUCF	♦ Compared with the 2nd National Communication, the inventories of our sector are more complete, and classify land into six types according to utilization: woodland, agricultural land, grassland, wetland, construction land and other land in reference to the six land-use types of *IPCC Good Practice Guidance for Forestry*. The inventories of carbon reserve changes in agricultural land, grassland and wetland and the inventories of CH_4 emissions in wetland are the main supplements to the inventories of our sector. ♦ The biomass of different tree species in each year is computed by combining national continuous forest inventory and growth model of tree species.
Waste	♦ The estimates on CH_4 and N_2O emissions derived from biological treatment are increased; ♦ Important parameters are received through investigations and professional consultations on the composition of household waste and the treatment methods of solid waste and waste water.

3.3.2 Uncertainty Analysis

The *IPCC GPG 2010* were followed to analyze the uncertainty of National GHG Inventory of 2010. Tier 2 method (Monte Carlo method) is applied to quantitize the uncertainties of GHG emission from road traffic, CH_4 emission from rice fields and soil carbon sequestration in croplands, and Tier 1 method (error transfer method) is applied to quantitize the uncertainties of other emission sources. Tier 1 method was applied to quantitize the overall uncertainty of China's GHG Inventory of 2010 Results showed that the uncertainty of China's GHG Inventory of 2010 was -5.3%-5.5%. Please see Table 2-14 for more details.

Table 2-14 Results of Uncertainty Analysis of National GHG Inventory of 2010

Sector	Emission (Mt CO_2 eq)	Uncertainty
Energy	8,283	-5.2%~5.4%
Industrial processes	1,301	-3.8%~3.8%
Agriculture	828	-19.0%~20.1%
LULUCF	-993	-21.2%~21.2%
Waste	132	-23.7%~23.7%
Overall uncertainty	-5.3%~5.5%	

Chapter 4 National Greenhouse Gas Inventory of 2005

4.1 2005 GHG Inventory Recalculation

As the estimation methods were improved constantly, the scope of calculation was expanded properly and the underlying data were updated necessarily, the GHG inventory of 2005 was recalculated by the same methods used in 2010 inventory.

The scope of energy inventory was expanded to include: CH_4 and N_2O emissions of all stationary sources except the electricity and heat production sector; CO_2 emissions from fossil-fuel contained in the item of “other energy” in the energy balance table; CH_4 fugitive emissions from oil and natural gas exploration; CH_4 and N_2O emissions from biogas burning in rural households, biomass burning for electricity generation (agricultural and forestry residual, biogas, biomass-based municipal waste). Activity data for 2005 energy inventory is updated with revised China’s energy consumption statistics of 2005 according to the third economy general survey. CH_4 and N_2O emissions from road transportation is recalculated since higher tier approach is applied.

Compared with the previous 2005 IPPU inventory, the recalculation was expanded to cover more sources: CO_2 emissions from glass production in mineral industry; CO_2 emissions from soda ash production in chemical industry; CO_2 and CH_4 emissions from ferroalloy production, and CO_2 emissions from magnesium, lead and zinc production in metal industry.

In the recalculated 2005 agricultural inventory, CH_4 and N_2O emissions from open burning of residuals were included. In addition, he second agricultural general survey were carried out in 2007, based on which the National Bureau of Statistics revised the livestock data in 2000-2006. Therefore, the revised year-end breeding stock of pigs, cattle and sheep in 2005 was used to update the original activity data.

IPCC Good Practice for Forestry was used in the recalculation of 2005 LULUCF inventory. *Therefore, the scope was expanded to cover new sources, including,* the emission and/or removals of agricultural land, grassland, wetland, settlements and other lands.

Compared to the previous 2005 waste inventory, CH_4 and N_2O emissions from biological treatment of municipal waste and from waste incineration are newly included.

4.2 Results of 2005 GHG Inventory Recalculation

4.2.1 Overview

In 2005, China's total GHG emissions (with LULUCF) is 7,249 Mt CO_2 eq (Table 2-15), of which CO_2, CH_4, N_2O and fluorinated gases account for 77.0%, 14.4%, 6.9% and 1.7%, respectively. The removals of GHG in LULUCF is 766 Mt CO_2 eq.

Excluding removals of LULUCF, the GHG emission in China in 2005 is totaled as 8,015 Mt CO_2 eq, among which CO_2, CH_4, N_2O and fluorinated gases account for 79.6%, 12.6%, 6.2% and 1.6%, respectively.

4.2.2 Emission of CO_2

Energy-related activities and IPPU are two main sources of CO_2 emission in China. In 2005, China's CO_2 emission (without LULUCF) was 6,381 Mt, of which 5,665 Mt is from energy-related activities, accounting for 88.8%; 713 Mt was from IPPU, accounting for 11.2%; 3 Mt was from burning of fossil-based municipal waste, accounting for a rather small proportion. CO_2 removals in LULUCF sector was 803 Mt and China's CO_2 emissions (with LULUCF) in 2005 is 5,578 Mt.

Table 2-15 GHG Inventory of China in 2005（Mt CO_2 eq）

	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Total
Total (w/ LULUCF)	5,578	1,046	500	109	6	10	7,249
Energy	5,665	497	81				6,243
Industrial processes	713	NE	33	109	6	10	871
Agriculture		431	357				788
Waste	3	81	29				113
LULUCF	-803	37	NE, IE				-766
Total (w/o LULUCF)	6,381	1,009	500	109	6	10	8,015

Note: 1. Shaded cells do not require entries;

2. 0 indicates that the value is less than 0.5;

3. NE indicates that the emissions and removals from the existing sources are not calculated, and IE indicates that the emission source is calculated and reported in other sub-industries;

4. Due to rounding, the aggregation of various items may have slight difference with the total.

4.2.3 CH_4 Emission

Energy and agriculture were main sources of CH_4 emissions in China. China's CH_4 emissions in 2005 were 49.81 Mt (1,046 Mt CO_2eq) of which 47.5% was from energy, 41.2% from agriculture, 7.7% from waste disposal and 3.5% from LULUCF.

4.2.4 N_2O Emission

Agriculture and energy is main sources of N_2O emissions in China. In 2005, N_2O emissions in China were 1.61 Mt, an equivalent of 500 Mt CO_2 eq, of which emissions from agriculture account for 71.4%; energy 16.2%; IPPU 6.6%; and waste 5.9%.

4.2.5 Fluorinated Gas Emission

China's Fluorinated Gas emissions in 2005 were mainly from IPPU (about 125 Mt CO_2 eq).

4.3 Trend Analysis

China's annual growth rate of GHG emission between 2005 and 2010 is 5.7% and 5.6%，respectively, when including and excluding LULUCF. See Table 2-16 for more details. The annual growth rate in IPPU is the highest, being 8.4%, and that from the agricultural sector is the lowest, being 1.3%. When including LULUCF, China's annual growth rate of CO_2 emissions is 6.7%; when excluding LULUCF, China's annual growth rate of CO_2 emissions is 6.5% (Figure 2-6).

Table 2-16 China's GHG Emissions by Gas in 2005 and 2010

	2005 (Mt CO_2 eq)	2010 (Mt CO_2eq)	Annual growth rate (%)
Total (w/ LULUCF）	7,249	9,551	5.7
1. Energy	6,243	8,283	5.8
2. Industrial processes	871	1,301	8.4
3. Agriculture	788	828	1.0
4. LULUCF	-766	-993	5.3
5. Waste	113	132	3.3
Total (w/o LULUCF)	8,015	10,544	5.6

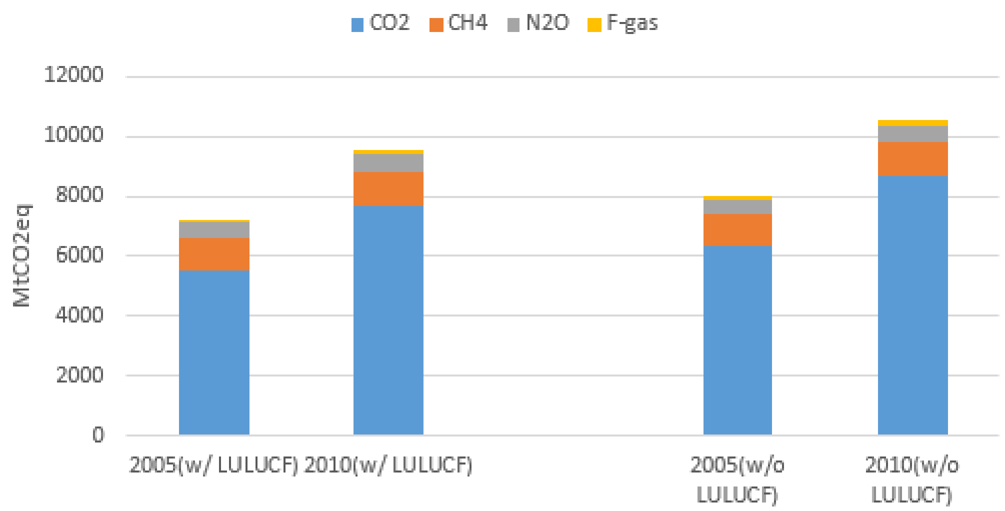

Figure 2-6 2005-2010 GHG Emissions by Gas

The growth of China's GHG emissions between 2005 and 2010 was mainly due to the rapid increase of CO_2 emissions from energy-related activities which increased by 34.6% during the period. The CO_2 emissions increase was mainly driven by the sustained growth of fossil fuel consumption. During these five years, the consumptions of coal, petroleum and natural gas were increased by 43.4%, 35.5% and 131.8% respectively.

At the same period, energy structure optimization and energy efficiency improvement partially offset the emission growth. The CO_2 emissions per unit of GDP was reduced by 20% from 2005 to 2010 (without LULUCF).

Chapter 5 Trends of Future CO_2 Emissions

5.1 Scope and Information Source

China's future CO_2 emissions under scenarios cover the carbon emissions from energy-related activities, the carbon emissions from the industrial processes of major industries, and the CO_2 emissions that can be absorbed during forest growth; they are estimated as follows:

Total CO_2 emissions = carbon emissions from energy-related activities + carbon emissions from the industrial processes of major industries - increase in carbon sinks from forest growth.

The information on future carbon emissions from energy-related activities are mainly from the Energy Production and Consumption Revolution Strategy (2016–2030) issued by the NDRC and the National Energy Administration, and the results of modelling and scenario analysis by such institutions as Tsinghua University, the ERI, the State Grid Energy Research Institute, CNPC Economics & Technology Research Institute, SINOPEC Economic & Development Research Institute and the International Energy Agency (IEA). The models include top-down computable general equilibrium energy economy models, bottom-up energy system optimization models and sector analysis models.

China's major industrial processes emitting CO_2 are the production processes of cement, lime, iron and steel, and calcium carbide. In light of the activity data and carbon emissions factors of industries in the future, the CO_2 emissions from their industrial processes are estimated. The future activity data is mainly from the results of the research by Tsinghua University, the Energy Research Institute of National Development & Reform Commission, and the State Information Center; the data of future carbon emissions factors are mainly from the joint research by Tsinghua University and relevant industry associations.

With respect to the increases in carbon sinks from future forest growth, based on the data from China's seventh and eighth forest resources survey, regression growth equations of stock volume per unit of area and age are established, the IPCC's volume-derived biomass method is adopted, the data of the areas of the dominant tree species at various age level in different provinces and regions are used to estimate the carbon sink potentials of high forest of the country, and those by region and by source, and the total net increase in sinks of the country between

2010 and 2030. The data on the future increase in carbon sinks from forest growth are mainly based on the results of the research of Beijing Forestry University.

5.2 Scenario Assumptions

As a developing country, even China's annual GDP growth maintains at around 5-7% before 2030, its GDP per capita may still be lower than USD 15,000 by 2030, while corresponding energy consumption and CO_2 emissions may continue to grow. Besides economic growth rate, the main factors influencing future energy consumption and CO_2 emissions are as following:

Industrial structure: China is currently in the post-industrialization period, and the energy consumption of the secondary industry still takes up a relatively large proportion. The proportion of the energy consumption of the six major high energy-consuming industries, namely, steel, nonferrous metals, building materials, petrochemical, chemical and electric power, in total industrial energy consumption has always been higher than 70%. By 2030, by transforming and upgrading the industrial structure and inhibiting excessive growth of high energy-consuming industries, the industrial structure will be constantly optimized and adjusted, the proportion of China's tertiary industry will be improved and that of the secondary industry will be reduced accordingly.

Population growth and household consumption: From 2000 to 2015, the annual average growth of China's population was over 7 million, while the urbanization level increased by 1.3 pps per year on average. By 2030, China will be in the rapid development stage of urbanization, and China's population will continue to grow slowly. With the growth of population, the increase of urbanization level and the improvement of residents' living standards, China's future household energy consumption per capita and total household energy consumption will continue to increase.

Energy consumption structure: From 2000 to 2015, the proportion of coal in total energy consumption continued to decrease, while that of non-fossil energy increased steadily. By 2030, China will vigorously develop new energy and renewable energy, striving to increase the proportion of non-fossil energy in primary energy consumption to 15% by 2020, and continue to improve the energy consumption structure on that basis.

Technological level: From 2000 to 2015, even though China's energy consumption per unit of GDP decreased significantly, the energy consumption per unit of product of high energy-consuming products was, on the whole, higher than the international advanced level. By 2030, by encouraging participants to increase R&D investment and enhance technical innovation, focusing on the energy conservation work in major areas such as industry, construction, transportation and public institutions and continuing to promote advanced energy conservation technologies and products and other measures, China will vigorously promote energy conservation and emissions reduction.

According to the Energy Production and Consumption Revolution Strategy (2016–2030) issued by the NDRC and the National Energy Administration, and the results of the research by such institutions as Tsinghua University, ERI, the State Information Center, the State Grid Energy Research Institute, CNPC Economics & Technology Research Institute, and SINOPEC Economic & Development Research Institute, three scenarios for China's future carbon emissions from energy-related activities are proposed in this report, which are reference scenario, policy scenario I and policy scenario II.

Reference scenario: Considering economic policies promoting economic transformation and upgrading, spontaneous improvement in energy efficiency, and no strict control and restraint on future carbon emissions, the future carbon intensity will decrease by about 3% annually. Assuming that China's total population will be around 1.45 billion in 2030. The annual GDP growth rate between 2015 and 2020 will be around 6.5%, decrease to about 6% between 2020 and 2025, and further decrease to around 5% between 2025 and 2030; the proportion of the tertiary industry will reach around 55% in 2020, and exceeds 60% in 2030; the emission factor per unit of industrial processes of cement, lime, crude steel and calcium carbide will decrease slightly, and the existing measures, such as shutting down of outdated facilities, reducing of excess inventory and cutting of overcapacity, will be continued. For carbon sinks, the forest area and forest management measures in the 8th forest resource inventory are adopted as the baseline scenario.

Policy scenario I: Considering economic policies promoting economic transformation and upgrading, strict control and restraint on future carbon emissions, the future carbon intensity will decrease by about 4% to 5% annually. The population assumptions are the same as those for the reference scenario. Specific policies and measures in energy field include a higher promotion proportion of low carbon technologies, strict energy conservation standard, active encouragement policies for renewable energy and natural gas, introduction of national carbon emissions trading system, etc. For the industrial processes emissions, as the room for changes of chemical components of raw materials is relatively small, the assumptions on the carbon emission factor per unit of product from the industrial production process of cement, lime, crude steel, calcium carbide, etc. are the same as that in the reference scenario, and strict measures to close down backward production facilities are considered. For carbon sinks, considerations include barren hills and wasteland suitable for afforestation in China are afforested, low efficiency forest and secondary forest are transformed and forest policies such as forest management and carbon sink increasing measures are improved.

Policy scenario II: Considering economic policies promoting economic transformation and upgrading, strict control and restraint on future carbon emissions, the future carbon intensity will decrease by about 5% to 6% annually. The population assumptions are the same as those for the reference scenario. With respect to categories, the policies and measures in the field of energy under the policy scenario II are basically the same as those under the policy scenario I, but the implementation of policies is strengthened significantly. The assumptions on the carbon emission factor per unit of product from the industrial production process of cement, lime, crude steel, calcium carbide, etc. remain unchanged, but stricter measures of closing down backward production facilities, reducing capacity and restricting capacity expansion are considered to adopt. For carbon sinks, considering the restrictions of the area of barren hills and wasteland suitable for afforestation in China and tree growth characteristics, on the basis of the policy scenario I, forest area is slightly increased and forest management measures are improved.

5.3 Energy Consumption and Carbon Emissions in Different Scenarios

Under the reference scenario, by 2020, the total energy consumption in China will increase to about 4.8 to 5.2 billion tons, while China’s CO_2 emissions from energy-related activities will increase continuously to around 10.6 to 10.9 billion tons; the CO_2 emissions from the industrial processes of cement, lime, crude steel and calcium carbide will be about 1 to 1.11 billion tons, the net carbon sinks from forest growth will be 0.5 to 0.55 billion tons; considering the three parts, the total CO_2 emissions will be 11.1 to 11.5 billion tons. By 2030, the total energy consumption in China will be about 5.8 to 6.3 billion tons, while China's CO_2 emissions from energy-related activities will increase continuously to around 12 to 12.9 billion tons; the CO_2 emissions from the industrial processes of cement, lime, crude steel and calcium carbide will be about 0.7 to 0.78 billion tons, the net carbon sinks from forest growth will be 0.39 to 0.43 billion tons; considering the three parts, the total CO_2 emissions will be 1.23 to 1.33 billion tons.

Under the policy scenario I, by 2020, the total energy consumption in China will be about 4.7 to 5.1 billion tons, while China's CO_2 emissions from energy-related activities will be around 9.8 to 10.5 billion tons; the CO_2 emissions from the industrial processes of cement, lime, crude steel and calcium carbide will be about 0.97 to 1.07 billion tons, the net carbon sinks from forest growth will be 0.54 to 0.6 billion tons; considering the three parts, the total CO_2 emissions will be 10.2 to 11 billion tons. By 2030, the total energy consumption in China will increase to about 5.6 to 6.2 billion tons, while China's CO_2 emissions from energy-related activities will be around 10.5 to 11.5 billion tons; the CO_2 emissions from the industrial processes of cement, lime, crude steel and calcium carbide will be about 0.69 to 0.77 billion tons, the net carbon sinks from forest growth will be 0.47 to 0.52 billion tons; considering the three parts, the total CO_2 emissions will be 10.7 to 11.7 billion tons.

Under the policy scenario II, by 2020, the total energy consumption in China will be about 4.6 to 5 billion tons, while China's CO_2 emissions from energy-related activities will be around 9.6 to 10 billion tons; the CO_2 emissions from the industrial processes of cement, lime, crude steel and calcium carbide will be about 0.93 to 1.03 billion tons, the net carbon sinks from forest growth will be 0.54 to 0.6 billion tons; considering the three parts, the total CO_2 emissions will be 10 to 10.4 billion tons. By 2030, the total energy consumption in China will increase to about 5.5 to 6 billion tons, while China's CO_2 emissions from energy-related activities will be around 9.8 to 10.6 billion tons; the CO_2 emissions from the industrial processes of cement, lime, crude steel and calcium carbide will be about 0.68 to 0.75 billion tons, the net carbon sinks from forest growth will be 0.47 to 0.52 billion tons; considering the three parts, the total CO_2 emissions will be around 10 to 10.8 billion tons.

Figure 2-7 shows the future trends of China's CO_2 emissions from energy-related activities under three scenarios.

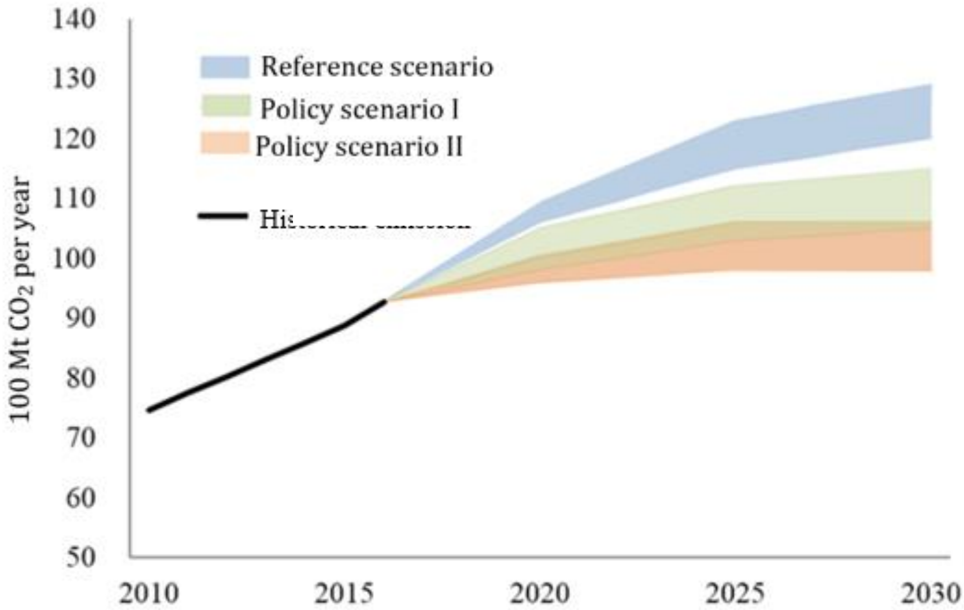

Figure 2-7 2010-2030 Changes in Total CO_2 Emissions under Three Scenarios

5.4 Uncertainty Analysis

China has adopted and will continue to adopt strong policies and measures to strive to achieve the GHG emissions control targets including reducing CO_2 emissions per unit of GDP by 2020, developing non-fossil energy and peaking CO_2 emissions by around 2030. However, according to the available results of the scenario research in CO_2 emissions, there are great uncertainties in China's future CO_2 emissions.

Scenario analysis is a qualitative or quantitative description of various environmental, social and economic conditions in the future, but not a forecast or prediction of the future. Many domestic or foreign research institutions have researched on the future energy and CO_2 emissions scenarios; the results indicate that, due to the rapid economic development of China, the uncertainties in China's future energy and CO_2 emissions are still higher than those in developed countries.

The uncertainties in China's future CO_2 emissions mainly involve three aspects, uncertainties in socio-economic development, uncertainties in technologies and uncertainties in policies. Much of the uncertainty for the future CO_2 emissions derived from future economic growth rate. If the annual average growth of GDP from 2015 to 2030 increases or decreases by one pps, the corresponding total CO_2 emissions in 2020 will probably increase or decrease by around 5% accordingly and that in 2030 by more than 10%. Secondly, there are uncertainties in technologies. Technologies, in particular, some key low carbon technologies, are one of the decisive factors behind the future energy landscape. If great breakthroughs can be made in the key technologies supporting the development of energy conservation, distributed energy and smart power grid, and their costs can be reduced significantly, efficient and renewable energy will account for a significantly greater proportion in the whole energy system, thus the carbon emissions from energy-related activities can be reduced significantly. The last factor is uncertainties in policies; the changes in renewable energy, fiscal, taxation and financial policy, and international trading policies all have a considerable impact on China's total CO_2 emissions. Besides, the scenario results of CO_2 emissions vary among different models and methodologies.

Part III Impacts of Climate Change and Adaptation

Climate change has exerted and will continue to exert major influence on China's natural environment, society and economy. Attaching great importance to climate change adaptation, the Chinese government has developed the *National Climate Change Adaptation Strategy*, issued sectoral climate change adaptation policies and taken effective actions to strengthen its capacity to adapt to climate change.

Chapter 1 Characteristics and Trends of Climate Change

Over the past century, China's climate has changed significantly. Trends can be discerned in air temperature, precipitation, sunshine, wind speed and extreme climate events.

1.1 Characteristics of Climate Change

1.1.1 Air Temperature

In the last hundred years, China's annual mean surface air temperature has increased by 1.15°C (Figure 3-1) with an increasing rate of 0.10°C/decade, close to the global average increasing rate for terrestrial land areas. Since the early 1950's, an increasing trend in China's annual mean air temperature rise has become more obvious. During 1951-2016, the increasing rate in average air temperature has reached 0.23°C/decade. However, excluding the effects of urbanization, China's climate warming was close to the global average rate in the last half century.

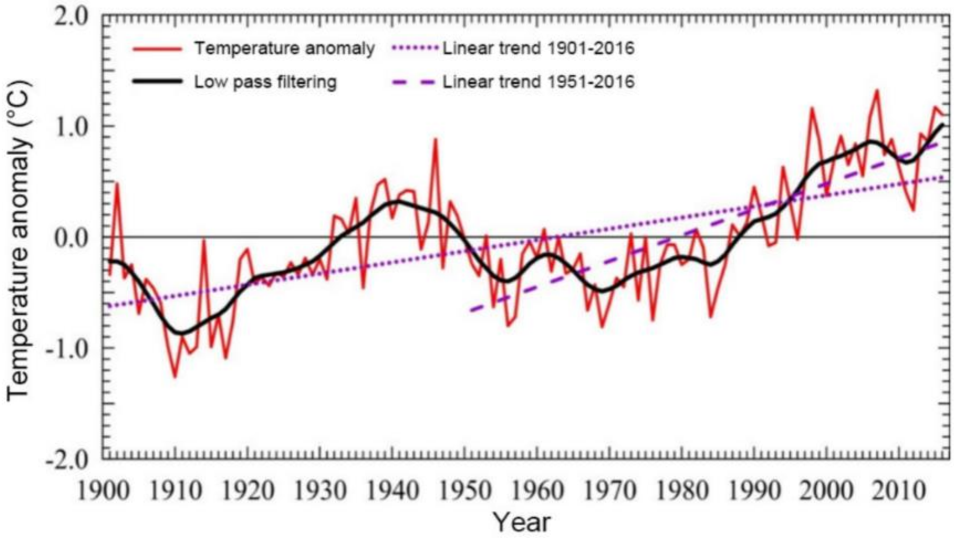

Figure 3-1 Variation in Annual Mean Surface Air Temperature in China during 1901-2016[1]

Since the middle of the 20th Century, there have been regional differences in climate warming in China. Warming has been most obvious in Northeast China, the northern North China, Northwest China and the Tibetan Plateau, and weaker in Southwest China, the Sichuan Basin, the Qinling-Bashan Mountains and the southern North China Plain (Figure 3-2).

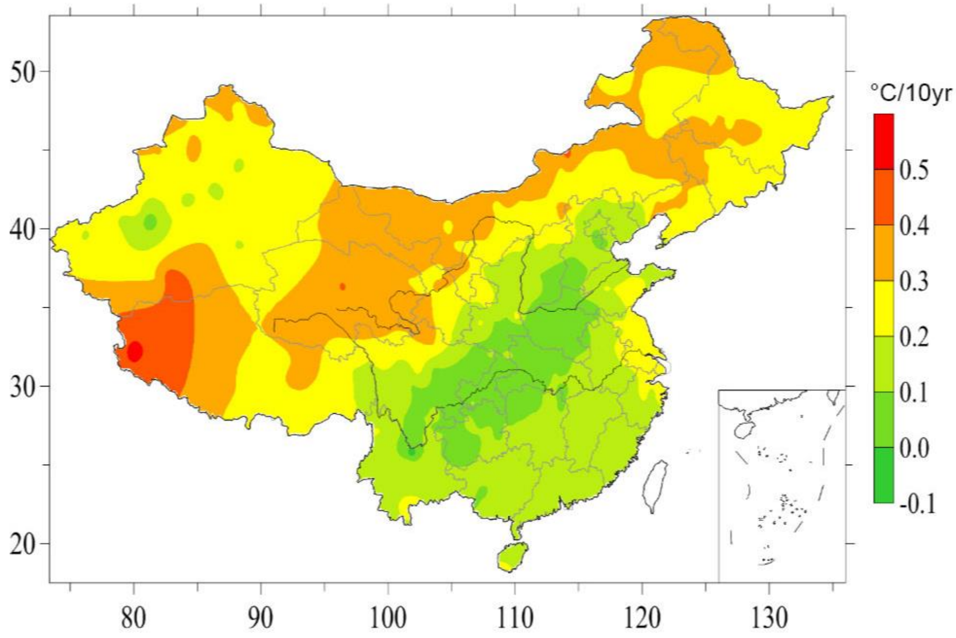

Figure 3-2 Variation in Decadal Mean Surface Air Temperature Trends during 1961-2016

As the pace of global warming has slowed down, China's annual rate of increase in mean air temperature in recent period (1998-2016) has also fallen down. However,

[1] Temperature anomaly is the difference relative to the average level of 1971- 2000.

the seasonal mean air temperature in summer has mainly kept rising, and in the Tibetan Plateau the mean air temperature trend shows no sign of decreasing. The slowing in climate warming may largely be due to multi-decadal scale natural variability within the climate system.

1.1.2 Precipitation

Since the middle of the 20th Century, there has been some increase in annual precipitation in China. Change in precipitation has varied by regions. Northwest China has seen a significant increase. The eastern Tibetan Plateau, northern Northeast China, the Yangtze-Huaihe area, regions south of the Yangtze River and Southern China have seen a slight increase, while North China, southern Northeast China and Southwest China have experienced obvious decreases in precipitation (Figure 3-3). Since the beginning of the 21st century, the area with a decrease in precipitation has tended to shift from North China to Central and Southwest China. During the last 10 or more years, there has been a significant decrease in precipitation in Southwest China.

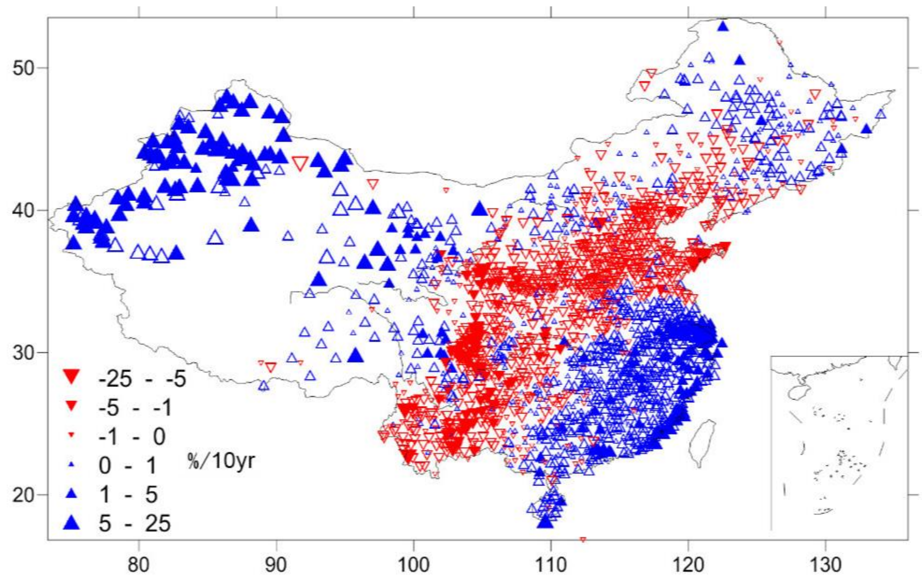

Figure 3-3 Variation in Annual Precipitation Trends in China during 1961-2016

Precipitation trends in China have clear seasonal characteristics. Since 1961, precipitation has increased significantly in winter and decreased in autumn. In summer, there has been flooding in the south contemporaneous with drought in the north. The main cause of long-term change in precipitation in China may be related to natural variation on a multi-decadal scale.

1.1.3 Other Climate Factors

Since the middle of the 20th Century, daily sunshine hours (Figure 3-4) and solar radiation in China have significantly decreased, particularly in North China and the middle and lower reaches of Yangtze River. The decreasing trend was especially obvious before the early 1990s, since when daily sunshine hours has been stable at a lower level. The reduction in sunshine hours or solar radiation is mainly related to the effects of various pollutants emitted from human activities.

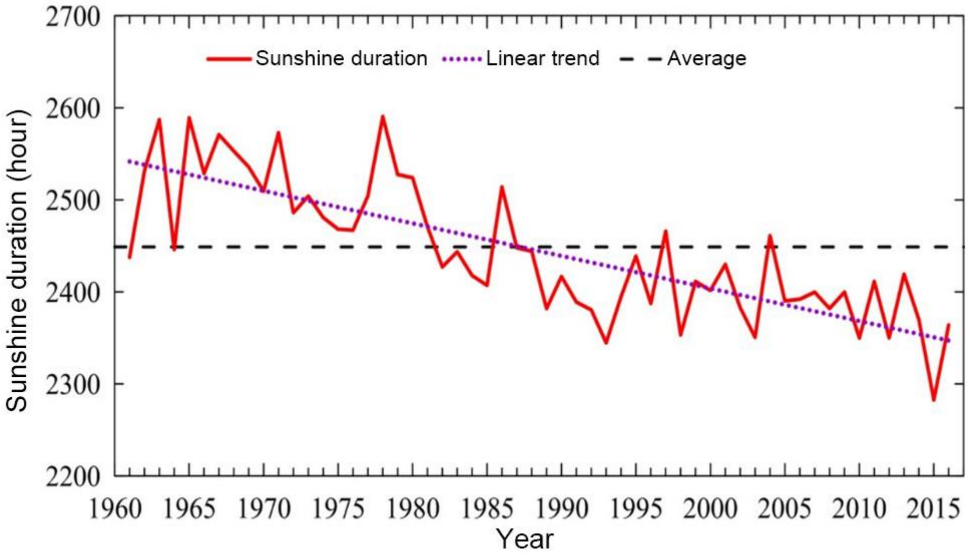

Figure 3-4 Trend in Annual Sunshine Hours during 1961-2016[1]

Since the middle of the 20th Century, annual and seasonal mean near-surface wind speed in China has significantly decreased, especially between the early 1970s and the end of the 20th Century. Since the beginning of the 21st Century, the decreasing trend has weakened, but wind speed remains at a low level. The decrease in near-surface wind speed has been rather obvious in the east. The main reason for the decrease in near-surface wind speed has been urbanization and the changes in the observation environment around the meteorological stations, and cannot be attributed solely to global climate warming.

1.2 Change in Extreme Climate Events

1.2.1 Extremely Cold and Hot Events

Since the middle of the 20th Century, the characteristics of change in extreme events have been basically consistent with global trends, with a significant

[1] Source: *China's Climate Change Monitoring Bulletin 2016*.

decrease in the frequency of extreme cold events and a clear increase in the frequency of extreme hot events. In general, there has been an increase in high temperature and heatwave events in the east, especially in the Southeast and North China. Long-term variation in the frequency of extreme temperature events and record-breaking temperature events (especially those related to daily minimum air temperature) has been consistent with the spatial pattern of annual mean climate warming trends, which has been relatively more obvious in the north.

1.2.2 Extreme Rainfall Events

Since the middle of the 20th Century, there has been a clear increase in annual rainstorm days, extreme intense rainfall days and the amount of precipitation. There have been increases to varying degrees in the maximum rainfall in one day, three consecutive days and five consecutive days, with the most obvious increase in maximum precipitation in one day (Figure 3-5). It is worth noting that since 2010, maximum rainfall in one day, three consecutive days and five consecutive days have exceeded the average level by about 10% and are at their highest level in the past 60 years.

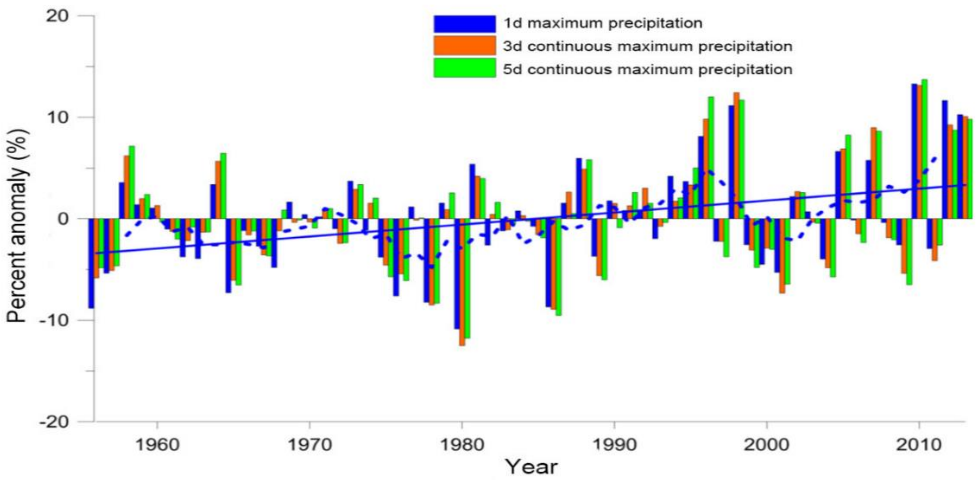

Figure 3-5 Trends in Anomalies of Maximum Precipitation of in one day, 3 Consecutive Days and 5 Consecutive days in China during 1956-2016

Note: The blue dotted line shows the three-year moving average of maximum precipitation in one day. The blue solid line shows the linear trend in maximum precipitation in one day.

Since the middle of the 20th century, the west of Northeast China, North China and the Sichuan Basin have experienced fewer annual rainstorm days, but the middle and lower reaches of the Yangtze River and South China have experienced more annual rainstorm days. The variation in rainstorm days mainly reflects the situation of summer. In winter, there has also been some level of increase in heavy snowfall events in some regions, such as Northeast China and Northwest China.

1.2.3 Meteorological Drought

Since the middle of the 20th Century, there has been little variation in the occurrence of regional meteorological drought events in China, which in general have slightly increased but not significantly (Figure 3-6). The frequency and spatial extent of meteorological drought has decreased in Northwest China for the same period, and decreases have begun in North China and southern Northeast China over the last decade. However, drought has begun to emerge as a problem in Southwest China in recent years.

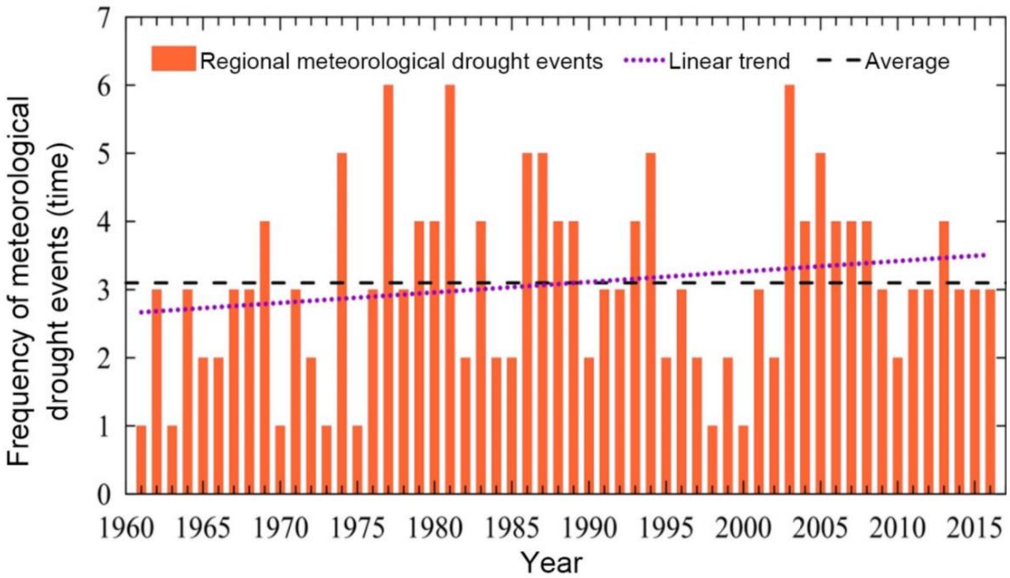

Figure 3-6 Trends in the Frequency of Regional Meteorological Drought Events during 1961-2016[1]

1.2.4 Tropical Cyclones/Typhoons

Since the middle of the 20th Century, the number of tropical cyclones and typhoons originating in the northwest Pacific Ocean shows a decreasing trend (Figure 3-7), which is mainly related to the variation in the ocean surface temperature in the tropical Pacific sea on a decadal scale. In the same period, the accumulated precipitation resulting from tropical cyclone landings in mainland China has also been decreasing.

[1] Source: *China's Climate Change Monitoring Bulletin 2016*.

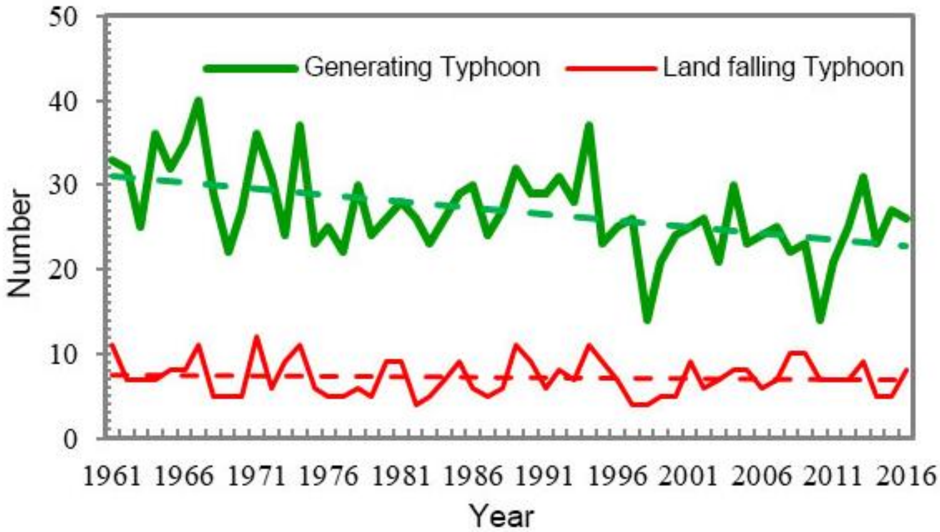

Figure 3-7 Number of Tropical Cyclones (typhoons) Generated in the Northwest Pacific Region and Landing in China during 1961-2016

1.2.5 Strong Winds and Dust Storms

Since the middle of the 20th Century, especially since the early 1970s, the frequencies of dust storms and strong dust storms in Northern China have significantly decreased. During 1999 to 2012, when Northern China experienced a drought anomaly, dust storm events increased, but did not become as frequent as during the 1960s and 1970s. The decrease in dust storms in Northern China was mainly related to significantly decreases in average near-surface wind speed and the number of strong wind days, as well as a general increase in precipitation in dust storm source areas (e.g. Northwest China, central and western Inner Mongolia). The decreases in average wind speed and the frequency of strong wind days were largely due to urbanization near meteorological stations, but also partly due to changes in large-scale atmospheric circulation. The construction of the Three-North Shelterbelt Programme and ecological restoration programmes also reduced local wind speeds to some extent.

1 Source: *China's Climate Change Monitoring Bulletin 2016*.

2 The data are from Jiang J., et al. , 2015, *Projected climate change against natural internal variability over China*, Atmos. Oceanic Sci. Lett., 8, 193–200.

1.3 Future Climate Change

1.3.1 Air Temperature and Precipitation

Under different representative GHG concentration scenarios (RCP scenarios), the results of several global climate model simulations suggest that China's annual mean air temperature in different future periods will continue to increase (Figure 3-8). Between 2011 and 2100, under low, medium and high GHG concentration scenarios, respectively, China's annual mean surface air temperature increase will be 0.08°C/decade, 0.26°C/decade and 0.61°C/decade. Compared to the period between 1986 and 2005, by the end of the 21st Century (i.e., the average between 2081 and 2100), under the high concentration scenario, China's annual mean air temperature might increase by about 5.0°C, while under low and medium concentration scenarios, it may increase by 1.3°C and 2.6°C, respectively.

Different concentration scenarios suggest that annual mean air temperatures in all regions of China will increase, but with regional characteristics in the rates of increase. In general, the rate of projected increase grows larger from the southeast to the northwest, and is larger in the north than in the south. Clear increases in temperature are projected for the Tibetan Plateau, northern Xinjiang and some areas in the northeast (Figure 3-8).

Under different concentration scenarios, China's annual precipitation will continue to increase (Table 3-1). Between 2011 and 2100, under low, medium and high concentration scenarios, projected precipitation increases are 0.6%/decade, 1.1%/decade and 1.6%/decade, respectively, suggesting a rate of increase above the global average level. Under low and high concentration scenarios, by 2100 precipitation might increase by about 5% and 14%, respectively, compared with 1986-2005. In terms of the spatial distribution of precipitation variation, most areas will experience increases in precipitation in each future period, with greater increases in the Northwest, North and Northeast of China.

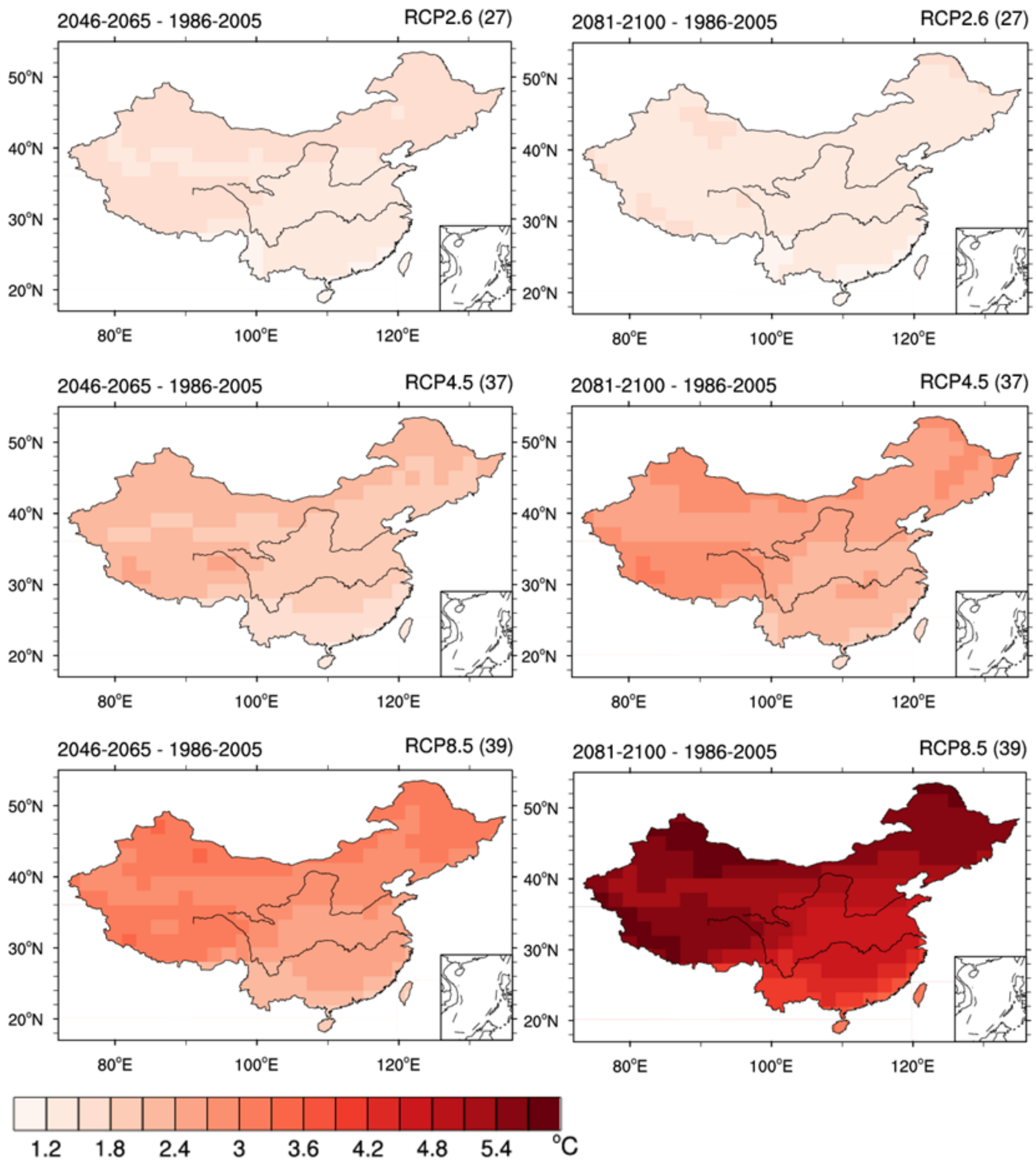

Figure 3-8 Change in Annual Average Air Temperature in China

Note: Change in annual average air temperature in 2046-2065 (left) and 2081-2100 (right) compared with 1986-2005; RCP2.6, RCP4.5 and RCP8.5 indicate low, medium and high GHG concentration scenarios, and Figures in parentheses show the number of global climate models in each combined projection[2]

[2] The data are from Jiang J., et al. , 2015, *Projected climate change against natural internal variability over China*, Atmos. Oceanic Sci. Lett., 8, 193–200.

Table 3-1 Projected Changes (compared with the period 1986-2005) in Future Precipitation in China[1]

GHG concentration scenario	Decade		
	2040	2070	2100
Low	1.0%	3.0%	5.0%
Medium	2.0%	5.0%	8.0%
High	2.5%	7.5%	14.0%

1.3.2 Extreme Climate Events

According to global and regional climate models, under different future concentration scenarios, there may be clear variation in extreme temperature events in China, with increases in high temperature events, decreases in low temperature events, and increases in the frequency and strength of extreme heavy precipitation events in most regions.

1.3.3 Uncertainty of Climate Projections

There are still some deficiencies in the reproduction of real climate characteristics and trends using global climate models, and there is a need to increase the simulation capabilities of current climate models. Therefore, there is some uncertainty when projecting future climate change trends using global climate models. The reliability of global climate models is lower when applied to small regions and to the near future, or when used to project trends in extreme climate events, and further research is required.

Chapter 2 Climate Change Impacts and Vulnerability Assessment

Climate change has had and continues to have significant impacts on China's ecological environment, society and economy. Moreover, most impacts to date have been negative. Future climate change is expected to have broad impacts in China, with agriculture, water resources, ecosystems, coastal and offshore ecosystems, and human health being particularly vulnerable.

[1] Data source: *Third National Climate Change Assessment Report*.

2.1 Climate Change Impacts on Agriculture and Vulnerability

Climate change has significantly impacted cropping systems in China, as well as the occurrence, development and damage caused by disease and pests, and the growth, development and yield of crops.

2.1.1 Evidence of Climate Change Impacts in Agriculture

1) Impacts of climate change in agricultural climate resources and cropping systems

There have been significant changes in China's agricultural climate resources. Compared with 1961-1980, the average temperature in China during 1981-2007 increased by 0.6°C. Cumulative temperature greater than or equal to 0°C and 10°C have increased by 123 and 126 degree-day, respectively. Compared with the 2000s and the 1960s, average temperatures during the growing periods for wheat, maize and rice have increased by 1.1°C, 0.8°C and 0.8°C, respectively, and sunshine hours have decreased by 84.2, 97.4 and 115.7 hours, respectively.

China's agricultural heat resources have increased and the northern limits of cropping systems have shifted northward. The northern limits of rice in Northeast China, of winter wheat in North and Northwest China, and of maize in northeast China and Northwest China have shifted northward. The northern limits of multiple cropping have shifted towards higher latitude and higher elevation areas. Compared with the period 1950s-1980, during 1981-2007, the northern limits of double cropping and triple cropping systems significantly shifted northwards, and the northern limits of winter wheat and double rice cropping systems shifted northward and westward (Figure 3-9). The area suitable for single rice cropping decreased by 11%, while the areas suitable for early rice, mid-season rice and late rice in the triple rice cropping system increased by 3%, 8% and 10%, respectively.

2) Impacts of climate change on agricultural disease and pests

Harm caused by disease and insect pests has been increasing and prevention and control have become more difficult. Climate warming has increased the annual number of reproductive generations of major crops diseases and insects, shifted the northern limits of diseases and insect pests northward and upwards into higher elevation areas, and increased the spatial area affected by crop pests and diseases. During 1961-2010, the area affected by crop diseases nationwide increased from 15 million ha to 124 million ha, and the area affected by insect pests increased from 43 million ha to 246 million ha. Linear fitting of temperature and sunshine hours to area affected by disease and insect pests shows that when the average growing period temperature increases by 1°C, the areas of wheat, maize and rice affected by disease and pests increases by 28.5 million, 17.6 million and 59.4 million ha, respectively. When sunshine hours decrease by 100 hours, the areas of wheat, maize and rice affected by disease and insect pests in China increases by 27.5 million, 14.3 million and 53.4 million ha, respectively.

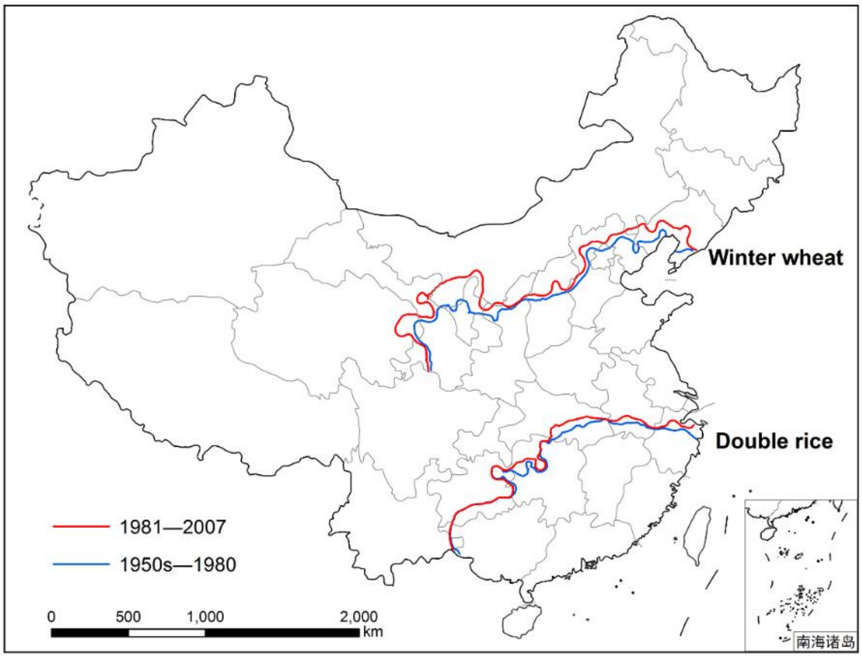

Figure 3-9 Changes in the Northern Boundaries of Winter Wheat and Double Rice Cropping Systems in the Past 50 years[1]

3) Impacts of climate change on crop yields

The impacts of climate change on China's major food crops vary by crop types and region. Climate change has had negative impacts on wheat, maize and double-season rice, but positive impacts on single-season rice. During 1961-2010, increases in average temperature during the crop growing period reduced winter wheat, maize and double-season rice yields by 5.5%, 3.4% and 1.9%, respectively, but increased single-rice yield by 11%. Climate change has had positive impacts on agricultural production in cold and cool climate regions. In the past 30 years, rice and maize yields in Northeast China have increased significantly. Climate

[1] Source: YANG Xiaoguang, LIU Zhijuan, CHEN Fu. 2010. *The Possible Effects of Global Warming on Cropping Systems in China I. The Possible Effects of Climate Warming on Northern Limits of Cropping Systems and Crop Yields in China*, Scientia Agricultura Sinica 2010, 43(2):329-336.

change has had negative impacts on agricultural production in regions vulnerable to droughts. Decreasing solar radiation is another factor that significantly impacts crops yields. During 1981-2009, decreases in solar radiation caused yields in the rice-wheat rotation system to decrease by 1.5%-8.7%.

4) Vulnerabilities to climate change in agricultural production

Agricultural production in China is relatively sensitive and vulnerable to climate change. In China's main grain producing regions, more than 50% of land is cultivated to at least one crop type that has experienced a decrease in yield. In the Loess Plateau, central Northeast China, southern parts of Southwest China and some areas of Yangtze River basin, yield reduction trends have been observed in at least two crop types. The arable land area that has experienced a decrease in yield accounts for 18.7% of all arable land area. The Loess Plateau is the most vulnerable to climate change, with yield reduction observed for one crop type on 90% of arable land area, and for two crop types on 55% of the arable land areas (Figure 3-10).

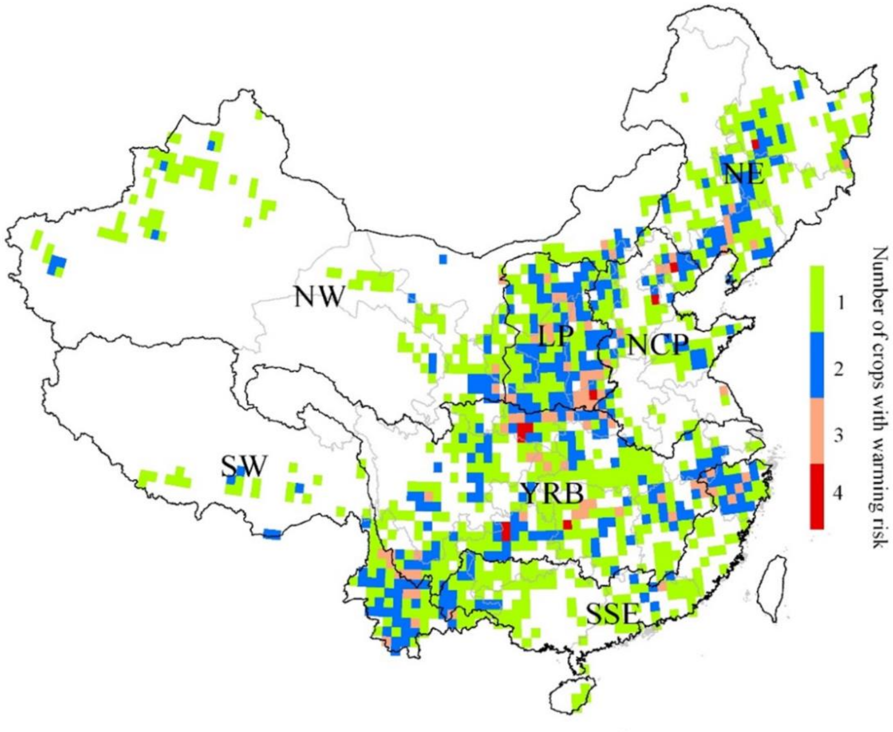

Figure 3-10 Distribution of Agriculturally Vulnerable Areas[1]

Note: NE: Northeast China; NW: Northwest China; NCP: North China Plain; LP: Loess Plateau; YRB: Yangtze River Basin; SW: Southwest China; SSE: southern and eastern China.

[1] From Xiong, W., Holman, I.P., etc. (2013) *Impacts of observed growing-season warming trends since 1980 on crop yields in China*. Regional Environmental Change 14, 7-16.

2.1.2 Impacts of and Vulnerabilities of Agriculture to Future Climate Change

1) Impacts of future climate change on crop growing periods and cropping systems

Future climate change will further shorten crop growing periods. If temperature increases by 1°C, 2°C and 3°C, the maize growing period in China will shorten by 4.3%-13.0%, 10.8%-22.5% and 12.3%-30.3%, respectively, and the wheat growing period will shorten by 3.9%, 6.9% and 9.7%. If temperature increases by 1°C, the growing period of rice will shorten by 4.1-4.4 days. Climate warming will cause the limits of multiple cropping systems to continue to expand toward areas of higher latitude and higher elevation. In the medium GHG emissions scenarios[1], compared with 1950-1980, the limits of double cropping and triple cropping systems will move northward to different extents by 2011-2040 and 2041-2050.

2) Impacts of future climate change on crop disease and pests

Future climate warming will increase the frequency, affected area and damage caused by most types of disease and insect pests in China. According to projections, pest insects will migrate northward in spring earlier and southward later, and reach a larger spatial extent. Occurrence of pests will be more frequent. This situation will benefit overwintering and propagation of crop pathogens, expand the spatial extent of diseases, and increase crop damage in temperate and cool regions that were formerly less affected by diseases. At the same time, the risks of outbreak of diseases and pests that favour warmth and are sensitive to low temperatures will increase. Under future climate change scenarios, the limits to safe overwintering for crop pests will move northward by 1-3.5 degrees of latitudes, and the number of reproductive generations will increase by 1-2 generations.

3) Impacts of future climate change on crop yields

The impacts of temperature increase by 1.5°C and 2.0°C on maize, wheat and rice yields have been estimated by integrating four global climate models and crop models. When the CO_2 fertilization effect is not considered, compared with 2006-2015, under temperature increases of 1.5°C and 2.0°C, China's maize yield would decrease by 0.1% and 2.6%, respectively (Figure 3-11). If temperature increased by 1.5°C, wheat and rice yield would increase by 1.2% and 0.7% respectively.

[1] Special report on IPCC emission scenarios, A1B scenario.

However, if temperature increases by 2.0°C, wheat and rice will experience adverse impacts and yields will decrease by 0.9% and 2.4%, respectively. When the CO_2 fertilization effect is considered, compared with 2005-2015, a temperature increase of 1.5°C would increase maize, wheat and rice yield by 0.2%, 8.6% and 9.4%, respectively, while a temperature increase of 2.0°C would decrease maize yield by 1.7%, and increase wheat and rice yields by 3.9% and 4.1%, respectively.

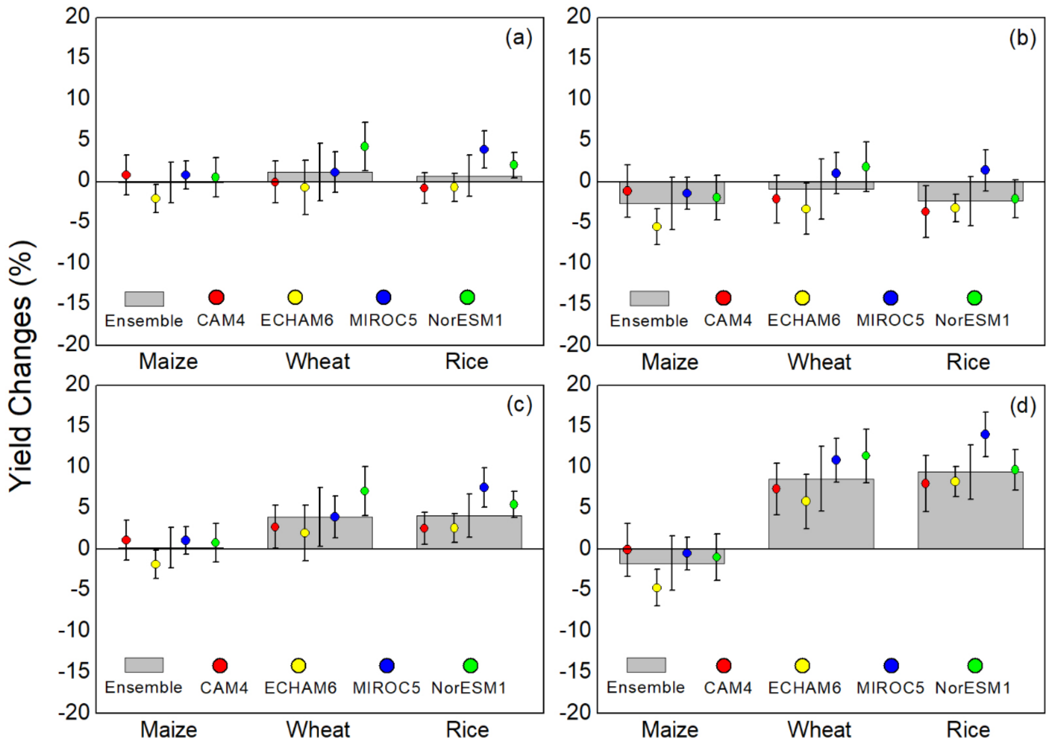

Figure 3-11 Effects of 1.5°C and 2°C Temperature Increases on China's Crop Yield Compared with 2006-2015[1]

Note: Temperature increases by 1.5°C (a, c); Temperature increases by 2°C (b, d); Not considering CO_2 fertilization effect (a, b); Considering CO_2 fertilization effect (c, d); Error bars represent standard errors.

2.2 Climate Change Impacts on Water Resources and Vulnerability

2.2.1 Evidence of Climate Change Impacts on Water Resources

The observed runoff of China's major rivers has changed significantly. Compared with observed runoff before the 1980s, in the past 30 years, runoff in rivers in southern China has changed little, while runoff reductions have been observed in

[1] Yi Chen, etc., 2018. *Impacts of climate change and climate extremes on major crops productivity in China at a global warming of 1.5 and 2.0 ℃*. Earth Syst. Dynam., 9, 543–562.

all stations of rivers in northern China (e.g. Yellow River, Haihe River and Liao River). The Haihe River basin has seen the most prominent reductions in runoff, with observed runoff reduced by 40%-80%. Observed runoff in the Yellow River and Liao River basins has decreased by more than 30% since 1980 (Figure 3-12). Human activities are the main reasons for decreasing runoff in northern China's rivers. Human activities accounted for 60%, 85% and 82% of runoff reductions in the Yellow River basin, Haihe River and Liao River, respectively, while climate change accounted for 40%, 15% and 18% of reduced runoff in each of these river basins.

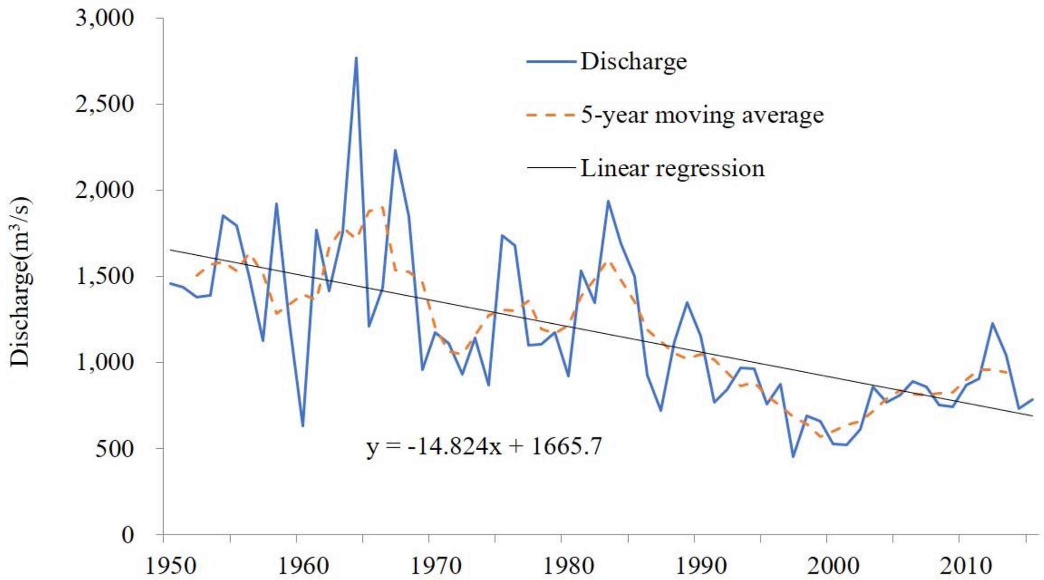

Figure 3-12 Changes in Measured Flow at Huayuankou Station on the Yellow River

Snow cover and glaciers have been significantly impacted by global warming. Glacial retreat in China has been prominent. Since the 1960s, about 82% of glaciers in China have been in a state of retreat or disappeared. Only 18% of glaciers have been advancing or remaining stable. The biggest proportion of glacial retreat is due to glaciers on the edge of the Qinghai-Tibetan Plateau. For example, during 1966-1997, the terminus of Rongbuk Glacier at Mount Everest in the central Himalayas retreated by 5-8 meters each year, accelerated to 7-9 meters each year since 1997. During 2003-2012, there has been a significant seasonal change in snow cover in the Qinghai-Tibetan Plateau, where there are clear snow cover and snow melt season, with a slight decrease in the area of snow cover in the last 10 years.

2.2.2 Evidence of Climate Change Impacts on Floods and Droughts

There has been an upward trend in damage caused by regional floods in China.

Rainstorms and floods were most frequent during the 1930s, 1950s, 1960s and 1990s, and less frequent in the 1940s and 1970s. However, no monotonic increasing or decreasing trends in decadal variation have been identified. During the last 50 years, the overall trend of rainstorms and floods in northern China has been downward, while in southern and western China it has been upward. Since 2000, however, flood disasters in urban areas have become prominent. The probability of basin-wide floods in the Huai River basin has increased. During 1981-2015, the frequency of extreme flood in 23 typical sections of the Pearl River basin increased significantly. In particular, since 1990, the frequency of floods with return periods longer than 10 years has increased significantly.

An increasing trend in the frequency of droughts. During the last 50 years, there has been a clear trend in drought along a belt from the southwest to the northeast of China. The southwest of Northeast China, North China, Huai River basin and Southwest China have experienced higher drought frequency and intensity. During 1980-2015, droughts graded as 'severe' or worse occurred in 18 years. One drought graded 'severe' or worse has occurred in China every two years, on average. In particular, drought conditions in humid and semi-humid regions have been expanding and intensifying. Since 1980, 23 provinces and autonomous regions have been struck by droughts graded 'severe' or worse droughts, including 5 provinces or autonomous regions that had not previously experienced such droughts.

2.2.3 Impacts of and Vulnerabilities to Future Climate Change in Water Resources

Climate change will intensify hydrological cycles, alter the temporal and spatial distribution of water resources, expand vulnerabilities of water resources and bring severe challenges to the management, exploration and utilization of water resources. In regard to the spatial distribution of vulnerability, areas with vulnerable water resources are mainly located in Haihe River basin, Huai River basin, Yellow River basin, Liao River basin and some areas of northwestern inland river basins. Most areas of river basins in southwestern China and the upstream regions of Yangtze River basin are basically not vulnerable or have low levels of vulnerability. Water resources of the Pearl River delta and the Yangtze River delta are obviously more vulnerable than those in central regions (Figure 3-13). Under the two-fold impacts of climate change and increased water demand, water resource vulnerability in China has been intensifying. By the middle of this century, the Haihe River basin, Yellow River basin, Huaihe River basin and Song-Liao River basins will experience significantly intensified water resources vulnerabilities, while water resources vulnerabilities in northwestern inland river basins will decrease somewhat, but overall vulnerabilities of water resources will remain intense.

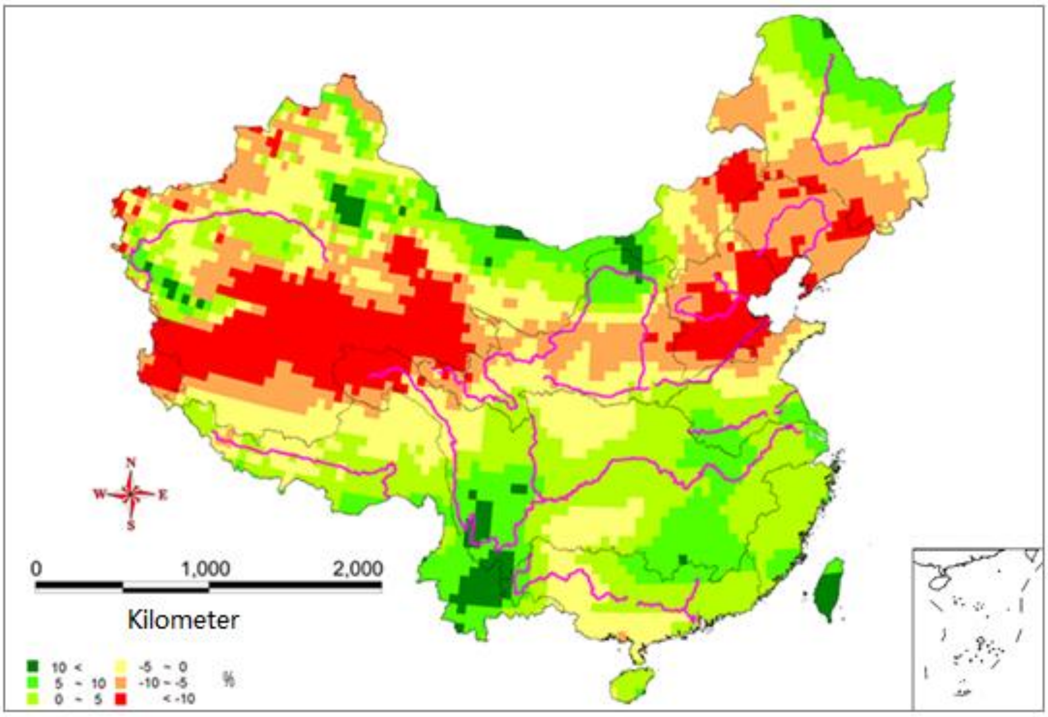

Figure 3-13 Changes in Water Resources in 2021-2050 Compared with that in the Reference Period (1961-1990) under a Medium GHG Concentration Scenario

Climate change will increase the vulnerability of the cryosphere. In the future, temperatures in the Qinghai-Tibetan Plateau will increase significantly and snow cover days and snow depth will decrease. In the future, the distribution of vulnerabilities of China's cryosphere to climate change impacts will gradually increase from east to west. Central and eastern parts of the Plateau will show slight or mild vulnerabilities, while some areas in Tibet will experience great or extreme vulnerability.

2.3 Climate Change Impacts on Terrestrial Ecosystems

2.3.1 Evidence of Climate Change Impacts on Terrestrial Ecosystems

1) Forests

In the past several decades, climate change has had some impacts on forest phenology, distribution, composition, and productivity, forest fires, and pests and diseases. The start of growing season in spring in Northeast China, North China, Northwest China and the Tibetan Plateau has advanced, while the end of the season has delayed, resulting in a longer growing season. The suitable distribution range of tree species such as the Dahurian larch in the Greater Khingan Range, spruce, fir and redwood in the Lesser Khingan and eastern mountain ranges have shifted northwards. The distribution of tree species in Southwest China and the southeastern Tibetan Plateau has changed, while community density has increased. The community structure of China's subtropical monsoon broad-leaf evergreen forest has changed, which affects the function of the monsoon broad-leaf evergreen forest as a carbon sink and its ecosystem services. The biomass of forest in northeastern China and the Qinling Mountains has increased, and net primary productivity of forest in eastern Northeast China, southeastern Shaanxi, southern Yunnan, and eastern Guangxi has increased significantly, the risks of forest fire and outbreaks of pests or disease have increased in some regions.

2) Grasslands

In the past 50 years, climate change has had considerable impacts on the phenological phases, vegetation cover and productivity of grasslands. As a consequence of rising temperature, green-up occurs earlier than before in grasslands in Inner Mongolia and on the Tibetan Plateau, while yellowing is delayed, and the vegetation growing season is prolonged. Warming and drying in northern grassland regions have resulted in a decline in forage yield and carrying capacity, with the greatest decline in productivity occurring in central-eastern Inner Mongolia and southeastern Gansu. There have been varying impacts on forage yield and carrying capacity of grasslands in different parts of Western China, where climate trends have tended towards warming with increased precipitation, with the greatest increase in forage productivity occurring in southwestern Xinjiang and eastern Tibet. Because the level of increase in precipitation in northern and eastern Xinjiang and southern Qinghai over the past 50 years has been limited, forage yields and carrying capacity have declined somewhat.

3) Wetlands

Climate change has resulted in a contraction of wetlands and a decline in its functions over the past decades. In the past 45 years, the wetlands in the source regions of the Yangtze and Yellow Rivers have become significantly degraded, as evidenced by a contraction in area and fragmentation. The areas of typical marsh meadow and alpine peat bog in the source region of the Yangtze River have shrunk by 29% and 45%, respectively, while the typical marsh meadow and alpine peat bog in the source region of the Yellow River have shrunk by 30% and 54%, respectively. Temperature rise has been the main cause of the degradation of alpine wetland. In the past 50 years, rain-fed wetlands have been shrinking and their functions have declined. Wetland in northwestern arid regions have shrunk the most, followed by those in the Sanjiang Plain and the Yangtze Plain. Human activities were the biggest contributing factor behind the contraction of wetlands in the Sanjiang Plain, while temperature rise and a decrease in precipitation were secondary factors.

4) Lakes

Climate change has resulted in significant change in the water level and area of lakes over the past decades. Between 1971 and 2004, the area and volume of Namtso (Lake Nam) in Tibet increased by 2.37 square kilometers/year and 237 million m^3/year, respectively. Increasing precipitation and related runoff contributed 47% of the increment in total recharge of Lake Nam, while increasing glacial melt-water contributed the remaining 53%, demonstrating that the increase in glacial melt-water due to climate warming has been the main cause of the rapid expansion of Lake Nam. In the past 40 years (1976-2014), Siling Lake in Tibet expanded by 42%, with an annual average expansion of about 18.7 square kilometers. The increase in recharge from melt-water due to a continuous temperature rise might be the main cause of lake expansion, while slower evaporation from the lake due to decreasing wind speeds might be another cause.

5) Biodiversity

In the past 50 years, the distributions of wildlife and wild plants has changed due to human activities and climate change. Some resident birds and migratory birds have moved northwards or westwards. The distribution of some amphibians has been shifting westwards. Some reptiles have moved northwards or westwards, bats have moved northwestwards, and some plants originally only found in the tropics have been found in warm temperate or high elevation areas. There has been a change in the distribution of some wild plant relatives and wider distribution of some pests. The biggest factor behind the change in biological diversity has been human activity, with climate change as a secondary factor.

2.3.2 Impacts of Future Climate Change on Terrestrial Ecosystems

1) Forests

Future climate change will have significant impacts on the distribution of forests, their functions and disasters. Under future climate change scenarios, the boundary of humid forests will shift northwards, while Northeast China will no longer have cold temperate zone humid forests. If temperature rises by 1°C, the Dahurian larch forests in the northern Greater Khingan Range will shrink, and the southern edge of deciduous-coniferous forests will shift northwards by 1 degree of latitude. If temperature rises by 2°C, the distribution of the Dahurian larch forests in the Greater Khingan Range will further shift northward, Dahurian larch forests will shrink, and the southern edge of deciduous-coniferous forests will shift northwards by 1.5 degrees of latitude. Climate change will result in change in the net primary productivity of forests. The results of multi-model ensemble evaluations suggest that, in a low GHG concentration scenario, the area of forest affected by decreasing net primary productivity will become smaller, while in a high GHG concentration scenario, it is projected that after 2050 the area of forest affected by decreasing net primary productivity will increase, with the area at high risk of decreasing net primary productivity increasing from 5.4% (2021-2050) to 27.6% (2071-2099) of total forest area. High risk areas are mainly concentrated in the southern subtropical zone and the tropics. In a medium or high GHG concentration scenario, during 2021-2050, the total value of forest ecosystem services in China will increase, except in a few regions (central Xinjiang, western Inner Mongolia, northwestern Gansu, southeastern Tibet, some forest edges in northeastern China and southern China), with a greater increase in the value of forest ecosystem services in the east and south than in the west and north. Under future climate change scenarios, the frequency and area affected by forest fires in northern China will increase, while the length of the forest fire season will be significantly extended. The suitable habitat of pine wood nematode will gradually expand, and some regions originally not suitable for its distribution will become suitable habitats due to change in the climatic environment, and the risk of forest pests and disease will increase.

2) Grasslands

Future climate change will change the distribution and productivity of China’s grassland ecosystems. Temperature rise will result in the further shift of the alpine grassland boundaries to higher elevations on the Tibetan Plateau, the Tian Shan and the Qilian Mountains. Under the influence of rising temperature, compared with the reference period (1961-1992), alpine meadow area on the Tibetan Plateau will shrink, the alpine steppe area will expand, and the net primary productivity of alpine grasslands will decrease. The productivity of most grasslands in western Inner Mongolia will decrease, while the productivity of meadow grassland and typical steppe in Northeast China will increase.

3) Wetlands

Future climate change will result in change in the distribution of wetland and will cause contraction in wetland area. Compared with 1961-1990, in a future high GHG concentration scenario, during 2011-2040, the area in the three northeastern provinces with a suitable climate for wetlands will shrink considerably and wetlands will severely degrade. The region with a highly suitable climate will shift to the southern part of the three northeastern provinces. Future climate change will result in contraction of the wetland area in the Greater Khingan Range and cause severe degradation of wetlands, with about 30% of wetland disappearing by 2050, and about 60% disappearing by 2100. The distribution of the regions with a suitable climate for alpine wetlands on the Tibetan Plateau will change, and the suitable area will shrink. Under a low GHG emission scenario, it is projected that by the mid-21st Century, the alpine wetland on the Tibetan Plateau will shrink by 35.7%, and the wetland meadow and the salt marsh in the Changtang drainage basin will vanish. Under future climate change scenarios, the important functions of some wetlands, such as carbon sequestration, water retention, and wildlife habitat, will be at risk.

4) Biodiversity

Chinese scientists have assessed the impacts of future climate change on angiosperms, gymnosperms, ferns, bryophytes, birds, fauna, amphibians and reptiles. In various climate scenarios[1], compared with the suitable distribution range of flora and fauna during 1951-2000, their suitable distribution range will narrow in 2026-2050. The number and proportion of species losing more than 60% of their suitable distribution range is shown in Table 3-2.

[1] For example, the comprehensive evaluation results using 5 models (GFDL-ESM2M, HadGEM2-ES , IPSL-CM5A-LR, MIROC-ESM-CHEM and NorESM 1 -M), and 4 climate scenarios (atmospheric radiative forcing of 2.6 $W.m^{-2}$, 4.5 $W.m^{-2}$, 6.0 $W.m^{-2}$ and 8.5 $W.m^{-2}$).

Table 3-2 Proportion of Suitable Distribution Ranges for Animal and Plant Groups Lost and Number of Species Affected under Future Climate Change Scenarios

Species/groups of fauna and flora	Number of species assessed	Proportion of suitable distribution range lost	Number of species
Angiosperm	79	⩾60%	2-4
Gymnospermae	109	⩾60%	2-8
Pteridophyte	109	⩾80%	3-11
Bryophyte	115	⩾60%	4-8
Bird	114	60%-80%	1-6
Fauna	118	⩾80%	1-4
Amphibian	91	⩾80%	2-6
Reptile	115	⩾80%	1-3

2.4 Climate Change Impacts on Coastal Zones and Ecosystems, and Vulnerability

2.4.1 Climate Change Impacts on Sea Level and Extreme Marine Events

1) Observations of sea level and extreme marine events in the past 50 years

The trend in sea level in China has been increasing with fluctuations (Figure 3-14) From 1980 to 2017, the coastal sea level in China rose at an average rate of 3.3 millimeters/year. Annual rates of sea level rise of the Bohai Sea, the Yellow Sea, the East China Sea and the South China Sea were 3.2 millimeters/year, 3.4 millimeters/year, 3.2 millimeters/year and 3.4 millimeters/year, respectively, all of which were higher than the global average rate of sea level rise (Figure 3-15).

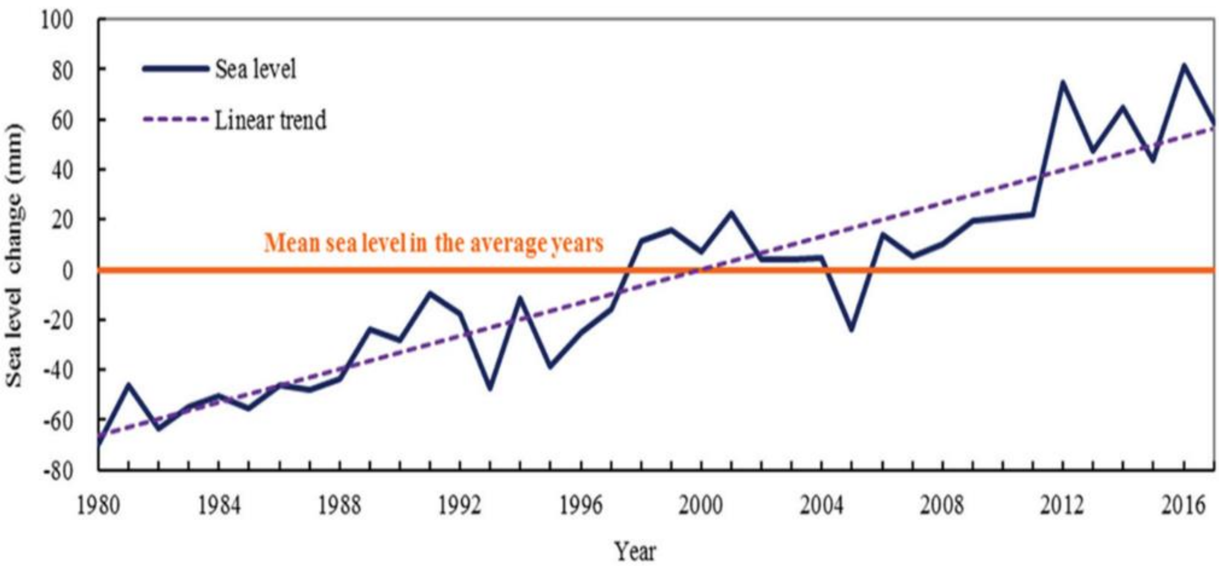

Figure 3-14 Trend in Coastal Sea Level Rise in China,

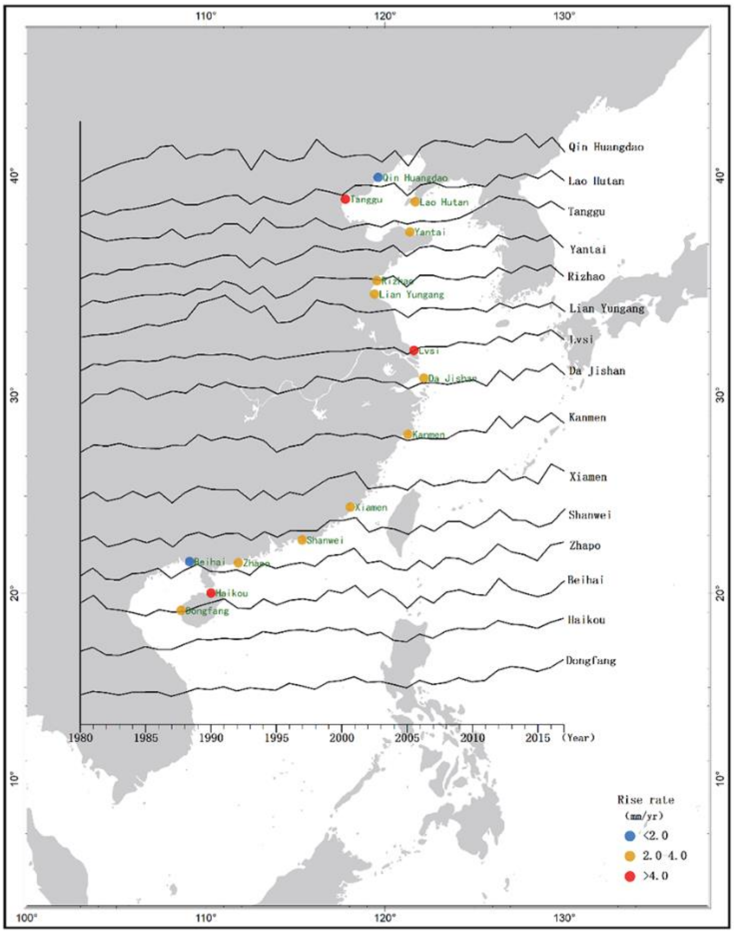

Figure 3-15 Sea Level Changes at Major Monitoring Stations along the Coast of China in 1980-2017

Sea surface temperature has been rising. In the past 50 years (1962-2011), the most significant rise in sea surface temperature in China's coastal waters has been in winter, at 0.55°C/decade. The rates of increase in spring, autumn and summer were 0.45°C/decade, 0.35°C/decade and 0.25°C/decade, respectively.

The incidence of storm surges in China's coastal zones has been decreasing. According to the Bulletin of Marine Disasters in China published by the State Oceanic Administration between 2005 and 2017, in the past 13 years, the frequency of storm surges in China's coastal zones decreased by 1.2 times per year on average. The rate of the decrease between 2012 and 2017 was twice that between 2005 and 2011, but there was no significant change in the frequency with which disasters occurred.

2) Evolution of disasters in China's coastal zones in the past 50 years

In the past 50 years, estuaries and coastal zones experienced intensified seawater intrusion. Exceptionally high sea level and a decrease in the groundwater level resulted in intensified seawater intrusion, thus freshwater resources in coastal zones have been severely polluted and the effective utilization of land resources has been restricted by soil salinization. Owing to the combined effects of rising sea level and spring tides, the Yangtze River estuary and Pearl River estuary suffered more frequent seawater intrusion and the coastal plain of the Bohai Sea has suffered severe and widespread seawater intrusion.

Climate change has resulted in rising sea level and increasing tide range, which has aggravated coastal erosion. Coastal erosion disasters are a common occurrence on China's more than 18,000 kilometers of mainland coastlines and the more than 14,000 kilometers of island coastlines, and almost all open muddy coasts and about 70% of sandy coasts have suffered erosion to different degrees.

The rise in sea level will heavily influence flood discharge at the estuaries. Most of China's coastline, such as in the Bohai Bay, the Yellow River Delta, the Yangtze River Delta and the Pearl River Delta in particular, are at a low elevation. With extremely high water levels, a slight rise in the sea level will aggravate the flooding of a large area of land.

3) Climate change impacts on coastal terrestrial ecosystems

The rise in sea level will aggravate seawater intrusion and coastal erosion, heavily influence coastal ecosystems, result in deterioration of the structure, physical and chemical properties of soil, and decrease in ecological fertility, change highly productive arable land into saline-alkaline wasteland, degrade land resources and plant communities, and decrease ecosystem service function.

With the combined influence of rising sea level and land reclamation activities, China's coastal wetlands have been severely damaged. 57% of intertidal zone wetlands have disappeared, and the ecosystem service functions of wetlands in the southern Yellow Sea and the coastal zone of the East China Sea have declined by 30%-90%.

Due to rising sea surface temperature, coral bleaching and death has occurred in China's tropical sea areas. Since 2000, coral bleaching and death have been observed to different extents in southern China and southeast coastal zones, with severe coral reef bleaching on Weizhou Island in Beibu Bay in the South China Sea.

Considering the rise in sea level, regional social, economic and environmental quality, the intensity of the factors causing disasters, and regional capacities for resisting disasters, the estuary ecosystems of the Yellow River, the Yangtze River and the Pearl River in China have been identified as the most sensitive to rising sea level.

2.4.2 Potential Impacts of Future Climate Change

1) Sea level rise

It is project that in the coming 30 years, the coastal sea level of the Bohai Sea will rise by 70-150 millimeters, and those of the Yellow Sea, the East China Sea and the South China Sea will rise by 80-160 millimeters, 75-160 millimeters, and 70-160 millimeters, respectively.[1] The rise in sea level will lead to a significantly shorter return period of the average extreme water level in China's coastal zones. For example, by 2050, in Shandong Province the return period for a 100-year extreme water level will be shortened to 10-30 years, and by 2100, the return period for the 1000-year extreme water level will be shortened to 10 years.

2) Climate change impacts on the coastal environment

In the coming 30 years, the Yangtze River Delta, the Pearl River Delta and the Yellow River Delta will be the most vulnerable zones. By 2050, such important coastal economic belts as the Pearl River Delta, the Yangtze River Delta and the Yellow River Delta will face high risk of being flooded due to rising sea level (Figure 3-16), which will aggravate seawater intrusion, coastal erosion and flooding of lowland areas.

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[1] *2017 Bulletin of Sea Levels in China.*

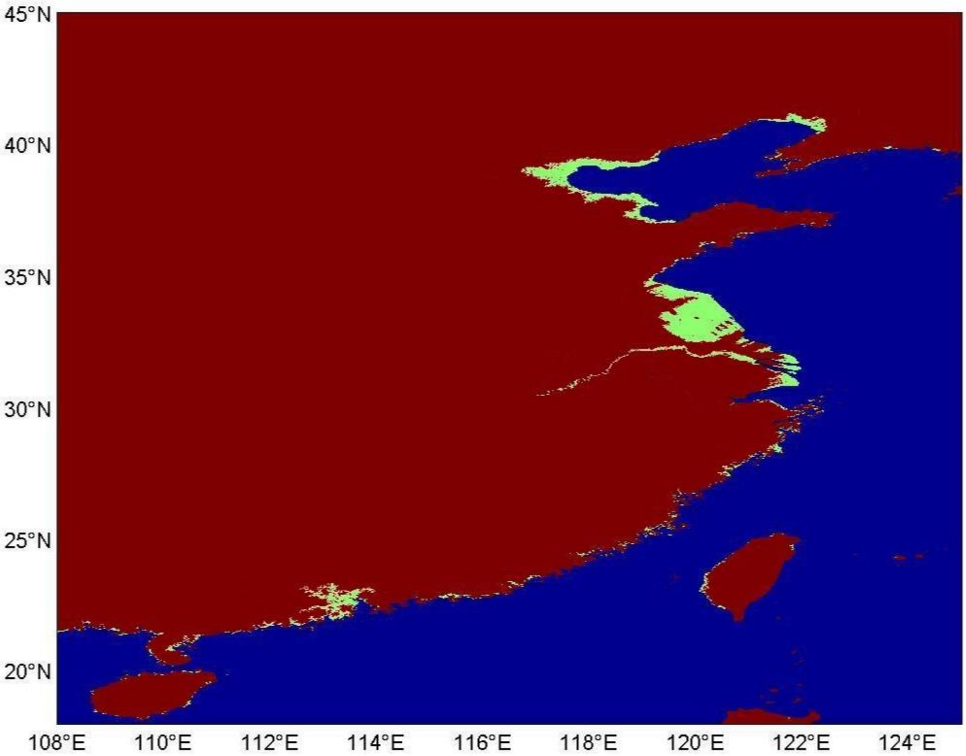

Figure 3-16 Areas that may possibly be affected by a 100-year water level along the coast of China in 2050

3) Vulnerability and risk analysis

The comprehensive assessment of coastal land elevations, the grade of shore protection infrastructure, storm surge intensities and ecosystems found that in the future the five main vulnerable zones subject to climate change influence in China will be the Yellow River Delta, Bolai Bay coasts, Subei Plain, the Yangtze River Delta, the Pearl River Delta, the Liaodong Bay area, and the lowland area of the western coast of Taiwan. With existing dikes, by 2050, if the historical maximum tide level or the 100-year high tide level occurs, over 100,000 square kilometers of coastal land might be affected.

2.5 Climate Change Impact on Public Health

2.5.1 Impact of Climate Change on Human Chronic Diseases

The most direct impact that climate change has on human chronic diseases is the heat effect due to extreme high temperature. Future climate change scenario modelling suggests that this effect will become more frequent, extensive and lasting. For example, during the summer heat wave in China in 2013, 5,758 cases of sunstroke were reported, representing an increase of nearly 200% over previous years. In terms of excess mortality, there were more than 5,000 additional cases of premature death in 16 provincial cities in central and eastern China, of which most were due to cardiovascular diseases and respiratory diseases and affected the aged over 65. Risk assessment of chronic diseases associated with climate change suggests that under a high GHG concentration scenario, health risks due to high temperature will become increasingly significant, especially among the population in rural areas.

2.5.2 Impact of Climate Change on Human Infectious Diseases

Climate warming will lead to pathogenic recovery and transmission and influence the spatial and temporal distribution and quantity of vectors and intermediate hosts, pathogenesis, and the distribution of diseases. Under future climate change scenarios, areas at risk from dengue fever in China will expand northward significantly and the population at risk will increase significantly. For example, under low and high GHG concentration scenarios, the number of counties or districts at high risk of dengue fever in China will increase from 142 today to 228-257 by 2100 and the population at high risk will increase from 168 million today to 230-490 million by 2100. In addition, climate change might also influence the marine environment, the quality of surface water, and further affect the occurrence of water-borne communicable diseases.

2.5.3 Vulnerability of Population Groups to Climate Change

Climate change will aggravate the vulnerability of human health. In terms of different diseases, those with cardiovascular disease, cerebral apoplexy, acute myocardium infarction, ischemic heart disease, respiratory disease and chronic obstructive pulmonary disease are vulnerable to climate change. In terms of by individual characteristics, the aged and infants are vulnerable to climate change. By region, the population in northern areas will be more susceptible to future warming due to their long-term physical adaptation, and the population in rural areas will also be more vulnerable because they will have a higher risk of exposure due to their lack of effective response measures.

Chapter 3 Climate Change Adaptation Policies and Actions

3.1 Climate Change Adaptation Goals and Tasks

According to the *Outline of the 12th Five-Year Plan for National Economic and Social Development of the People's Republic of China* (hereinafter referred to as *Outline of* *the 12th FYP*), 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 *Outline of the 13th FYP*) and the *National Climate Change Adaptation Strategy (2013-2020)*, China will further pro-actively adapt to climate change and 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. China will strengthen systemic observation and research on climate change, improve systems for forecasting and giving early warnings, become better able to respond to extreme weather conditions and climatic events. The objectives to achieve by 2020 are a significant increase in adaptation capacity, to implement all key tasks, and to establish regional spatial and function planning for adaptation.

Agriculture: By 2020, the proportion of crops under comprehensive crop protection to prevent and control major crop diseases and insect pests will exceed 40%, water use efficiency for arable land irrigation will increase to over 0.55, water use efficiency of crops will increase to over 1.1 kg/m^3, and the effectively irrigated arable land area will exceed 1 billion ha, and the penetration rate of practical adaptation technologies among the rural labor force will reach 70%.

Water resources: By 2020, total national water consumption will be controlled within 670 billion m^3, water consumption per ten thousand Yuan of GDP will decrease by 23% compared to 2015 levels, and water consumption per ten thousand Yuan of industrial value added will fall to 65 m^3. Watershed management measures will be applied in 244 important rivers with a watershed of 3,000 km^2 or greater, the water quality of urban water supply sources will basically comply with standards, and 80% of the main water functional areas, such as rivers, lakes and reservoirs, will be compliant with water quality standards.

Land and coastal ecosystems: By 2020, forest coverage will increase to 23.04%, forest stock volumes will increase to over 16.5 billion m^3, the proportion of forests affected by fire will be reduced to below 1‰, and the proportion affected by forest pests will be reduced to below 4‰. The treatment of grassland affected by desertification, salinization and degradation will be strengthened to achieve an overall vegetation cover of 56%. The proportion of effectively protected natural wetlands will exceed 60%. More than 95% of key wild animals under state protection and more than 90% of wild plant species with extremely small populations will be effectively protected. Soil erosion control measures will be applied to an additional area of 0.27 million km^2, and over 50% of the treatable desertificated area will be treated. Sea reclamation will be strictly controlled, with no less than 35% of the natural shoreline retained.

Urban areas: By 2020, climate change adaptation indicators will be incorporated into the urban and rural planning system nationwide, as well as construction standards and industrial development plans. Thirty pilot cities for climate change adaptation will be established, and the management level for climate change adaptation in representative cities will be significantly raised. The proportion of green buildings will reach 50%. The step-wise achievements made by pilot climate-resilient cities will then be assessed and disseminated.

3.2 Climate Change Adaptation Policies and Actions

3.2.1 Agriculture

Since the 11th FYP period, China has issued such policy documents as the *12th FYP for National Agricultural and Rural Economic Development*, the *National Plan for the Development of Modern Agriculture (2011-2015)*, the *National Plan for Agricultural Modernization (2016-2020)*, the *13th FYP for National Rural Economic Development*, the *Work Plan for National Demonstration Activities on Water-saving Farmland* and the *Plan on Scientific Responses to El Nino for Disaster Relief and Harvest Protection*, and has actively taken preventive measures against the adverse effects on agricultural production of regional drought and floods, plant disease and pests outbreaks, and extreme climate events induced by climate change. Local governments have actively developed water-saving agriculture and popularized such adaptation technologies as dryland farming, drought control and soil moisture conservation, and striven to improve the quality of arable land, supporting crop residue management and soil fertility improvements. Capacities for crop breeding have been greatly enhanced, and cultivated crop species with strong adaptation and resistance to high temperature, low temperature and drought have been developed.

3.2.2 Water Resources

Since the 11th FYP period, China has published such policy documents as the *13th FYP for Construction of Water-saving Society*, the *Water Function Regionalization of*

Nationally Important Rivers and Lakes (2011-2030) and *Opinions on the Implementation of the Strictest Water Resources Management System*, which has implemented the strictest water resources management system across the country, established a four-level (i.e., province, city, county and township) river chief system, and made comprehensive arrangements for the protection of water resources, management of rivers and lake shorelines, prevention and control of water pollution, control of the water environment, restoration of water ecology and supervision of law enforcement. During the 12th FYP period, it has also accelerated the establishment of a water-saving society throughout the country by conducting 100 national water-saving society construction pilots and 200 provincial pilots, and implementing ten water-saving actions (including agricultural water-saving measures compatible with productivity increase, industrial water-saving with efficiency increases, and urban water-saving with consumption reduction), conducted comprehensive control and protection of water resources across the country, boosted the hygienic inspection and monitoring of drinking water, improved urban and rural water supply capacity and constructed a batch of major hydraulic projects to improve flood risk management, stabilize dangerous reservoirs and prevent geological disasters such as landslides.

3.2.3 Terrestrial Ecosystem

The protection of forest ecosystems has been strengthened. In line with the *12th FYP for Forestry Development* and the *13th FYP for Forestry Development, China has introduced the Program for Forestry Actions on Climate Change Adaptation (2016-2020)* and *Key Points for the Five-year Action on Responding Climate Change in Forestry*, where the proportion of fire-resistant, drought (moisture)-resistant, disease and pest-resistant and extreme temperature-resistant tree species is increased in afforestation, climate change adaptation forest cultivation and management models are promoted, the protection of natural forest is intensified, and the monitoring, prevention and control of fire, pest invasion and other forest disasters are strengthened in order to improve forest systems' adaptation capacity in the face of climate change.

A virtuous circle of grassland ecology has been promoted. Through the *13th FYP for National Grassland Protection*, *Construction and Utilization and the Plan for the Rehabilitation of Arable Land, Grassland, Rivers and Lakes (2016-2030)*, China has intensified the role of climate change adaptation elements in the design of top-level policies, supporting the transformation of grassland-based animal husbandry production models and expanding the conversion of marginal arable land to forest and grassland. During the 12th FYP period, the state invested 77.55 billion in the Grassland Ecology Conservation and Subsidy and Reward policy, which has implemented enclosure from grazing on 82 million ha of grassland, implemented grass-livestock balanced management on 174 million ha of grassland, and supported cultivation of grass on 8 million ha each year.

Wetland protection and desert control have been strengthened. Wetland recovery and comprehensive management works have been implemented to strengthen the protection and carbon storage of wetlands. Land greening, desert species protection, desertification and rocky desertification monitoring and land vegetation recovery actions have been taken to boost the comprehensive control of desertification, karst rocky desertification and soil erosion.

The protection of ecosystems has been intensified. The division of three control lines for ecological protection, permanent arable land and urban development limits have been completed, and the ecological safety barrier system has been optimized. The rehabilitation system for arable land, grassland, forest, rivers and lakes has been improved and market-oriented and diversified eco-compensation mechanisms have been established. Ecological corridors and biodiversity protection networks has been preliminary developed, and such major ecological conservation and restoration projects as protection of wild fauna and flora, and development of nature reserves, have been implemented to improve the quality and stability of ecosystems.

3.2.4 Coastal Zone and Coastal Ecosystems

Since the 11th FYP period, China has revised the *Marine Environment Protection Law*, introduced plans or administrative regulations on national marine industry development, marine observation and forecasting, disaster prevention and relief, increased punishments for marine environment pollution, and strengthened institutions for marine adaptation to climate change. Coastal ecological restoration and vegetation protection, coastal forest shelterbelts and tidal defense engineering, and improved the resistance of coastal zones and coastal ecosystems to climate disasters have all been strengthened. Three-dimensional monitoring, forecasting and early warning of marine disasters, such as storm surge, waves, sea ice and coastal erosion, have been strengthened. Technical guidelines on impact assessment of sea level rise on vulnerable areas have been published, and vulnerability assessment has been conducted in major areas, such as coastal provinces and cities. Surveys have been conducted to assess the impact of sea level change and coastal erosion monitoring and evaluation has been conducted. Studies have been made of long-term trends in marine disasters and environmental factors China's coastal waters, and projections have been made of the possible effects of future climate change on marine disasters.

3.2.5 Human Health

Capabilities to secure the adaptation of human health to climate change have been improved. China has improved capacities and management levels of the government in providing public services to adapt to climate change by boosting the establishment of health monitoring, survey and risk assessment systems and standard systems, and by providing good medical and health services in high temperature weather; strengthening control and prevention of diseases closely related to climate change; monitoring epidemic dynamics and studying influencing factors; preparing public health emergency plans and relief mechanisms for epidemics such as Middle East Respiratory Syndrome, human infection with H7N9 avian influenza and Dengue Fever, which are closely related to climate change; establishing pilots in each province, autonomous region and municipality in China to monitor public health hazard factors in public places; monitoring the impact of smog conditions on human health and establishing high temperature, heat wave and health risk early warning systems; strengthening the study of climate change adaptation in the sphere of human health, organizing and implementing climate change adaptation and human health protection projects, and improving the public's ability to take precautions during extreme weather events, such as high temperature and heat waves.

3.2.6 Major Adaptation Areas

The whole nation is divided into three categories of adaptation zone: urbanization, agricultural development and ecological safety. Adaptation tasks with different focus have been set for these adaptation areas by comprehensively considering the different influences that climate change exert on the production and life of people living in different areas. In urbanization zones, at the same time as promoting urbanization, urban infrastructure adaptation capacities have been strengthened to improve the human settlement environment and guarantee the safety of people's production and living environment. In agricultural development zones, the focus has been on guaranteeing the safe supply of agricultural products and people's livelihoods. In ecological safety zones, the focus has been on securing national ecological safety and promoting harmony between human and nature.

3.3 Climate Change Adaptation Progress and Achievements

Agriculture: The effectively irrigated arable land area in China has increased from 55 million ha in 2005 to 65.8 million ha in 2015, and irrigation water use efficiency has increased from 0.45 in 2005 to 0.53 in 2015.

Water resources: China further optimized water resources allocation. By October 2017, Phase 1 of the central route of the South-to-North Water Diversion Project has supplied a total of 10.858 billion m^3 of water to northern China. Water safety has been further strengthened, the urban sewage treatment rate having increased from 82.3% in 2010 to 90.2% in 2015. The integrated flood control and disaster relief system has been further improved, and during the 12th FYP period, 2,058 county-level torrential flood monitoring and warning systems and public monitoring and prevention systems were established across the country, increasing the number of flood reporting stations to 97,000, and the number of deaths and missing people due to floods has fallen to its lowest level since the founding of the People's Republic of China.

Terrestrial and coastal ecosystems: All commercial felling of natural forest in major state-owned forest areas has been stopped, and in 2015 national forest cover reached 21.66%, with forest stock volume reaching 15.1 billion m^3. During the 12th FYP period, the total area of comprehensively controlled soil erosion across the country was 266 thousand km^2. By the end of 2017, over 270 marine reserves of various levels and types had been created in China, covering an area of over 120,000 square kilometers, amounted to about 4.13% of the sea area under China's jurisdiction.

Urban: Following national requirements, 28 climate-resilient urban construction pilot areas have prepared implementation plans for climate-resilient urban construction, current and future climate change impact assessments have been organized, and climate change risk analysis has been conducted in key sectors and fields, and the urban meteorological disaster monitoring, early warning and prevention system has been gradually improving.

Part IV Policies and Actions for Climate Change Mitigation

The Chinese government has focused on the goals and tasks of controlling GHG emissions and made a positive achievement in climate change mitigation by adjusting industrial structure, optimizing energy structure, saving energy and enhancing energy efficiency, controlling non-energy GHG emissions and increasing carbon sinks. China will make further efforts to bring the strategy of addressing climate change into the economic and social development plan and take the goal of NDC as an important task of ecology and environmental protection in the current and future period. China will actively control GHG emissions, promote mechanism and institution innovation, and thus to make new contributions to protecting the global climate.

Chapter 1　Targets and Actions for GHG Emission Control

With much importance attached on the work of addressing climate change, the Chinese government has taken a series of policies, measures and action plans to effectively control GHG emissions and has made a positive progress in addressing climate change.

1.1　Goals of China's Nationally Determined Actions

In 2009, China declared the nationally appropriate mitigation actions to the international community, that is, by 2020 the CO_2 emission per unit of GDP (hereafter referred to as carbon intensity) will be reduced by 40% to 45% than the 2005 level, 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 compared with 2005 level. In 2015, the Chinese government submitted the NDC to the UNFCCC: China will peak CO_2 emissions by around 2030 and strive to peak it earlier, and by 2030 carbon intensity will be reduced by 60% to 65% than that in 2005, the share of non-fossil energy in primary energy consumption will be increased to around 20%, and the forest stock volume will be increased by 4.5 billion m^3 compared to 2005 level. These actions were determined autonomously by China according to its national circumstances and indicated the direction of actively addressing global climate change for a long term in China.

1.2 Progress and Performance of the Policies and Actions Taken

In 2011, the *Outline of the 12th Five-Year Plan for National Economic and Social Development* (hereinafter referred to as *Outline of 12th FYP*) specified the Chinese goals of controlling GHG emissions by 2015; and *the 12th Five-Year Work Plan for Controlling Greenhouse Gas Emission* (hereinafter referred to as *GHG Control in 12th FYP*) was issued to deploy relative policies and actions.

China has used various approaches, such as adjusting industrial structure, optimizing energy structure, saving energy and enhancing energy efficiency, increasing forest carbon sinks and strengthening system innovation to significantly reduce energy intensity and carbon intensity, and effectively control GHG emissions.

According to the published statistical information, China has made major achievements in terms of GHG emission control.

The carbon intensity has been reduced dramatically. Based on the preliminary calculation, from 2010 to 2015, the energy-related CO_2 emission per unit of GDP was cumulatively reduced by around 22%, exceeding the indicator of the 12th FYP, which laid a solid foundation to achieve the goal of a 40%-45% decline from 2005 to 2020.

Industrial structure has been gradually optimized. In 2010, the value added of service industry accounted for 44.1% of the GDP, 2.8 pps higher than that of 2005. In 2015, the value added of service industry accounted for 50.2% of the GDP, 6.1 pps higher than that of 2010, exceeding the target of the 12th FYP.

The energy intensity has been reduced significantly. From 2005 to 2010, the energy consumption per unit of GDP (energy intensity) fell by 19.3%, completing the task of the 11th FYP. From 2010 to 2015, the energy consumption per unit of GDP fell by 18.4%, exceeding the target of the 12th Five-Year Plan.

The energy structure has been continuously improved. In 2010, the share of non-fossil energy in primary energy consumption was 9.4%, up 2 pps against 2005 level. In 2015, the share of non-fossil energy in primary energy consumption was 12.1%, 2.7 pps higher than that of 2010, and exceeding the target of the 12th FYP.

Forest carbon sinks has been increased constantly. From 2004 to 2008, the percentage of forest cover in China was increased to 20.36%, and the forest stock volume reached 13.7 billion m^3. By 2015, the percentage of forest coverage was increased to 21.66%, and the forest stock volume reached 15.1 billion m^3, reaching the goal of 2020 at an earlier time.

1.3 Key Objectives and Tasks Raised for the 13th FYP Period

To effectively implement the *Outline of 12th FYP* and the NDC, the Chinese government compiled *the 13th Five-Year Work Plan for Controlling Greenhouse Gas Emission* (hereinafter referred to as *GHG Control in 13th FYP*) in 2016, which proposed the major goals, including: by 2020 the CO_2 emission per unit of GDP will be reduced by 18% than 2015, and the total carbon emission will be effectively controlled; the total energy consumption will be controlled below 5,000 Mtce, and the energy consumption per unit of GDP will be reduced by 15% than 2015, the share of non-fossil energy in primary energy consumption will reach around 15%; and the percentage of forest cover will reach 23.04%, and the forest stock volume will increase to 16.5 billion m^3.

Looking into the 13th FYP period, China still faces many challenges in terms of GHG emission control. China needs to continuously strengthen legal support, enhance policy coordination, improve fundamental ability and guide public opinion. The Chinese government will make further efforts to strengthen the policies and actions in controlling GHG emission, build a sound, low-carbon, and recycling economic system, construct a clean, low-carbon, safe and efficient energy system, and encourage the simple, moderate, green and low-carbon ways of life. Reducing carbon intensity constantly, China will also effectively control the total carbon emission to lay a solid foundation to achieve the goals of NDC.

Chapter 2 Adjustment of Economic and Industrial Structures

From the middle and later periods of the 12th FYP, China's economic development has gradually entered the new normal stage, in which China's economic structure has been optimized and upgraded constantly, the development pattern has been transformed from the factor- and investment-driven stage to the service- and innovation-oriented stage. However, China's industry sector, especially some energy-intensive industries, still occupy a large proportion, and the development of tertiary industry needs to be further strengthened. Adjusting economic and industrial structures can effectively promote the economical use of resources and energy, and help achieve the action goals of climate change mitigation.

2.1 Key Policies and Actions

Since 2006, the Chinese government has emphasized adjusting economic and industrial structure, strengthening the guidance of industrial policies and plans, and reducing resource and energy consumption by promoting economic transformation so as to address climate change. The *Outline of the 11th Five-Year Plan for the National Economic and Social Development* (hereinafter referred to as *Outline of 11th FYP*) proposed that by 2010, the share of value added of service industry in GDP will be 3 pps higher than the 40.3%[1] of 2005. The *Outline of 12th FYP* proposed that by 2015, the share of value added of service industry in GDP will be 4 pps higher than the 43%[2] of 2010.

2.1.1 Accelerate the Development of Service Industry

During the 12th FYP period, the Chinese government issued the *12th Five-Year Development Plan of Service Industry* [3、4], which aims at accelerating the development of eleven production-related service industries, including financial service, transportation, modern logistics, high-tech service, design consultation, science and technology service, commercial service, e-commerce, engineering consultation, human resources, and energy saving and environmental protection; vigorously developing living service industries mainly including business and trade, culture and tourism; and rapidly improving the rural service level.

2.1.2 Promote the Transformation and Upgrade of the Industry

The Chinese government issued the *Industry Transformation and Upgrading Plan (2011-2015)*[5], which proposed transforming the development mode of industry to accelerate the transformation of industrialization from the traditional mode to a new mode, and fully optimizing the structure of technology, organization, layout and industry to push the overall improvement of industrial structure.

First of all, closing down outdated production facilities and restricting overcapacity rapidly is a major measure of transforming development mode, adjusting industrial structure, improving economic growth quality and economic

[1] As the Chinese government has adjusted GDP data in recent years, the data 40.3% used in the reference year of *Outline of 11th FYP* was inconsistent with the updated data as shown in Figure 4-1.

[2] As the Chinese government has adjusted GDP data in recent years, the data 43% used in the reference year of *Outline of 12th FYP* was inconsistent with the updated data as shown in Figure 4-1.

[3] *The 12th Five-Year Development Plan of Service Industry* issued by the State Council in 2012.

[4] *The Guiding Opinions of the State Council on Accelerating the Development of the Production-related Service Industry and Promoting the Adjustment and Upgrade of Industrial Structure* issued by the State Council in 2014.

[5] *The Industry Transformation and Upgrading Plan (2011-2015)* issued by the State Council in 2011.

benefits, and accomplishing the goal of energy saving and emission reduction. During the 11th FYP period, the related departments of the Chinese government compiled the industrial adjustment and revitalization plans for ten major industries like iron and steel, issued the concrete phase out programs for calcium carbide and coking industries and so on and proposed related policy requirements on the work of restricting overcapacity.[1] Entering the 12th FYP period, China has made more efforts to eliminate backward production facilities and restrict overcapacity, and set the goals of eliminating backward production facilities in the 19 major industrial fields, such as ironmaking, steelmaking, coking, electrolytic aluminum and cement. At the same time, various places were required to seriously implement the *Implementing Plan of Assessing the Work of Eliminating Backward Production Facilities*. The Chinese government made the captioned work an explicit priority in industrial restructuring to be put in place to "digest, transfer, integrate and phase out" the excess capacity by giving full play to the role of the market mechanism and by improving supporting policies.

Secondly, the Chinese government set the admission standards of energy-intensive industries, and enhanced the market access standards of the energy saving and environmental protection industry to control the excessive growth of energy-intensive and emission-intensive industries and to promote the optimization and upgrade of the internal structure of energy-intensive industries.

2.1.3 Cultivate and Develop High-Tech Industries and Emerging Sectors of Strategic Importance

Entering the 12th FYP period, the Chinese government, on the basis of strengthening and expanding high-tech industries, has made great efforts to cultivate and develop emerging sectors of strategic importance[2], mainly focusing on the seven fields including energy saving and environmental protection, new-generation information technology, biology, high-end equipment manufacturing, new energy, new materials and new energy vehicles. The *Outline of 12th FYP* also proposed the development idea of emerging sectors of strategic importance, pointed out the goals of trying to make the value added of such industries be around 8% of the GDP till 2015, and forming a general pattern capable of promoting the healthy development and coordinated growth of emerging sectors

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[1] *The Several Opinions of the State Council on Restricting Overcapacity and Repeated Construction in Some Industries and on Guiding the Healthy Development of Industries* issued by the State Council in 2009.

[2] *Decisions on Speeding up the Cultivation and Development of Strategic Emerging Industries* issued by the State Council in 2010.

of strategic importance. In addition, the Chinese government developed *the 12th FYP National Strategic Emerging Industry Plan*[1], which made a more detailed deployment and planning for the cultivation and development of the seven industries and formulated the development route of each industry by 2020.

2.2 Progress and Effect of Policies and Actions

2.2.1 Tertiary Industry is Thriving, Bringing a Steady Improvement in the Industrial Structures

During the 11th FYP period, China kept improving the structure of the Three Industries, and saw an increasing share of value added of service industry in GDP (as shown in Figure 4-1). In China, the share of value added of service industrial in GDP increased from 41.3%[2] in 2005 to 50.2% in 2015, when for the first time the value added of service industrial accounting for half of GDP, representing an increase of approximate 8.9 pps compared to that of 2005, fulfilling growth targets set for the 11th FYP and 12th FYP.

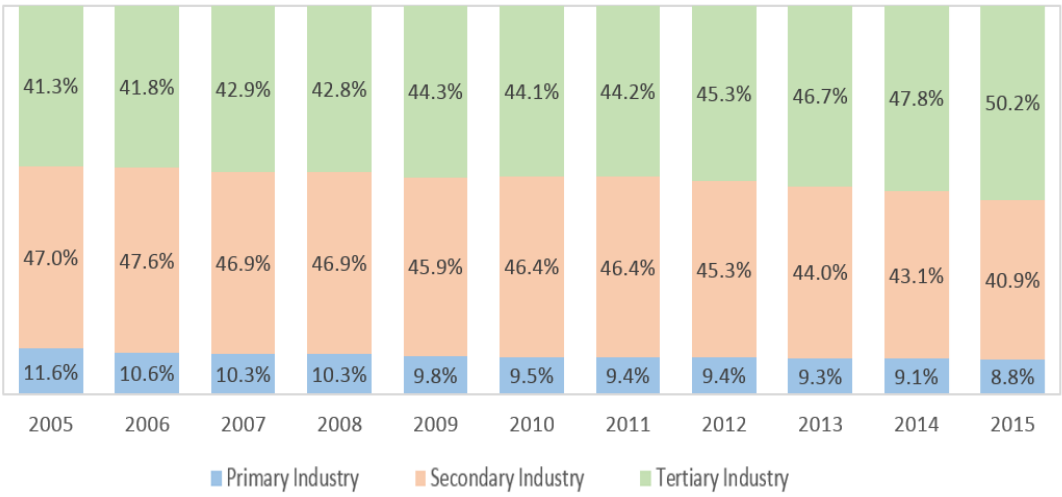

Figure 4-1 China's Three Industrial Structure Changes in 2005-2015

The booming of production-oriented service industry provided a strong driving force for restructuring and stable economic growth, and the key fields of production-oriented service industry are being adjusted continuously along with the development of economy and society. Based on the statistics information released by some provinces (autonomous regions, municipalities), the

[1] *The 12th FYP National Strategic Emerging Industry Plan* issued by the State Council in 2012.

[2] The Chinese government has made some adjustments to its GDP data in recent years, so the proportion of value added of service industry in GDP in 2005 mentioned here may not match 40.3% given as a reference year data when the Outline of 11th FYP was issued.

production-oriented service industry plays an important role. Take Beijing, Tianjin and Guangdong province as examples, in 2015, the share of value added of the production-oriented service industry in that of service industry were respectively 66.4%, 71.4% and 53.1%, and the proportion in regional GDP were 52.9%, 37.1% and 26.9%, with a significant increase over previous years[1].

2.2.2 Industrial Restructuring, Transformation and Upgrading

The work on elimination of outdated capacity has made positive achievements. During the 12th FYP period, China eliminated a total of outdated capacity of 90.89 Mt in iron production, 94.86 Mt in steel production, 97 Mt in coke production, 2.05 Mt in electrolytic aluminum production, 656.51 Mt in cement production, 168.86 million weight case in flat glass production and 34.33 Mt in paper production. China did a great work on elimination of outdated capacity, with over-fulfilled results for each target[2].

The development of energy intensive industries was effectively controlled, and the investment growth rate apparently slowed down. For example, data[3] from the National Bureau of Statistics of China shows that, between 2013 and 2015, investment in energy intensive industries increased annually by 9.9% in China, 2.6 pps lower than the annual average growth rate of industrial investment. The investment in five overcapacity industries, namely, iron and steel, cement, electrolytic aluminum, flat glass, metal ship products, had negative growth within the three years, with annual decline of 6.3%, 11.3%, 9.2%, 6.8% and 15.4%, respectively.

The energy intensive industries also went through structural optimization and upgrading. Between 2005 and 2010, firstly in the electric power industry, the proportion of installed capacity of over 300 MW thermal power generating units grew from 50% to 73%; secondly in the iron and steel industry, the proportion of production from large blast furnace over 1,000 m^3 increased from 48% to 61%; thirdly in the building material industry, the production of new dry process cement

[1] Source: *Opinion of the Beijing Municipal People's Government on Further Optimizing and Improving Production-oriented Service Industry and Accelerating the Construction of Economic Structure toward High Grade*, *High Precision and Advancement, Development Plan of the Production-oriented Service Industry in Tianjin City for 13th FYP*, and *Development Plan on Production-oriented Service Industry in the Industry and Information Technology Field in Guangdong Province for 13th FYP*.

[2] Data Source: *Notice Regarding Targets for Phasing Out Backward Production Capacity of Key Industrial Sectors in the 12th FYP Period*; and information bulletin on the fulfillment of the backward production capacity out-phasing targets for 2011, 2012, 2013, 2014 and 2015, by MIIT.

[3] Source: *Accelerated Optimization of Investment Structure and Significantly Improved Shortcomings- China's Investment Operation after the 18th National Congress of the CPC*, by the National Bureau of Statistics of China.

clinker rose from 39% to 81%[1].

2.2.3 A Rapid Development of High-Tech Industries and Emerging Sectors of Strategic Importance

During the 12th FYP period, seven emerging sectors of strategic importance, including energy saving and environment protection, new generation information technology, new energy and so on, achieved a rapid development. In 2015, the share of valued added of the emerging sectors of strategic importance in GDP in China was around 8%[2], also, the innovation ability and profitability were greatly improved, with a successful job on meeting the targets set for early period of 12th FYP. Besides, China developed a great number of emerging industry clusters with production value over 100 billion yuan during the 12th FYP period, providing strong support for regional economic transformation and upgrading.

2.3 Key Objectives and Tasks of 13th FYP Period

During the 13th FYP period, the Chinese government will continue to deepen economic reform with the focus on "change of pace in economic growth, structure adjustment and transformation of the drivers of growth", strive to make breakthroughs in optimizing structures, enhancing impetus, resolving contradictions and lengthen short stave, and essentially transform the way of Chinese development, improve the quality and efficiency of development.

2.3.1 Striving for a Quality and Efficient Development of Service Industry

China will strive to increase the share of value added of service industrial in GDP to 56% by 2020, speed up actions for the development of a modern service industry, expand the opening up of service industry, optimize environment for the development of service industry, and promote the transformation of production-oriented services toward the high end of value chain with professionalism, as well as the transformation of consumer-oriented services toward refinement and high quality.

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1 Data Source: *Plan for Energy Conservation and Emission Reductions in the 12th FYP Period*.

2 Source: *The 13th FYP for Developing National Strategic and Emerging Industries*.

Box 4-1 Developing National Emerging Sectors of Strategic Importance in the 13th FYP period

01	**New-generation information technology industry innovation:** Develop the integrated circuit industry system, artificial intelligence, intelligent hardware, new display, mobile intelligent terminal, 5G mobile communication, advanced sensor and wearable equipment as new growth points.
02	**Biological industry multiplication:** Speed up the application of genomics and other biological technologies in a large scale, build a network application demonstration system, and advance the scale development of new-generation biotechnological products and services, such as personalized medicine, new drugs and biotechnology breeding. Propel the construction of basic platforms of gene pool and cell bank.
03	**Intelligent perception of spatial information:** Accelerate the construction of national civil space infrastructure centered on multi-mode remote sensing, broadband mobile communication and Beidou's global satellite navigation to build up systematic technological support and industrial application capability to serve for the fields of global communication, disaster prevention and reduction, resource investigation and supervision, urban management, meteorological and environmental monitoring, location-based service, etc. Speed up the commercial use of Beidou Satellite and remote sensing satellites.
04	**Energy storage and distributed energy:** Try to achieve the breakthroughs and industrialization of core technologies, such as new generation photovoltaic, high-power and efficient wind power, biomass energy, hydrogen energy, fuel cell, smart power grids, and new energy storage device.
05	**Advanced materials:** Strive to develop intelligent materials like shape memory alloy and self-healing material, functional nano materials like graphene and metamaterial, next-generation semiconductor materials like InP and SiC, new structural materials like high performance carbon fiber, vanadium-titanium and high temperature alloy, and degradable materials and biosynthetic materials
06	**New energy vehicles:** Implement the plan of promoting new energy vehicles, and encourage the use of such vehicles in urban public transportation and the taxi industry. Make efforts to develop battery electric vehicles and plug-in hybrid electric vehicles, break through the critical technologies of energy density and high-low temperature adaptability, build charging infrastructure service networks in compliance with the same standards and compatible with each other, and perfect the sustainable supporting policy system to make the accumulated sales amount of new energy vehicles up to five million in the country. Propel the recycle and treatment of waste batteries of new energy vehicles.

2.3.2 Deepening the Supply-Side Structural Reform

China will cultivate and strengthen new industries, transform and upgrade traditional industries, build a new system for modern industries with strong innovation ability, excellent service quality, close cooperation and friendly environment, Promote the development of the manufacturing industry toward the direction of high-end, intelligence, green and service. Accelerate the development of new manufacturing industry, promote the transformation and upgrading of traditional industries, and address the overcapacity problems in a steady and active manner.

2.3.3 Supporting Development of Emerging Sectors of Strategic Importance

China will put great efforts for making the share of value added of emerging sectors of strategic importance in GDP reach 15% by 2020, provide support for the development of industries covering new generation information technology, new energy vehicles, biotechnology, green and low-carbon development, high-end equipment and materials, digital creativity, and put great efforts in promoting the innovation and industrial development of emerging industries at frontier areas including advanced semiconductors, robots, additive manufacturing, intelligent systems, new generation aviation equipment, integrated service system for space technologies, intelligent transportation, precision medicine, highly efficient energy storage and distributed energy system, intelligent materials, efficient energy saving and environmental protection, virtual reality and interactive film and television, which will be developed into new growth points, and strive to foster a range of emerging sectors of strategic importance such as aerospace and marine areas, information network, life sciences and nuclear technology.

Chapter 3 Energy Conservation and Improvement of Energy Efficiency

Giving priority to energy conservation is a major strategy in the economic and social development of China. China has promoted energy conservation through policies and measures including improving laws and regulations on energy conservation, strengthening performance assessment of energy conservation targets, implementing key energy conservation projects, implementing economic incentive policies for energy conservation, improving energy efficiency standards and labeling, enhancing energy conservation in major areas and enhancing support of energy conservation technologies and building of service system, and has made significant progress.

3.1 Key Policies and Actions

Since an around 20% reduction in energy consumption per unit of GDP in 2010 from 2005 was set as an obligatory target in the *Outline of 11th FYP* for the first time, the *Outline of 12th FYP* has adopted a 16% reduction in energy consumption per unit of GDP as an obligatory target. To achieve the development targets set in the FYP, the Chinese government has compiled *Comprehensive Work Plan on Energy Conservation and Emission Reduction*, *Comprehensive Work Plan on Energy Conservation and Emission Reduction during 12th FYP period* and *12th FYP for Energy Conservation and Emission Reduction*, which have become general action plans guiding China's energy conservation and energy efficiency improvement work during the 11th FYP period and the 12th FYP period.

3.1.1 Improving Laws and Regulations on Energy Conservation

Energy Saving Law is the fundamental law guiding China's energy conservation work. To motivate the whole society to save energy, improve energy utilization efficiency, protect and improve the environment and facilitate comprehensive, coordinated and sustainable economic and social development, the NPC Standing Committee revised the law on October 28, 2007 and July 2, 2016.

China has further improved its laws and regulations on energy conservation and issued *Industrial Energy Saving Management Scheme* since 2011[1], to promote the implementation of the basic national policies on resource saving and environmental protection in industrial sectors, strengthen management of energy for industrial use, adopt technologically feasible, economically reasonable and environmentally and socially sustainable measures, reduce energy consumption on all links of industrial sectors, reduce pollutant emission, and utilize energy efficiently and reasonably. Such regulations and rules as the *Measures for Energy Conservation Supervision*, the *Measures for the Administration of Energy Labels*, the *Measures for the Energy Conservation Examination of Fixed-Asset Investment Projects* and the *Measures for the Administration of Energy Conservation of Major*

[1] *The Industrial Energy Saving Management Scheme* issued by MIIT in 2016.

Energy-Consuming Entities were formulated and issued to further complement the law & regulation system for energy conservation. In accordance with those laws and regulations and based on local situations, local governments have developed corresponding implementation measures. For example, the Xinjiang Uygur Autonomous Region and Shandong Province have issued their own implementation measures.

3.1.2 Strengthening Performance Assessment of Energy Conservation Targets

China has broken down the energy conservation target of reducing energy consumption per unit of GDP and assigned it to provinces, autonomous regions and municipalities directly under the central government, and has established target-oriented responsibility system to hold accountable local governmental officials who fail to accomplish target tasks. In the meantime, on the basis of the Energy Conservation Action by Over One Thousand Enterprises during the 11th FYP period, China has implemented the Energy Conservation and Low Carbon Action by Over Ten Thousand Enterprises during the 12th FYP[1] period, propelling about 17,000 major energy using units to do well in energy conservation during the 12th FYP period. Every year China sums up and announces the assessment results of the local energy conservation targets of over ten thousand enterprises, and includes the target completion situation and the implementation situation of energy conservation measures in the provincial governments' performance assessment system of energy conservation targets.

Every year Chinese provincial, autonomous region and municipal governments report their performance of energy saving targets to the State Council. Energy Saving Law stipulates that energy using units should establish energy conservation target responsibility system and reward collectives and individuals who make achievements in energy conservation work; public institutions should set annual energy conservation targets and prepare an implementation plan, strengthen energy consumption measurement and monitoring management and submit an energy consumption report of the previous year to the organ of the local government that administers office work; the energy using units with an annual comprehensive energy consumption of over 10 ktce and the energy using units designated by relevant State Council department or provincial, autonomous region

[1] National Development and Reform Commission and other departments, *Implementation Plan of Energy Conservation and Low Carbon Action by Over Ten Thousand Enterprises*, 2011.

or municipal government's energy conservation administration who have annual comprehensive energy consumption of more than 5 ktce but less than 10 ktce should submit an energy utilization report of the previous year, including such content as energy consumption, energy utilization efficiency, performance of energy conservation targets, energy conservation benefit analysis and energy conservation measures, to the energy conservation administration every year.

3.1.3 Implementing Key Energy-Conservation Projects

China has proposed the implementation of "Ten Major Energy Conservation Projects" in the *Outline of 11th FYP*, those are, Low-efficiency Coal-fired Industrial Boiler (Furnace) Improvement Project, Regional Combined Heat and Power (CHP) Project, Exhaust Heat and Excess Pressure Use Project, Petroleum Saving and Replacement Project, Energy Conservation Project of Motor System, Energy System Optimization Project, Building Energy Conservation Project, Green Lighting Project, Government Agency Energy Conservation Project, Energy Conservation Monitoring and Technical Service System Building Project. In *Outline of 12th FYP*, China has clearly proposed the implementation of Improvement Project for Energy Conservation, People-Benefiting Energy Conservation Product Project, Industrialization Demonstration Project of Energy Conservation Technologies, Energy Performance Contracting (EPC) Promotion Project, etc.

During the 12th FYP period, the whole social investment in the energy conservation field in China was more than 2 trillion yuan, of which the fund investment from the central finance was more than 210 billion yuan. Compared to that before the implementation of the improvement project for energy conservation, the energy conservation capacity formed was about 360 Mtce[1]. The proportion of Chinese new urban buildings that implement the mandatory standard on energy conservation was basically 100%. The total energy-saving building area increased by 7 billion square meters, and the proportion of energy-saving building area in urban civil building area was over 40%. Beijing, Tianjin, Hebei, Shandong, Xinjiang, etc. already started to implement the 75% energy conservation standard for construction of new urban residential buildings[2].

[1] Source: Zhongnengshitong (Beijing) Investment Consulting Service Center, China Energy Efficiency Investment and Assessment Committee CERS. *China Energy Efficiency Investment Progress Report (2015*). Beijing: China Science and Technology Press, 2017.

[2] The building data is from *13th Five-year Plan for Development of Building Energy Conservation and Green Buildings*.

Box 4-2 Example of Best Energy Conservation Technologies and Best Energy Conservation Cases in China

Low-grade industrial exhaust heat in Qianxi County, Hebei Province is used for urban centralized heating project

Qianxi County in Hebei Province has used the low-grade industrial exhaust heat from steel mills to supply heat for urban civil buildings, replacing original coal-fired water boilers, which has significantly reduced coal consumption, greatly improved industrial enterprises' energy utilization efficiency, realized good environmental benefit and economic benefit and innovated business model.

Chifeng Heran Energy-saving Technology Service Co., Ltd. has used the low-grade exhaust heat from the steel mill 10km from the outskirts of Qianxi County to supply heat from 3.6 million ㎡ civil buildings in the county, replacing seven 40-ton coal-fired boilers. To achieve stable, efficient system operation, the project has developed special-purpose vertical absorption-type heat exchangers, which have reduced the return water temperature of the primary network, realized big temperature difference heating, increased exhaust heat recovery rate and improved the transportation capacity of the pipeline network; the project has set up a project company at the heat supply network and the heat source respectively, combined the EPC model with the public-private partnership (PPP) model and developed a "network-source integration" operation model suitable for the situation in China in the file of heating with low-grade exhaust heat, achieving changes in heat supply operation models and heat supply technologies and offering a feasible model for promoting application of low-grade industrial exhaust heat in urban centralized heating projects.

According to the operating situation of the Phase I of the project, the total recovered industrial exhaust heat is 0.064 Mtce ever year, reducing CO_2 emission by 0.168 Mt, SO_2 emission by 543 tons and NOx by 473 tons and saving 0.38 Mt of water, with an overall energy saving rate of more than 85%.

Chifeng Heran Energy-saving Technology Service Co., Ltd. has transformed traditional heat supply models, used long-distance low-grade industrial exhaust heat in urban heating and successfully turned it into commercial operation. Its practice is an active exploration into the industrial low-temperature exhaust heat utilization field and has offered an innovative business model for centralized heating in places in the three north regions of China which have tight supply of heating sources and high energy consumption and are rich in low-grade industrial exhaust heat in surrounding industrial enterprises.

Source: NDRC

3.1.4 Implementing Economic Incentive Policies for Energy Conservation

It's proposed in *Comprehensive Work Plan for Energy Conservation and Emission Reduction* that governments at all levels should appropriate certain funds from their financial budget to support major energy conservation projects and other financial policies by granting subsidies, rewards, etc., reduce or remit corporate income tax for energy conservation projects, offset corporate income tax or other taxes with investment in special equipment for energy conservation, and encourage and guide financial institutions to increase credit support to energy conservation technology improvement projects, etc. During the 12th FYP period, China continued to improve economic policies that promote energy conservation, and promote market-oriented mechanisms for energy conservation.

In terms of budget, China has set up Special Fund for Energy Conservation and Special Fund for Resource Conservation and Environmental Protection to support research of key policies in the energy conservation field, building of major projects, promotion of efficient energy-saving products, energy conservation communications, etc. and give financial rewards to energy conservation transformation of existing buildings and elimination of backward production capacity.

In terms of finance, the Chinese government issued relevant supporting policies[1, 2, 3], to increase support to green economy, low carbon economy and circular economy, support enterprises' offering of green bonds and support energy using units to improve energy utilization efficiency and reduce energy consumption. The policy serving areas include industrial, building, transport and other relevant areas.

With respect to taxation, China abolished the consumption tax on low-emission autos and motorcycles; the vehicle & vessel taxes on energy-saving vehicles and new energy vehicles were halved, new energy vehicles were exempted from vehicle purchase taxes; the compensation for mineral resources was reduced to zero, unreasonable charges and funds introduced for energy resources were canceled, and the resource tax rate was set a reasonable level; several preferential policies on environmental protection tax and tax reduction & exemption were introduced to encourage clean production, centralized treatment and recycling by enterprises.

With respect to price, the tiered pricing system for household electricity was introduced in the whole country, and the peak-valley electricity price system was

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[1] China Banking Regulatory Commission, *Guide to Green Credit*, 2012.
[2] National Development and Reform Commission, *Guide to Offering of Green Bonds*, 2015.
[3] China Banking Regulatory Commission & National Development and Reform Commission, *Guide to Energy Efficiency Credit*, 2015.
[4] Source: State Grid Corporation of China, China Southern Power Grid Company Limited.

promoted (Figure 4-2); a tiered electricity pricing system was applied for industries with high energy consumption, high pollution or severe overcapacity, such as electrolytic aluminum, cement, and iron and steel.

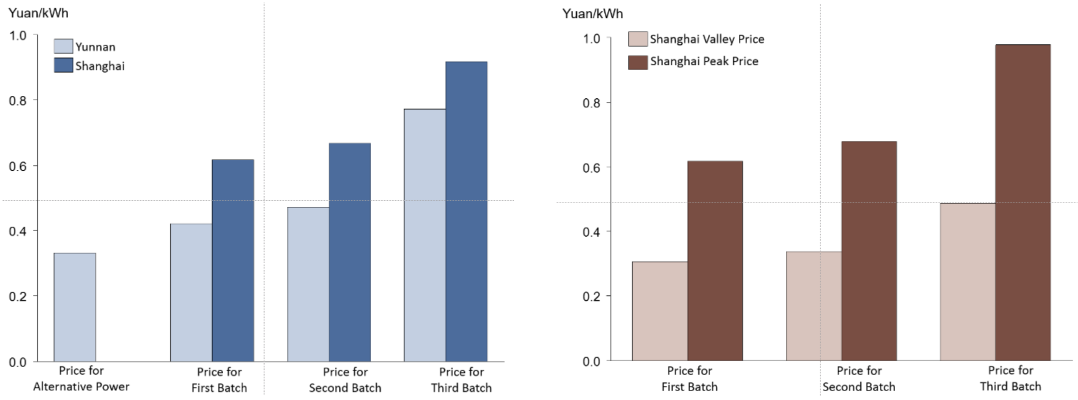

Figure 4-2 Prices of Household Electricity of Some Region in 2017[4]

3.1.5 Improving Energy Efficiency Standards and Labeling

Since the Chinese government compiled *The First Catalog of Products Adopting Energy Efficiency Labeling in the People's Republic of China* in 2004, by 2017 China had issued 14 Catalogs of Products Adopting Energy Efficiency Labeling. Since 2011, the Chinese government has launched two phases of "One Hundred Energy Efficiency Standard Promotion Projects" and approved and issued 206 basic national standards on energy efficiency, energy consumption limitations and energy conservation. As of 2017, China had compiled and implemented 64 mandatory standards on energy efficiency, 106 mandatory standards on energy consumption limitations and some 150 recommended national standards on energy conservation, which played an important role in resolving excess production capacity, optimizing the industrial structure and achieving energy conservation targets[1].

3.1.6 Enhancing Energy Conservation in Major Areas

China has focused on energy conservation in major areas such as industrial, building, transport, agricultural, rural, commercial, civil and public institutions and has improved energy utilization efficiency significantly since 2006.

Energy conservation in enterprises. China has focused on promoting energy conservation in power, coal, iron and steel, non-ferrous metal, petrochemical, chemical, building materials, paper-making, textile, printing and dyeing and food processing industries, defined clear targets and tasks, strengthened industry

[1] National Development and Reform Commission, *Proposal on Building of Energy Conservation Standard System*, 2017.

guidance, promoted advancement of technologies and enhanced supervision and management; developed CHP, promoted distributed energy and implemented intelligent grid pilots; promoted clean utilization of coal, increased raw coal washing proportion and accelerated coal-bed methane (CBM) development and utilization; implemented energy efficiency improvement plans for industrial and information industries; and promoted energy conservation transformation of information and data centers, telecommunication machine rooms and base stations.

Energy conservation of buildings. China has developed and implemented Action Plan of Green Buildings to promote building energy conservation on all sides from planning, regulations, technologies, standards and design; urged new buildings to strictly implement building energy conservation standard to improve standard implementation rate; promoted heat metering and energy conservation transformation of existing buildings in northern regions with heating provision, carried out the "Energy-saving Warm Houses" project, renewed old heat supply pipeline networks, and adopted heat-metering-based charging and energy consumption quota management; done well in energy-saving reconstruction of buildings in areas featuring hot summer and cold winter; promoted integrated application between renewable energy and buildings, promoted the use of new energy-saving building materials and recycled building materials, and continued to promote bulk cement; strengthened the building of the monitoring system on energy conservation of public buildings, improved energy auditing and energy efficiency notification, and promoted energy conservation transformation and operation management; developed building lifecycle management system and adopted stricter building demolition management; and enhanced city lighting management and strictly prevented and corrected excessive decoration and brightness.

Energy conservation in transportation. China has accelerated the building of a comprehensive transportation system and promoted the adjustment of the transportation structure and actively enacted multi-mode integrated development; Developed urban public transport as a priority, scientifically and reasonably allocated urban transport resources, and orderly advanced the construction of urban rail transport. The approach of highway transportation with plates was promoted, and the electronic toll collection (ETC) system was fully introduced in the whole country. Accelerated the elimination of outmoded cars, locomotives and vessels, basically phased out all "yellow-label vehicles" or heavy-polluting vehicles registered before 2005, and accelerated in improving the quality of auto fuel; Standardization of freight trucks was promoted. Ships for inland waters were standardized, the application of LNG powered vessels was furthered, and ships docked at harbors were strongly encouraged to use shore power. The proportion of the railway electrification system was increased, waterways and air routes were optimized, the energy conservation and emission reduction in aviation and ocean transportation industries were promoted. Carried out energy conservation transformation in airports, wharfs and stations; implemented the Phase IV emission standard of motor vehicles, and gradually implemented the Phase V emission standard in major cities and areas with conditions; and explored city regulation on motor vehicle ownership, and actively promoted energy-saving and new energy vehicles.

Agricultural and rural energy conservation. China has accelerated elimination of outmoded agricultural machines and tools and promoted energy-saving agricultural machinery, equipment and fishing boats; advanced the building of energy-saving residences, promoted upgrading of firewood and coal saving stoves, and carried out transformation for hydropower efficiency improvement and capacity expansion in rural areas; and developed household methane and medium- and large methane projects and strengthened operation management and maintenance service.

Commercial and household energy conservation. China has carried out energy conservation actions in trade service and tourist industries such as retail, accelerated energy conservation transformation of facilities, strengthened energy use management, and guided consumer behaviors; required hotels, commercial buildings, office towers, airports, stations, etc. to strictly implement the standard on the setting of air conditioner temperature in summer and winter; and promoted the use of efficient, energy-saving household appliances and lighting products among residents, encouraged the purchase of energy-saving, environment-friendly cars, supported the riding of public transport and advocated green travel.

Energy conservation in public institutions. The energy saving objective responsibility system was being introduced by public institutions. Energy efficiency retrofit was conducted on such energy consuming systems as heating, air conditioning and lighting. Carried out the selection of model conservationminded public institutions; Energy-efficient and environment-friendly products were established as compulsory items or priority items in purchasing. The application of new energy vehicles was promoted. The knowledge on energy conservation and low carbon was popularized to foster energy conservation and low carbon culture. The energy resource utilization efficiency was increased continuously.

3.1.7 Enhancing Support of Energy Conservation Technologies and Building of Service System

China has accelerated the development, promotion and application of energy conservation technologies, and the energy conservation service industry has seen rapid development since 2006. China increased support to R&D of energy conservation and emission reduction technologies in relevant national, departmental and local science and technology plans and projects, and improved relevant technology innovation system; continued to promote actions on energy conservation and emission reduction technologies and organized development of key and frontier technologies for efficient energy conservation; established the Energy Conservation Technology and Equipment Industry Alliance and continued to increase efforts in R&D of energy conservation and emission reduction technologies through National Engineering (Technology) Research Center; implemented major energy conservation and emission reduction technology and equipment industrialization projects, gave major support to key technology and equipment industrialization projects such as rare-earth permanent magnet coreless motors, semiconductor lighting, use of low-grade exhaust heat and application of geothermal energy and shallow geothermal energy, and accelerated the construction of industrialization bases; continued to prepare the catalog of national major energy conservation technologies for promotion, established selection, evaluation and promotion mechanisms for energy conservation technologies; focused on promotion of such energy conservation technologies as gradient utilization of energy, power generation with low-temperature exhaust heat, advanced coal gasification, high-voltage frequency conversion, dry quenching, regenerative heating furnaces, absorption-type heat pumps for heating, ice storage and high-efficiency heat exchangers; and strengthened communication and cooperation with relevant international organizations and governments in the field of energy conservation, actively introduced advanced energy conservation technologies from overseas and increased efforts in promotion.

During the 12th FYP period, a standardized and orderly Chinese energy conservation service market took an initial shape, people working in the energy conservation service industry increased quickly, the energy conservation service industry grew steadily, comprehensive energy conservation service capacity improved significantly, the financing channels for energy conservation service continued to expand, and the energy conservation service system was further improved. And EPC became one of the most important ways of energy using units to transform energy conservation technologies. The number of enterprises engaged in the energy conservation service market in China reached 5,426, the number of workers in the industry was 607,000, the total output was more than 300 billion yuan, and the annual growth was 30.19%; the total investment was 371.072 billion yuan, and the corresponding annual energy conservation capacity formed was 124 Mtce.

3.2 Progress and Effect of Policies and Actions

During the 11th FYP period, China saw a decrease of 19.3% in energy consumption per unit of GDP, made steady progress on energy conservation, emission reduction, and ecological and environmental protection, fulfilled targets and tasks of 11th FYP. During the 12th FYP period, China had a decrease of 18.4% in energy consumption per unit of GDP, over-fulfilled targets for energy conservation, and made great contributions to economic restructuring, environmental improvement, and global climate change addressing. Between 2006 and 2015, China saved a total of 1,576 Mtce, with 3,659 Mt CO_2 emissions avoided.

3.2.1 Reduction of Energy Consumption from the Production of Main High Energy Consuming Products

China saw a widespread decrease in energy consumption from the production of main high energy consuming products (Figure 4-3), such as, a decrease of 14.9% in coal consumption as per unit power generation at thermal power plants, a decrease of 8.1% in comprehensive energy consumption for cement production as per unit power generation, a drop of 12.0% in comparable energy consumption for steel production as per unit production, a drop of 7.0% in electricity consumption for electrolytic aluminum production as per unit production, a drop of 20.4% and 9.4% in comprehensive energy consumption respectively for ethylene and synthetic ammonia production as per unit production, and a decrease of 24.3% in comprehensive energy consumption for paper and cardboard production as per unit production.

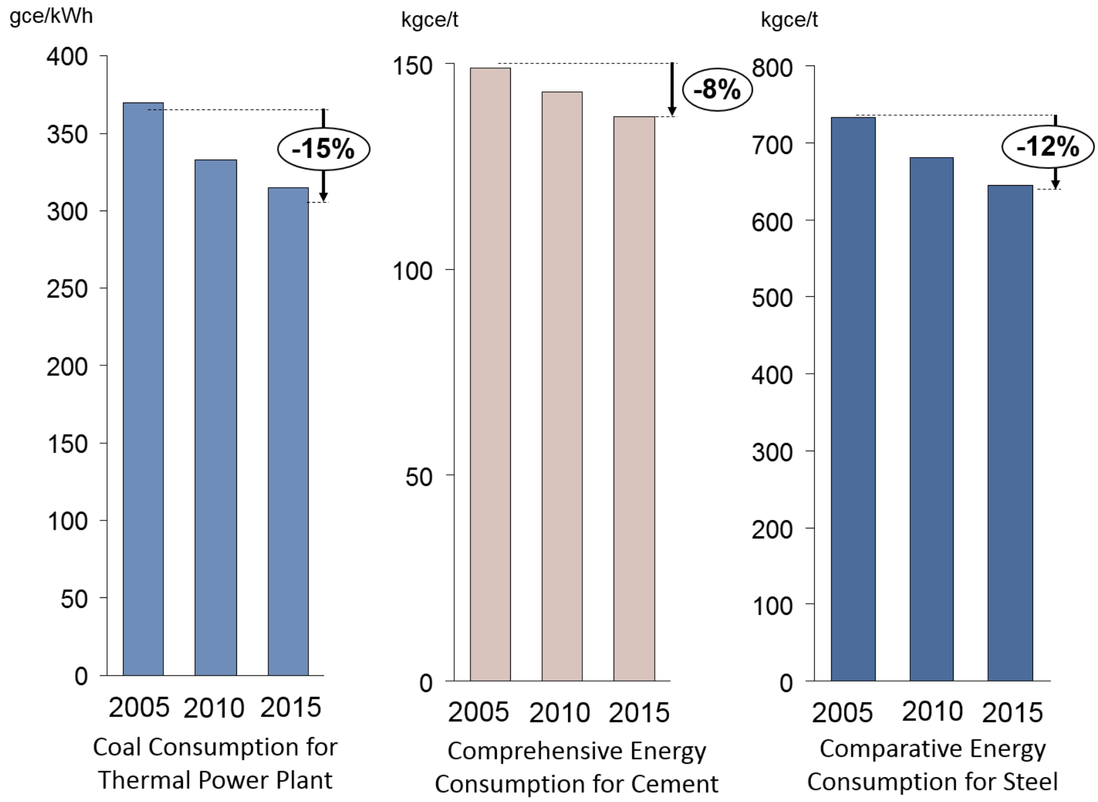

Figure 4-3 Energy Consumption of Energy-intensive Products of China[1]

3.2.2 Progress on Energy Conservation in Buildings

During the 12th FYP period, China has achieved great progress on the cause of energy efficient buildings and green buildings, kept raising energy efficient building standards, and experienced a leap-forward development of green buildings, conducted in full swing residential renovation directed for energy efficient buildings in cold and chilly areas, increased regulation on energy efficient requirements for public buildings, and pushed steadily for energy efficient transformation in key cities and schools, hospitals and other areas(Table 4-1).

[1] Source: *China Energy Statistical Yearbook 2016*.

Table 4-1 Indicators of Energy Efficient Buildings and Green Buildings[1]

Region	2010	2015
Implementation level of energy conservation standards for newly built buildings in cities and towns (%)	95.4	100
Areas of renovated space for energy conservative buildings in cities and towns located in cold and chilly areas (100 million square meters)	1.8	11.7
Areas of renovated space for energy efficiency in buildings in cities and towns located in areas featuring hot summers and cold winters (100 million square meters)	-	0.7
Areas of renovated space of public building for energy efficiency (100 million square meters)	-	1.1
Number of projects labeled for green buildings (unit)	112	4,071

3.2.3 Progress on Energy Conservation in Transportation

Regarding the railway transportation, comprehensive energy consumption per unit of transport workload in 2015 was 4.68 tce/million converted tKm[2], a decrease of 27.8% compared with 6.48 tce/million converted tKm[3] in 2005, showing a significant drop.

Regarding the highway and waterway transportation, between 2005 and 2015, the energy consumption per unit transport turnover of operating vehicles and ships went down by 15.9% and 20% respectively[4]. For road transport, energy consumption per 100 ton kilometer was 1.9 kilogram coal equivalent (kgce) in 2015, with an decrease of 13.6% from 2.2 kgce in 2011; for ocean and coastal freight enterprises, energy consumption per 1000 ton-nautical mile was 5.2 kgce in 2015, with a decrease of 25.7% from 7 kgce in 2011; for port enterprises, energy consumption per 10,000 ton was 2.6 tce in 2015, with a decrease of 17.7% from 3.16 tce in 2011.[5]

China civil aviation's energy consumption per ton-km in 2015 dropped by 13.5% from 0.294kg/ton-km in 2005 (basis year for target of energy conservation and emission reduction of this industry); during the 12th FYP period, China civil aviation's energy consumption per ton-km dropped nearly 5% compared with that

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1 *Notice on Printing and Distributing of the 13th FYP for the Development of Energy-Saving Buildings and Green Buildings issued by* Ministry of Housing and Urban-Rural Development (MoHURD), March 2017.

2 Source: *Statistical Bulletin of Development of China's Transportation Industry in 2015*.

3 Source: Ma Chaoyun, Liang Xiao, Mao Baohua, Jia Shunping, *Analysis of Current Situation of Energy Consumption for Rail Transportation*, China Railway, 2010(11):51-55.

4 Source: *The People's Republic of China First Biennial Update Report on Climate Change (1BUR)*.

5 Source: *Statistical Bulletin of Development of China's Highway and Waterway Transportation Industry in 2011* and *Statistical Bulletin of Development of China's Transportation Industry in 2015*.

during the 11th FYP period[1].

3.2.4 Progress on Regional Energy Conservation

During the 11th FYP period, China assigned its national energy conservation task for reducing energy consumption per unit of GDP to 31 provinces, autonomous regions and municipalities on mainland China. All regions fulfilled the assigned targets for energy conservation, excluding Xinjiang which had a separate examination, and 28 regions over-fulfilled their targets. During the 12th FYP period, China again assigned the national energy conservation task to all regions on mainland China, among which, through examination and review,10 provinces (autonomous regions, municipalities) over fulfilled their tasks, 20 provinces (autonomous regions, municipalities) fulfilled their tasks, and Xinjiang partially fulfilled its task (Table 4-2).

Table 4-2 Fulfillment of Energy Saving Target for 12th Five-year Period by Area

Region	Energy saving objectives (%)	Review results	Region	Energy saving objectives (%)	Review results
Beijing	17	Outperformed	Hubei	16	Outperformed
Tianjin	18	Fulfilled	Hunan	16	Fulfilled
Hebei	17	Outperformed	Guangdong	18	Outperformed
Shanxi	16	Fulfilled	Guangxi	15	Fulfilled
Inner Mongolia	15	Fulfilled	Hainan	10	Fulfilled
Liaoning	17	Fulfilled	Chongqing	16	Fulfilled
Jilin	16	Fulfilled	Sichuan	16	Fulfilled
Heilongjiang	16	Fulfilled	Guizhou	15	Outperformed
Shanghai	18	Outperformed	Yunnan	15	Fulfilled
Jiangsu	18	Outperformed	Tibet	10	Fulfilled
Zhejiang	18	Outperformed	Shaanxi	16	Fulfilled
Anhui	16	Outperformed	Gansu	15	Fulfilled
Fujian	16	Fulfilled	Qinghai	10	Fulfilled
Jiangxi	16	Fulfilled	Ningxia	15	Fulfilled
Shandong	17	Fulfilled	Xinjiang	10	Almost Fulfilled
Henan	16	Outperformed			

[1]Source: *Statistics Bulletin on Development of Civil Aviation Industry in 2015*.

3.3 Key Objectives and Tasks of 13th FYP Period

The *Outline of 13th FYP* set forth main targets to save energy and improve energy efficiency in China for the 13th FYP period (2016-2020), including the obligatory target for reducing energy intensity by 15%. To push for revolution of energy consumption. To implement all-for energy conservation action, promote energy efficiency in areas including industry, buildings, transportation and public institutions, and upgrade systems of boiler (furnace), lighting and motor, and carry out major projects like "warming city through waste heat". To put vigorous effort in developing and promoting energy-saving technologies and products, and perform major technology demonstrations. To implement the "Hundred-Thousand-Ten Thousand" action and voluntary energy conservation activities among key energy consuming entities, promote the construction of energy management system, metering system and on-line energy consumption monitoring system, and perform energy assessment and performance evaluation. To implement plans to improve energy efficiency in buildings and develop a complete industry chain related to green buildings. To promote the implementation power dispatching through energy-saving and low-carbon. To promote the arrangement of comprehensive energy and cascade use.

After printing and distributing the *Comprehensive Work Plan on Energy Conservation and Emission Reduction for 13th FYP* in 2016, the Chinese government required all regions, departments, and central stated-owned enterprise to come up with specific implementation plans according to their practical conditions and the work plan, make clear targets and responsibilities, focus on plan implementation and execution, attach great importance on examination and accountability, ensuring the realization of 13th FYP targets for energy conservation. Later, the Chinese government formulated the Nationwide Energy Conservation Action Plan during the 13th FYP period where it put forward ten major actions including action to promote energy efficient products, action to improve energy efficiency in key energy consuming entities, action to improve industrial energy efficiency, action to improve buildings' energy efficiency, action to promote energy efficiency in transportation area, action to take the lead in energy saving by public institutions, action to multiply energy-saving services industry, action to support energy saving technologies, action to save energy among residents, and action to promote major energy saving projects, in an effort to promote the revolution of energy production and consumption in China, greatly improve the efficiency of energy & resources development and utilization, effectively control total energy consumption, and promote development of energy-saving industries, ensuring the realization of targets on energy conservation for 13th FYP period.

Chapter 4 Build Low Carbon Energy System

China has actively adjusted and optimized energy structure and taken a series of measures such as vigorously developing non-fossil energy, promoting clean and efficient use of fossil energy and strictly controlling coal consumption to construct a low-carbon, efficient and sustainable energy system. Looking into the 13th FYP period, China will further promote the construction of the low-carbon energy system to lay a foundation for achieving the goals of non-fossil energy development and carbon emission peaking in 2030.

4.1 Key Policies and Actions

China has always developed non-fossil energy while pursuing clean and efficient use of fossil energy. It also takes the development of clean and low-carbon energy as the main direction of adjusting energy structure. The *12th Five-Year Plan for Energy Development* compiled by the Chinese government in 2013 further proposed the main goals and tasks of optimizing energy structure during the 12th FYP period: to lift the share of non-fossil energy consumption to 11.4%; increase the ratio of installed power generation capacity of non-fossil energy to 30%; increase the share of natural gas in energy consumption to 7.5%; and reduce the share of coal consumption to around 65%.

4.1.1 Actively Develop Non-Fossil Energy

1) Strive to develop new energy and renewable energy

In the 11th FYP period, China revised the *Renewable Energy Law of the People's Republic of China* (hereinafter referred to as the *Renewable Energy Law*) and compiled the *Medium and Long-term Development Plan for Renewable Energy* and the *11th FYP for the Development of Renewable Energies*, which made a scientific planning for the development of Chinese renewable energy and set forth the guidelines and fundamental principles of developing and using renewable energy in China. The *Medium and Long-term Development Plan for Renewable Energy* put forward the general goal of developing renewable energy in China in the coming 15 years, that is, to increase the share of renewable energy in energy consumption, address the power questions of remote areas and shortage of living fuels in rural areas, implement the energy utilization of organic waste, and promote the industrial development of renewable energy technologies. During the 11th FYP period, the Chinese government also introduced a series of finance and taxation policies to push the development of renewable energy[1].

During the 12th FYP period, China increased the support to the development of new renewable energy, such as wind, solar, geothermal and bioenergy. The Chinese government has released the *12th FYP for Renewable Energy Development*, *12th FYP for Wind Power Development*, *12th FYP for Solar Power Development* and *12th FYP for Bioenergy Development*[2], which proposed the development goals, planning and layout, and construction emphasis of Chinese renewable energy, formulate and improve the policies of on-grid priority, full-scale purchase, favorable price and social apportionment for renewable energy, and establish special funds for renewable energy development, which were used to support resource assessment and investigation, relative technical R&D, pilot and demonstrative projects, and exploitation and utilization of rural renewable resources. In 2015, China lifted the price of renewable energy power used for the purposes except residents' living and agricultural production to 0.019 yuan/kWh according to the additional tariff collection standard[3], which was 0.004 yuan/kWh higher than the previous price.

2) Develop nuclear power safely and efficiently

Since the 12th FYP period, China has attached more importance to the safe and efficient development of nuclear power. The *Outline of 12th FYP* proposed to efficiently develop nuclear power while ensuring security. The Chinese government approved the *Medium and Long-term Plan for Nuclear Power Development (2011-2020)* and the *Nuclear Power Security Plan (2011-2020)*, which

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[1] *Interim Measures for the Administration of Special Funds for the Industrialization of Wind Power Generation Equipment*, *Interim Measures for the Administration of Financial Subsidies for the Golden-sun Demonstration Project*, *Interim Measures for the Administration of Financial Subsidies for the Application of Building-integrated Photovoltaics*, and *Notice on Improving the Policies of On-Grid Wind Power Prices*.

[2] *Guiding Opinions on Promoting the Development and Utilization of Geothermal Energy*, *Several Opinions of the State Council on Promoting the Healthy Development of Photovoltaic Industry*, *Interim Measures for the Administration of Special Funds for Renewable Energy Development*, *Interim Measures for the Administration of Additional Subsidies for Renewable Energy Power Price*, *Measures for the Administration of Full-scale Guaranteed Purchase of Renewable Energy Power*, *Interim Measures for the Administration of Distributed Power Generation*, and *Notice on Further Promoting the Application of Building-integrated Photovoltaics*.

[3] *Notice on Reducing the On-grid Tariff of Coal-fired Power Generation and the Prices of General Industrial and Commercial Power* issued by the NDRC in 2015.

made an overall deployment for China's nuclear power development in the future period. The *12th FYP for Energy Development* further deepened the tasks and goals of safely and efficiently developing nuclear power, including strictly implementing the "Nuclear Power Security Plan" and "Medium and Long-term Plan for Nuclear Power Development", continuously performing safety transformation for in-service and under-construction nuclear power units, reinforcing nuclear power security management in an all-around way, and improving the capacity of nuclear accident emergency response.

4.1.2 Promote the Development of Natural Gas

1) Accelerate the development of natural gas

China has established the strategic guideline of "working on oil and gas simultaneously" to encourage the exploitation and utilization of natural gas. The *12th FYP Natural Gas Development* released by the Chinese Government set the targets of in 2015 a domestic natural gas supply capacity of 176 billion m^3 and import volume of about 93.5 billion m^3, along with development targets for conventional natural gas, synthetic natural gas, coal bed methane, shale gas, natural gas penetration rate and infrastructure etc. According to the working program for air pollution prevention and control[1], the share of natural gas (excluding coal gas) will be respectively above 7% and 9% in 2015 and 2017. The "Scheme" also set forth the tasks and measures of guaranteeing the long-term and stable supply of natural gas[2] and the policies of financial subsidy for distributed energy system, feeding power into grid, and electricity subsidy to further promote the distributed energy development of natural gas[3]. In order to regulate the CTL and CTG Industries for orderly development[4], access parameters were proposed regarding energy conversion efficiency, energy consumption, water consumption, CO_2 emission, pollutant discharge to regulate the operation of coal-to-liquids (CTL) and coal-to-gas (CTG) projects.

[1] *Working Program of the Energy Industry for Strengthening Air Pollution Prevention and Control* issued by NDRC, NEA and MEE in 2014.

[2] *Several Opinions on Building a Long-term Mechanism to Guarantee Stable Supply of Natural Gas* issued by the NDRC in 2014.

[3] *Guiding Opinions on Developing the Natural Gas Distributed Energy* and *Rules of Implementing the Demonstration Projects of Natural Gas Distributed Energy* issued by NDRC in 2014.

[4] *Notice on Standardizing the Development of Coal-to-liquids and Coal-based SNG Industries and Sciences* issued by the National Energy Administration (NEA) in 2015.

2) Accelerate the development of coal-bed gas and shale gas

In the 12th FYP period, the Chinese government worked out the *12th FYP for the Development and Utilization of Coal-bed Gas (Coal-mine Gas)*, which set forth the general scheme of governing and using coal-mine gas to guide and encourage the use of coal-mine gas and the exploitation of ground coal-bed gas, and set the goals that till 2015, the yield of coal-bed gas (coal-mine gas) would reach 30 billion m^3, the installed capacity of power generation of gas exceed 2.85 MW, the number of households using gas power beyond 3.2 million, and the new proved geological reserves of coal-bed gas be one trillion m^3. The Chinese government also developed the *Shale Gas Development Plan (2011-2015)*, which proposed the goal that till 2015, the yield of shale gas will be 6.5 billion m^3 and arranged special funds to support the exploitation of shale gas[1]. China also formulated related industrial policies[2] to promote the scientific and efficient development and use of coal-bed gas and shale gas.

4.1.3 Strictly Control on Coal Consumption

1) Put more efforts in total coal consumption control

The Chinese government has constantly strengthened the policy of controlling the total coal consumption since 2011. The *Outline of 12th FYP* proposed the tasks of "optimizing energy structure and controlling the total energy consumption in a rational way" and gradually identified the control requirements on total coal consumption through a series of policies[3]. The *GHG Control in 13th FYP* further emphasizes the goal and requirements for controlling total coal consumption. China has set the medium and long-term goals of controlling the national total coal consumption and proposed the goal in the *Energy Development Strategy Action Plan (2014-2020)* that till 2020, the total coal consumption will be controlled to around 4200 Mt.

2) Reduction of coal consumption by alternative sources

In 2013, China proposed that by the end of 2017, the reduction amount of total coal consumption of Beijing and Tianjin cities and Hebei and Shandong provinces would be 83 Mt, and the reduced coal consumption of each of the four regions

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1 *Notice on Issuing the Subsidy Policies of Exploring and Utilizing Shale Gas* issued by the MOF and NEA in 2012.

2 *Coal-bed Gas Industrial Policy* and *Shale Gas Industrial Policy* issued by NEA in 2013.

3 *Notice of the State Council on Issuing the 'Comprehensive Work Program for Energy Conservation and Emission Reduction 12th FYP period', Notice of the State Council on Issuing the '12th FYP for Energy Conservation and Emission Reduction'*, and *Notice of the State Council on the Approval of the '12th FYP for Air Pollution Prevention and Control in Major Areas'*.

would respectively be 13 Mt, 10 Mt, 40 Mt and 20 Mt[1]. In 2014, China took the measures of weight-reduction substitution and cleaning substitution of bulk coal at the same time, for the purpose of realizing clean utilization of bulk coal for the residents in the Beijing-Tianjin-Hebei region till the end of 2017[2]. Guangdong, Jiangxi, and Chongqing proposed that in 2017, the goals of respectively reducing the ratio of coal below 36%, 65%, and 60%. The *Energy Development Strategy Action Plan (2014-2020)* set forth the policies of implementing coal consumption weight-reduced substitution, reducing the share of coal consumption, and cutting down the total coal consumption in the Beijing-Tianjin-Hebei region, and Shandong province, Yangtze River Delta and Pearl River Delta; and proposed the goals and programs of coal consumption weight-reduced substitution for Beijing, Tianjin, Hebei, Shandong, Shanghai, Jiangsu, Zhejiang, and the Pearl River Delta of Guangdong[3]. In 2015, China further strengthened coal consumption control of key Air pollution control cities, set the target of achieving negative increase as against the previous year in the coal consumption of the Top 10 cities of poor air quality[4].

4.2 Progress and Effect of Policies and Actions

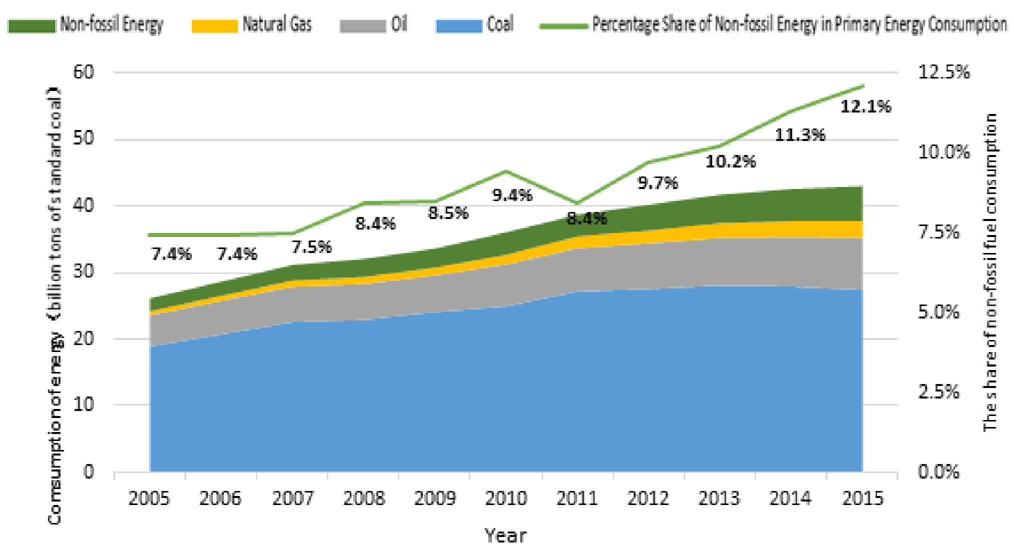

Figure 4-4 China's Energy Consumption Mix

[1] *Rules of Implementing the Air Pollution Prevention and Control Plan in the Beijing-Tianjin-Hebei Region and Surrounding Areas* issued by MEP and NDRC in 2013.
[2] *Working Program of Clean Governance for Bulk Coal in the Beijing-Tianjin-Hebei Region* issue by NDRC and NEA in 2014.
[3] *Interim Measures for the Administration of Weight-reduced Substitution for Coal Consumption in the Major Areas* issued by NDRC, MIIT, MOF, MEP, NBS and NEA in 2014.
[4] *Working Program of the Energy Industry for Strengthening Air Pollution Prevention and Control* issued by NDRC, MEP, NEA in 2015.

Rapid Development of Non-Fossil Energy. Since 2011, the scale of development and utilization of new energy and renewable energy has grown significantly in China. By the end of 2015, China's power generation capacity of non-fossil energy occupied 27.2% of the national gross generating capacity. The share of non-fossil energy consumption went up from 7.4% of 2005 to 12.1% of 2015, with a growth of 4.7 pps (See Figure 4-4). The installed hydro, on-grid wind, photovoltaic (PV) and nuclear power capacities reached 320, 130, 42.18 and 27.17 GW, or 2.7, 123, 603 and 3.9 times of those in 2005, respectively.

Efficient Use of Natural Gas. Since 2011, the scale and level of natural gas utilization has been enhanced constantly. In 2015, China produced 134.61 billion m^3, imported 61.14 billion m^3 and consumed 193.17 billion m^3 of natural gas. The share of natural gas in the total energy consumption grew to 5.9% in 2015 from 4.0% in 2010. By 2015, a total of 64,000 km of natural gas pipelines have been built in China to bring into shape a national gas transmission pipeline network. In 2015, the quantity of drainage of national coal-bed gas (coal-mine gas) was 14 billion m^3, in which 7.7 billion m^3 were used; the yield of coal-bed gas (ground extraction) was about 4.4 billion m^3, in which 3.8 billion m^3 were used; the yield of shale gas was 4.6 billion m^3.

Strict Control on Coal Consumption. From the middle and later periods of the 12th FYP, the growth of China's coal consumption was slowed down and even showed a falling trend. In 2014 and 2015, the national total coal consumption was respectively 4116 and 3970 Mt, falling by 3.0% and 3.5% on a year-on-year basis. In the 12th FYP period, China's coal consumption had an annual average growth rate of 2.6%, which was 4.8 pps lower than the annual average growth rate of the 11th FYP period. The share of coal in Chinese total energy consumption has decreased constantly from 72.4% of 2005 to 63.7% of 2015 (as shown in Figure 4-4). Compared with 2012, coal consumption in Beijing-Tianjin-Hebei region has decreased in 2015 with a reduction of CO_2 emission by 56 Mt.

4.3 Key Objectives and Tasks of 13th FYP Period

The 13th FYP period is the deciding period for China to achieve its target of raising non-fossil energy consumption to 15% of the energy mix by 2020 as well as the key period for China to establish foundations for peaking carbon emissions by around 2030. Therefore, China will further adjust and optimize energy structure, push forward the development of new energy industries, step up to establish and improve a modern energy system that is clean, low carbon, safe and efficient. First, the total energy consumption was to be controlled. "Double controls" of the total energy consumption and the intensity of energy consumption will be implemented. Secondly, China will optimize energy consumption structure, expand natural gas consumption and increase the share of natural gas and non-fossil energies in the energy consumption. China aims to have natural gas account for 10% of total energy consumption by 2020, increase non-fossil energies to more than 15% of total energy consumption; reduce coal consumption to lower than 58%; and increase coal consumption for electricity to more than 55% of total coal consumption. Thirdly, China will push forward sustainable development of non-fossil energies, give priority to hydropower development, safely and stably push forward nuclear power development; comprehensively coordinate development of wind power, solar energy and other renewable energies; consider local conditions to develop bioenergy, geothermal energy, ocean energy and other new energies. By 2020, China strives to increase installed capacity of conventional hydropower to 340 GW; steadily increase installed capacity of nuclear power and capacity under construction; increase installed capacity of wind power to more than 210 GW, and basically achieve on-grid price parity of wind power and coal electricity; increase installed capacity of solar power generation to more than 110 GW, of which 60 GW from distributed photovoltaic power, 45 GW from phtotovoltaic power stations, and 5 GW from solar thermal power, also, achieve user-side on-grid price parity of photovoltaic power generation; increase installed capacity of bioenergy power generation to 15 GW and utilization of geothermal energy to more than 70 Mtce.

Chapter 5 Stabilization and Increase of Carbon Sinks

According to overall planning in addressing climate change, with rigorous afforestation, scientific forest management, strict forest protection, the forest resources in China has continuously increased, wetland protection continuously strengthened and forest carbon sink stably increased. These efforts have significantly contributed to copping with climate change, expanding development scope and developing ecological civilization.

5.1 Key Policies and Actions

During the 11th FYP period, China implemented the Forestry Action Plan to

Address Climate Change[1] and set the target of significantly increasing forest carbon sinks: by 2015, increase forest coverage to 21.66%, forest stock volume to more than 14.3 billion m^3, and total carbon stocks in forest vegetation to 8400 Mt; newly improving desertification lands by more than 10 million ha; increasing wetland area to 42.48 million ha and natural wetland protection rate to more than 55%; bringing forest fire damage rate steadily under 1‰; and retaining disaster rate of forestry pests under 4.5‰. During the 12th FYP period, China included forest coverage and forest stock volume as binding indicators, specified key areas and major activities of forestry in mitigating climate change, which mainly included stepping up afforestation and greening, conducting nationwide forest tending and management, strengthening forest resources management as well as prevention and control of forest disasters[2].

5.1.1 Rigorously Push Forward Afforestation and Greening and Forest Management

China actively pushed forward territory greening, made efforts to improve forest quality and continuously increased forest carbon sinks. The Chinese government released *Forestry Development Planning during the 12th FYP* period and *National Afforestation and Greening Planning Outline (2011-2020)*, brought forward afforestation and greening targets and tasks during the 12th FYP period and next 10 years, and further assigned concrete targets and tasks to all regions and departments. It is imperative to strengthen supervision on implementation of afforestation and greening plan, to advance afforestation and greening in dry areas, Beijing-Tianjin-Hebei region and other key areas, and to expand the scale of a new round of forestry programmes, to speed up the implementation of key forestry projects such as Grain to Green, Integrated Stony Desertification Control, Desertification Control for Areas in the Vicinity of Beijing and Tianjin, Northwest-North-Northeast China (Sanbei) and Yangtze River Forest Shelterbelt Development, and Natural Forest Resources Conservation. China established the Leading Group on Forest Tending and Management under the State Forestry Administration, which set up a working system, specified responsibilities and initiated pilot projects receiving central finance subsidiaries for forest tending. It released *National Forest Management Planning (2016-2050)*, emphasized the

[1] *Forestry Action Plan to Address Climate Change* issued by State Forestry Administration in 2009.
[2] *Forestry Action Key Points in Addressing Climate Change* during the 12th FYP issued by State Forestry Administration in 2011.

establishment of forest management system, implemented subsidiary policies for forest tending, enhanced scientific forest tending and steadily pushed forward the establishment of forest management exemplary bases.

5.1.2 Strengthen Forest Resources Protection

China strengthened forestry resources protection to maximize forestry GHG emissions reduction. China strengthened forest resources protection and management, strictly implemented plans of forested land protection and utilization, strictly protected national public forest, actively pushed forward forest harvest and tree cutting management reform, enhanced forest land utilization management and control, strictly struck illegal embezzlement of forest lands, resolutely retained the trends of forest land loss and worked hard to reduce forest carbon emissions caused by resources damage. Efforts have also been made to strengthen natural forest resource protection, implement protective policies of natural forest, expand the protection scope of the natural forest resources, and to stop commercial lumbering of natural forests. China enhanced construction of natural reserves and effectively protected those regions in China that have the richest biodiversity, most precious natural ecosystems, most important ecological functions and most beautiful natural landscapes. China strengthened forest fire prevention by in advance motivation and deployment, conducting overall real-time monitoring, proactively preventing and pre-alarming. Also, China reduced carbon emissions from forest fires by organizing scientific firefighting activities. China enhanced prevention and control of forest pests, focused on dealing with sever incidents of adventive pests intrusion, deeply pushed forward joint prevention and joint management, pollution-free prevention and management, and prevention and management in key ecological areas, improved forest health and reduced carbon emissions caused by disasters. China enhanced wetland protection and restoration, strongly pushed forward constructions of wetland protection and restoration projects, which gradually elevated carbon sink functions of wetland ecosystems.

5.1.3 Strengthen Scientific and Technological Support

China established and improved technological support system for forestry in addressing climate change, strengthened capability building of forestry in addressing climate change. China actively pushed forward the development of forest carbon accounting and monitoring systems, infrastructure and technical standards of forestry carbon sink, and provided data support for scientific decision-making in dealing with climate change. Benefiting from special research funds for public welfare industries, Introduction of International Advanced Agricultural Science and Technology Program (948 Program), National Science and Technology Support Program and other science and research platforms, China conducted researches on key areas and technologies in climate change mitigation by forestry to solve scientific difficulties and to address climate change.

5.2 Progress and Effect of Policies and Actions

5.2.1 Forest Carbon Sinks Functionality Steadily Strengthened

According to the outcomes of the 8th National Forest Inventory (2009-2013), China's forests area has reached 208 million ha, which accounted for 60% of the country's forest increase target by 2020; forest stock volume is 15,137 million m^3, which means China has achieved the target of increasing forest stock volume by 2020 in advance; forest coverage increased from 20.36%to 21.63%; and total carbon stock in forest vegetation increased from 7,811 Mt to 8,427 Mt during last five years. During 2013-2015, in average, China completed afforestation of 6.1 million ha per year, obligatorily planted more than 2.4 billion trees per year, achieved forest tending areas of more than 7.8 million ha per year. Both forest area and forest stock volume continued to increase. In 2015, China added 400 thousand ha' wetland protection zone, recovered 20 thousand ha' wetland, designated 3 wetlands as Wetland of International Importance (WII), and designated 137 wetlands as pilot National Wetland Parks (NWP). The carbon sink function of the wetland ecosystem was gradually enhanced[1].

5.2.2 Effectively Protected Carbon Sink Function of Forests

China effectively protected forests as carbon sinks by strengthening forest resources protection and management, natural forests protection and construction of natural reserves. The areas under management and protection of China's natural forest resources protection project reached 115.4 million ha. Forest area and forest stock volume both increased, and water conservation and carbon sinks and other ecological services are prominently strengthened. By the end of 2015, China's forestry system has established 2,228 natural reserves of different types at different levels (including 345 national natural reserves), which

[1] *Forestry Strategies and Action Agenda on Climate Change Response 2015* by National Forestry Administration in 2016.

cover a total area of 124 million ha or 12.99% of China's territorial area.

China reduced GHG emissions from disasters by strengthening forest fire prevention and strengthening forest pests' prevention and management. Compared with the average value since 1999, the occurrence of forest fires, damaged forest area, human injuries and deaths caused by forest fires were reduced by 54.6%, 81.3% and 18.3% respectively, and forest fire damage rate was steadily controlled under 1‰; disasters caused by main forest pests was controlled under 4.5‰, pollution-free prevention and management rate was higher than 85%, which improved forest health and reduced carbon emissions from disasters[1].

5.2.3 Strengthened Capability Building of Forestry in Addressing Climate Change

During the 12th FYP period, China released a series of technical standards and regulations about forest carbon sinks, including *Technical Regulation of Carbon Sink Afforestation*, *Guidance for Afforestation Projects Carbon Sink Measuring and Monitoring*. Also, major achievements were made in preparations of regulations including *Technical Guidance for Forestry Carbon Sink Measuring* and *Monitoring and Technical Guidance of Forestry ecological system Carbon Pool Research*. China recorded and compiled *Methodologies of Carbon Sink Afforestation Projects*, *Methodologies of Carbon Sink Forest Management Projects* and other methodologies for forestry carbon sink projects. Active progresses were achieved in forestry carbon sink trading.

China conducted researches on response patterns of forestry ecological system to climate change, researches on service functions of typical lake, swamp and wetland ecosystem, themed researches on carbon stock in desertification lands, preliminary researches for tackling important difficulties for carbon-monitoring satellites, technical researches on forestry carbon sink measuring and carbon sink increases, etc. Also, progressive achievements are made in policy researches on forestry in addressing climate change, themed study on "the Convention", researches on forestry carbon sink increase and emission reduction targets after 2020, national strategies in reducing emissions from deforestation and forest degradation (REDD+), and researches on forest carbon sink property right. China newly released 4 observation industrial standards for located observation and

[1] *Forestry Strategies and Action Agenda on Climate Change Response 2015* by National Forestry Administration in 2016.

research stations of ecosystem observation, which increased the total number of such standards to 26. China newly built 26 located observation and research stations of forest ecological system. 166 located observation and research stations are listed as national terrestrial ecosystem observation and research stations. These stations provided important support for capability evaluation and scientific researches of climate change mitigation in forestry.

5.3 Key Objectives and Tasks of 13th FYP Period

The overarching tasks are to implement China's comprehensive plan to address climate change and to achieve "two increases" in forestry (increase in forest area and stock volume); to this end, afforestation is to be promoted, forest management, and protection of forest land and wetlands are to be strengthened, in addition, more efforts are to be devoted to increase in carbon sequestration by forests and reduction in carbon emission from forests[1]. By 2020, China is to increase 40 million ha of forest area compared to 2005, achieve the forest coverage of over 23%, the forest growing stock volume of over 16.5 billion m^3, wetland areas of no less than 800 million mu; more than 50% of controllable decertified land is to be controlled and the total carbon stocks in forest vegetation is to reach around 9.5 billion tons[2].

Chapter 6 Control of Non-CO_2 GHG Emissions

The Chinese government attaches great importance to the control of non-CO_2 GHGs and has produced a remarkable effect by the extraction and utilization of coal seam gas, and a number of targeted measures in the sectors of industrial processes, agriculture-related activities and waste disposal.

6.1 Key Policies and Actions

In its *China's National Climate Change Program* published in 2007, Chinese government stated that, by 2010, the emissions of N_2O from industrial processes would remain stable as that in 2005, and a number of measures would be taken to control the growth rate of CH_4 emissions from the agriculture.

GHG Control in 12th FYP issued by the State Council in 2012 sets out the objectives

[1] *Forestry Action Key Points in Addressing Climate Change during the 12th FYP* issued by State Forestry Administration in 2016.

of controlling the emissions of non-CO_2 GHGs including CH_4, N_2O, HFCs, PFCs. and SF_6, and states that, the emissions from the industrial processes of calcium carbide, refrigerant, adipic acid, and nitric acid are to be reduced by improving their processes; the emissions from agriculture are to be controlled by improving crop varieties and planting techniques; the disposal and comprehensive utilization of the waste from the animal husbandry and urban waste are to be strengthened to control the growth in the emissions of CH_4; the technologies for controlling the emissions of HFCs, PFCs and SF_6 are to be researched, developed and promoted to improve control over the emission of non-CO_2 GHGs.

6.1.1 Enhance the Extraction and Utilization of Coal-bed Gas to Control CH_4 Emission

The Chinese government formulated the *12th FYP for the Development and Utilization of Coal-Bed Gas (Coal-Mine Gas)*. China would give more financial support, and adopt such preferential policies as immediate refund upon payment of value-added tax for the power generation with coal-mine gas and low tax on coal-bed Gas to accelerate the development and utilization of coal seam gas[1, 2, 3]improve the utilization of coal-bed gas (coal-mine gas) and minimize the CH_4 emission from coal mining.

6.1.2 Control the Emissions of Non-CO_2 Gases from Industrial Processes

In the 12th FYP period, Chinese government formulated the *Action Plan for Addressing Climate Change in Industry (2012-2020)*[4], which stated that the production processes of the industries of chemical fertilizer, adipic acid, nitric acid and caprolactam were to be improved, and emission control technologies were to be adopted to cut the N_2O emissions from industrial processes. Such measures as using appropriate protective gases, making innovations in operation process and conducting research and development of alternatives were to be taken to significantly reduce the emissions of fluorinated gas from industrial processes. Outdated atmospheric pressure method and comprehensive method for the nitric acid process were listed into the catalog of those restricted[5], so as to accelerate the elimination of high-emission processes. Tail gas treatment devices were applied to

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[1] *Several Opinions on Accelerating the Extraction and Utilization of Coal-Bed Gas (Coal-Mine Gas)* by General Office of the State Council in 2006.

[2] *Opinions on Further Accelerating the Extraction and Utilization of Coal-Bed Gas (Coal-Mine Gas)* by General Office of the State Council in 2013.

[3] *Coal-Bed Gas Industry Policy* by National Energy Administration in 2013.

[4] *Action Plan for Addressing Climate Change in Industry (2012-2020)* by MIIT, NDRC, MOST and MOF in 2012.

[5] Catalog for Guiding Industry Restructuring by NDRC in 2011.

control the emissions of N_2O from the producers of adipic acid. Overcapacity was addressed, specifications for the aluminum industry were formulated, tiered electricity pricing policy was adopted for the electrolytic aluminum industry in order to eliminate outdated facilities for aluminum smelting[1, 2]. Chinese government further strengthened the management of HFCs emissions[3], formulated the management plan to eliminate the use of HCFCs at a faster pace under the Montreal Protocol so as to accelerate the elimination and replacing of HFCs.

6.1.3 Control the Emissions of CH_4 and N_2O from Agriculture-related Activities

In the 12th FYP period, China stated that a work focus would be on popularizing the technology for the efficient application of fertilizers[4], and such approaches as the application of fewer fertilizers, reuse, and recovery of resources were to be adopted to reduce energy consumption, pollution, and emission, and improve the sustainability of agriculture. The central finance set up special funds to support the standardized transformation of large-scale livestock farms, and the construction of associated feces treatment facilities, such as cesspools and feces discharge pipe network, to cut GHG emissions from the animal husbandry. In 2015, China devoted great effort to the development of water-saving agriculture, implemented the action for the zero growth in the use of chemical fertilizers and pesticides, promoted the control of pollution from farming, furthered such series of actions for the recovery of resources from stalks[5] in order to control both pollution from non-point sources and GHG emissions.

6.1.4 Reduction of GHG Emissions from Waste Sector

Since 2006, the Chinese government has closely followed the progress of GHG emission reduction in the sector of waste disposal, continuously perfected the standards, laws and regulations of urban waste disposal[6], promoted the

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[1] *Guiding Opinions of the State Council on Resolving Serious Production Overcapacity Conflicts* by State Council in 2013.

[2] *Notice on Issuing the Opinions on Clearing up Illegal Projects in the Industries of Iron and Steel, Electrolytic Aluminum and Ship* by NDRC and MIIT in 2015.

[3] *2014-2015 Action Plan for Energy Conservation, Emissions Reduction and Low Carbon Development* by General Office of the State Council in 2014.

[4] *Opinions on Further Strengthening Energy Conservation and Emission Reduction for the Agriculture and in Rural Areas* by MOA in 2011.

[5] *Opinions on Fighting a Successful Uphill Battle for the Prevention and Control of Pollution from Non-Point Sources in the Agriculture* by MOA in 2015.

[6] *Policy on the Treatment and Disposal of Sludge in Urban Sewage Plants, and the Technologies for the Prevention and Control of Pollution (for trial implementation)* by MoHURD in 2009.

application of advanced waste incineration technologies, formulated incentive policies to promote the recycling of landfill gas, and thus effectively reduced the GHG emissions in the sector of waste disposal. Industrial standards[1] and national compulsory standards[2] were formulated, and the standards specified that landfills must be set up with facilities for the diverting and discharging of landfill gases; when the designed landfill capacity is no less than 2.50 Mt, and the landfill thickness is no less than 20 meters, utilization of landfill gas is advisable; when the landfill is not available for utilization of landfill gases, torches shall be used to have the gas combusted; the landfill process that can effectively reduce the generation and emission of CH_4 shall be used; the standards detailed the estimation, diverting and discharging, transportation, utilization and safety of landfill gas and its utilization rate. In the 12th FYP period, Chinese government formulated the *Plan for the Construction of Urban Sewage Treatment and Recycling Facilities in China in the 12th FYP Period*[3] and the *Plan for the Construction of the Bio-Safety Disposal Facilities for Urban Household Refuse in China in the 12th FYP Period*[4] for actively controlling CH_4 emissions from urban sewage treatment and waste disposal.

6.2 Progress and Effect of Policies and Actions

6.2.1 Achievement in Methane Emission Reduction by Extraction of Coal-bed Gas

Since 2011, the volume of the extracted and utilized coal-mine gas has been increasing considerably year by year. Up to 2015, the volume of the coal-mine gas extracted underground and utilized in China amounted to 4.8 billion m^3. In the 12th FYP period, total 34.0 billion m^3 of coal-bed gas (coal-mine gas) were utilized and equivalent to 40.80 Mtce, or emission reduction of 510 Mt CO_2 eq[5].

6.2.2 Reduction of GHGs from Industrial Processes

By eliminating outdated facilities for aluminum smelting, China has shut down a capacity of total 2.05 Mt for aluminum smelting. China phased out backward production capacities in cement and iron and steel productions, and adopted

[1] *Technical Code on the Projects for the Collection, Treatment and Utilization of the Landfill Gas from Household Refuse Landfills (CJJ 133-2009)* by MoHURD in 2009.
[2] *Technical Code on the Sanitary Landfill of Household Refuse (GB 50869-2013)* by MoHURD in 2013.
[3] *Plan for the Construction of Treatment and Recycling Facilities in Urban Sewage Plants in China in the 12th FYP* by General Office of the State Council in 2012.
[4] *Plan for the Construction of the Bio-Safety Disposal Facilities for Urban Household Refuse in China in the 12th FYP* by General Office of the State Council in 2012.
[5] *12th FYP for the Development and Utilization of Coal-Bed Gas (Coal-Mine Gas)* by National Energy Administration in 2016.

secondary and tertiary treatment methods to control N_2O emissions from nitric acid production, and promoted the producers of such materials as adipic acid to conduct international cooperation in CDM projects, thus the emissions of such GHGs as N_2O, HFCs, PFCs and SF_6 from industrial processes were well controlled. China[1] allocated investment and financial subsidies within the budget of the central government to support the elimination and disposal of HFC-23, and actively organized key actions to control HFCs, while the HFC-23 disposed of was equivalent to 357 Mt CO_2 eq.

6.2.3 Achievements in the Control of GHGs from Agriculture-related Activities

Up to 2015, the technologies for the fertilizer use based on the results of soil tests were applied in over 80%, the nitrogenous fertilizer utilization efficiency was increased by 7.2 pps than that in 2005; the nitrogenous fertilizer utilization rate for the three major food crops reached 35.2%; the increase in utilization rate led to the reduction in the use of chemical fertilizers and the pollution from non-point sources, and the emission of N_2O from farmlands was effectively controlled. In 2014, China's silage production reached 72 Mt, CH_4 emission from ruminants like cattle and sheep was effectively restrained. In 2015, 41,933,000 households countrywide adopted domestic biogas systems and 110,975 biogas projects of diverse types were constructed. Annul production of biogas nationwide reached 15.8 billion m^3, which accounted for about 5% of national natural gas consumption and replaced fossil energy of 11 Mtce. In 2016, biogas systems in rural areas treated nearly 2000 Mt of animal manure from raising livestock and poultries, stalks and organic household refuse, and yearly reduced GHG emission equaling more than 63 Mt CO_2 eq[2].

6.2.4 Effect of Reduction of GHG Emissions from Waste Sector

Since 2006, advanced technologies for waste incineration, and recycling of landfill gases were developed and popularized, the volume of the solid waste treated by landfill gas was reduced, the comprehensive utilization rate in the recovery of resources from waste was improved and thus GHG emission reduction was realized. China completed the survey reports on the pilot program for the recycling of landfill gases from urban household refuse, and those on the basic information

1 *Notice on Organizing the Works Related to the Disposal of HFCs* by NDRC, Ministry of Foreign Affairs, MOF and MEP in 2014.

2 *The 13th FYP on the Development of Marsh Gas in China's Rural Areas* by NDRC, and MOA in 2017.

of household waste incineration plants; there were 50 CDM projects on the recycling of the CH_4 from landfills, and the recycled CH_4 totaled about 0.34 Mt, which was 7.2 Mt CO_2 eq.

6.3 Key Objectives and Tasks of 13th FYP Period

In the NDC, China has clearly stated that China will strengthen the recycling of vent natural gas and oilfield associated gas, gradually reduce the production and use of chlorodifuoromethane (HFC-22) with controlled use, reducing its output by 35% by 2020 from 2010 and by 67.5% by 2025, and effectively control trifluoromethane (HFC-23) emission by 2020; promote low carbon development in agriculture, strive to achieve zero growth in fertilizer use by 2020, control CH_4 emission in rice fields and N_2O emission in farmland, build a recycling agricultural system, promote comprehensive utilization of stalk, resource utilization of agricultural and forest waste and comprehensive utilization of excrement of livestock.

In *GHG Control in 13th FYP*, China has implemented the NDC targets and stated that by 2020 China will further increase efforts to control emissions of non-CO_2 greenhouse gases such as HFCs, CH_4, N_2O, PFCs and SF_6 and that it's necessary to adopt various measures to control emissions of non-CO_2 greenhouse gases. China will actively develop and use natural gas, CBM and shale gas and strengthen the recycling of vent natural gas and oilfield associated gas; formulate and implement action plans on HFCs emission control and effectively control CHF3. In agriculture, China will implement the zero-growth action of fertilizer use, promote soil testing and formulated fertilization, reduce farmland N_2O emission and strive to hit the peak of farmland N_2O emissions by 2020; promote resource utilization of livestock and poultry waste and strive to increase the proportion of supporting waste disposal facilities in large-scale livestock and poultry farms and breeding zones to over 75%. China will also collect and use CH_4 in refuse landfills and sewage treatment plants, having synergistic effect of waste disposal and methane emission control.

Chapter 7 Strengthen Building of GHG Emission Control Systems and Mechanisms

China attaches great importance to strengthening top-level design of national-level climate management systems, and explores models for building of GHG emission control systems and mechanisms that are suitable for the national circumstances, based on existing national economy, energy and environmental management systems and through effective methods such as comprehensive policy instruments, legal and administrative means, market forces and demonstration pilots.

7.1 Target Control, Breakdown, Assessment Mechanisms and Peaking by Some Regions First

7.1.1 Implement Control on Carbon Intensity under Classification Guidance

Since the beginning of the 12th FYP, while taking into full account the development stages, resources, strategic positioning, ecological and environmental protection and other factors of different regions, China has broken down national carbon emission control targets into provincial (regional, municipal) targets, and defined provincial-level carbon emission control targets (Table 4-3). During the 13th FYP period, provincial-level carbon emission intensity control targets are to reduce carbon emission by 20.5%, 19.5%, 18%, 17% and 12% respectively.

7.1.2 Promote Some Zones to Reach CO_2 Emission Peak First

China supports optimizing development zones to reach the peak of carbon emission first. China encouraged other places to propose CO_2 emission peak goals and define the routes of reaching the goals, and conducted a pilot project on control of total carbon emission in some developed provinces and cities. It encouraged the regions first reaching the carbon emission peak and others with appropriate conditions to increase efforts to reduce emissions, improve policy measures and try to reach the CO_2 emission peak goals ahead of schedule.

At present, 23 Chinese provinces, regions or cities with low carbon pilots have proposed reaching the peak of CO_2 emissions before 2030, of which 8 cities including Ningbo and Wenzhou have proposed reaching the peak during the 13th FYP period (2016-2020), 7 cities including Wuhan and Shenzhen have proposed reaching the peak during the 14th FYP period (2021-2025) and 8 provinces and cities including Yan'an and Hainan have proposed reaching the peak during the 15th FYP period (2026-2030).

Table 4-3 Control Targets of Reduction in Carbon Intensity by Area

Region	CO_2 emission per unit of GDP reduce during the 12th FYP period (%)	CO_2 emission per unit of GDP reduce during the 13th FYP period (%)	Region	CO_2 emission per unit of GDP reduce during the 12th FYP period (%)	CO_2 emission per unit of GDP reduce during the 13th FYP period (%)
Beijing	18	20.5	Hubei	17	19.5
Tianjin	19	20.5	Hunan	17	18
Hebei	18	20.5	Guangdong	19.5	20.5
Shanxi	17	18	Guangxi	16	17
Inner Mongolia	16	17	Hainan	11	12
Liaoning	18	18	Chongqing	17	19.5
Jilin	17	18	Sichuan	17.5	19.5
Heilongjiang	16	17	Guizhou	16	18
Shanghai	19	20.5	Yunnan	16.5	18
Jiangsu	19	20.5	Tibet	10	12
Zhejiang	19	20.5	Shaanxi	17	18
Anhui	17	18	Gansu	16	17
Fujian	17.5	19.5	Qinghai	10	12
Jiangxi	17	19.5	Ningxia	16	17
Shandong	18	20.5	Xinjiang	11	12
Henan	17	19.5			

Seen from the implementation of the peak targets, most cities including Wenzhou, Jincheng and Nanping have clearly defined major tasks, key projects and guarantee measures, with peaking as the main development target in their implementation plans for low-carbon city pilot work; Suzhou, Qingdao, etc. have formulated low carbon development planning, putting forward peaking road map by phase and by region; Ganzhou has issued suggestions on building a low-carbon city, setting peaking as soon as possible as the main target of its urban transformation; Zhenjiang, Wuhan, etc. have stated in their Scheme Outline for 13th FYP that it's necessary to reach peak carbon emissions as soon as possible.

7.1.3 Strengthen Reviews on Task Fulfillment and Responsibility Taking

In 2013, NDRC together with relevant departments, formulated the *Implementation Programme for the CO_2 Emission per Unit of GDP Control Target Assessment System in the 12th FYP Period*. Proposed in this document was an accountability assessment system consisting of 12 basic indicators plus one reference indicator of the provincial governments' fulfillment of the GHG emission control targets. They are used to check upon target fulfillment, task and measure implementation, fundamental work and capacity building, and institutional innovations. Efforts were made to update the provincial government carbon emission intensity target accountability assessment system, to gradually establish the provincial GHG inventory quality assessment system and the system of GHG emission verification on enterprises in key industries. The target-oriented, vertical co-mobilization and clear-cut responsibilities mechanism was strengthened to improve the quality of the provincial and enterprise-specific emission data.

7.2 Construction of GHG Statistical Accounting System

7.2.1 Improve Basic Statistical System

China has established a statistical indicator system on climate change[1], and by including basic statistical indicators on GHG emission into the government statistical indicator system, China has established a basic statistical system matching the preparation of GHG inventories. In 2014, NBS, together with NDRC, Ministry of Transport, and other relevant departments, set up a 23-member Leading Group on Climate Change Statistics. The operational mechanism is to put the government statistical authority at the core with collaboration and coordination from member departments. China has actively carried out capacity building of the basic statistical team on climate change.

7.2.2 Make Inventory Compilation and Accounting Work a Normal Practice

China has completed the compilation of the National GHG Inventories for 1994, 2005, 2010 and 2014. China has further improved relevant data management system, providing technology support for the normalization and standardization of compilation of GHG inventories, and has strengthened CO_2 emission accounting and situation analysis of the performance of carbon emission intensity reduction targets. In 2010, China launched provincial-level GHG inventory compilation[2]. By the end of 2014, 31 provinces (autonomous regions, municipalities) and the Xinjiang Production and Construction Corps completed compilation of GHG inventories for 2005 and 2010, and the assessment format table and joint review indicator system of provincial-level GHG inventories took an initial shape. In 2015, China further arranged the compilation work of provincial-level GHG inventories

1 NDRC & NBS, *Suggestions on Strengthening Statistical Work on Climate Change*, 2013.
2 *Notice on Launching Provincial GHG Inventory Preparation* by NDRC in 2010.

for 2012 and 2014 in provinces (autonomous regions, municipalities)[1]. To support the compilation work of provincial-level GHG inventories, China organized relevant capacity building programs to train the capabilities of the personnel working at inventory compilation institutions, enhancing local GHG inventory compilation capacity.

7.2.3 Establish a Preliminary GHG Emission Reporting System

In 2014, China launched the compilation work of GHG emission reports of key enterprises (institutions)[2], and launched the research and construction platform of direct reporting system on greenhouse gases of key enterprises and gradually carried out reporting capacity building among enterprises. The seven carbon emission trading pilots, i.e., Beijing, Shanghai, Tianjin, Chongqing, Guangdong, Shenzhen and Hubei, compiled local regulations on reporting of GHG emissions, developed the GHG emission accounting methods for local enterprises in key industries and established respective greenhouse gas emission reporting platforms. A total of 19 cities without such pilots, including Jiangsu, Zhejiang, Hunan and Yunan, established or launched the building of local reporting platforms and successively carried out relevant work on reporting of GHG emission data of key enterprises (institutions) and so on.

7.3 Carbon Emissions Trading Mechanisms

7.3.1 Voluntary Emission Reduction Trading Mechanism

In 2012, China launched the management work on voluntary GHG emission reduction trading[3], establishing a methodology system on voluntary GHG emission reduction, a audit agency, a registration system and a trading platform, and assessed and filed methodologies that are suitable for domestic voluntary emission reduction programs, laying a foundation for the filing procedures and regulations on voluntary emission reduction programs. After the national voluntary emission reduction trading registration system officially went online in January 2015, the NDRC gradually established the market system for domestic voluntary emission reduction trading.

As of the end of 2015, the Chinese government had filed and announced about

[1] *Notice on Carrying Out Provincial GHG Inventory Preparation for the Next Stage* by NDRC in 2015.
[2] *Notice on the Preparation of GHG Emission Reports of Key Enterprises (Institutions)* by NDRC in 2014.
[3] *Interim Measures for Administration of Voluntary GHG Emission Reduction Trading* and *Guide to Audit and Certification of Voluntary GHG Emission Reduction Programs* by NDRC in 2012.

more than 180 voluntary GHG emission reduction methodologies, 7 trading agencies became GHG emission reduction trading platform through filing and 10 audit agencies became qualified for auditing and certifying voluntary emission reduction trading programs through filing. China had announced a total of some 2,000 audited voluntary GHG emission reduction programs, some 700 filed programs and about 200 filed programs on emission reductions, with total field emission reductions of more than 50 Mt CO_2 eq.

7.3.2 Local Carbon Emission Trading Pilots

In 2011 China launched carbon emissions trading pilot work[1], approving seven provinces or cities including Beijing, Tianjin, Shanghai, Chongqing, Hubei (Wuhan), Guangdong (Guangzhou) and Shenzhen to carry out carbon emissions trading pilots, strengthened the top-level design of pilot carbon emissions trading system, developed and issued local laws and government regulations, established carbon emission accounting, reporting and verifying system, determined carbon emission allowance allocation method, trading rules and fulfillment mechanism, established carbon trading platforms and registration system and gradually formed institutional arrangements that conform to actual local situation. The pilot provinces and cities each established a pilot carbon trading market that is complete with institutional elements, has begun to take shape and has its own characteristics, carried out carbon market supervision and organized duty fulfillment and law enforcement work. As of the end of 2015, all of the 7 pilot carbon markets had been launched, which included some 20 industries and more than 2,600 key emission discharging units, with an annual emission allowance of about 1240 Mt CO_2 eq. The key emission discharging units included in the Beijing, Tianjin, Shanghai, Guangdong and Shenzhen markets already completed carbon emissions permit fulfillment twice; the accumulated emission quota trading volume of the 7 pilot carbon markets was about 67 Mt CO_2 eq and the accumulated trading amount was about 2.3 billion yuan.

7.3.3 Building National Carbon Emissions Trading Market Mechanism

In 2014 China started to organize the building of a national carbon emissions trading market and conduct research on institutional design, total quota of national carbon market and allocation methods, national carbon trading registration system, etc. In 2014 the Chinese government issued *Interim Measures*

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[1] *Notice on Launching Carbon Emissions Trading Pilots* by General Office of the NDRC in 2011.

for Administration of Carbon Emissions Trading, which has defined the train of thought on the building of a national carbon market. To enhance basic capacity, China developed and issued the guide on accounting methods and reporting of GHG emissions in 24 key industries, established the direct reporting system on GHG emissions data of enterprises and put third party audit agencies and trading agencies on file. In 2016, China put forward the main work tasks that need to be solved for the launch[1], which mainly include working out the list of enterprises to be included in the national carbon emissions trading system, checking, reporting and verifying the historical carbon emissions of the enterprises to be included, training and selecting third party verification agency and personnel, enhance capacity building, etc.

In 2017 China officially launched the national carbon emissions trading market[2]. The targets and tasks are to adhere to the work positioning of the carbon market as a policy instrument for GHG emission control to effectively prevent risks in finance and other aspects; With the power generation industry as the first sector, to be the first to launch a national carbon emissions trading system, cultivate main market players, improve market supervision, gradually expand market coverage and enrich trading categories and forms; to gradually build itself into an open, transparent carbon market with clear ownership, strict protection, smooth transfer, supervision effectiveness and international influence; to adopt appropriately tight total emission allowance and reasonably moderate prices, effectively stimulate enterprises' emission reduction potential, promote transformation and upgrading of enterprises and achieve GHG emission control targets.

7.4 Low-Carbon Piloting and Demonstration

7.4.1 Launching Pilots of Low-Carbon Provinces and Cities

In 2010, China initiated low-carbon provinces and cities pilot project, determining to practice exploratively in five provinces including Guangdong, Liaoning, Hubei, Shaanxi and Yunnan and eight cities including Tianjin, Chongqing, Shenzhen, Xiamen, Hangzhou, Nanchang, Guiyang and Baoding. In 2012, China organized and

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1 *Notice on Doing Well in Major Work for the Launch of National Carbon Emissions Trading Market* by NDRC in 2016.

2 *Notice on Building Plan of National Carbon Emissions Trading Market (Power Generation Industry)*" by ND RC in 2017.

launched the pilot of the second-batch 29 low-carbon provinces and cities[1] including Beijing, Shanghai, Hainan and Shijiazhuang. All pilot areas compiled work implementation plan, explored and established the target-oriented responsibility system to control GHG emission, accelerated the establishment of low-carbon industrial, building, traffic and energy system, strengthened the building of basic capacity in GHG emission accounting and inventory preparation, and advocated green and low-carbon lifestyle and consumption mode. By achieving positive results, they drove and promoted the nationwide green and low-carbon development. In 2016, the Chinese government organized the assessment and summary of experience from the pilot in first-batch and second-batch low-carbon provinces and cities, which showed that those pilot provinces and cities pioneered in practicing the nation's major low-carbon policy and formed a series of experience and practices that can be produced and promoted in strengthening organizational leadership, implementing the low-carbon concept, exploring institutional innovation, improving supporting policies, establishing market mechanism, improving statistical system, reinforcing evaluation and examination, coordinating pilot demonstration and carrying out cooperation and communication. In 2017, China determined to carry out the third-batch pilot in 45 cities (districts and counties) including Wuhai, Inner Mongolia. By this time, there had been 87 low-carbon provinces and cities involved in the pilot project.

7.4.2 Launching Low-Carbon Industrial Park Pilots

In 2013, China initiated the low-carbon industrial parks pilot[2]. In 2014, the list of national low-carbon pilot industrial parks was made public after being approved, and the corresponding evaluation index system and supporting policies were studied and launched. In 2015, the implementation plans of 51 national low-carbon pilot industrial parks were approved officially. The pilot parks took various low-carbon actions and measures to promote the realization of low-carbon industries, enterprises, products, infrastructure and services, explore the low-carbon management mode of industrial parks adapted to the national circumstances, and guide and lead the industrial low-carbon transformation and development.

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[1] *Notice on Carrying out the National Second Batch of Pilot Low-carbon Provinces and Cities* by NDRC in 2012.

[2] *Notice on Organizing and Carrying out the National Low-carbon Industrial Parks Pilot* by MIIT and NDRC in 2013.

7.4.3 Carrying Out Low-Carbon Communities Pilot

In 2014, China initiated the low-carbon communities' pilot[1]. In 2015, China compiled *Guidelines on the Construction of Low-carbon Community Pilot*, organized and carried out the study of carbon emission accounting methodology and evaluation index system in low-carbon communities, guided the construction of low-carbon communities in various regions, conducted national low-carbon community demonstration and selection, planned to construct about 1000 low-carbon pilot communities nationwide and picked among them to construct a batch of national low-carbon demonstration communities, so as to forge a batch of distinct low-carbon communities in line with different characteristics of each area and different levels of development, and to provide guidance and reference around effective control of GHG emission from the living of urban and rural residents. As of July 2017, the low-carbon communities' pilot had been carried out in 27 provinces, and the quantity of provincial low-carbon communities had exceeded 400.

7.4.4 Carrying Out Low-Carbon Cities (and Towns) Pilot

In 2015, China initiated the low-carbon cities (and towns) pilot[2] by selecting eight cities (and towns) including Shenzhen international low-carbon city as the first-batch national low-carbon pilot cities (and towns) and guiding each pilot city (or town) in exploring a low-carbon development mode in line with their regional characteristics around several aspects such as integration of industrial development and urban construction, optimization of spatial distribution, integrated and comprehensive utilization of resources, low-carbon and environmentally-friendly infrastructure, low-carbon and efficient production and low-carbon and livable life.

7.4.5 Boosting the Pilot in Other Fields

Boosting the experiment and demonstration of carbon capture, utilization and storage (CCUS). In 2013, China initiated the work[3] by compiling the special plan for scientific and technological development[4] and technology roadmap, and

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[1] *Notice on Carrying out the Low-carbon Communities Pilot* by NDRC in 2014.
[2] *Notice on Accelerating the National Low-carbon Cities (and Towns) Pilot* by NDRC in 2015.
[3] *Notice on Promoting the Experiment and Demonstration of Carbon Capture, Utilization and Storage* by NDRC in 2013.
[4] *Special Plan on the Technological Development of National Carbon Capture, Utilization and Storage for the 12th FYP* by MOST in 2013.

guiding the environmental risk management of CCUS projects[1]. China organized and implemented such CCUS cooperative projects as China-EU Near Zero Emission Coal (NZEC) and China-Australia CO_2 Geological Storage (CAGS), and China Resources Group together with UK-China (Guangdong) CCUS Centre initiated the carbon capture test platform program.

Launching pilots for constructing low-carbon transportation system. China carried out low-carbon transportation system construction pilot in 26 cities to accumulate practical experience on urban green and low-carbon transportation system, Carried out the Low Carbon Transportation Action of One Thousand "Vehicle, Vessel, Road and Port" Enterprises in depth. Major regional eco-friendly transportation projects were launched and developed in 4 eco-friendly transportation provinces, including Jiangsu, Zhejiang, Shandong and Liaoning, and 27 eco-friendly transportation cities such as Beijing and Xiamen, thereby playing a leading role in promoting the development of eco-friendly transportation industry and the forming of a new industrial pattern of energy conservation and emission reduction.

China will implement demonstration projects for near-zero carbon emission zones. With plan investigation and survey organized and carried out by the Chinese government, Shaanxi and Guangdong provinces carried out the near zero carbon emission zone demonstration project.

7.5 Regulations and Standards Construction

7.5.1 Pushing Climate Change-Related Legislation

In 2011, the NPC Environmental and Resources Committee, the NPC Commission of Legislative Affairs, Legal Affairs Office of the State Council and 17 relevant departments have jointly established a leading group to promote the work of drafting laws to tackle climate change. The NDRC took the lead in carrying out legislation investigation, survey and drafting, and widely seeking for the advices of various interested parties. With legislative procedure accelerated, the Climate Change Response Law and Regulations on the Administration of Carbon Emission Trading were listed among “items for study” and “items for preparation” respectively in the Legislative Plan of the State Council for 2016. Local legislation process was accelerated by Shanxi and Qinghai’s introduction of Measures for

[1] *Notice on Strengthening the Environmental Protection in Carbon Capture, Utilization and Storage Experiment and Demonstration Program* by MEP in 2013.

Responding to Climate Change, and Shijiazhuang and Nanchang's introduction of Regulations on the Promotion of Low-carbon Development.

7.5.2 Compiling Corporate Carbon Emission Accounting Standard

China compiled guidelines on corporate GHG emission accounting methods and reporting for 24 industries in three batches, which defined the terms, accounting boundary, quality assurance, filing, reporting contents and formats etc. related to corporate GHG emission accounting and reporting. In 2015, the Chinese government compiled the first-batch corporate accounting standards for 10 major industries, and issued one general rule for industrial enterprise GHG emission accounting.

7.5.3 Improving Low-Carbon Product Certification

In 2013, China established low-carbon products certification system officially[1, 2]. In 2013 and 2016, China compiled the Low-carbon Products Certification Directory in two batches. In the low-carbon products certification directory that the nation introduces currently are seven categories of products. As of 2016, China had issued 171 national low-carbon product certificates to 47 enterprises and 200 carbon footprint or labeling certificates to 96 enterprises. In 2016, China integrated low-carbon products and other series products into green products. By 2020, China will establish a systematic, scientific, open, inclusive, index advanced, authoritative and unified green product standard, certification and identification system[3].

[1] *Interim Provisions for Administration of Low-carbon Products Certification* by NDRC, Certification and Accreditation Administration in 2013.

[2] *Measures on Administration of Energy-saving and Low-carbon Products Certification* by General Administration of Quality Supervision, Inspection and Quarantine, NDRC in 2015.

[3] *Opinions on Establishment of a Unified Green Product Standard, Certification and Identification System* by the State Council in 2016.

Part V Finance, Technology and Capacity-Building Needs

As a developing country, China always focuses on improving the quality of social and economic development and actively promoting ecological civilization construction and green and low-carbon transformation, and has made strenuous efforts to tackle climate change in the aspects of financial input, technology R&D and promotion, and capacity building. But the country still demands great supports in finance, technology and capacity building to comprehensively implement the strategic goals of tackling climate change and Nationally Determined Contribution (NDC). While the supports from developed country are very limited no matter in coverage, in strength or in scale. Therefore, it is necessary to strengthen subsequent actions for these aspects.

Chapter 1 Finance Needs and Support Received for Addressing Climate Change

1.1 Finance Needs for Addressing Climate Change

Adequate finance is an indispensable prerequisite for China to mitigate and adapt to climate change. To realize the objectives of nationally determined contributions, and implement relevant policies, actions and measures, China needs substantial finance to address climate change. To fulfill the said needs, domestic governments, enterprises and social organizations shall be encouraged and motivated to increase input; on the other hand, according to relevant requirements of the Convention, “new” and “additional” climate finance support from developed countries is required.

1.1.1 China’s Finance Needs for Climate Change Mitigation

In order to fulfill the policy objectives in the nationally determined contributions for carbon emission peaking and intensity, non-fossil energy and forest carbon sink, China needs to further implement national strategies to actively address climate change, improve its regional policies and actions for addressing climate change, build a low carbon energy system, set up an energy saving and low carbon industrial system, control the emissions from the sectors of building and transportation, increase forest carbon sinks, advocate low carbon lifestyle, and perfect the social participation mechanism, which necessitates further increase in the financial input for climate change mitigation.

Due to the difference in accounting boundary, scale, methodology, hypothesis and scenario setting, the estimation results concerning China's future investment needs as required by mitigating climate change vary significantly. The average finance needed is normally estimated to be 1.3 to 2.9 trillion yuan per year. According to the measurement of NCSC, from 2016 to 2030, China will cumulatively spend about 32 trillion yuan (based on the 2015 price) in completing the mitigating goals of the nationally determined contributions, equal to an average annual cost of about 2.1 trillion yuan, in which the newly increased energy-saving investment demand will be approximate 13 trillion yuan, the low-carbon energy investment demand be 17.6 trillion yuan, and the forest carbon sink investment demand be 1.3 trillion yuan.

1.1.2 Finance Needs for Climate Change Adaptation

In order to fulfill the goals in its nationally determined contributions, and practically and comprehensively enhance overall climate resilience, China will continue to adapt to climate change, form effective mechanisms and capability against climate change risks in major fields such as agriculture, forestry and water sources and in cities, coastal areas and ecologically vulnerable areas, and gradually improve observation, forecasting and early warning and disaster prevention and reduction systems, which also need to further increase the finance to adapt to climate change.

At present, there is little research on China's financial needs in climate change adaptation; similar to that of mitigation, the results of the assessment of the financial needs in climate change adaptation are also affected by coverage, quantitative methodologies, time horizon, future emission path, and ambition of adaptation, so there is great uncertainty. According to the most recent estimation from NCSC, from 2016 to 2030, China will spend about 24 trillion yuan, averaged to 1.6 trillion yuan annually, to achieve the adaptation goals of national independent contribution.

1.1.3 Total Financial Needs for China to Achieve NDC

Comprehensively, from 2016 to 2030, within 15 years, China's total finance needs for fulfilling its goals will reach about 56 trillion yuan, averaged to 3.7 trillion yuan annually, which is equivalent to 6.3% of the national fixed asset investment in 2016. At the same time, as more efforts will be made to tackle climate change and more risks of climate change will appear, the yearly average financial needs for tackling climate change will show a tendency of accelerating growth.

1.2 Financial Inputs for Addressing Climate Change

To address the financial needs in addressing climate change, the Chinese government has made some successful attempts in leveraging climate finance and reaped first fruits. *GHG Control in 13th FYP* issued by the State Council highlighted that, "comprehensive supporting policies shall be formulated, climate investment & financing mechanisms shall be improved, the China Clean Development Mechanism (CDM) Fund shall be better utilized, such approaches as public-private partnerships (PPP) and green bonds are to be adopted to support the addressing of climate change and low carbon development"; the Plan further stated that, during the 13th FYP period, "the focus would be on guiding with investment policies, strengthening financial support, and further promote climate investment & financing pilot cities".

1.2.1 Scale and Use of Climate Finance

Since 2005, finance has been provided for the field of climate change in China by direct grants, "awards in place of subsidies", tax reduction or exemption, policy-introduced funds, and investment in state-owned assets, and a large number of actions aimed to address climate change have been supported, and with substantial finance has been won from the society. The source, channel, tool and use of Chinese climate finance is as shown in Figure 5-1.

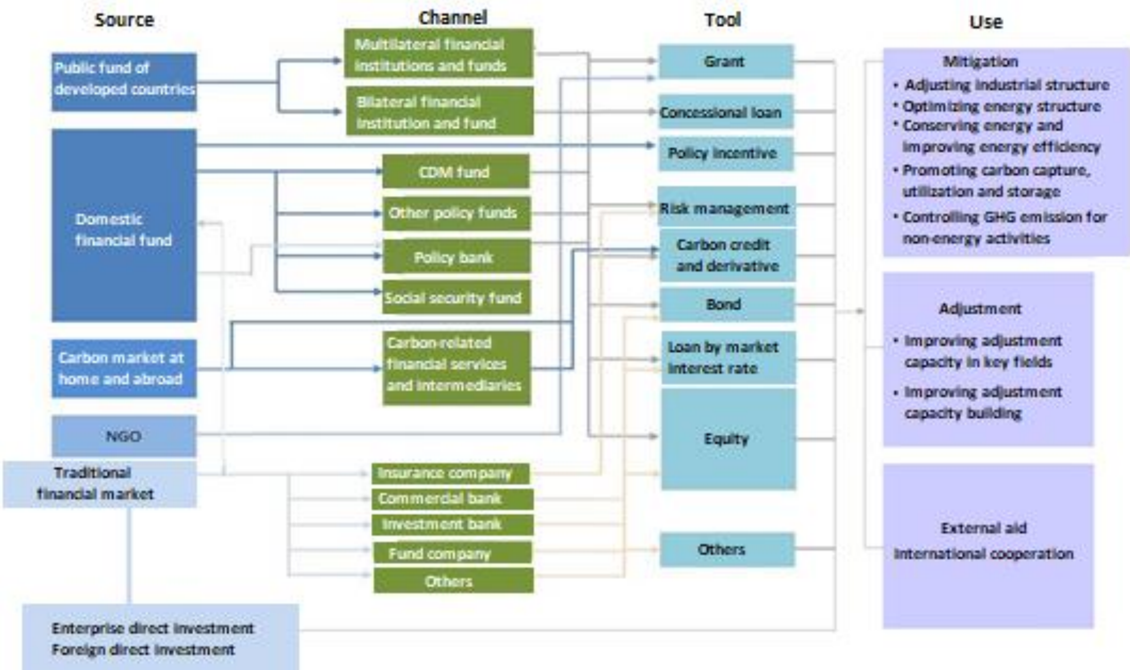


Figure 5-1 Source, Channel, Tool and Use of China's climate finance

With respect to the scale of finance, according to the latest estimation by the NCSC, in the 12th FYP period, the financial inputs to mitigate climate change amounted to about 8 trillion yuan, and the annual input was 1.6 trillion yuan; the financial input to adapt to climate change amounted to about 3.9 trillion yuan, and the annual input was 0.78 trillion yuan. The total financial input for addressing climate change amounted to 2.38 trillion yuan a year on average. However, considering the annual financial needs of about 3.7 trillion yuan between 2016 and 2030, there is still a shortfall of about 1.3 trillion yuan per year. It is imperative to increase climate finance and strengthen climate investment & financing.

With respect to the use of finance, China's climate finance for climate change mitigation was mainly used as follows: first, it was used to optimize energy structure and focus on developing non-fossil energy, and in the 12th FYP period, new investment in low carbon energy totaled about 4.4 trillion yuan; second, it was used to save energy, improve energy efficiency, and support the energy efficiency retrofit in key industries, and in the 12th FYP period, new investment in energy conservation totaled about 2.7 trillion yuan; third, it was used to increase carbon sinks and support afforestation, and in the 12th FYP period, new finance to carbon sinks totaled about 0.9 trillion yuan. The finance for climate change mitigation was also used to: (1) adjust industrial structure, and promote the development of strategic emerging industries by establishing finance and granting subsidies; (2) control the greenhouse gas emissions from non-energy-related activities, and provide operation subsidies for the devices to eliminate HFC-23; (3) promote the feasibility research and demonstration of such advanced technologies covering carbon capture, utilization and storage. Due to the lack of statistics, this part of the finance was not accounted.

At the same time, to tackle climate change, China's climate finance were mainly used for: First, on infrastructure, China amended relevant construction standards, strengthened infrastructure's ability to combat extreme climate events, and established and completed the disaster monitoring and warning emergency systems that ensure everyday operation of the major infrastructures. During the 12th FYP period, China newly invested 2.4 trillion yuan into infrastructure for climate change adaptation. Second, on agriculture, China strongly promoted technologies including water-saving irrigation, dry farming, soil moisture conservation, and conservation tillage, enhanced adaptability of the farming industry, and steered the livestock and poultry industry as well as the aquaculture industry in the correct direction. New investment in agricultural sector for climate change adaptation in the 12th FYP period reached 0.3 trillion yuan. Third, on water resources, China made efforts to protect water resources, control soil erosion, and guarantee water supply. New investment in water resource for climate change adaptation in the 12th FYP period totaled 0.3 trillion yuan. Fourth, in relevant coastal and sea areas, China improved marine disaster observation, warning, prevention and alleviation systems, started sea level change monitoring and influence evaluation, strengthened targeting forecasts concerning major protected sites, and perfected the marine fishery production safety safeguard and service systems. New investment in marine sector for climate change adaptation in the 12th FYP period reached 0.1 trillion yuan. Fifth, on forestry and other ecosystems, China implemented wetland protection and recovery projects, improved adaptability of wetland ecosystems, effectively controlled forest disasters, and reinforced ecological protection and management. New investment in ecological protection for climate change adaptation in the 12th FYP period added up to 0.7 trillion yuan. Sixth, on human health, China further upgraded its epidemic prevention system, initiated evaluation of the influences of climate change on vulnerable populations, established and perfected health-related weather monitoring and warning networks plus public information service systems, prepared for hygienic emergencies, formulated contingency plans for extreme weather such as high and low temperatures, rain and snow disasters, and fog and haze. New investment in health care sector for climate change adaptation in the 12th FYP period reached 0.2 trillion yuan.

1.2.2 Sources and Channels of Climate Finance

The sources and channels of China's climate finance mainly include government budgets, policy banks, other public finance, finance for public welfare undertaking and investment from private sectors.

1) Government budgets

Government budgets were used to support the actions to address climate change through reward for energy conservation and carbon reduction, loans with low interest rates, tax reduction or exemption, financing support, and government procurement. According to Figure 5-2, since 2007, China's expenditure from climate change-related government budgets [1] grew significantly, and its

[1] As detailed time series data are not available, the said data include the financial expenditure on pollutant control and emission reduction.

proportion in the budgets was also growing and increased from 2% in 2007 to 2.5% in 2016; the total financial expenditure between 2007 and 2016 amounted to 2.92 trillion yuan. According to the latest available department data, the finance from the national budget directly used to support climate change mitigation and adaptation in 2016 amounted to 266.07 billion yuan[1] (see Table 5-1); among them, the financial expenditure on the area of energy efficiency amounted to 62.27 billion yuan, which is mainly used to the energy conservation and emission reduction in transportation, special finance for the energy conservation and emission reduction in civil aviation, the comprehensive demonstrations of the financing and policies on energy conservation and emission reduction, new energy vehicle promotion, subsidies for generalizing energy-efficient products, and finance for the energy conservation in buildings; the financial expenditures on the area of renewable energy amounted to 8.61 billion yuan, which were mainly used for subsidies to renewable energy development and application, bioenergy, and development and utilization of renewable energy.

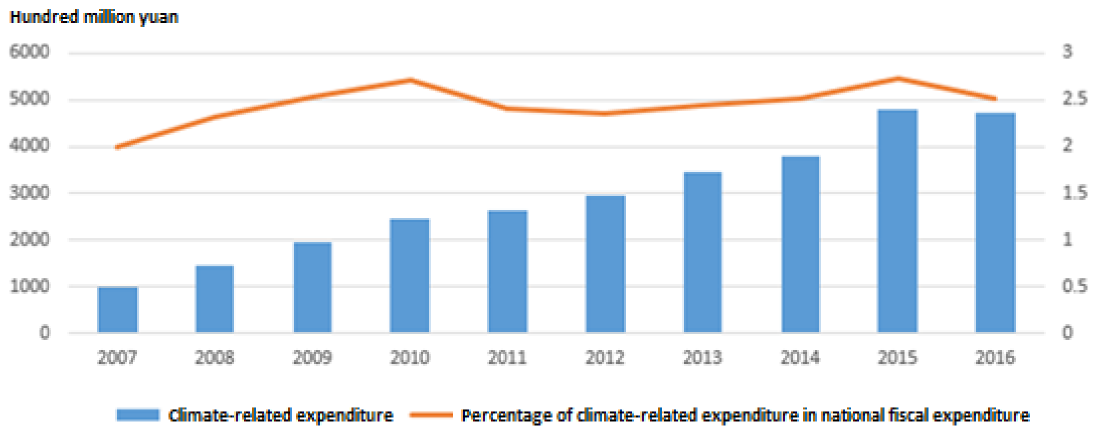


Figure 5-2 Sum of Climate-related Expenditure and its Proportion in National Fiscal Expenditure in 2007-2016

[1] Source: *China Statistical Yearbook-2017*.

Table 5-1 Financial Expenditure for Climate Actions by China in 2016[1](100 million yuan)

Items of expenditure related to climate	Budget amount	Final amount	Proportion of final amount in budget amount
Total	2,802.03	2,660.69	95.0
Natural ecology conservation	309.43	326.54	105.5
Natural forest resources conservation	239.74	274.09	114.3
Grain to green project	345.39	276.04	79.9
Sandy desert governance	42.45	43.45	102.4
Restoration of grazing back to grassland	17.61	23.99	136.2
Restoration of cropland which was converted from grassland back to grassland	0.17	4.26	2,505.9
Efficient energy utilization	817.92	622.65	76.1
Renewable energy	184.56	86.12	46.7
Recycling economy	71.06	61.62	86.7
Energy management affairs	218.26	151.44	69.4
Other expenditures of energy saving and environmental conservation	555.44	787.49	141.8

2) Policy bank

The policy banks in China include China Development Bank, Export-Import Bank of China and Agricultural Development Bank of China, which mainly provide support to the long-cycle projects requiring high investment and a long time for gaining economic benefit in the sector of addressing climate change. Up to 2016, the balance of the green credits by China Development Bank amounted to nearly 1.6 trillion yuan, and the balance of the loans for the industries of new energy and renewable energy amounted to 405.9 billion yuan[2]. Export-Import Bank of China established a green credit product system that focuses on re-loaning, loans for energy conservation and environmental protection, loans for transformation and upgrading, and traditionally superior loans; up to the end of 2015, the balance of the loans amounted to 100.6 billion yuan[3]。

[1] Source: *Finance Yearbook of China 2017*.
[2] Source: http://www.xinhuanet.com/fortune/2016-08/19/c_129242931.htm.
[3] Source: http://www.eximbank.gov.cn/tm/medialist/index_26_30747.html.

3) Other public finance

Besides government budgets and policy banks, China utilized other extra-budgetary public finance, such as the national proceeds from CDM projects, and the proceeds from the renewable energy development finance, for addressing climate change.

In September 2010, with the approval from the State Council, seven ministries and commissions including the Ministry of Finance (MOF) and the NDRC jointly issued the *Measures for the Administration of the Clean Development Mechanism Fund* and established a CDM Fund to support the national government in addressing climate change; the sources of the fund include the national proceeds from CDM projects, and the proceeds from fund operation, donations from domestic or foreign institutions, organizations or individuals, and others. Up to 2016, the CDM Fund arranged total 1.13 billion yuan of grants and 522 grant projects were supported. In addition, the CDM Fund approved 246 entrusted loan projects, which involved total 26 provinces (autonomous regions or municipalities directly under the central government) in China, arranged 14.87 billion yuan of loans, and mobilized 79.27 billion yuan from the private sector[1].

In 2006, China established a system of fixed electricity rate and expense splitting to support the development of renewable energy power; at the end of 2011, a Renewable Energy Development Fund was established, additional subsidies for renewable energy electricity prices were levied in China and used for subsidies to renewable energy electricity prices, grid connection expenses, and subsidies to independent operation of renewable energy. Between 2006 and 2011, the NDRC granted electricity price subsidies for 8 stages through adjustment of the additional finance for renewable energy electricity prices, and the subsidies totaled 33.9 billion yuan. Since 2012, the subsidies for renewable energy electricity price were granted by the Renewable Energy Development Fund, and the subsidies from the fund between 2012 and 2016 totaled 213.8 billion yuan[2].

4) Finance for public welfare undertakings

In China, the finance for public welfare undertakings related to climate change were mainly from donations by enterprises, social organizations and individuals, and they were invested in the sector of climate change by publicly offered green finance and corporate social responsibility actions. In China, the publicly offered

[1] Source: Official website of China Clean Development Mechanism Fund.
[2] Source: *CSY-2013, CSY-2014, CSY-2015, CSY-2016, CSY-2017*.

green finance included China Green Foundation and China Green Carbon Foundation; the finance of the foundations were mainly from domestic or foreign natural persons, legal persons or other organizations, government aids and appreciation in finance. In 2016, China received total 139.29 billion yuan of domestic or foreign donations year China [1], with 4.8% of them invested in ecological environment, disaster reduction and relief. Enterprises constituted a major part of donors, with nearly a half donated by private enterprises.

5) Investment from private sectors

The investment from private sectors including traditional financial markets, and direct investments by enterprises or foreign-funded enterprises. Traditional financial institutions, including insurance companies, commercial banks, investment banks and fund management companies, adopted innovative green financial instruments, and provided diversified fund and credit support channels involving risk management, bond and loan. Up to the end of 2016, the balance of the green credits from the 21 major financial institutions in banking totaled about 7.51 trillion yuan, which accounted for about 8.83% of the balance of various types of loans; among them, the balance of the loans for such emerging industries as energy conservation and environmental protection, new energy, and new energy vehicles, totaled 1.70 trillion yuan. In addition, China grew into the world's largest green bond market in 2016, with its green bonds amounting to 238 billion yuan[2].

By giving full play to the guiding and driving role of government finance, China has also attracted different categories of enterprises to directly investing in addressing climate change, the public-private partnerships (PPP) were leveraged for the green and low carbon sector, the project investment return mechanisms were being improved, social finance began to play a role in the field of climate investment & financing. Up to 2016, green and low carbon PPP projects totaled 7826, and the total investment amounted to 6.44 trillion yuan.[3]. Between 2005 and 2017, China invested total 781.9 billion dollars in clean energy, surpassed the European Union and became the largest investor in the world since 2014[4].

1.3 International Climate Finance Received by China

China has received international financial support in forms of donations and concessional loans from diversified channels such as finance mechanisms, multi-lateral development institutions and bilateral cooperation mechanisms under the

[1] Source: *2016 Report of Charity Donations in China*.
[2] Source: *2016 Report on the Green Bond Markets in China*.
[3] Source: PPP Project Databse of the MOF.
[4] Source: *Clean Energy Investment Trends 2017* by Bloomberg New Energy Finance.

Convention.

1.3.1 Financial Support Received by China within the Financial Mechanism under *the Convention*

From the years of 2010-2016, China received Global Environment Facility (GEF) grant commitments of about USD 132 million in total for 19 national climate change projects mainly covering such fields as energy efficiency improvement, low-carbon transportation, energy-efficient buildings, low-carbon city demonstration projects. See Table 5-2 for details on the financial support for specific projects, see.

Moreover, China has not received any financial support from GCF so far.

Table 5-2 Financial Support Received by China within the Financial Mechanism under *the Convention*[1](10,000 dollars)

	Project name	Finance source	Finance amount	Project cycle
1	Joint demonstration project of fuel cell vehicles of China	GEF	823	2016-2020
2	Project on advancing transformation of semiconductor lighting market and promoting energy-saving and environment-friendly new light sources	GEF	624	2016-2020
3	Demonstration project on cooperation of green logistics platforms of Zhejiang	GEF	291	2016-2020
4	Promote the project to develop clean, green and low-carbon city of China through international cooperation	GEF	200	2016-2017
5	China efficient electric motors promotion project	GEF	350	2015-2020
6	Project on sustainable management of forest and improving adaptability of forest to climate change of China	GEF	715	2015-2021
7	Production of climate-intelligent staple food crops	GEF	510	2014-2019
8	Third national communication on climate change	GEF	728	2014-2018
9	China urban-scale building energy efficiency and renewable energy application	GEF	1,200	2013-2018
10	Energy efficiency improvement project of industrial heating system and high energy consuming special equipment	GEF	538	2014-2018
11	Promotion project of energy conservation and emission reduction of Hebei	GEF	365	2013-2018
12	Jiangxi Ji'an sustainable urban transport project	GEF	255	2014-
13	Jiangxi Fuzhou urban integrated infrastructure improvement project	GEF	255	2013-

[1] Source: MOF.

	Project name	Finance source	Finance amount	Project cycle
14	Renewable energy large-scale development program phase II	GEF	2,728	2013-2018
15	Green energy schemes for low-carbon city in Shanghai	GEF	435	2013-2018
16	Project on easing urban traffic jam and reducing GHG emissions	GEF	1,818	2013-2018
17	Research and pilot project on comprehensive traffic development strategies of city clusters of China	GEF	480	2011-2016
18	Energy efficiency improvement project of Chinese industrial enterprises	GEF	400	2011-2016
19	Technology need assessment on climate change	GEF	500	2012-2016
	Total		13,215	

1.3.2 Financial Support from Multilateral Agencies

The Chinese government attaches much importance to the multilateral cooperation with the Asian Development Bank (ADB). Between 2010 and 2016, China reached agreements with ADB on 23 technical assistance projects, with a total contract amount of USD 18.15 million, and with other multilateral institutions on 1 technical assistance projects, with a total contract amount of USD 8 million. There were total 24 projects amounting to 26.15 million dollars. See Table 5-3 for details on the financial support for specific projects.

Table 5-3 Financial Support Received by China from Multilateral Institutions[1] (10,000 dollars)

	Project name	Finance source	Finance amount	Project cycle
1	Strengthening capacity in the implementation of the green financing platform for the greater Beijing–Tianjin–Hebei region	ADB	50	2016-2018
2	Promoting partnerships for South-South cooperation	ADB	40	2015-2019
3	Developing cost-effective policies and investments to achieve climate and air quality goals in the Beijing–Tianjin–Hebei region	ADB	83	2016-2018
4	Shaanxi energy efficiency and environment improvement financing program	ADB	60	2015-2016
5	Research on sustainable and climate-resilient land management in the western regions in China	ADB	525	2015-2019

[1] The finance have been uniformly converted into US dollars at the exchange rate of 2015. In that year, the exchange rate of US dollars to euro was 0.937. Due to rounding, the aggregation of various items may have slight difference with the total.

	Project name	Finance source	Finance amount	Project cycle
6	Developing innovative financing mechanism and incentive policies to promote demand-side management in the electricity sector	ADB	70	2015-2017
7	Strategic analysis and recommendations for achieving the 2020 low-carbon goal	ADB	95	2014-2016
8	Improving energy efficiency, emission control, and compliance management of the manufacturing industry in China	ADB	35	2014-2016
9	Qingdao smart low-carbon district energy project	ADB	60	2014-2016
10	Strengthening capacity for promoting distributed renewable energy utilization in Hebei province	ADB	30	2014-2015
11	Low-Carbon district heating modification project in Hohhot in Inner Mongolia Autonomous region	ADB	60	2013-2016
12	Strengthening capacity for low-carbon development in Ningbo	ADB	50	2013-2015
13	Chemical industry energy efficiency and emission reduction project	ADB	70	2013-2016
14	Gansu Jinta concentrated solar power project	ADB	55	2013-2015
15	Strengthening capacity for implementing the new energy city program in Gansu province	ADB	75	2012-2015
16	Pilot on advancing Shanghai carbon market through emissions trading scheme	ADB	50	2012-2014
17	Promoting energy-efficient products by strengthening the energy efficiency labeling scheme	ADB	40	2012-2014
18	Program of energy system for strengthening low-carbon development of China	ADB	72	2012-2015
19	Pilot on developing Tianjin emission trading system	ADB	75	2012-2013
20	Heilongjiang energy efficient district heating project	ADB	55	2011-2013
21	Shaanxi energy efficiency and environment improvement program	ADB	55	2011-2013
22	Promoting energy conservation in Tianjin	ADB	40	2010-2013
23	Renewable energy development in Qinghai	ADB	70	2010-2012
24	Partnership for market readiness project on China's carbon emission trading	PMR	800	2014-2018
	Total		2,615	

In addition, from 2010 to 2016, 14 provinces (districts and cities) have received accumulative USD 4.08 billion concessional loans from WB and ADB, which were mainly used in the 43 projects in the fields of urban sustainable development, sustainable transportation system construction and clean energy supply. See Table 5-4 for details on the financial support for specific projects.

Table 5-4 Concessional Loans Projects Received by China from Multilateral Institutions[1`2]

(million dollars)

	Project name	Finance source	Finance amount	Program cycle
1	Ningbo sustainable urbanization project	WB	150	2016-2021
2	Hebei air pollution control project	WB	500	2016-2018
3	Huaxia bank air pollution control project	WB	500	2016-2022
4	Hebei clean heating demonstration project	WB	100	2016-2021
5	Hebei rural new energy development Project	WB	72	2015-2020
6	Climate smart staple crop production in China	WB	25	2014-2020
7	Shanghai energy conservation of buildings and low-carbon district construction demonstration project	WB	100	2013-2018
8	Liaoning urban Infrastructure and environmental governance project in the coastal economic belt	WB	150	2013-2018
9	China energy efficiency financing project	WB	100	2011-
10	Beijing-Tianjin-Hebei emission governance policy reforms program	ADB	300	2015-2017
11	Jiangxi Ji'an sustainable urban transport project	ADB	120	2015-2020
12	Low-carbon district heating project in Hohhot in Inner Mongolia Autonomous region	ADB	150	2015-2020
13	Xinjiang Akesu integrated urban development and environment improvement project	ADB	150	2016-2021
14	Anhui intermodal sustainable transport project	ADB	100	2014-2021
15	Qinghai Delhi concentrated solar thermal power project	ADB	150	2014-2019
16	Hubei Yichang sustainable urban transport project	ADB	150	2014-2018
17	Heilongjiang energy saving demo district heating project	ADB	150	2013-2018
18	Hebei energy efficiency improvement and emission reduction project	ADB	100	2014-2018
19	Jiangxi sustainable forest ecological system project	ADB	40	2011-2017

1 Source: the official website of the World Bank, Asian Development Bank and MOF.
2 The finance has been uniformly converted into US dollars. Due to rounding, the aggregation of various items may have slight difference with the total.

	Project name	Finance source	Finance amount	Program cycle
20	Henan Xinyang wind power project	EIB	64	2009-2010
21	Hainan Dongfang wind power project	EIB	27	2009-2010
22	Guangdong Zhanjiang Dengloujiao wind power project	EIB	27	2009-2010
23	Guangdong Zhanjiang Yongshi wind power project	EIB	27	2009-2010
24	Inner Mongolia carbon sink forest demonstration project	EIB	27	2011-2015
25	Jiangxi biomass energy forest demonstration project	EIB	27	2009-2013
26	Post-Sichuan-Earthquake restoration and reconstruction project	EIB	85	2009-2013
27	Shandong Jinan comprehensive energy conservation transformation project for cogeneration	EIB	33	2015-2017
28	Hubei Yichang small hydropower development project	EIB	28	2009-2012
29	Energy conservation and emission reduction project of China Aohua chemical group	EIB	71	2010-2013
30	Liaoning forestry project	EIB	32	2014-2017
31	Hunan Camellia Oleifera Abel development project	EIB	37	2015-2019
32	Energy conservation transformation project of existing buildings in Harbin, Heilongjiang	EIB	53	2013-2015
33	Energy conservation transformation project of existing public buildings in Urumuqi, Xinjiang	EIB	43	2015-2018
34	Chongqing forestry development project	EIB	32	2015-2019
35	Regional forestry project (national forestry and grassland administration bundling rare tree species)	EIB	107	2015-2019
36	Shandong coastal protection forest building project	EIB	35	2015-2019
37	Shanxi ecological restoration and forestry project along the Yellow River	EIB	27	2015-2019
38	Fujian forestry project	EIB	32	2016-2020
39	Henan Gushi county biomass cogeneration project	EIB	32	2014-2017
40	Shandong Weifang heating and cooling energy conservation and emission reduction renovation project	EIB	41	2015-2017
41	Guizhou Qiandongnan sustainable management of forest	EIB	27	2016-2020

	Project name	Finance source	Finance amount	Program cycle
42	Forest quality improvement demonstration project in Poyang Lake Basin in Jiangxi	EIB	27	2016-2020
43	Heilongjiang sustainable cultivation project of special northern trees	EIB	27	2016-2020
Total			4,075	

1.3.3 Financial Supports Received from Bilateral Channels

China also seeks to conduct pragmatic cooperation with Annex II Parties to the Convention in the fields of climate change and green and low-carbon development. China has carried out many fruitful program-level cooperation projects with EU, Germany, France, Italy, Norway, Denmark, Switzerland, etc. in the fields of carbon market, energy efficiency, low-carbon city and adaptation to climate change[1], as shown in Table 5-5.

Table 5-5 Supports Received by China from Bilateral Cooperation Programs for Addressing Climate Change[2`3] (10,000 dollars)

	Project name	Finance source	Finance amount	Project cycle
1	Sino-Swiss low carbon cities project	Switzerland	693	2015-2019
2	EU-China emission trading capacity building project	European Union	534	2014-2017
3	Europe-China eco-cities link (EC-LINK) project	European Union	999	2014-2017
4	Chongqing & Guangdong low-carbon product certification project	European Union/UNDP	96	2013-2014
5	Sino-Italian capacity building for environmental protection: climate change	Italy	299	2012-2017
6	Research on the application of China's national strategy for climate change adaptation in the 12th five-year period	Norway	10	2010-2016
7	Sino-Norwegian biodiversity and climate change project	Norway	232	2011-2014
8	Sino-Danish renewable energy development (RED) program	Denmark	1,430	2009-2013
9	Shanxi Jinzhong centralized heating	France	2,988	2010-
10	Shanxi Taiyuan centralized heating	France	4,269	2010-
11	Energy conservation of public buildings in Wuhan, Hubei	France	2,134	2010-

[1] Source: The data of financial supports from bilateral channels derives from *1BUR*. Some projects whose details and amount of aid unavailable are not listed in this table.

[2] The financial supports from EU, Norway, Denmark and Switzerland were respectively paid in euro, Norwegian krone, Danish krone and Swiss franc, and the finance have been uniformly converted into US dollars at the exchange rate of 2015. In that year, the exchange rate of US dollars to euro was 0.937, to Norwegian krone was 8.392, to Danish krone was 6.991, and to Swiss franc was 1.001.

[3] Due to rounding, the aggregation of various items may have slight difference with the total.

	Project name	Finance source	Finance amount	Project cycle
12	Hubei Xiangyang small hydropower	France	2,241	2010-
13	Shandong Jinan centralized heating	France	4,269	2012-
14	Hunan sustainable operation of forestry	France	3,266	2013-
15	Heilongjiang Yichun cogeneration	France	3,735	2014-
16	Shandong Qingdao national high-tech industrial development zone CCHP	France	2,134	2016-
17	Shandong Zibo central district heating	France	2,732	2016-
18	Sino-German cooperation project: key stakeholder capacity building for China's building energy efficiency	Germany	208	2013-2016
19	Sino-German public building energy efficiency project	Germany	320	2011-2015
20	Building energy efficiency and climate protection: energy-consumption baseline research for existing residential buildings in north China	Germany	213	2010-2013
21	Qingdao Kai Yuan group Xujiadongshan centralized heating	Germany	3,821	2011-
22	Sichuan sustainable operation of forestry	Germany	1,067	2011-
23	Energy conservation renovation of existing buildings in Tonghua, Jilin	Germany	3,882	2012-
24	Energy conservation renovation of existing residential buildings in government-subsidized housing project of Tangshan, Hebei	Germany	2,455	2012-
25	Centralized heating in Dongqu, Tianshui, Gansu	Germany	1,654	2012-
26	Urban heating in Wuwei, Gansu	Germany	7,150	2013-
27	Regional centralized heating in Qiaokao and Sanhecun heating source plant area by Inner Mongolia Hohhot Chengfa investment & management Co., Ltd.	Germany	3,735	2013-
28	Centralized heating in urban area of Linxia, Gansu	Germany	4,269	2014-
29	Centralized heating in Pingyao county and Qixian county, Shanxi	Germany	38,815	2014-
	Total		99,650	

1.3.4 Barriers and Challenges

Firstly, the overall scale of financial supports from developed countries are not enough to close the finance gap to tackle climate change. From 2016 to 2030, China needs 1.3 trillion yuan in average per year to implement nationally determined contribution Since 2010, China has only received nearly USD 5.2 billion grants and concessional loans based on the finance mechanism of the Convention and the multilateral and bilateral channels, which are not sufficient to meet the growing fund need in tackling climate change. Developed countries need to further expand finance scale to provide sufficient, stable and effective financial support for China to tackle climate change.

Secondly, the received international financial supports are mainly targeted for climate change mitigation, while support targeted for climate change adaptation is much less. Of the finance received by China no matter through the finance mechanism of the *Convention*, or the multilateral or bilateral channels, most were targeted for climate change mitigation. While the projects for climate change adaptation were much less in total number and financial amount. Under the heavy tasks of adapting to climate change, China has an increasing demand on financial support, but it cannot obtain sufficient financial support to meet the actual adaptation needs. So it is increasingly urgent for China to obtain the financial support for climate change adaptation.

Chapter 2 Technology Needs for Addressing Climate Change

2.1 China's Action on Technology for Addressing Climate Change

2.1.1 Strategies and Policy Actions on Technology Development for China to Address Climate Change

On the basis of the overall national science and technology innovation strategy, considering factors of low-carbon development objectives, strategic tasks, policy measures, mechanisms and systems, China has formulated and continuously improved its strategies, plans and policies on the development of science and technology to address climate change.

Establishing strategy and policy systems to promote the development of low-carbon technologies. *The Scheme Outline for National Plan of Medium-and Long-term Development of Science and Technology (2006-2020)* made low-carbon energy technologies a key area for national science and technology development; the subsequent *National Scientific and Technological Actions on Climate Change During the 12th FYP period* set more comprehensive policy measures to address climate change; the *Several Opinions of the State Council of the CPC Central Committee on Deepening the Reform of Institutional Mechanism and Speeding up the Implementation of Innovation-driven Development Strategy* specifically proposes to implement targeted access policies for new energy vehicles, wind power, photovoltaic and other fields, in order to support the development of low-carbon technologies.

Carrying out R&D and capacity-building for climate change in key areas. China has made core technologies of climate change mitigation a priority area, and incorporated into *The Scheme Outline for National Plan of Medium-and Long-term Development of Science and Technology*. For relatively mature technical fields, take the following themes concerning energy areas as priorities: industrial energy saving, efficient development and utilization of clean coal, liquefaction and multi-product co-generation, exploration and development and utilization of oil and gas resources under complex geological conditions, low cost large scale development and utilization of renewable energy, and super large-scale power transmission and distribution and power grid security; for cutting-edge technologies, the following advanced energy technologies are proposed: hydrogen and fuel cell technology, distributed energy supply technology, fast neutron reactor technology and magnetic confinement fusion technology, etc. Regarding specific measures, the Outline stated that China should increase input into research and development, improve independent innovation ability, combine technology introduction with domestic digestion, absorption and innovation, and accelerate the industrialization of advanced technologies.

Improving laws, regulations and institutional systems to address climate change. China has further strengthened its construction of mechanism and institution, such as, laws, regulations, policies, to promote research and development of mitigation and adaptation technologies for climate change, as well as to boost large-scale industrialization. China complied and issued the *National Plan on Climate Change (2014-2020)*, and improved laws and regulations related to energy, energy conservation, renewable energy, circular economy, environmental protection, forestry, agriculture and other areas, in order to promote the development and application of technologies for climate change in key areas.

Strengthening technology development, scientific research and talent cultivation. The Nationally Determined Contribution explicitly proposes to enhance R&D and industrialization demonstration of low-carbon technologies related to energy conservation and consumption reduction, renewable energy and advanced nuclear energy, and CCUS, promote the utilization of CO_2 oil recovery and coal bed methane recovery technologies; research on extreme weather forecast and early warning technologies; develop biological fixation of nitrogen, green prevention and control of plant diseases and insect pests, and greenhouse agriculture technologies, intensify R&D of integrated water-saving and sea water desalination technologies, upgrade the science and technology support system for addressing climate change, build effective mechanisms for the integration of governmental, industrial, academic and research stakeholders, and improve the cultivation of climate change professionals.

2.1.2 China's Support to Domestic Technologies Promotion

Since 2010, according to the requirements set by the *Energy Conservation Law of the People's Republic of China*, the *Decision of the State Council on Strengthening Energy Conservation*, and the *Notice of the State Council on Issuing Comprehensive Work Plan for Energy Saving and Emission Reduction*, the NDRC has begun to formulate the Directory of National Key Promoted Energy Saving Technologies. Currently, there are six such directories. Besides, the NDRC begun to formulate the *Directory of National Key Promoted Low-carbon Technologies* in 2014, and finally produced the *Directory of National Key Promoted Energy Saving & Low Carbon Technologies*. Since 2015, the Ministry of Science and Technology (MOST), together with Ministry of Ecology and Environment (former Ministry of Environmental Protection, MEP) and Ministry of Industry and Information Technology (MIIT), compiled and issued two batches of *Directory of Promoted Technology Transformation related to Energy Saving, Emission Reduction, and Low Carbon*, providing guidance to users like industrial enterprises, national financial investment, industrial technology fund, or public welfare foundations, private equities and venture capitals that are involved in various green and low carbon areas on technology upgrading and improvement for energy saving and GHG emission reduction. In 2017, China's MOST organized the establishment of a green technology bank, and promoted the introduction and demonstration of green technology to domestic and international markets by way of "technology plus finance".

2.1.3 China's Support to Global Technologies Promotion

In 2010, the MOST issued the *Applicable Technology Manual: South-South Cooperation on Science and Technology to Address Climate Change*. The manual listed mature technologies that China applies to tackle climate change and that are appropriated to be promoted in developing countries, covering various areas including renewable energy, agriculture, forestry, waste utilization, water resources, resource environment, desertification prevention and control, building energy efficiency, industrial energy conservation and emission reduction, civil and commercial energy conservation and emission reduction, disaster mitigation and prevention, and health. The manual and directory were issued and spread through diversified channels, providing guidance to improve South-South cooperation on science and technology. Meanwhile, the China Science and Technology Exchange Center collected information on technologies from domestic scientific research institutions and enterprises and their successful application cases in developing countries, and extensively listened to suggestions from developing countries on appropriate technology requirements. It launched an English-language website on scientific and technological cooperation in response to climate change (http://www.cstec.org.cn/en/), allowing free download of manuals and other materials.

2.2 Technology Needs for Addressing Climate Change

The People's Republic of China Second National Communication on Climate Change contains a list of technologies needed for climate change mitigation and adaptation. The mitigation technology needs concentrates on five sectors which are energy, iron and steel, transportation, building and general technologies, covering specific needs such as IGCC power generation, new nuclear power, large-scale offshore wind power generation, renewable energy, hydrogen energy and fuel cell, smart grid and energy storage, carbon capture and storage, large gas turbine, smelting reduction, direct steelmaking, high-efficiency electric vehicles, building energy efficiency, new materials for road construction, new-type wall materials; the adaptation technology needs concentrate on five sectors which are comprehensive observation, numerical prediction, agriculture, coastal zone protection and ecosystem.

According to the technology needs listed in the Second National Communication on Climate Change, with World Bank's project on technology need assessment on climate change for China to address climate change, as well as China's recently-released strategic plans and actions plans to tackle climate change, the NDRC has updated the technologies in need for China to address climate change, and set thirteen industries and sectors as priority fields in need of those technologies, including coal mining, oil and gas exploration and development, thermal power, renewable energy, steel, building materials, chemical industry, non-ferrous metals, transportation, civilian and commercial buildings, agriculture, forests and land use, carbon capture and storage and waste disposal, covering a vast majority of potentials of China in current and future emissions reduction; and in terms of adaptation technology needs, has chosen four areas as priority sectors in need these technologies, including agriculture, forest and ecosystem, water resources, cities, disaster forecasting and meteorological monitoring.

2.2.1 Technology Needs for Climate Change Mitigation

China has made some progress in technologies for climate change mitigation, but the marginal cost for emission reduction is still high. With coal being a major source of energy, China is unlikely to effect a fundamental change in its pattern of consumption in the long term. The high-parameter & large capacity ultra-super critical power generation technology, and the combined gas and steam cycle power generation technology are critical mitigation technologies for China at present. Besides, to develop nuclear power in an efficient, reasonable and safe manner, to strengthen the capability for developing and manufacturing nuclear power equipment, and to accelerate the research of shale gas technologies and the development of renewable resources, are of great strategic importance for optimizing energy resource structure, improving energy efficiency, promoting energy conservation & emission reduction, and socio-economic development. So, China is in urgent need of such technologies as advanced nuclear power technology, technology for developing and utilizing of shale gas, double reheat power generation technology, offshore wind power technology, and thin-film photovoltaic battery technology. Besides, the iron and steel industry, the transportation industry, the construction material industry, and the chemical industry are all important basic industries. Their reduction in energy consumption is vital to China's low carbon development. Among other things, the smelting reduction iron making technology, and the key core technologies in the fields of electric vehicles and aircraft engines, the intelligent optimization and control system for cement kiln, the technology for the production of methanol with high CO_2-content natural gas, and the CO_2 emission free pulverized coal pressure conveying technology are technologies with high priority as needed by China. See Table 5-6 for detail list.

Table 5-6 List of Prioritized Mitigation Technologies Needs

Sectors	Technology Type	Core technology and its description
Energy	1,000 MW high-parameter & large-capacity ultra-super critical power generation technology	Design and manufacturing of associated boilers and steam turbines: the main technical equipment includes high-parameter and large-capacity ultra-super critical boilers and steam turbines. Boilers can provide high-efficiency working substance with steam pressure higher than 30 MPa and temperature higher than 620°C.
	Combined gas and steam cycle power generation technology (150 MW level)	For the power generation system adopting lower heating value (LHV) gas in a combined cycle power plant (CCPP), such byproduct gases as those from blast furnaces of iron and steel enterprises are transferred through the iron and steel energy pipe network, purified with a dust collector, pressurized, and mixed with the air that is purified with air filter and pressurized, before entering into the combustion chamber of the gas turbine for mixed combustion; high temperature & high pressure flue gas expands and works in the gas turbine, drives the air compressor and the generator for single-cycle power generation.
	Shale gas development technology	Equipment and technology in shale gas development: CO_2-ESGR technology refers to the injection of CO_2, which features great flowing through shale reservoir pores and better absorption into shale matrix, into the shale reservoir to expel and replace shale gas. The technology not only improves shale gas yield and daily production, but stores CO_2 in the reservoir.
	Nuclear power generation technology	By research and development of the large forgings for key nuclear power equipment and key parts, such key technology for the melting, forging, machining and bending of large stainless steel forgings are to be grasped.
	Steam turbine systems retrofit	Advanced steam turbine design (including blade profile and stage number) is employed to improve the structure of the steam turbine, the tightness of its cylinders and its efficiency.
Renewable energy	Offshore wind power technology	Direct drive electric machines, flexible gearboxes for doubly-fed electric machines, offshore wind turbine foundation, technology for the design and laying of submarine cable, and technology for the protection of wind turbines against typhoon; at the same height, the speed of wind is usually 25% higher than that on the road 10 kilometers offshore. As offshore wind has a low turbulence intensity and a stable prevailing direction, the unit carries low fatigue load, and will have a longer life; as the wind shear is less, the tower can be set lower. In addition, an offshore wind power is normally close to the load center since most coastal areas in China are developed regions.
	Thin-film photovoltaic battery technology	Thin-film battery uses TCO glass substrates, and thin-film battery industrialization making techniques with efficiency higher than 10% (sputtering technology): the battery uses a little silicon thus to reduce more costs; besides the product is energy efficient one, and new-type building material, which can be better

Sectors	Technology Type	Core technology and its description
		integrated with a building. The thin-film battery has another unique advantage, that is, little power loss by the negative influence of shade.
Iron and steel industry	Smelting restoration technology for iron making (including COREX and FINEX)	COREX C-3000 core technologies: improvement of furnace structure, operation of shaft furnace, adjustment in gas distribution, improvement and repair of equipment, prolonging of the life of COREX, and optimization of furnace operation. FINEX's core technologies: (1) craft of fluidized bed reduction of iron ore; (2) craft of placing partially reduced briquette iron into a melting gasifier; (3) approach to add coal; (4) equipment to remove CO_2 from coal gas. The FINEX process is a major improvement and continuous technological innovation for the COREX process; in particular, the development and application of the pulverized coal utilization technology and the export gas utilization technology significantly enhance the technological competitiveness of the process. As for the current COREX process, the problem in the design of large shaft furnaces and the problem in the smooth running for the connection between the shaft furnace and the gasifier have to be addressed, major improvement and innovation have to be made in expansion of coal resources, utilization of pulverized coal, quality of the fuel for the furnace, optimization of fuel composition, and effective utilization of export gas, the costs of crude fuel and molten iron have to be significantly reduced before the competitiveness of this process can be enhanced.
Construction material industry	The intelligent optimization and control system for cement kiln	Thermal equipment for the pretreatment of household refuse before their being fed into the kiln: such advanced algorithms as fuzzy logic, neural network and genetic optimization are adopted to establish the models related to the calcination in the cement kiln; in light of the features of crude fuel and production conditions, the production and control parameters are adjusted in an intelligent manner to stabilize production conditions and reduce heat consumption by calcination.
Transportation industry	Electric vehicles	Battery grouping technology: the electric vehicle is a vehicle adopting on-board battery as the power output, driving wheels with motor, and complying with the requirements in the regulations on road traffic safety and national standards.
	Aircraft engine	Aircraft engine energy-conservation renovation: by retrofitting of aircraft engines for energy conservation, the lives of engines can be significantly prolonged, aircraft maintenance costs and fuel oil consumption can be significantly reduced.
	Freight transportation organization model optimization technology	It is mainly to adopt the information-based technology that combines GPRS, GPS and vehicle-mounted terminals for real-time dispatching, monitoring and management of vehicles and goods collection, loading, unified distribution, etc., and based on vehicle features, supply of goods and operation lines, to make scientific use of efficient transportation organization modes such as drop and pull transportation and optimize transportation model, so as to improve the actual load

Sectors	Technology Type	Core technology and its description
		rate and operation efficiency of freight vehicles.
	Road transportation enterprise energy consumption monitoring and statistical analysis technology	It is mainly to use vehicle-mounted terminals to collect motor running data, vehicle information, driver's driving behavior and GPS positioning information and transmit such information to the data processing center in real time. The data processing center conducts real-time analysis and sorting of the mass data it has received and provides detailed and real quantized data to such links as corporate operation management, driver management, vehicle oil consumption quota setting and vehicle matching.
Residential building and commercial building	External insulating intumescent fire-retardant paint for foam material and cellulose material	Expanded polystyrene (EPS) modified with graphite: EPS modified with graphite, invented by BASF, a German chemical enterprise, is the raw material for graphite EPS boards; there are two production processes: suspension polymerization and extrusion polymerization. Expanded polystyrene (EPS) modified with graphite: EPS modified with graphite, invented by BASF, a German chemical enterprise, is the raw material for graphite EPS boards. There are two production processes: suspension polymerization and extrusion polymerization.
	Self-expanding seal tape for energy-efficient windows	Self-expanding seal tape for energy-efficient windows: the tape is used for sealing the seams between doors, windows and walls, the external thermal insulation systems for window boards and outer walls, and those between penetrating members and insulation layers. It features protection against wind and water, as well as gas tightness and acoustic insulation.
	Heat and moisture exchange membrane for heat recovery from fresh air and exhaust air	Heat and moisture exchange membrane for heat recovery from fresh air and exhaust air: the material with such technology can realize high-efficiency (more than 75%) heat and moisture exchange between the air flows at two sides; and the air flows will not mix or pollute with each other, and the material features bacteriostasis and antibiosis. The material may be used in the heat recovery for the ventilation with the outside in the air conditioning system of residential buildings or commercial buildings, to recover the heat and moisture in exhaust air, preheat and humidify fresh air (winter), or precool and dehumidify fresh air (summer), reduce the load of the air conditioning system, and improve its energy efficiency.
Waste disposal industry	Combined gas-steam cycle for incineration plants and power plants (waste-to-energy and gas turbine, WtE-GT).	Internal combustion engine, steam turbine and micro turbines: the waste incineration power plant and the natural gas power plant are combined for operation (WtE-GT); the tail gas exhausted by the gas turbine is used to further increase the temperature of the steam from the waste incineration heat recovery steam generator (HRSG), and thus to improve the thermal efficiency of the waste incineration plant.
	Reheat cycle system	Reheat cycle system: in a waste incineration power plant, the boiler superheater heats saturated steam into superheated steam, which enters the high-pressure casing of the steam turbine through the superheated steam outlet for working; the vent from the high-pressure casing enters the boiler again through pipes, and gets heated by the reheater in the

Sectors	Technology Type	Core technology and its description
		boiler to improve its temperature and enthalpy; the reheated steam enters the low-pressure casing for working again through the reheater outlet pipe; after working, the vent from the LP casing enters the condenser to form condensate, which is pumped into the boiler by the feed pump.
Chemical industry	Production technology of methanol with high CO_2 content natural gas	Top-fired reformer; water-cooled shell-and-tube methanol reactor system: the natural gas with high content of CO_2 and N_2 is adopted as raw material, with CO_2 and N_2 being more than 20%, and CH_4 less than 60%. The most representative and proprietary water-cooled shell-and-tube methanol reactor system of LURGI is adopted, and it is a reactor with the highest heat recovery efficiency, the evenest distribution of bed temperatures, the least byproducts, simplest loading and unloading of catalyst, operation and control, and the largest unit production capacity among the reactors of the same type.
	CO_2-free pulverized coal pressure conveying technology	High-pressure dynamic sealing technology, sealing material and high-density conveying technology: the traditional pulverized coal pressure conveying technology and system adopt pressure and pneumatic conveying with lock hopper. This process consumes and discharge large amount of CO_2, and has such disadvantages as high energy consumption, slow speed, and excessive equipment dimension, while the new-type pulverized coal pressure conveying system can avoid CO_2 emission.

2.2.2 Technology Needs for Adaptation to Climate Change

China's needs for adaptation technologies bear some similarity to those of other countries. Among other things, China has the most technology needs in the field of agriculture, which currently need such adaptation technologies as agricultural water-saving technology, selection and breeding of stress-resistant agricultural varieties, and agronomic water conservation technology. Demands on technologies for water resource industry are more subject to modern technologies like solar PV water-lifting irrigation water-saving technologies, while disaster warning more subject to high-and-new technologies like assessment technologies for integrated impacts of climate and climate change, and meteorological data reanalysis technology. As for urban planning and infrastructure developing, adjustment technologies like sponge city plan and practical technology, urban green space layout and optimization technology, rooftop greening technology, and permeable pavement application technology to improve the city’s capacity in climate change adaptation. See Table 5-7 for detail list.

Table 5-7 List of Prioritized Adaptation Technologies Needs

Sector	Sub-sector	Core technology and its description
Agricultural forest and ecological environment	Agricultural water-saving technology	Degradable mulch production technology: degradable moisture conservation materials include photo degradable and biodegradable mulch. Degradable mulch is mainly used to raise the ground temperature, store water and conserve moisture, reduce the evaporation of soil water, improve the physic-chemical properties of soil, suppress weeds and increase plant photosynthetic efficiency, thus improving the survival rate of afforestation and promoting the growth of saplings.
	Selection and breeding of stress-resistant agricultural varieties	Technologies including insect-resistant cotton, illness-resistant rice, scab-resistant wheat and drought-resistant wheat and corns: These technologies are about designing and building new varieties with specific traits by virtue of identified genes. For example, the toxin genes of resisting helicoverpa armigera can be implanted into the genome of cotton seeds to produce cotton with insect resistance. Peasants can apply less pesticide or none while planting the variety of cotton, which not only protects the environment but also increase peasants' income.
	Forestry ecological system	Develop climate-adaptation measures on forest management by applying landscape disturbance model LANDIS-II, and set different adaptation forest management plans for forest felling and fell application: (1) Scale control measure. Form gaps in different spatial position and scales by felling, with the purpose of diversifying the stand age structure and species and improving the forest's resistance to climate change. (2) Stand Age Control Measure Fell the mature stands to boost and accelerate their update on the progress towards climax, so as to improve the forest's resistance to influences brought by climate change. (3) Composition Control Measure. Decide whether a variety is felled or retained based on its response to climate change and the simulated result of management value. (4) Forest management technologies considering both forest products and service supply ability: Apply the process-based forest model LandClim to analyze the forest dynamic and its goods and services function under different climate change and management scenarios, the intrinsic connection between wood production and forest diversification as well as the most valuable capability for goods and services.
	Water source engineering construction	Solar photovoltaic water lifting, irrigation and water saving technology: photovoltaic water lifting is about converting the polar radiant energy into electric energy which drives water pump for irrigation. Solar photovoltaic water lifting system is comprised of photocell, controller and solar photovoltaic water pump.

Sector	Sub-sector	Core technology and its description
Urban adaptation	Develop and improve infrastructure facility	(1) Sponge city plan and practical technology: prepare a whole-process plan to realize a sound urban water circulation with several technological methods including "seepage, retention, storage, purification, utilization and drainage" and improve the urban capabilities for run-off rainwater seepage, regulation, storage, purification, utilization and drainage. China still far lags behind foreign countries in sponge city whole-process planning method and specific LID project design. (2) Key technology for long-range high-lift mass-flow water diversion works: replace the domestic traditional multistage lifting way with one-stage pump station, so as to reduce energy consumption and construction investment, of which high-lift mass-flow pump is the key preparation. (3) Roof greening technology: apply such technologies as roof plants configuration and plant roots penetration avoidance to improve plants' resistance to wind, enhance the roof load, insulate and preserve heat for buildings and mitigate surface runoff. (4) Permeable road surface application technology: pave permeable materials such as permeable asphalt, permeable concrete, porous turf and open joint blocks on the road surface to improve the infiltration of surface runoff. Meanwhile, regular road surface maintenance should also be configured to keep its effective drainage.
	Urban planning	Urban green space layout and optimization technology: it is about forming an effective urban ventilation corridor by establishing a basic database, simulating on software digital platform, deducing and generating an optimized measure, and implementing the microclimate measure into urban green space of different levels and scales.
Disaster warning and weather monitoring	Impact assessment and adaptation	Assessment technologies for integrated impacts of climate and climate change: to study the interaction of climate change's natural and biological process with human activities, the major interdisciplinary coordination involved, in particular the relationship between nature, society and economy, as well as the feedback on Integrated Assessment Model for climate change.
	Data analysis	Meteorological data reanalysis technology (including global and regional products for atmosphere reanalysis): utilize the numerical weather forecast data assimilation system to carry out various model experiments and diagnostic analysis in the context of past weather development digitalization and compare different simulation tools, so as to help people learn how atmosphere moves, the climate change and its rate of change in different spatial and temporal scales.

2.3 Technical Support Received by China and Challenges

2.3.1 Technical Support to China from Developed Countries

China has conducted a series of technology development and transfer tackling climate change through international cooperation. Table 5-8 shows the information of developed countries in terms of the technology cooperation in China to tackle climate change. Overall, these activities are mainly research projects on feasibility studies for advanced technologies, capacity building or incentive policies, but rarely projects related to actual transfer of specific technologies; meanwhile, these cooperation projects are concentrated in climate change mitigation for energy sector, therefore, support and cooperation about core technologies contained in the list of technologies in need shall be strengthened.

Table 5-8 Technical Support to China from Developed Countries in the Biennial Report

Supporting parties	Information source	Target area	Sectors	Type of technology support
Australia	First biennial report	Mitigation	Energy	Co-research, capacity building
European Union	First biennial report	Mitigation	Energy	Feasibility study
Germany	First biennial report	Mitigation	Energy	Technical renovation, case study, capacity building
Italy	First biennial report	Mitigation and adjustment	Transportation	Capacity building, case study
Norway	First biennial report	Mitigation	Energy and industry	Capacity-building
Australia	Second biennial report	Mitigation	Energy	Research finance, capacity building
Denmark	Second biennial report	Mitigation	Energy	Capacity-building
Germany	Second biennial report	Mitigation	Transportation:	Software technology, organization mechanism
Italy	Second biennial report	Mitigation and adjustment	Energy, transportation	Technology transfer, capacity building, software technology
Japan	Second biennial report	Mitigation	Energy	Feasibility study
Norway	Second biennial report	Mitigation	Energy and industry	Capacity-building
Spain	Second biennial report	Mitigation	Energy	Policy support
USA	Second biennial report	Mitigation	Energy	Policy support

In private sector, there are many successful cases about China working with other countries in various fields on technology cooperation and transfer, such as, ultra-supercritical technology in thermal power industry, Chongqing offshore installment project in renewable energy industry, combined gas and steam cycle power generation from low heating value technology in steel industry, technology of cement kiln co-processing of municipal household refuse (RDF in kiln) in construction material industry, Yunnan Copper Corporation's Isa Furnace project in non-ferrous metal industry, high-speed rail project in transportation industry, and China-Ukraine cooperation on aircraft engine manufacturing, etc.

2.3.2 Problems and Challenges

Developing countries face many obstacles in access to effective technology transfer and support under the *Convention*.

1) Policy obstacles

Some countries set in place obstacles to block export and transfer of advanced technologies, and implement measures of export license to limit export control classification, destination, end user, and end application. Even with the consent from technology suppliers to sell relevant technologies, these technologies still face difficulties to pass the customs due to relevant policy restrictions set by the host country.

It is helpful to conduct foreign merge through foreign investment and cooperate with foreign companies which hold advanced low-carbon technologies for companies of both sides so as to improve their ability in technology innovation. Nevertheless, in fear of receiving countries getting access to advanced technologies, countries with technical advantage often have security reviews on foreign investment, which is negatively affecting the transfer of technologies tackling climate change, particularly to developing countries.

2) Obstacles in technology blockage

Under a marketized system, in order to prevent the leak of private technologies, technology suppliers, in pursuit of maximized interest, enterprises are deploying a lot of measures to essentially block technology transfer, such as, adopting technology blockade policies, or set up wholly-owned plants, transfer technology within internal system, of selling equipment, instead of setting up joint companies, selling technology license. Regarding technologies related to climate change which feature global positive externalities, countries with technical advantage should encourage their companies to shoulder social responsibilities and to lessen actions to block climate-friendly technology, in an effort to promote faster and broader technology transfer to developing countries.

3) Information obstacle

Having conducted rounds of technology needs assessment, China obtained the list of prioritized technology needs to tackle climate change. However, developing countries quite lack information about the list of advanced technology suppliers, and have obstacles blocking their way to access information of this sort. Besides, there are lack of effective and common practiced assessment criteria and methods for developing countries to evaluate and prioritize the advanced technologies for climate change.

Chapter 3 Capacity Building Needs for Addressing Climate Change

As the largest developing country, China has a relatively strong need in capacity building in the areas of mitigating climate change, improving measures to tackle climate change, provide education and trainings to tackle climate change and increase public awareness. In addition, China should be willing to conduct practical cooperation to further improve its capacity to tackle climate change.

3.1 Capacity Building Needs for Climate Change Mitigation

Preparation of greenhouse gas inventories, and strengthening of the capability for the statistical work and MRV of GHG emissions are fundamental for addressing climate change, and there are great needs for capacity building in these fields. China has not entered an institutionalized phase for national GHG inventories preparation, the work is still organized or performed based on bidding project management, with multiple challenges from finance, personnel and inter-government coordination; China needs to improve its capacity building in its mechanism for inventory preparation, and work hard to build a sound, stable and efficient mechanism for inventory preparation. In addition, China has almost all GHG categories identified in IPCC guidelines, showing a dramatic difference in emissions between regions or industries. In order to reduce the uncertainty of national GHG inventories, China needs to improve the capacity for the preparation of both national and local GHG inventories, increase the communication and cooperation on the national and local GHG inventories preparation, prepare more country specific emission factors, improve the relevant statistical approaches, and reduce the uncertainty of activity data and country-specific emission factors. Besides, China needs to improve the technical capacity and competence of the inventory compilers from statistics departments, enterprises and local research institutes by cooperation, exchange, and personnel training.

The local governments in China have carried out much exploration in the pilot programs for addressing climate change and pursuing low carbon development, but there are still greater needs for capacity building compared with the provinces, states and regions of developed countries. Chinese local governments need support to improve the systematic design and strategic planning capacity and further enhance its technological support for low-carbon development, complete the policy system for low-carbon development sector, accelerate local legislative progress, and improve talents' building in a bid to improve technological R&D capacity for low-carbon development.

China has much capacity building needs for market mechanism and for promoting enterprises' participation in emission reduction. Although China initiated the national carbon emissions trading system in 2017, China needs to continue its exploration for establishing carbon emissions trading rules that suit its national circumstances and development requirements, and cover major industrial sectors such as iron and steel, electric power, chemistry, construction material, paper-making and non-ferrous metal, enhance its capacity building for data reporting and submission, registration, establishment of detailed rules on trading, perfecting trading rules and improve the capability of technical experts that work in local authorities, major organizations producing emissions, or third party audit institutions, and participating in the development of the carbon market.

3.2 Capacity Building Needs for Adapting to Climate Change

In order to reduce the impact of climate change and increase the capacity for adapting to climate change, China has huge capacity building needs for adapting to climate change. First, China needs to increase its capacity of resisting the negative impacts of climate change for the construction, operation, scheduling, maintenance and repair of infrastructure, the capacity for adapting to climate change in the fields that are vulnerable to climate change, such as agriculture, water resources, ecosystem, cities, human health, and major projects, and the capacity of developing and utilizing of the climate resources. China needs to increase its capacity for the comprehensive monitoring, forecasting and early warning of climatic disasters, strengthen the scientific research, observation and impact assessment of climate change, enhance the capacity building for addressing extreme weather and climate event, and reduce the disaster risk of extreme events. China needs to develop climate change adaptation projects through international cooperation and exchange, improve the capacity for interdisciplinary integrated research in key industries or fields that are subject to the influence of climate change, such as water-saving irrigation, water conservation irrigation, water resources allocation, and integrated coastal zone management and conservation.

3.3 Capacity Building Needs for Enhancing Climate Change Education, Training and Public Awareness

China should improve its education, publicity and training related to response to climate change, and enhance public awareness and public participation, which is a demand of lifestyle transformation from traditional production and consumption mode, and also is a requirement for fulfillment of the Convention. China has great capacity building needs for enhancing climate change education, training and public awareness, China needs to further create an ambience favoring enterprises' participation and the public's voluntary actions as guided by the government, raise enterprises' consciousness of social responsibility, improve public awareness and increase public participation capacity. China needs to continue to develop and improve its approaches for enhancing climate change education, training and public awareness, open more channels for public participation and strive to raise the public awareness for addressing climate change. China needs to increase the participation by experts and scientific research institutions, carry out international cooperation to provide education and training to government officials, enterprise managers, media practitioners, and relevant professional experts in respect of addressing climate change, improve their awareness and capacity, promote objective and continuous media coverage, raise the public awareness of global climate change and their initiative in taking corresponding actions for climate change.

Part VI Other relevant information for achieving the Convention targets

Outline of the 12th FYP and *GHG Control in 12th FYP* both emphasized climate change strategies that gave equal attention to mitigation and adaptation and outlined the need to advance climate change observation, scientific research, education and training, international communication, dialogs on policy, and South-South Cooperation. Concurrently, the Chinese government has also identified additional important activities that are crucial to the fulfillment of the convention.

Chapter 1 Climate System Observation

1.1 China's Climate System Observation

China's climate observation system relies on multiple departments to conduct joint observations. By utilizing advanced technologies including satellites, China has strengthened and standardized its continuous observations on terrestrial, marine and upper-air atmosphere, regional atmospheric composition, water cycle and carbon cycle, as well as land use, glacier, ice sheet and frozen soil changes and others (Figure 6-1).

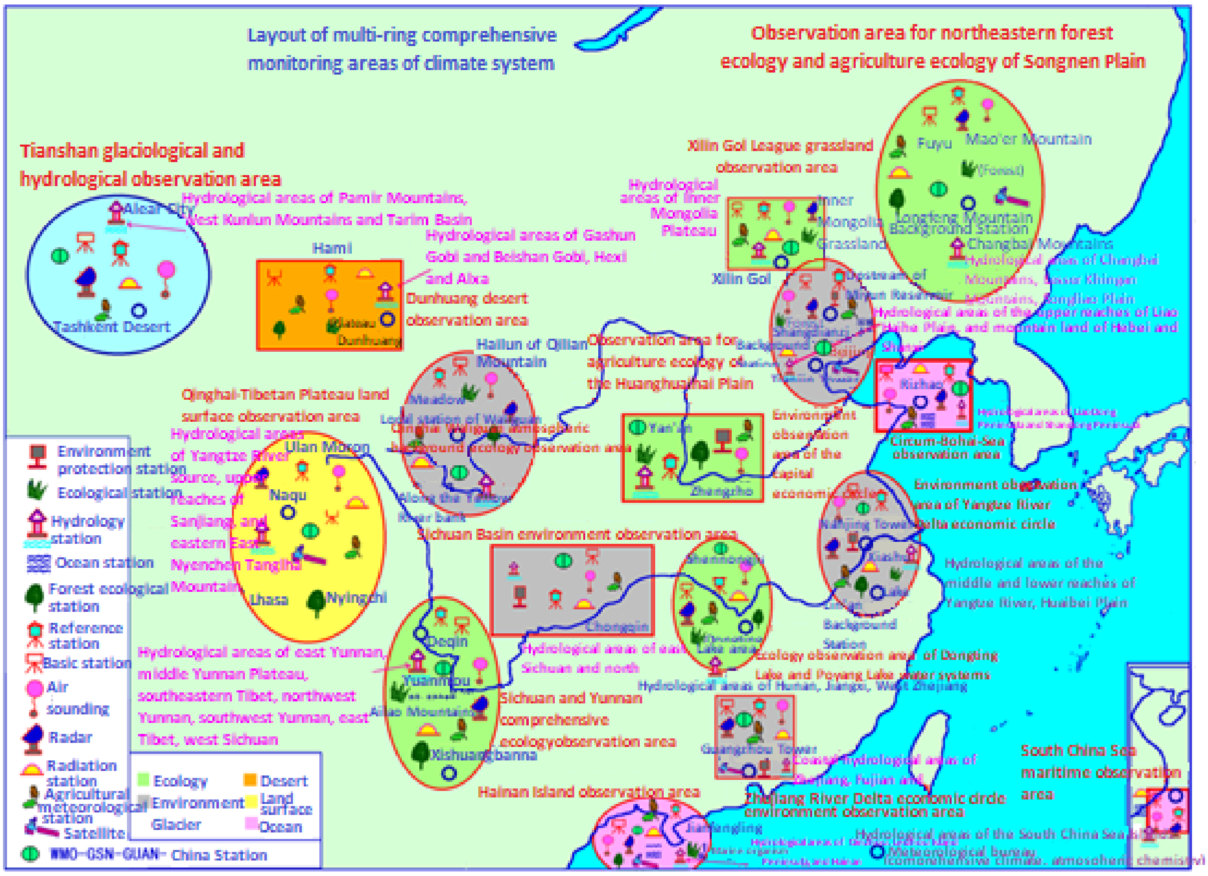


Figure 6-1 Layout of Multi-sphere Comprehensive Monitoring in China's Climate System

1.1.1 Atmospheric Observation

——Integrated land-based meteorological observation. China has preliminarily established a three-dimensional climate system observation network of surface, upper-air and spatial observation (Table 6-1). By the end of 2016, the meteorological department has established more than 60,000 land-based (marine) stations which cover more than 96% of villages and towns. 190 next-generation weather radars observe 58% of China's territory. China has established 5 particulate matter mass concentration observation stations, 376 acid rain observation stations, 29 sandstorm observation stations, 1 global atmospheric background station and 6 regional atmospheric background stations. Furthermore, it is actively building the atmospheric background observation, multi-sphere climate system and ecosystem monitoring and assessment systems. China has preliminarily established the national drought monitoring system with 2,075 automatic monitoring stations.

——**Meteorological satellites observation.** China has successfully launched and operated 16 meteorological satellites, of which 9 are functioning in orbit, including 1 scientific experiment satellite that monitors global CO_2 emissions. The ground application system includes 6 receiving stations situated in China and other global locations. Since 2016, China is capable of monitoring major GHG with satellites.

——**GHGs observation.** Waliguan station in Qinghai Province (WLG) is one of the 31 global atmospheric background stations of the World Meteorological Organization (WMO)/Global Atmosphere Watch (GAW), as well as the only continental global background station in the inland area of Eurasia. Other 6 background stations, i.e. Shangdianzi in Beijing (SDZ), Lin'an in Zhejiang (LAN), Longfengshan in Heilongjiang (LFS), Shangri-La in Yunnan (XGL), Jinsha in Hubei (JSA) and Akedala in Xinjiang (AKD) subsequently achieved on-line monitoring of major GHGs concentrations which represent atmospheric background characteristics of Beijing-Tianjin-Hebei, Yangtze River Delta, Northeast China Plain, Yunnan-Guizhou Plateau, Jianghan Plain and northern Xinjiang areas (Figure 6-2).

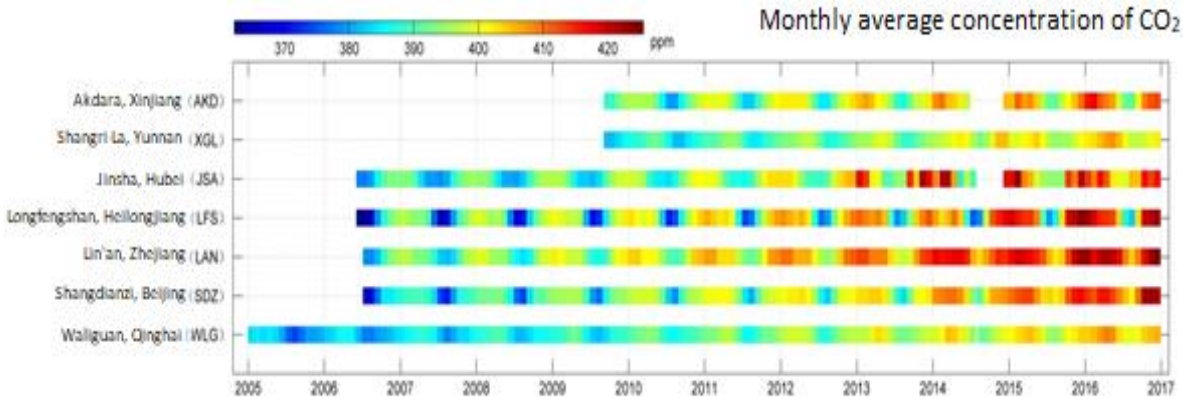


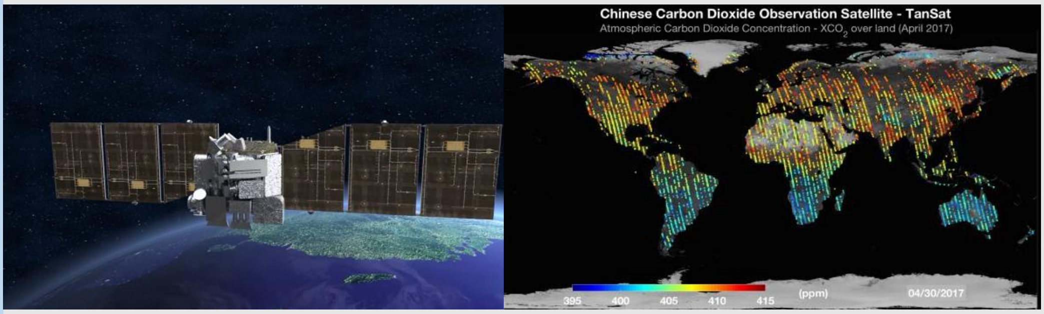
Figure 6-2 Monthly Average CO_2 Concentration at China's 7 Atmospheric Background Stations in 2005-2016

——**Climate change.** Since 2011, China has published the China Climate Change Bulletin annually, which report atmospheric, marine, cryosphere and terrestrial ecological conditions and driving factors of climate change. China published the China Greenhouse Gas Bulletin annually since 2012, which reported GHG background monitoring situation in China.

Table 6-1 Existing Integrated Meteorological Observation Facilities in China (by the end of 2016)

<table>
<tr><th colspan="2">Station (facility)</th><th>Quantity</th><th>Station (facility)</th><th>Quantity</th><th colspan="2">Station (facility)</th><th>Quantity</th></tr>
<tr><td rowspan="4">National ground observation station</td><td>Reference station</td><td>212</td><td>Soil moisture automatic station</td><td>2,075</td><td rowspan="4">Satellite data receiving station</td><td>Geostationary satellite station</td><td>342</td></tr>
<tr><td>Basic station</td><td>633</td><td>Lightening Observation</td><td>490</td><td>Fengyun-3 satellite provincial receiving station</td><td>16</td></tr>
<tr><td>Ordinary station</td><td>1,578</td><td>Wind energy measurement stations</td><td>275</td><td>EOS/MODIS receiving station</td><td>22</td></tr>
<tr><td>Total</td><td>2,423</td><td>Solar radiation</td><td>100</td><td>Total</td><td>380</td></tr>
<tr><td colspan="2">National automatic observation station</td><td>8,174</td><td>Acid rain</td><td>376</td><td rowspan="6">Mobile facility</td><td>L-band radiosonde</td><td>2</td></tr>
<tr><td colspan="2">Buoy</td><td>40</td><td>Atmospheric composition</td><td>28</td><td>Weather radars</td><td>45</td></tr>
<tr><td colspan="2">Regional automatic observation station</td><td>57,405</td><td>Air benchmark station</td><td>7</td><td>Wind profile radar</td><td>31</td></tr>
<tr><td colspan="2">L-band electronic radiosonde</td><td>120</td><td>Sandstorm</td><td>29</td><td>Portable automatic station</td><td>241</td></tr>
<tr><td colspan="2">Weather radars</td><td>190</td><td>GNSS/MET</td><td>950</td><td>Portable soil moisture automatic observation</td><td>708</td></tr>
<tr><td colspan="2">Agrometeorological stations</td><td>653</td><td>Spatial weather observation</td><td>84</td><td>Total</td><td>1,027</td></tr>
</table>

At 3:22 am, December 22, 2016, China launched its first scientific experiment satellite for monitoring global CO_2 levels, TanSat, from Jiuquan Satellite Launch Center. This is also the third satellite in the world dedicated to detection and monitoring of CO_2 levels in atmosphere (after GOSAT launched by Japan in 2009 and OCO-2 by USA in 2014). The satellite carries two instruments--the CO_2 Spectrometer, a high-resolution CO_2 spectrometer and the Cloud and Aerosol Polarimetry Imager. On August 31, 2017, after more than six months' in-orbit tests, TanSat successfully completed its in-orbit test and all performance indicators met the design requirements. On October 24, 2017, China officially opened its monitoring data from TanSat to global users, who can visit "FENGYUN Satellite Remote Sensing Data Center (http://satellite.nsmc.org.cn/)" and download and use China's carbon satellite data for free.



Box 6-1 China's Carbon Satellite Shares Data Worldwide

1.1.2 Marine and Ecological Observation

——Integrated ocean observation network. China's ocean observation network covers China's near-shore and offshore areas as well as middle to distant ocean areas, important global oceans and polar areas and consists of land-based, offshore, oceanic and polar stations. In recent years, following the principle of "one station, multiple functions", China has optimized deployment and planning of center stations and ocean stations (sites) (Table 6-2). Currently, China has established 124 ocean observation stations, 373 island observation stations and 97 buoys of different types, China has also set up 120 marine standard section investigation stations and has 2 in-orbit ocean satellites. Since the implementation of China Argo Program in early 2002, China has deployed 394 Argo profiling floats in Pacific Ocean, Indian Ocean and other sea areas. China deployed 2 deep-sea profiling floats in the Southern Ocean for the first time in 2017.

Table 6-2 Ocean Observation Facilities in China (by the end of 2016)

No.	Stations (facilities)	Quantity
1	Ocean observation station (point)	124
2	Island observation station	373
3	Buoy	97
4	Observation system for offshore oil/gas platform	41
5	Radar observation station	70
6	Mobile observation platform for emergency	13
7	Global positioning system observation station	159
8	Ocean investigation station for standard section	120
9	Ship automation station	52
10	Ocean satellite	2

——**Polar and oceanic investigations.** China conducts one Antarctic expedition each year and one Arctic expedition every 1-2 years. China has already conducted 5 Antarctic expeditions and 2 comprehensive Arctic Ocean expeditions. The Antarctic Great Wall Station, the Antarctic Zhongshan Station and the Arctic Yellow River Station are all preliminarily equipped with integrate oceanic and meteorological observation abilities. A total of 38 voyage oceanic surveys were organized, through which a large amount of basic data used to understand polar and global climate change was collected.

——**Marine biochemistry, sea level monitoring and products.** China has gradually built up monitoring activities of CO_2 exchange flux at offshore air-sea interface. The ecological restoration of island coastlines and ocean continued to be strengthened. 21 marine ecological monitoring zones were designated, and pilot monitoring for marine areas ecologically sensitive to climate change was carried out. China strengthened dynamic monitoring of terrestrial carbon emissions transferring into oceans and early warning function of ocean monitoring. In 2016, China focused on pilot monitoring work of ecological response to climate change in north yellow sea, southern Dalian and other water areas. China has 70 long-term tide gauge stations, of which nearly 50 stations provide data that could be used for sea level researches. China published the China Sea Level Bulletin every year.

——**Terrestrial ecosystem observation.** China's ecosystem observation mainly consists of Chinese Ecosystem Research Network - a long-term, large-scale research network managed by the Chinese Academy of Sciences, Chinese

Terrestrial Ecosystem Located Observation Research Network led by the forestry authorities, and rural ecosystem observation network of China Meteorological Administration. The Chinese Ecosystem Research Network has 44 stations, 5 sub-centers and 1 synthesis research center. It monitors meteorological elements, soil elements, hydrological elements and biological elements, etc. Chinese Terrestrial Ecosystem Located Observation Research Network consists of the Forest Ecological Stations Network (Figure 6-3), the Wetland Ecological Stations Network and the Dessert Ecological Stations Network. It focuses on the three major ecosystems of forest, wetland and dessert, and conducts long-term, continuous, located field science observation of ecosystems structure and functions and researches of key technologies for ecological processes. It currently has 188 stations, and 653 rural ecosystem observation stations of China Meteorological Administration.

——**Other elements of climate system.** The water conservancy department has more than 3,000 basic hydrologic stations, more than 15,000 rainfall stations and more than 12,000 underground observation wells. Besides these, the meteorological department and authorities of land and resources have corresponding rainfall, evaporation and underground observation wells as well.

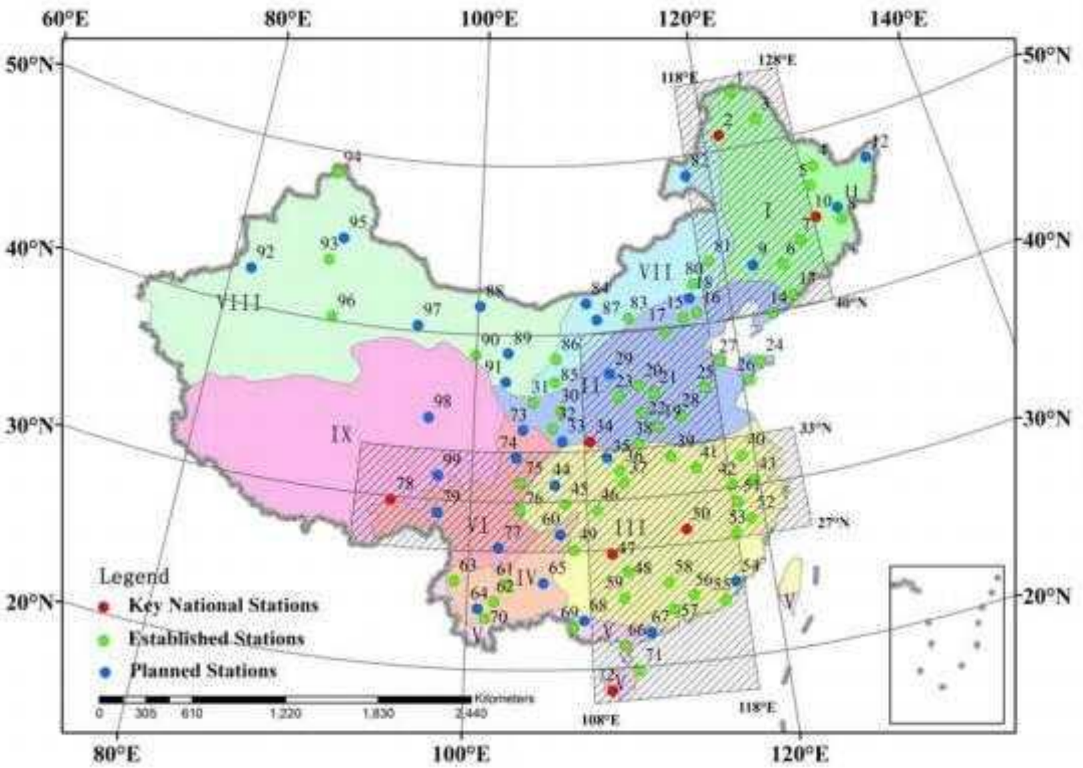


Figure 6-3 Chinese Forest Ecosystem Research Network

1.1.3 File and Data Management

China's climate system observation materials are collected and managed by meteorological, marine, water conservancy, environmental, agricultural and scientific research departments and institutions. The materials include meteorological observation data, atmospheric composition observation data and atmospheric reanalysis of atmospheric layers; marine environmental data and ocean reanalysis data that describe marine conditions; materials relevant to the earth's cryosphere; materials that describe terrestrial surface water conservancy and water resources characteristics; ecological elemental materials that record the earth's ecological system changes; and proxy data materials that are gained in analyzing tree rings, ice core, stalagmite and sporopollen and reflect the earth's climate situations. At the same time, China has established a long-term stably functioning remote sensing earth observation system, and a spatial earth observation satellite system comprised by meteorological satellites, ocean satellites, land resources satellites, environmental disaster relief satellites and other satellites. These systems are able to function stably in long-term. China has basically built the capability of observing and conducting dynamic monitoring of its own and neighboring regions as well as global atmosphere, oceans and land systems with its independently developed satellites. With multiple earth observation information products, China is able to cover its complete territory or key areas with spatial resolutions ranging from 30 meters to several dozen kilometers and report multiple major information and contents that may impact or reflect climate change, such as land use/land coverage, vegetation parameter, water area and water parameter. These materials can be used to support researches and evaluations in regard of climate change. Most data have their corresponding databases, and some data support data sharing service.

1.2 Problems and Future Development of the Climate Observation System

Generally, China's climate observation system has made a great progress, but still has a large gap compared with the developing mode of "one system, multiple uses" proposed in the new design plan of the global climate observation system. First of all, the function of current climate observation system network is not perfect; secondly, the monitoring ways, observation instrument and equipment, observation methods, data and product formats on climate change of different sectors are not the same and do not have a uniform standard; thirdly, the capabilities of coordinating between departments and sharing international and domestic materials demand to be improved.

In the future, China will further improve the planning and construction of the climate observation network, additionally observe the climate variables required to adapt to and mitigate climate change, provide climate services, and manage risks; orderly advance the standardization process for observation instrument, observation methods, and related data and product formats. The country will construct a modern climate observation system integrating surface observation and satellite remote sensing observation step by step and develop long-sequence, seamless, stable and consistent climate data sets of surface observation and satellite remote sensing observation. It will improve some observation technologies and capacities, and the level of data processing. It will build a network system with both adaptability and collaboration; play the role of China National Committee of Climate Observation System, a first-level consultation and coordination body of the country, to promote the exchange and sharing of the essential observation data and related economic and social data, basic geographic information and data offered by the departments of meteorology, ocean, environmental protection, scientific research and so on, and actively participate in the activities in relation to the global climate observation system and exchange of observation data at the international level, so as to meet the continuous requirements of the international community on climate observation and adapt to the changes of climate observation at the international level.

Chapter 2 Progress of Fundamental Research and Technology Innovation

As one of the world's pioneers in climate change research, China strives to push scientific advances and technological innovations in the field of climate change. In 2006, the Chinese government issued the "Outline of National Medium and Long-term S&T Development Plan (2006-2020)", in which energy and environment are defined as the field of science and technology to be developed with precedence, and the global environmental change monitoring and response scheme was clearly rated as a priority theme of the environmental area. In 2015, the MOST issued the Third National Assessment Report on Climate Change, which made an in-depth assessment on the progress of climate change research from 2010 to 2014. In 2016, to further perfect the national scientific and technological innovation system of addressing climate change and improve the country's innovation ability, the MOST and relevant departments issued the *13th Five-year Plan on National Scientific and Technological Innovation for Tackling Climate change*, which made an overall deployment for the scientific and technological work for tackling climate change in China. In the 13th FYP period, a series of climate change research projects were set up under the main body frames of the "973 Program", "863 Program" and other national major R&D programs; the special carbon research project of CAS was started up, and the projects of low-carbon macro strategy and technical catalogue were launched by the NDRC, thus promoting China's scientific research and technological development in tackling climate change to make important progress. The scientific and technological capacity of addressing climate change were comprehensively upgraded.

2.1 Current Status and Major Achievements of Climate Change Research

2.1.1 Climate Change Science

China has made significant progress in the essential fields of law and mechanism of climate change, observation system and simulation, earth system model, etc. It positively participated in the preparation of the "Fifth Assessment Report of IPCC" and improved international influence in this process. Its major achievements included uncovering the spatial-temporal change characteristics of natural seasonal phenomena in the east China monsoon region and the relation between climate change and phenological changes under the background of global climate change; building the new methods of forecasting the extreme weather events, such as El Nino, rainstorm, hail, and proposing better response strategies; rebuilding the spatial-temporal change sequences of climate for the east China monsoon region, the semi-arid and arid area in north China and the Qinghai-Tibet plateau, and unveiling the mechanism of millennium climate change in China's typical climate areas; researching and developing the earth system dynamics mode with Chinese innovative characteristics, which has reached international advanced level. According to the "Fifth Assessment Report of IPCC", China has played an important role in the research fields of atmospheric observation, paleoclimate, clouds and aerosols, climate model and regional climate.

2.1.2 R&D on Mitigation Technologies

Progress has been made in the R&D, promotion and application of energy-conservation and emission-reduction technologies in major industries. By using the new-generation recyclable steel process and technology, the clean steel production line of the Hebei Caofeidian Project can save hundreds of thousands of tons of standard coal each year; coal-fired power plants using the supercritical power generation technology achieved the installed capacity of hundreds of millions of kilowatts; the beneficiation-Bayer process for alumina production was widely used, forming the annual capacity of 0.6 Mt; the remanufacturing process for old machine tools increased the ratio of recycled materials to above 85% and saved over 80% energy compared with manufacture of new machine tools, thus promoting the formation of the waste product recycling and process industry and the green re-manufacture industry; the R&D of hybrid buses and their key parts saved 30% oil consumption of the whole vehicle; constructing the passive ultra-low energy consumption buildings, green ecological demonstration city-zones, and green building industry cluster demonstration zones drove the development of green building-related industry chain, making the national green building area exceed 300 million m^2; the bioethanol industry has made significant progress, that is, the utilization of fermentable sugar of stalks was enhanced to 95% of the Theoretical transformation value; the new CO_2 collector can reduce the capture energy consumption of coal-fired power plants by 30%, and the megaton whole-process demonstration project integrating CO_2 capture, transportation, and displacement of reservoir oil has been started; China has developed and completed the first large-scale salt water carbon storage demonstration project; CO_2 was used more efficiently as a type of resource for displacement of reservoir oil and for chemical and biological purposes.

Multiple advances have been made in the R&D of cutting-edge technologies in the energy field. China has built up the world's first 500W dye-sensitized solar cell demonstration system, and constructed the country's first 10MW solar power tower plant and combined it to the grid; industrialized the 1.5MW direct-driven permanent-magnet wind turbine generator set and combined the 3MW wind turbine generator set to the grid; successfully assembled the complete equipment of 5MW wind turbine generator set, filling the technical gap of high-power wind generator set through independent research and development; is building the world's first MTO industrial unit with annual capacity of 0.6 Mt; has made the

Chinese experimental fast reactor reach the critical for the first time; started the high temperature gas cooled reactor demonstration project; developed the new gasification technology of multi-burners opposed entrained-flow bed with independent intellectual property; carried out the test on the 250MW integrated gasification combined cycle (IGCC) generation system, and completed the integrated modeling for the 500MW IGCC generation system, achieving ultra-low emissions of the circulating fluidized bed boiler; made important progress in the exploitation technology of non-conventional natural gas, and implemented continuous mining in the Chongqing Fuling Oilfield of Sinopec Jianghan Oilfield Company.

2.1.3 Research on Adaptation Technologies

China has assessed the impacts of climate change on main basins, regions and industries of the country. The country assessed the impacts of climate change on the basis of Three Gorges, Yellow River, Peal River, Liaohe River, Tarim River, Poyang Lake, etc.; assessed the impacts of climate change on the characteristic industries of potatoes in the arid area of northwest china and Shaanxi apples; assessed the impacts of climate change on urban lifelines including the planning and design standards of drainage system among the typical city cluster in the Yangtze River delta and in Beijing city; adopted the technology for assessing the impacts of climate change to work out and adjust the standards of tackling climate change of projects, and adjusted the storage capacity and water supply capacity of existing and new reservoirs; used new adaptation standards and innovative techniques to strengthen the building of adaptation capacity of irrigation and water conservancy infrastructure.

Important progress has been made on the adaptation technologies in various fields. We have improved the adaptation capacity of tackling climate change by studying the impacts of climate change on farmland, wetland, coastal zone, water resource, forest and other ecological systems as well as the law of climate change; cultivated and spread the high-yield, high-quality and stress-resistance species and promoted the disaster reduction and pest control techniques in agriculture; carried out a series of work in regionalization of meteorological disaster risks, development and utilization of meteorological resources, and established a relatively perfect artificial precipitation system; made technological breakthroughs in terms of assessment of regional water resource development potential and optimized dispatch of water resources; perform pilot application for the technologies of tackling sea level rise, guaranteeing flood control security and water supply security, and restoring the typical degraded ecological systems; proposed the innovative roadmaps of regularly adapting to climate change for regions and domains.

2.1.4 International Science and Technology Cooperation

China has expanded cooperation relative to climate change with international organizations. China actively carried out project cooperation and technological discussion with the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), Asian Development Bank (ADB), Global Environment Facility (GEF) and other international organizations. China's scientists have extensively participated in international major scientific research and observation programs on climate change, including the program of Intergovernmental Panel on Climate Change (IPCC), "World Climate Research Programme", "Global Climate Observation System" and "Future Earth", and many of them hold the post of co-chairman.

China has strengthened exchange and cooperation with developed countries, for example, China and the USA have deepened the cooperation in the science and technology field for tackling climate change; China and Europe have conducted pragmatic cooperation in the aspects of building carbon emission trading capacity, low-carbon towns, low-carbon communities and so on; China has carried out cooperation with the USA, Germany, Denmark and Britain on the research of ultra-low-energy building technology; and conducted international pilot cooperation with the USA, Germany, Canada, EU and Finland on building low-carbon ecological cities.

The South-South cooperation is deepened step by step. China has strengthened cooperation with relative countries in Asia, Africa and the southern Pacific Ocean in the fields of satellite monitoring, exploitation and utilization of clean energy, agricultural drought-resistant technology, utilization and management of water resources, control of desertification, ecological protection and so on. The MOST has convened four times of "International South-South Cooperation Symposium on Tackling Climate change with Science and Technology" with the NUDP, UNESCO, UNEP and other international organizations, and organized foreign-aid training courses for developing countries to promote the transfer of climate change adaptation technologies through the South-South cooperation. In 2012, State Forestry and Grassland Administration (the former National Forestry Administration) and the People's Government of the Ningxia Hui Autonomous Region held China-Arab States Desertification Prevention and Control Cooperation Forum; in June 2015, State Forestry and Grassland Administration and the Arab Center for the Study of Arid Zones and Drylands signed a Memorandum on the Cooperation in the Monitoring, Prevention and Control of Desertification, and promoted a number of projects for the cooperation in the prevention and control of desertification with the Arab world; from 2010 to 2015, State Forestry and Grassland Administration held seminars on the prevention and control of desertification towards Africa for several consecutive years, and improved Africa's comprehensive capacity in the prevention and control of desertification, which is highly recognized by Ban Ki-moon, the then Secretary-General of the United Nations.

2.1.5 Capacity Building

In terms of construction of fundamental platform and observation of monitoring system, China has set up a networked research platform of major agricultural ecological regions; built the database cluster covering the information about national hydrology, meteorology, geography situations and flood and drought disasters, and the spatial database of typical forest soil organic carbon in China's main climate zones; basically formed the large-scale observation and research network covering the national main ecological regions and other important scientific and technological innovation platforms; established provincial-level climate change service platform, laying a foundation for carrying out climate change research.

2.2 Shortage and Gap of Climate Change Research

The essential theories in the climate change field need to be deepened, and the comprehensive research needs to be strengthened. China is still lack of understanding on the climate change mechanism. The self-developed climate model needs to be improved in terms of simulation performance and predictive ability. The assessments on the impacts and risks of climate change on various fields and regions are not enough, and there is yet no comprehensive quantitative evaluation model. The mitigation and adaptation technologies fall behind the international advanced level. For example, the key materials, equipment, core processes and technologies in industries, such as energy, steel and building are still mainly relied on import, and the technologies for agricultural water conservation technologies and industrial and regional adaptation, as well as the comprehensive social and economic assessment methods still need to be improved. In addition, it is required to deepen and improve the research on the legal construction of tackling climate change.

2.3 Main Areas of Future Research on Climate Change in China

(1) Fundamental research on tackling climate change. The coupling mechanism between carbon-nitrogen cycle and the water-energy cycle on land and in ocean; the coupling relation between water cycle and carbon-nitrogen-phosphorus biochemical cycle; changes of terrestrial and marine carbon pools and carbon sinks and climate sensitivity of GHG; climate change of the South Pole, North Pole and Qinghai-Tibet Plateau; database cluster of long-sequence high-precision climate change and effects with international influence, and big-data platform research of climate change.

(2) Research on the technologies of assessing climate change impacts. Quantitative relation and comprehensive assessment on the impacts of climate change on major fields, industries, and important projects and regions; national standards and operability assessment technology specifications; classified assessment technologies for the impacts of climate change and extreme events on fragile fields, such as agriculture, forestry, husbandry, fishing, oceanic environment and water resources, quality of atmosphere, water and quality environment as well as human health.

(3) R&D on climate change mitigation technologies. Large-scale R&D on low-cost and operable carbon capture, utilization and storage technologies and low-carbon and emission-reduction technologies; technologies for sequestering carbon and increasing carbon sinks in the main ecological systems of forest, grassland, farmland, wetland, etc.; development roadmaps and standards of the climate change mitigation technologies in the major industrial and fields.

(4) R&D on climate change adaptation technologies. R&D on the key climate change adaptation technologies in the major fields of agriculture, husbandry, fishery, water resources and so on; and in the major regions of coastland, ecologically vulnerable area, marginal transition zone, ecological barrier area, and major engineering area.

Chapter 3 Improvement of Education, Outreach and Public Awareness

China has constantly strengthened the education, training and publicity in climate change to drive all sectors to take positive actions, and carried out climate change themed activities with rich contents and in various forms. As a result, the public awareness of climate change has been significantly raised and their ability of responding to climate change has also been strengthened.

3.1 Education and Training

The National Plan for Response to Climate Change (2014-2020) points out that climate change education should be incorporated into the national education system, to allow the knowledge of climate change response into schools and classrooms and to be popularized. It is a must to strengthen training on addressing climate change, so as to improve the awareness and handling capacity of government officials, enterprise managers, media professionals about climate change; it is also necessary to carry out vocational training on response to climate change, and incorporate low-carbon vocational training into the national vocational training system.

3.1.1 Constantly Expanding and Deepening the Climate Change Contents in National Basic Education and Professional Education Systems

In terms of basic education. Reinforce the school education further by explicitly requiring students to learn about the basic concepts of climate change and ecological environment and the related hazards and impacts in such courses as science and comprehensive practices.

In terms of higher education. First, strengthen the construction of climate change related disciplines and organizations. According to incomplete statistics, by 2016, there had been 22 stations of atmospheric sciences-related disciplines, 719 stations of environmental science and engineering-related disciplines, 367 stations of new energy-related disciplines and more than 240 energy-saving and environmental protection-related disciplines. Such degree awarding units as Peking University, Nanjing University and Chinese Academy of Agricultural Sciences had set independently 222 second level disciplines related to climate change and environmental protection. Many colleges and universities including

University of Chinese Academy of Sciences, Peking University, Tsinghua University and Sun Yat-sen University have set research institutes related to climate change response and low-carbon development such as Low-carbon Development Research Center of Peking University, Climate Change International Policy Research Center of Tsinghua University, and China Meteorological Administration-Nanjing University Joint Laboratory for Climate Forecast Research etc. The set-up of these disciplines and organizations has played a positive role in cultivating top professionals for the climate change field. Second, strengthen the construction of online open courses. The Ministry of Education organized and constructed more than 60 open video courses and essential resources sharing courses related to atmospheric pollution control and ecological civilization construction for students to learn on line, with the aim of raising their awareness of low carbon and environmental protection. Third, carry out various low-carbon and environmental protection practice activities targeting colleges and universities. Since 2008, the Ministry of Education has organized College Students Energy Saving and Emission Reduction Social Practice and Science and Technology Competition themed by energy saving, emission reduction and green energy on a yearly basis.

3.1.2 Organizing and Carrying Out Various Training Sessions, Seminars and Lectures

Since 2011, various study sessions, training sessions, seminars and lectures have been organized and carried out to comprehensively improve the ability of leaders at all levels and from all sectors in understanding and responding to climate change issues.

First, the Political Bureau of the Central Committee of the CPC organized collective learning based on the theme of ecological environment and green development. In 2017, the Political Bureau of the Central Committee of the CPC organized collective learning themed by “promoting to form green development mode and lifestyle”. Xi Jinping, General Secretary of the Central Committee of the Communist Party of China, pointed out again that citizens’ awareness of environment should be strengthened to form a frugal, moderate, green, low-carbon, civilized and healthy lifestyle and consumption mode.

Second, relevant departments under the State Council organized theme training to strengthen the administrative staff’s ability of responding to climate change. The NDRC held 7 sessions of special training on the national development and reform system's response to climate change and held several corporate GHG accounting training sessions (Figure 6-4); the MEE (former MEP) held 14 sessions of dialogues on sustainable development and low-carbon innovative policies at *World Environment* magazine between 2012 and 2016; the MOST organized several sessions of local climate change response capacity building training; the National Forestry and Grassland Administration (former State Forestry Administration) held national forestry training courses each year on response to climate change and carbon sink measurement and monitoring system construction; the National Government Offices Administration held several training courses on energy-saving management for cadres from national public sectors and colleges and universities, training more than 9,000 various energy conservation administrative staffs at all levels accumulatively.

South China and Northwestern China Special Training on Response to Climate Change by National Development Reform System

Business Greenhouse Gas Accounting Report Training Session

Figure 6-4 NDRC Training Activities Concerning Response to Climate Change

Third, local governments actively carried out training around climate change response and carbon market capacity building. According to incomplete statistics, the number of trainees has exceeded 30,000. Local authorities have also established professional research institutes on climate change response and low-carbon development such as Beijing Climate Change Response Research and Talents Cultivation Base and Tianjin Low-carbon Development Research Center, to strengthen local ability of providing science& technology and policy support for climate change response (Figure 6-5).

Figure 6-5 Training Sessions on Development of Carbon Trade Markets

3.2 Outreach and Popularization

The Chinese government attaches great importance to the publicity on addressing climate change. For many years, guided by the government, diversified media outreach and various theme publicity has greatly raised the entire people's awareness of response to climate change. And such situation that the whole society pays attention to and involves in climate change response has been formed gradually.

3.2.1 Outreach through Conferences

Over recent years, international and domestic conventions have been utilized to showcase actively China's policies and practices in responding to climate change, to share its experience in response, and to promote international cooperation.

In 2015, Chinese President Xi Jinping attended the Paris Climate Change Conference, emphasizing that all countries should be confident in jointly building a win-win, fair and reasonable climate change governance mechanism. In 2016, Xi

Jinping presented China's Ratification of *the Paris Agreement on Climate Change* to Ban Ki- Moon, Secretary General of the United Nations during G20 Hangzhou Summit. With its own action, China has facilitated the global climate governance. Besides, Chinese then vice Premier Zhang Gaoli also attended several important international events including Climate Summit in New York and the High-level Signing Ceremony for the Paris Agreement on Climate Change.

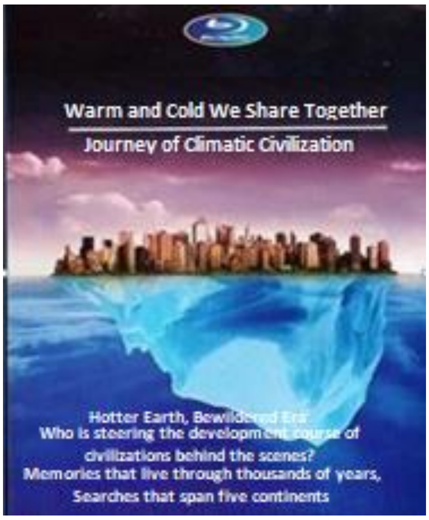
During the United Nations Climate Change Conference, the Chinese delegation also organized a series of publicity activities such as "China Pavilion".

Relevant departments held various conventions. Conventions around low-carbon and green development, urban adaptation to climate change and carbon market building have been held to showcase the latest achievements made in the climate change field.

Local governments actively held various climate-change-themed international conferences. From 2012 to 2017, Shenzhen has held several International Low-carbon City Forums successively, which attracted over 15,000 guests from nearly 50 countries for participation accumulatively. In 2016, Beijing hosted the second China-US Climate Intelligent/Low-carbon City Summit for the purpose of strengthening the pragmatic cooperation between China and US on low-carbon city development. In the same year, Wuhan also held "China-EU Low-carbon City Conference".

3.2.2 Media Outreach

Major central news media and internet media including *People's Daily*, Xinhua News Agency, China National Radio, China Radio International, CCTV, *China Daily* and China News Service have paid high attention to major climate change response-related news events such as United Nations Climate Change Conference and China's release of NDC and utilized multiple forms (figure, text, video etc.) to report them comprehensively, publicized and reported the introduction of important strategic planning and policy documents in low-carbon field and interpreted them deeply to guide the public attention and form good public opinion atmosphere. Since 2008 till now, the NDRC has organized the preparation and introduction of *Annual Report on China's Climate Change Policies and Actions* to publicize the results of climate change response. Domestic media agencies prepared and published a series of climate change related popularization and publicity brochures and produced several films including *Facing Climate Change*, *A Warming Earth*, *Awareness on Climate Change* and *Warm and Cold We Share Together* (Figure 6-6). China Meteorological Administration organized and produced *Addressing Climate Change -- China in Action* series TV promotional videos and brochures. Meanwhile, multiple channels including new media "Internet Plus", Weibo and WeChat official account have been utilized to convey climate change-related knowledge to the public.



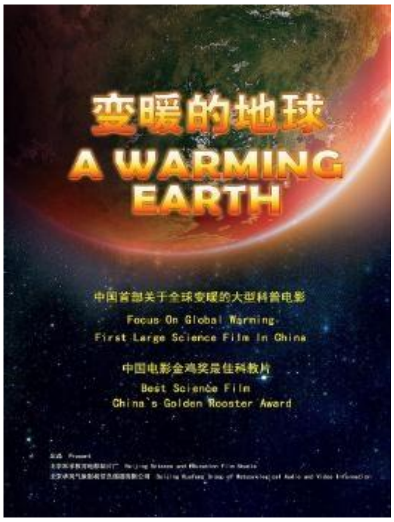


Figure 6-6 A Series of Promotional Videos

3.2.3 Thematic Outreach

Since 2013, the NDRC has joined hands with relevant departments to organize and carry out "National Low-carbon Day" activities, hold climate change response-themed exhibitions, and organize low-carbon activities into communities and campus for low-carbon publicity. During such activities as "Energy-saving Week" and "Low-carbon Day", various local departments have been mobilized to the greatest extent to carry out a variety of campaigns based on their reality, so as to raise the public awareness of energy saving, environmental protection, and green and low-carbon development. The NDRC has also carried out "Low-carbon China Tour" activities by organizing news media, academicians and experts to visit local regions for field research and holding low-carbon themed activities in several places including Beijing, Shanghai, Chongqing, Guangzhou, Hangzhou and Baoding in multiple forms (Figure 6-7). The MEE (former MEP) carried out various climate change response themed publicity activities by combining with the World Environment Day and Earth Day. China Meteorological Administration took advantage of the World Meteorological Day on March 23 to carry out climate change knowledge popularization and publicity. The State Oceanic Administration carried out ocean and climate change knowledge popularization publicity on June 8, the World Ocean Day. The All-China Women's Federation joined hands with several departments to carry out several theme activities including "Chinese Family Low-carbon and Environmentally-friendly Travel".

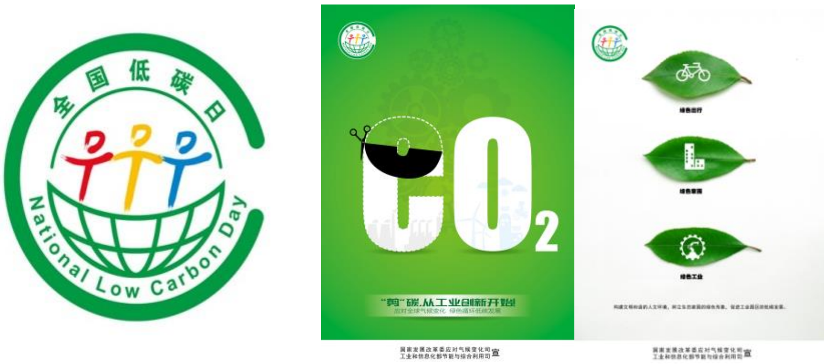


Figure 6-7 National Low-Carbon Day Logo and 2017 National Low-Carbon Day Poster

3.3 Widespread Public Participation

As climate change education, training, and publicity were being promoted, the public chose on their own initiative low carbon lifestyle, including low carbon transportation, diet, and building and energy-efficient low carbon products. They tended to first choose low carbon transportation, namely public transportation, and implement the principle of "one, three and five" for going around, namely, walking for a distance of 1 kilometer, a bicycle ride for 3 kilometers and bus ride for 5 kilometers or more; Up to 2017, there were 184 cities undertaking to organize car-free day events on September 22 each year. Catering companies and the public actively executed the "clean your plate" campaign. The provinces and cities in China actively piloted low carbon communities, a total of 27 provinces participated in the pilot program, and there were over 400 provincial low carbon communities involved in the pilot program. The China Alliance for Low Carbon Action organized the activity for the soliciting, selecting and appraising of low carbon enterprises, to create such an atmosphere that low carbon actions are spotlighted and implemented by the public. The China Green Carbon Foundation initiated the establishment of "Zero-Carbon Creative Pavilion" to attract public participation through publicity and trial. Between 2007 and 2016, China Youth Climate Action Network (CYCAN) hosted seven sessions of the program of energy conservation in institutions of higher learning, and total 200,000 young people participated in the program research.

Through effective climate change education, training and publicity, public awareness of climate change increased significantly. *The Research Report on Awareness of China's Citizens in Climate Change and Climate Knowledge Dissemination* published showed high awareness of climate change among the Chinese public; the respondents strongly supported the government's relevant policies concerning mitigation and adaptation of climate change, and most of them supported the implementation of *the Paris Agreement* in China and the Chinese government in the international cooperation in addressing climate change. Chinese public went into action to actively address climate change.

By taking the lead in international cooperation for addressing climate change, China became an important participant, contributor and torchbearer in building an ecological civilization in the world. China would take more creative and effective approaches for climate change education and publicity, and assume a more aggressive and open stance in conducting international cooperation in the field of climate change publicity and education, to make its contribution to building a community with a shared future for mankind.

Chapter 4 International Exchanges and Cooperation

4.1 Bilateral and Multilateral Exchange and Cooperation

China not only established frameworks for cooperation with developed countries including those in Europe and America in addressing climate change, but also developed many forms of cooperation mechanisms with developing countries. This provided assistance consistent with its capacity to the small island countries in the southern Pacific and the Caribbean, to improve their climate change adaptability. In recent years, the Chinese government has cooperated with organizations such as the United Nations Development Program, the United Nations Environment Program, international institutions including the World Bank, the European Investment Bank, the Asian Development Bank and the Global Environment Facility, participated and implemented relevant projects, and strengthened information communication, resource sharing and concrete cooperation with those organizations.

4.1.1 Bilateral or Multilateral Exchanges and Cooperation with Major Developed Countries including those in Europe, America, and Japan

Since the establishment of a partnership on climate change in 2005, China and the EU have fostered increased cooperation in such key issues as CDM, renewable energy, increase in energy efficiency, carbon capture and storage. As the relationship between China and the EU is deepening and evolving, the partnership in addressing climate change is growing in importance; the two sides have continuously reached a common understanding and thus promoted the development of the international climate governance mechanism[1].

The Joint Statement on Europe-China Clean Energy Center signed during the 11th EU-China Summit in May 2009 proposed that a Europe-China Clean Energy Center and demonstration parks were to be established to promote the cooperation in clean energy between China and the EU[2].

To strengthen the political will of China and the EU for bilateral and international cooperation, during the 17th EU-China Summit in 2015, the parties jointly issued *the EU-China Joint Statement on Climate Change*, which stated that the parties would promote the partnership on climate change for continued remarkable progress on the basis of the successful cooperation in the past 10 years[3]. Besides, *the EU-China 2020 Strategic Agenda for Cooperation* proposed to "help the global shift towards a low carbon economy", which promoted the cooperation in climate change between China and the European Union with new dimensions and elements.

In building the partnership on climate change, the Chinese government and European countries in fostered cooperation in many areas including the environment, energy and low-carbon emissions.

(1) China and Germany enhanced cooperation in climate change in the areas of carbon emission trading and reduction. Since the 1990s, China and Germany furthered the "Sino-German Climate Partnership and Cooperation on Renewable Energy"[4], adding separate clauses on cooperation in renewable energy in the

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[1] Pietro De Matteis, *The EU's and China's Institutional Diplomacy in the Field of Climate Change*, p.11.

[2] Xinhuaet.com: *The EU-China Clean Energy Center Is Launched in Beijing*, http://news.xinhuanet.com/2010-04/30/c_1266167.html.

[3] People.cn: *EU-China Joint Statement on Climate Chang*e, http://politics.people.com.cn/n/2015/0630/c70731-27227445.html.

[4] People.cn: *China and Germany Enhance Cooperation in Climate and Renewable Energy*, http://paper.people.com.cn/zgnyb/html/2017-07/31/content_1795071.htm.

treaties regarding environmental and climate protection, devoting much effort to support capacity building in the implementation of regional emission trading. Furthermore, assisting in the establishment of a domestic emission trading system, emission reduction in buildings, the development of low emissions and energy efficient transportation, the promotion of electric vehicles and the formulation of a low-carbon strategy.

(2) China and France strengthened joint actions to enhance their capacities for addressing climate change. First, the parties signed joint government statements. By signing *the Joint statement on Addressing Climate Change (2007)* and *the Joint Statement on Strengthening the Comprehensive Strategic Partnership (2010)*, China and France emphasized that they would maintain close cooperation in environmental protection, sustainable development and the addressing of climate change. This strengthened the partnership between China and France, addressing climate change, strengthening dialogue and developing cooperation in elements such as nuclear energy, and emerging fields, such as new energy, electric vehicle, circular economy and low carbon technology. At the end of April 2012, the Alliance Sino-European pour les Energies Nouvelles (the Sino-Europe New Energy Alliance, A.S.E.E.N.) was established by the Senate of France, which promoted the exchange and cooperation in the development and utilization of new energy between China and France. Second, the ministries and commissions of the parties fostered cooperation. In 2011, MOST, and the Ministry of Education and Higher Education jointly signed the meeting minutes of the *13th Commission Mixte Sino-Française sur la CoopérationScientifique et Technologique (Sino-French Joint Commission on Scientific and Technological Cooperation)*, which defined the priority fields for cooperation such as, sustainable development, green chemistry and technology, energy, future cooperation mechanism. This promoting the technology exchange and cooperation between China and France. Third, industry, university and research cooperation were fostered, the platform for industry, university and research cooperation and exchange was set up to promote the industrial application in the field of new energy technologies. Since 2009, technology cooperation has been conducted in the fields of CCS, advanced solar cell technology, the “coal to olefin” technology, and the preparation of liquid fuel and chemicals from biomass. In November 2015, *the China and France Joint Presidential Statement on Climate Change* was issued.

(3) The cooperation between China and the UK in the field of climate change focused on control of air pollution, clean energy, carbon capture and storage technology, climate change risk assessment, climatology and climate service; the parties conducted all-round cooperation in many ways and learned from each other. In 2015, relevant parties arrived at a strategic investment agreement on the joint construction and operation of Hinkley Point C Nuclear Power Plant in London, and this was the first time that a Chinese enterprise participated in the construction of civilian nuclear power plants in Europe[1].

(4) China and Italy enhanced cooperation in climate change with a focus on the marine ecosystem. China's State Oceanic Administration and Italy cooperated in the coastal ecosystem capacity building program. China and Italy renewed the partnership agreement memorandum for continuous cooperation and research in the areas of marine forecast and climate prediction.

(5) China and Norway strengthened their cooperation in terms of biodiversity and carbon capture. MEE (former MEP) launched the Sino-Norwegian Biodiversity and Climate Change Program, and the memorandum of understanding on cooperation signed in June 2017 promoted the cooperation in carbon capture between Norwegian and Chinese enterprises.

China and the US signed joint statements and organized a joint working group for cooperation in many fields. Between 2014 and 2016, China and the US issued *the US-China Joint Presidential Statement on Climate Change* and *the Joint US-China Statement on Climate Change*, and reached a major common understanding on strengthening the dialogues and cooperation in climate change. The parties would expand joint clean energy research and development, advance major carbon capture, utilization and storage demonstrations, enhance cooperation on HFCs, launching a climate-smart/low-carbon cities initiative, promote trade in green goods, and demonstrate clean energy on the ground. Beside, China and the US established the U.S.-China Climate Change Working Group, under which they fostered cooperation in eight areas, including emission reduction of trucks and autos, smart grids, carbon capture and storage, GHG data management, energy efficiency in buildings and industries, industrial boilers, forestry and climate change, and low-carbon cities[2]. In the area of climate change, a ministerial-level

[1] Chinanews.com: *The UK Government Announces the Approval for the Hinkley Point Nuclear Power Project with the Cooperation between China*, the United Kingdom and France, http://www.chinanews.com/gj/2016/09-15/8004941.shtml.

[2] China Climate Change Info-Net: http://www.ccchina.org.cn/list.aspx?clmId=58.

consultation mechanism was established between China and the United States. Under the framework of the U.S.-China Climate Change Working Group, the Yanchang Petroleum project of 1 Mt of CO_2 per year carbon capture, use and storage (CCUS) demonstration program was listed into the U.S.-China Strategic & Economic Dialogue Outcomes of the Strategic Track[1].

China and Japan continuously enhanced cooperation in energy conservation, environmental protection and energy technology. The two governments issued *the Joint Statement between the Government of Japan and the Government of the People's Republic of China on the Further Enhancement of Scientific and Technical Cooperation in Climate Change* and *the Joint Statement between the Government of Japan and the Government of the People's Republic of China on Climate Change* in 2007 and 2008 respectively, and established a partnership on addressing climate change. In May 2008, the two parties signed *the Joint Statement between the Government of Japan and the Government of the People's Republic of China on Comprehensive Promotion of a Mutually Beneficial Relationship Based on Common Strategic Interests*[2], reached a common understanding on various points related to the comprehensive promotion of a mutually beneficial relationship based on common strategic interests, and determined that the technical cooperation in energy conservation, environmental protection and energy between the two countries would be given priority. China and Japan also fostered cooperation in CDM programs in the fields of renewable energy, energy conservation, and energy efficiency. Japan International Cooperation Agency provided relevant training for China's local officials and technical personnel many times. Besides, the two countries established multilevel cooperation channels for addressing climate change, with the joint effort by the government and the people. They held the Japan-China Energy Conservation and Environment Forum to bring together relevant personnel from the spheres of industry, university, research and government of both countries, and exchanged about energy conservation, environmental protection rules, policies, experience and technology. The effective cooperation in climate change between China and Japan facilitated their strategic reassurance and thus helped to promote and enhance their cooperation in other fields.

China and Australia enhanced cooperation in geological carbon dioxide

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1 Finance column of China.com.cn:http://finance.china.com.cn/industry/energy/sytrq/20160614/3765222.shtml.

2 Xinhua News Agency (http://www.gov.cn/jrzg/2008-05/07/content_964157.htm).

sequestration. With the support from the Sino-Australia Clean Coal Working Group, China's NDRC organized domestic training in the technology for carbon capture, storage and utilization, conducted pilot studies on major issues, and the Sino-Australia research on the impacts and risks of the geological sequestration of CO_2.

China and Canada established a working group for the *Joint Declaration on Canada-China Clean Technology Cooperation*, enhanced the cooperation in clean technology and energy efficiency, and furthered the transformation of Canada-China cooperation to clean development.

4.1.2 Cooperation Mechanism with UN Agencies and Other International Organizations

China has conducted a number of fruitful cooperation programs with UN agencies. In 2014, China announced to provide US$ 6 million to support the UN Secretary-General's efforts to promote South-South cooperation on climate change. Former Secretary-General Ban Ki-moon incorporated South-South Cooperation on climate change into UN's climate change strategies, which stepped up UN's overall systematic support for South-South Cooperation on climate change. With supports from many developing countries including China, UN also launched the Southern Climate Partnership Incubator (SCPI) during signing period of the Paris Agreement. SCPI has developed into a long-term platform that promotes South-South Cooperation actions in addressing climate change.

China also played a role in APEC energy cooperation, "ASEAN+3" energy cooperation, EU-China Energy Dialogue, OPEC energy cooperation, SCO energy working group, "Global Methane Initiative", "Asia-Pacific Partnership on Clean Development and Climate", "Global Carbon Capture and Storage Institute", and other international mechanisms in addressing climate change.

In 2014, NDRC implemented the "Enhancing Capacity, Knowledge and Technology Support to Build Climate Resilience of Vulnerable Developing Countries" program of World Bank Global Environment Facility (GEF) ; implemented the "Roadmap for Carbon Capture and Storage Demonstration and Deployment in China" program supported by Asian Development Bank; and participated in the "Global Alliance for Clean Cookstoves" meeting convened by the UN Foundation and the Clean Cookstoves Alliance Secretariats and implemented pilot activities domestically.

The launching ceremony of China Committee of Global Alliance for Clean Cookstoves was held in Beijing in April, 2016. The Alliance aims to perform extensive international cooperation to promote the development of a global clean and efficient cook stoves market and advanced technologies, for the purpose of protecting the public, particularly reducing GHG emissions and environmental pollutions. In June, 2016, China-US+Clean Stoves Developing Strategy Forum was held in Beijing. The forum pushed forward the establishment of an international clean stove research platform and supported scientific research institutions and companies to conduct joint researches.

In 2015, a number of pilot cities including Nanchang participated in the "GEF China Sustainable Cities Integrated Approach Pilot" program, during which pilot cities received loans support from World Bank.

The Foreign Economic Cooperation Office (FECO) of MEE signed the Accreditation Master Agreement (AMA) with the Green Climate Fund (GCF). On signing the agreement, China officially became one of the 48 GCF Accredited Entities (AEs) globally and the first one in China. The two parties agreed to make joint efforts in developing GCF programs, controlling carbon emissions in key industries, promoting low carbon development in key sectors and making greater contribution to push forward ecological civilization construction, improve environmental quality and mitigate climate change.

In April, 2015, Shenzhen new district administrative committees reached a cooperation agreement with R20 - Regions of Climate Action, which preliminarily formed the research framework for waste management, i.e. Dapeng New District Waste Management Solution. Also, Chinese companies signed strategic cooperation agreements of energy conservation renovation with R20.

In March, 2017, more than 200 agricultural and climate change scholars from more than 20 countries and international organizations attended the 2nd Agriculture and Climate Change Conference, during which event they held in-depth exchanges and discussions on current climate change and cutting-edge researches in agricultural sector.

In recent years, many Chinese enterprises joined the "Science Based Targets" initiative jointly made by the World Wide Fund for Nature (WWF), Carbon Disclosure Project (CDP), World Resources Institute (WRI) and United Nations Global Compact (UNGC), and provided policy advices for energy planning during the 13th FYP period. Chinese Renewable Energy Industries Association (CREIA), US-China Energy Cooperation Program (ECP), Swedish Energy Agency and WWF co-hosted "Renewable energy drives future -—actions and innovation" side event during the 8th Clean Energy Ministerial (CEM-8)[1].

4.1.3 Regional International Cooperation Mechanisms

Now, developing low carbon, clean energy and renewable energy has become global consensus, thus providing a good opportunity for China to push forward low carbon development, adjust economic structure and build up capacity in addressing climate change. Up to today, China has conducted extensive exchanges with more than 100 countries on environmental protection, and signed nearly 150 environmental protection cooperation paperwork with more than 60 countries, regions and international organizations for intensive mutual assistance and cooperation in this regard[2].

In recent years, China has also established cooperation and exchange platforms with developing countries and less developed countries in a hope to collectively address the challenges posed by climate change.

China and India, its neighboring country and a big developing country, have conducted in-depth cooperation in addressing climate change. Efforts include jointly developing and utilizing water energy resources in international rivers' solar energy, bioenergy and other renewable energy-related activities. The two countries have made constant efforts to strengthen BASIC Ministerial on Climate Change mechanism and played important roles in the global climate governance processes. "India-China Think-Tank Forum" provided another opportunity for official think-tanks in the two countries to focus and exchange on climate issues[3].

In 2008, MOST of China and UNEP signed a *Memorandum of Understanding (MoU) on Framework of Technical and Institutional Cooperation on Environment in Africa*. Since then, under the framework, two projects of UNEP-China-Africa Cooperation Programme involving 16 African countries were completed in 2010 and 2014, in a bid to promote the South-South cooperation and improve African countries' capacity to addressing climate change.

China established China-ASEAN Environmental Protection Center and other dedicated agencies and compiled cooperation strategies, under which China

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[1] Chinese Renewable Energy Industries Association (CREIA) website: http://www.creia.net/news/creianews/3001.html.

[2] Http://www.ccchina.gov.cn/Detail.aspx?newsId=68524&TId=66.

[3] Gao Xiang, Zhu Qinhan, (2016): Climate Change Policy of India: Its Features and Impacts on China-India Cooperation, *South Asian Studies Quarterly, Issue 1.*

hosted a series of international training workshops in developing countries spanning to new energy and renewable energy, etc. These efforts are made aiming to foster technical personnel, scientific research personnel and management personnel in relevant sectors, increase energy efficiency and promote low carbon technologies. Developments in South-South Cooperation and green "Belt and Road" initiative promoted sharing of ecological civilization and green development experience.

As the "Belt and Road Initiative" boosted capacity building in addressing climate change, the Chinese government further stepped up international cooperation on climate change. In May, 2017, the Belt and Road Forum for International Cooperation (BRFIC) was successfully held in Beijing, during which China proposed a series of measures to push forward sustainable development cooperation among relevant countries.

4.2 South-South Cooperation

As a member of the South-South Cooperation, China conducted low carbon demonstration pilot zones, mitigation and adaptation programs and relevant training activities in developing countries. By donating renewable energy and climate change monitoring and early warning devices, this provided support for policy preparation and planning in addressing climate change. Additionally, it promoted climate-friendly technologies. China has provided many developing countries with finance, technology and many other supporting elements to help them respond to climate change (Figure 6-8, 6-9).

Figure 6-8 The Ceremony of China Donating Climate Change-related Household Items to Myanmar (in Nay Pyi Taw)

The Chinese government has donated energy conservation, low carbon products as well as hosted climate change workshops and other activities to actively push forward South-South Cooperation on climate change. These efforts have yielded fruitful results. Since 2012, the Chinese government has set aside 200 million yuan for 3-year international cooperation programs, which aimed to help small island countries, the least developed countries and African countries address climate change. In 2014, China announced the intention to double existing financial support from 2015. In September, 2015, when co-hosting the High-level Roundtable on South-South Cooperation at the UN headquarters in New York, President Xi Jinping announced that China would establish the Institute of South-South Cooperation and Development. In the same year, the Chinese government initiated South-South Cooperation on climate "10-100-1000" program, which aims to help build up 10 low-carbon pilot zones, launch 100 climate change mitigation and adaptation projects, and offer training programs for 1,000 climate-related professionals in developing countries. By the end of 2015, the NDRC had signed 22 MOUs for donating climate change-related items to 20 developing countries, and had donated a total of more than 1.2 million LED lights, more than 9,000 sets of LED road lamps, more than 20,000 sets of energy conservation air conditioners, and more than 8,000 sets of solar photovoltaic power generation systems. Among these, the 8 MOUs between China and Dominica, the Maldives, Tonga, Fiji, Samoa, Antigua and Barbuda, Myanmar and Pakistan were witnessed by President Xi Jinping and Premier Li Keqiang respectively. China hosted in total 11 training workshops on climate change and green low carbon development, which were attended by more than 500 officials and climate change technical professionals from 58 developing countries besides China.

Figure 6-9 China Donated Mobile Weather Stations to Bolivia

The Chinese government has actively promoted and supported the development of many developing countries through the South-South Cooperation mechanism. Through a series of pragmatic programs and beneficial activities, South-South Cooperation on climate change has become an effective approach for China and developing countries to strengthen solidarity, achieve mutual benefits and exemplary results.

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

Hong Kong is a special administrative region of the People's Republic of China. It is a vibrant city with mild climate, limited natural resources, high population density and highly developed service industry. It is also an eminent international financial, trading and shipping hub.

Chapter 1 Regional Circumstances

1.1 Natural Conditions and Resources

The Hong Kong Special Administrative Region (HKSAR, hereinafter referred to as 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. It has a land area of 1,106 square kilometers comprising Hong Kong Island, Kowloon, the New Territories and Outlying Islands. It is hilly with only less than 300 square kilometers developed for living and economic activities. More than 500 square kilometers of land has been designated for various purposes related to nature conservation, including country parks, special areas and conservation areas. Hong Kong is located within the sub-tropical region with mild climate. The annual mean temperature was 23.3°C and the average yearly rainfall was about 2,400 mm for the past 30 years. Extreme weather conditions that occur in Hong Kong include tropical cyclones, strong monsoons, monsoon troughs and strong convective weather. Sub-topical evergreen broadleaf forest is the main vegetation of Hong Kong. Hong Kong is rich in assemblage of marine species, including fish and crustaceans. However, fresh water resource is relatively scarce. Local rainwater accounts for about 20% to 30% of the fresh water supply, and the remaining 70% to 80% fresh water supply relied on Dongjiang water imported from Guangdong province.

1.2 Population and Society

The population of Hong Kong was around 7.34 million in 2016. The average annual population growth rate was 7‰ from 2010 to 2016. The labor force was around 3.92 million in 2016, of which 50.9% were males and 49.1% were females. In 2016, there were some 300,000 primary students and 310,000 secondary students studying in public and subsidized schools. Public expenditure on education amounted to HK$78.9 billion in the 2015-2016 financial year, which accounted for 18.1% of the total public expenditure.

1.3 Economic Development

Hong Kong is a highly urbanized economy. The current price Gross Domestic Product (GDP) of Hong Kong in 2016 was approximately HK$2.5 trillion, or about HK$ 339,500 per capita. The annual growth rates of GDP in 2015 and 2016 were 6.1 % and 3.9 % respectively. In 2016, the proportion of the three industries[1] was 0.1:7.7:92.2. Both the value added of the primary industry and the percentage of the workforce engaged in the primary industry were low. Since early 1980s, the manufacturing industry has substantially relocated to the Mainland, resulting in a gradual shrinkage in its contribution to the value added of Hong Kong's economy. On the other hand, the contribution of the tertiary industry (the service industry) has been increasing progressively. Of the tertiary industry, financial services, tourism, trading and logistics, and professional and producer services have become the pillar industries of Hong Kong. In 2016, the total value of external trade amounted to HK$7.6 trillion; the value added of the financial and insurance industry was HK$429.1 billion and the number of visitor arrivals was 56.65 million, of which 42.78 million arrivals were from the Mainland.

There is no primary energy production in Hong Kong. In 2016, the local primary energy demand was 11.165 Mt of coal equivalent (Mtce), with the ratio for coal, petroleum, electricity and natural gas being 1:40:50:9. Local thermal power is the main electricity supply in Hong Kong and nuclear power imported from Guangdong Province is a main supplement. In 2016, coal, natural gas, and nuclear power accounted for about 47%, 28% and 25% of Hong Kong's annual electricity consumption respectively.

Hong Kong has a well-developed public transport system, comprising railways, tramways, buses, ferries, etc. The public transport system on average carried 12.59 million passenger trips daily in 2016. This represented nearly 90% of the daily number of passenger trips. As at the end of 2016, there were around 746,000

[1] 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 industries.

licensed motor vehicles in Hong Kong, with around 536,000 of them being private cars. The motor vehicle and private car ownership were 101 and 73 per 1,000 people respectively.

The statistics on the summary of Hong Kong's circumstances in 2016 are set out in Table 7-1.

1.4 Institutional Arrangements for the Preparation of Climate Change Information

The HKSAR Government has all along been committed to combating climate change. To effectively manage and coordinate the work on addressing climate change, the HKSAR Government set up an Inter-departmental Working Group on Climate Change in 2007, which coordinates, in close consultation with relevant bureaus and departments and other bodies concerned, present and future work and activities to implement the relevant provisions of the United Nations Framework Convention on Climate Change (UNFCCC). It monitors and coordinates the efforts of relevant bureaus and departments in formulating and carrying out measures to control GHG emissions and facilitate adaptation to climate change, monitors closely the latest international developments on climate change and makes recommendations for appropriate actions taking account of these developments. It also formulates and coordinates other promotional and educational activities to promote public understanding of climate change and its effects.

In addition, the Paris Agreement, came into force in November 2016, applies to the Hong Kong as well. In the light of this, the HKSAR Government set up the Steering Committee on Climate Change in 2016. Chaired by the Chief Secretary for Administration and with members comprising 13 Policy Secretaries, the Steering Committee on Climate Change is responsible for examining experience outside Hong Kong in combating climate change and reviewing the scope for enhancing the mitigation, adaptation and resilience actions in Hong Kong to combat climate change.

Table 7-1 Summary of HK's Circumstances in 2016

Criteria	2016
Population (million, mid-year)	7.337
Land area (square kilometre)	1,106
GDP (HK$ billion, at current market prices)	2,490.78
Per capita GDP (HK$, at current market prices) (based on mid-year population)	339,500
Percentage share of industry in GDP[1]	7.7
Percentage share of services in GDP	92.2
Percentage share of agriculture, fishing, mining and quarrying in GDP	0.1
Land area for agriculture purposes [2] (square kilometre)	51
Cattle (head)	1,230
Horse (head)	1,817
Pig (head)	69,878
Forest area (square kilometer)	277
Life expectancy at birth (year)	Male: 81.3 Female: 87.3

The Environment Bureau (ENB)/Environmental Protection Department (EPD) is the secretariat of the Inter-departmental Working Group on Climate Change and the Steering Committee on Climate Change. It is also responsible for coordinating and preparing the chapter of "Basic information of the HKSAR on addressing climate change" in national communications and biennial update reports.

Chapter 2 Hong Kong's Greenhouse Gas Inventory of 2010

In the process of compiling the Hong Kong's GHG inventory, references had been made to *Revised 1996 IPCC Guidelines*, *IPCC GPG 2000* and *2006 IPCC Guidelines*. The reporting year was 2010, and it covered areas including energy, industrial processes, agriculture, land-use change and forestry, as well as waste. The reported GHGs cover carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride.

2.1 Overview

In 2010, Hong Kong's net total GHG emissions (including land-use change and forestry, LUCF) amounted to about $4,039.67 \times 10^4$ tons of carbon dioxide equivalent (10^4t CO_2 eq), amongst which the carbon sink from land-use change and forestry amounted to about 41.80×10^4 t CO_2 eq. Therefore, when excluding

[1] Industry includes manufacturing, electricity, gas and water supply, waste management and construction.
[2] Arable land.

land-use change and forestry, Hong Kong's total GHG emissions stood at about 4,081.47×10^4 t CO_2 eq, amongst which carbon dioxide accounted for about 3,744.42×10^4 t CO_2 eq, or 91.74%; methane about 206.78×10^4 t CO_2 eq, or 5.07%; nitrous oxide about 31.31×10^4 t CO_2 eq, or 0.77% (Table 7-2, Table 7-3); hydrofluorocarbons about 92.83×10^4 t CO_2 eq, or 2.27%; and sulfur hexafluoride about 6.13×10^4 t CO_2 eq, or 0.15% of the total (Table 7-4). Table 7-3 sets out Hong Kong's emissions inventory of carbon dioxide, methane and nitrous oxide in 2010 by categories. Table 7-4 sets out the major sources and inventory of fluorinated gas emissions in Hong Kong in 2010.

Table 7-2 Hong Kong's GHG Emissions in 2010 (10,000 metric tons of CO_2 eq)

	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Total
Total (with LUCF)	3702.62	206.78	31.31	92.83	0.00	6.13	4,039.67
1. Energy	3,681.76	3.94	12.58				3,698.28
2. Industrial processes	61.00	NE	NE	92.83	0.00	6.13	159.96
3. Agriculture		1.18	1.78				2.96
4. LULUCF	-41.80	NE	NE				-41.80
5. Waste	1.66	201.66	16.95				220.27
Total (without LUCF)	3744.42	206.78	31.31	92.83	0.00	6.13	4,081.47

Note: 1. Shaded cells do not require entries.

2. Due to rounding, a slight discrepancy may exist between table breakdowns and the total figure.

3. NE (Not Estimated) indicates that existing emissions and removals have not been estimated.

Table 7-3 Hong Kong's Emissions of Carbon Dioxide, Methane, Nitrous Oxide in 2010 (kt)

GHG sources and sink categories	CO_2	CH_4	N_2O
Total (w/o LUCF)	37,444.2	98.5	1.0
Total(w/ LUCF)	37,026.2	98.5	1.0
1. Energy	36,817.6	1.9	0.4
—Fuel combustion	36,817.6	0.9	0.4
♦Energy industry	27,262.2	0.8	0.3
♦Manufacturing industries and construction	726.8	0.0	0.0
♦Transport	7,314.2	0.1	0.0
♦Other sectors	1,514.4	0.0	0.0
—Fugitive emission		1.0	

♦ Oil and natural gas system		1.0	
♦ Coal mining		NO	
2. Industrial processes	610.0	NO	NO
—Cement production	610.0		
—Halocarbons and sulfur hexafluoride production			
—Halocarbons and sulfur hexafluoride consumption			
3. Agriculture		0.6	0.0
—Enteric fermentation		0.2	
—Manure management		0.4	0.0
—Rice cultivation		NO	
—Agricultural soils		NO	NO
—Prescribed burning of savannas		0.0	0.0
4. Land-use change and forestry	-418.0	NE	NE
—Changes in forest and other woody biomass stocks	-418.0		
—Forest conversion	NE	NE	NE
5. Waste	16.6	96.0	0.5
—Solid waste disposal on land	16.6	92.3	NO
—Wastewater handling		3.8	0.5
Memo Items			
—Special regional aviation	1,482.8	0.0	0.0
—Special regional marine	10,945.8	1.0	0.2
—International aviation	11,525.4	0.4	0.1
—International marine	18,545.6	1.7	0.6

Note: 1. Shaded cells do not require entries. Being rounded to the nearest whole numbers, the sums of all sub-items may slightly differ from the totals. 0.0 indicates calculation results that are negligible;

2. NO (Not Occurring) refers to the 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 between Hong Kong and the Mainland China.

Table 7-4 Emissions of Fluorinated Gas in Hong Kong in 2010 (kt CO_2 eq)

GHG source and sink categories	HFCs					PFCs		SF_6	Total
	HFC-32	HFC-125	HFC-134a	HFC-143a	HFC-227ea	CF_4	C_2F_6		
Total	2.7	17.9	850.8	8.5	48.4	0.0	0.0	61.3	989.6
Energy									
Industrial processes	2.7	17.9	850.8	8.5	48.4	0.0	0.0	61.3	989.6
—Mineral products									
—Chemical industry									
—Metal production						NO	NO		
—Production of halocarbons and SF_6	NO	NO	NO	NO	NO	NO	NO	NO	NO
— Consumption of halocarbons and SF_6	2.7	17.9	850.8	8.5	48.4	0.0	0.0	61.3	989.6
3. Agriculture									
4. LUCF									
5. Waste									

Energy activities are the primary source of GHG emissions in Hong Kong. In 2010, GHG emissions from energy accounted for 90.61% of the total GHG emissions, while GHG emissions from waste, industrial processes and agriculture accounted for 5.40%, 3.92% and 0.07% of the total emissions respectively. Figure 7-1 illustrates Hong Kong's GHG emissions by sources.

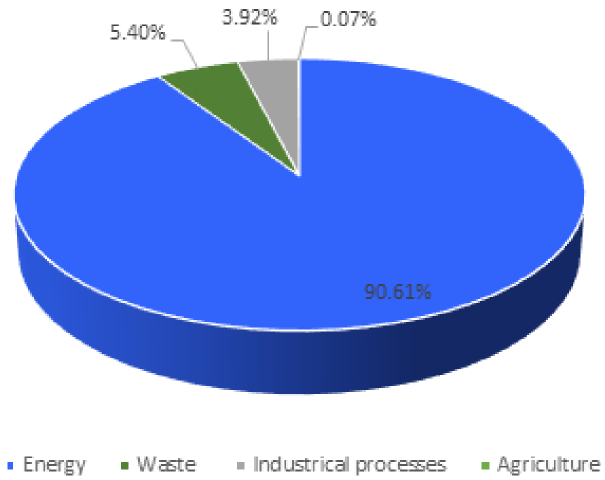

Figure 7-1 Hong Kong's GHG Emissions by Sources

The GHG emissions in Hong Kong are primarily carbon dioxide. In 2010, carbon dioxide accounted for 91.74% of the total emissions, while methane, fluorinated gases and nitrous oxide accounted for 5.07%, 2.42% and 0.77% of the total emissions respectively (See Figure 7-2).

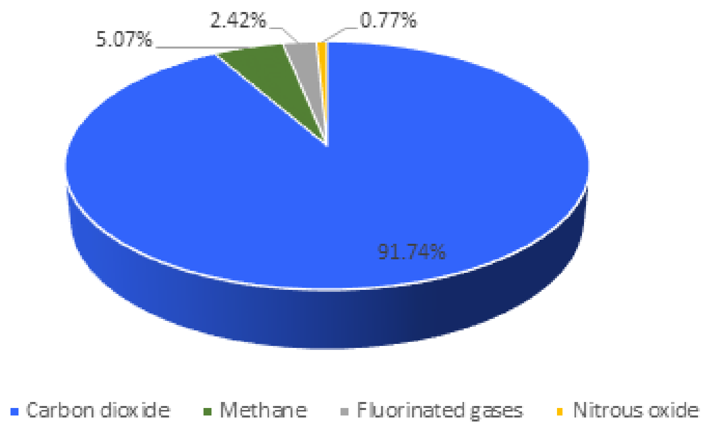

Figure 7-2 Hong Kong's GHG Emissions by Gas

In 2010, the GHG emissions from special regional routes and international bunker fuel of Hong Kong amounted to $4{,}279.21 \times 10^4$ t CO_2 eq, which included $1{,}249.90 \times 10^4$ t CO_2 eq from special regional marine and aviation emissions, and $3{,}029.31 \times 10^4$ t 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 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

2.2.1 Scope

The inventory for energy mainly covers emissions of carbon dioxide, methane and nitrous oxide from fossil fuel burning in energy industry, manufacturing industry, construction industry, transportation sector and other sectors; and fugitive methane emissions of oil and gas systems.

2.2.2 Methodologies

The calculation of emissions from energy in Hong Kong is mainly based on *2006 IPCC Guidelines*. Tier 3 method was adopted to calculate emissions of carbon dioxide, methane and nitrous oxide in electricity production. Tier 2 method was adopted to calculate carbon dioxide emissions while Tier 1 method was adopted to calculate methane and nitrous oxide emissions in town gas production. Tier 2 method was adopted to calculate carbon dioxide emissions while Tier 1 method was adopted to calculate methane and nitrous oxide emissions in utilizing landfill gas for energy purpose. As for the manufacturing and construction industries and other sectors, Tier 2 method was adopted to calculate carbon dioxide emissions while Tier 1 method was adopted to calculate methane and nitrous oxide emissions.

Tier 1 and 2 methods were adopted to calculate emissions of carbon dioxide, methane and nitrous oxide from local aviation and marine, rail, non-road transport and road transport sources.

Special regional transport means aviation and marine transport activities departing from Hong Kong with destinations in other parts of the mainland of China while international transport means aviation and marine transport activities departing from Hong Kong with destinations in places other than the Mainland of China. Tier 3(a) method was adopted for the calculation of emissions of carbon dioxide, methane and nitrous oxide from special regional and international aviation. Tier 1 method was adopted to calculate emissions of carbon dioxide, methane and nitrous oxide from special regional and international marine.

Tier 1 method was adopted to calculate fugitive methane emissions of methane from the gas transmission while Tier 3 method was adopted to calculate other fugitive methane emissions.

2.2.3 Emissions Inventory

In 2010, GHG emissions from energy activities in Hong Kong amounted to 3,698.28×10^4 t CO_2 eq, amongst them, 3,681.76×10^4, 3.94×10^4 and 12.58×10^4 t CO_2 eq were emissions of carbon dioxide, methane and nitrous oxide respectively. Carbon dioxide emissions from energy activities accounted for 90.20% of the total of such emissions.

Of Hong Kong's GHG emissions from energy activities in 2010, 2,736.07×10^4 t CO_2 eq, or 73.98% were from energy industry (electricity and town gas production); 735.49×10^4 t CO_2 eq, or 19.89% were from transport; 151.73×10^4 t CO_2 eq, or 4.10% were from other sectors (including commercial and residential sectors); 72.98×10^4 t CO_2 eq, or 1.97% were from manufacturing and construction industries; 2.01×10^4 t CO_2 eq, or about 0.05% were from fugitive emission of methane.

2.3 Industrial Process

2.3.1 Scope

The scope of reporting GHG emissions from industrial processes mainly covers the emissions of carbon dioxide from the production of cement; the emissions of hydrofluorocarbons and perfluorocarbons from refrigerating, air-conditioning and fire-fighting equipment; and the emissions of sulfur hexafluoride from electrical equipment.

2.3.2 Methodologies

According to clinker production and related data, Tier 2 method of the *Revised 1996 IPCC Guidelines* was adopted and reference was made to related parameters of *2006 IPCC Guidelines* in calculating carbon dioxide emissions from cement production. Tier 2(b) method of *2006 IPCC Guidelines* was adopted to calculate hydrofluorocarbons emissions from air conditioning of buses, rail trains, large-scale commercial establishments and government buildings, as well as industrial refrigeration. Tier 2(a) method was adopted to calculate hydrofluorocarbons emissions from air conditioning of motor vehicles, goods vehicles, industrial/commercial buildings, and refrigeration for domestic and commercial uses. Tier 1 method of *2006 IPCC Guidelines* was adopted to calculate perfluorocarbons emissions from solvents. Tier 1(a) method of *2006 IPCC Guidelines* was adopted to calculate emissions of hydrofluorocarbons and perfluorocarbons from fire-fighting equipment. Tier 3 method of the *2006 IPCC Guidelines* was adopted to calculate emissions of sulfur hexafluoride used in electrical equipment.

2.3.3 Emissions Inventory

In 2010, GHG emissions from industrial processes in Hong Kong were 159.96×10^4 t CO_2 eq, accounting for 3.92% of the total emissions, amongst which 61.00×10^4 t or 1.49% were emitted from cement production. Hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride emissions from refrigeration, air-conditioning, fire-fighting and electrical equipment were 92.83×10^4, 0 and 6.13×10^4 t CO_2 eq respectively.

2.4 Agriculture

2.4.1 Scope

The inventory for agriculture mainly covers emissions of methane and nitrous oxide from livestock enteric fermentation and manure management; emissions of nitrous oxide from agricultural soils; and emissions of carbon dioxide, methane and nitrous oxide from savanna burning.

2.4.2 Methodologies

Tier 1 method of the *Revised 1996 IPCC Guidelines* was adopted and reference was made to the default emission factors in *2006 IPCC Guidelines* in calculating methane emissions from enteric fermentation. Tier 1 method of the *2006 IPCC Guidelines* was adopted to calculate the direct and indirect emissions of nitrous oxide from agricultural soils. Tier 1 method of *2006 IPCC Guidelines* was adopted to calculate the emissions of methane and nitrous oxide from prescribed savanna burning.

2.4.3 Emissions Inventory

In 2010, GHG emissions from agricultural activities amounted to approximately 2.96×10^4 t CO_2 eq, or 0.07% of the total emissions. Methane and nitrous oxide emissions from livestock enteric fermentation and manure management amounted to 1.62×10^4 t CO_2 eq while nitrous oxide emissions from agricultural soils were approximately 1.34×10^4 t CO_2 eq.

2.5 Land-use Change and Forestry

2.5.1 Scope

The inventory for land-use change and forestry mainly covers the changes in biomass carbon stock caused by the conversion of forestland, cropland and grassland.

2.5.2 Methodologies

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

2.5.3 Emissions Inventory

In 2010, as carbon sinks, land-use change and forestry had a net removal of approximately 41.80×10^4 tons of carbon dioxide in Hong Kong. All of the carbon removals were caused by changes in the biomass carbon stock of forests and other woody biomass resulting from the conversion of forestland and grassland.

2.6 Waste

2.6.1 Scope

The inventory for waste treatment mainly covers methane emissions from solid waste landfilling; methane and nitrous oxide emissions from treatment of domestic sewage and industrial wastewater; and carbon dioxide emissions from waste incineration.

2.6.2 Methodologies

The calculation of emissions from waste treatment was mainly based on *2006 IPCC Guidelines*. Tier 2 method was adopted to calculate methane emissions from landfilling of solid waste. Tier 1 method was adopted to calculate the emissions of methane and nitrous oxide from wastewater treatment, and Tier 1 method was also adopted to calculate the emissions of carbon dioxide from chemical waste treatment.

2.6.3 Emissions Inventory

In 2010, GHG emissions from waste treatment in Hong Kong amounted to 220.27×10^4 t CO_2 eq, or 5.40% of the total emissions. Most of such emissions were methane which amounted to 201.66×10^4 t CO_2 eq, or 4.94% of the total methane emissions in Hong Kong.

2.7 Quality Assurance and Quality Control of the GHG Inventory

2.7.1 Quality Assurance and Quality Control in Compiling this Inventory

To improve the quality of the inventory compilation, the institutions engaged in inventory preparation were particularly mindful of enhancing the quality assurance and quality control efforts in the preparation of the inventory. The efforts mainly include:

1. In selecting the methodologies for compilation, the guidelines provided by the IPCC were strictly followed to ensure the scientificity, comparability and transparency of the inventory compilation;

2. In the process of collecting and analyzing the activity data, the institutions worked closely with the relevant departments to acquire authoritative first-hand official information, which was then managed, checked and examined by specialized personnel, to ensure the authoritativeness and rationality of the data used;

3. In determining the emission factors, emission factors in compliance with Hong Kong's actual circumstances were adopted as far as practicable. In the absence of emission factors possessing the characteristics of Hong Kong, reference was made to the default emission factors provided by the IPCC Guidelines to ensure the accuracy of the results in the inventory.

2.7.2 Uncertainty Analysis in this Inventory

Measures were implemented to reduce the uncertainties in a two-pronged approach. Firstly, the data collection process was improved. Official statistics, local measured emission factors and parameters, as well as the latest parameters of *2006 IPCC Guidelines*, were adopted. Secondly, appropriate methodologies were selected. Based on data availability, higher-tier methods were used where appropriate to calculate the emissions for the inventory.

Uncertainties in the inventory: Based on the analysis conducted in accordance with the propagation of error stated in *2006 IPCC Guidelines*, the uncertainty of Hong Kong's 2010 GHG inventory was around 4.34%. Emissions produced in the process of coal-fired power generation were the major reason for the uncertainty mainly due to the limitation of the statistics on the type and quantity of coal consumption at power plants.

2.8 Major Factors Affecting Emissions in the Future

The major factors that affect Hong Kong's GHG emissions in the future include: population, economic development and structural adjustment as well as changes in lifestyle. It is estimated that Hong Kong's total GHG emissions will be steady and show a gradually decreasing trend in the future.

2.8.1 Population Growth

Hong Kong's population was around 7.34 million in 2016. It is estimated that the population will reach 7.56 million in 2020, representing a growth of 3.0% over 2016. In 2030, the population will be 7.96 million, or a growth of around 8.5% as compared with 2016. Population growth increases the pressure on the control of GHG emissions.

2.8.2 Economic Development and Structural Adjustment

In the past 20 years, Hong Kong's economic growth was higher than the global average level in the same period. It is expected that Hong Kong's economy will still keep growing in the future. Continuous growth in economy will lead to a constant increase in the demand for energy, transportation, etc. On the other hand, having considered that there will be a constant increase in the output and ratio of tertiary industry, it is likely that Hong Kong's GHG emissions per unit of GDP will decline continuously.

2.8.3 Changes in Lifestyle and Consumption Patterns and Advance in Technology

With the active promotion of the HKSAR Government, more and more enterprises and members of the public participate in combating climate change. In the same time, local production, lifestyle and consumption patterns are also changing gradually; clean energy keeps developing; and low-carbon energy saving technologies continue to advance. New opportunities for green low-carbon development will be opened up for Hong Kong in the future, and the development of green low-carbon economy will help mitigate GHG emissions.

2.9 Trends in Carbon Dioxide Emission

2.9.1 Analytical Methods and Scenario Setting

In 2016, the HKSAR Government conducted assessments on the carbon dioxide emissions of the HKSAR in 2020 and 2030. An integrated energy-economic-environmental model, i.e. the Hong Kong MARKAL-MACRO model was used in the assessments. As electricity generation accounts for about two-thirds of the total carbon emissions of the HKSAR, the setting of scenarios was mainly based on the fuel structure, taking into account other factors including the energy efficiency of buildings, transport and electrical appliances, application of district cooling system, waste treatment and waste-to-energy.

As the HKSAR Government has already started reducing coal-fired electricity generation in 2020, the proportion of coal-fired electricity generation will be reduced from about 50% in 2015 to about 25% in 2020. At the same time, the proportion of gas-fired electricity generation will be increased from about 25% in 2015 to about 50% in 2020, while the nuclear power import will continue to account for around 25% of the total fuel mix, with further development of renewable energy and adoption of more demand side management measures. As such, one planning scenario will be set for 2020, whilst two scenarios will be set for 2030. In scenario 1, coal-fired electricity generation will be adopted to produce small amount of electricity, the remaining demand for electricity will be generated by gas-fired power (about 60%) and zero carbon energy. In scenario 2, coal-fired power generation will be completely phased out, and electricity will only be generated by gas-fired power (about 70%) and zero carbon energy.

2.9.2 Preliminary Analysis of the Modelling Results

The modelling results indicate that carbon intensity in Hong Kong in 2020 will be reduced by about 51% using 2005 as the base year, with carbon emissions reduced from 6.2 tons to 4.3 tons on a per capita basis. Carbon intensity in Hong Kong in 2030 will be reduced by 65% to 70% as compared with the 2005 level, which is equivalent to carbon emissions of 3.3 tons to 3.8 tons on a per capita basis. The modelling results are shown in Table 7-5. The results for 2030 achieve the carbon emissions reduction target set for 2030 by the HKSAR Government.

2.10 Hong Kong's Greenhouse Gas Inventory in the Past Years

In order to maintain the consistency with other parts of this report, this section will also provide an overview of the inventory information for the three historical years of the Initial and Second National Communications and the First Biennial Update Report, i.e. 1994, 2005 and 2012.

Table 7-5 Emissions Projection of the Future

Year	Scenario	Carbon intensity (tons CO_2 eq. per HK$10,000 GDP)[1]	Percentage reduced in carbon intensity as compared with 2005 (%)	Per capita carbon emissions (tons CO_2 eq.)	Emissions (10^4 tons CO_2 eq.)
2020	About 25% from coal; about 50% from natural gas; about 25% from nuclear power; further development of renewable energy and adoption of more demand management measures	0.119	51	4.3	3,255.1
2030	Scenario 1 Small amount of coal; about 60% from natural gas; about 25% from zero carbon energy	0.085	65	3.8	3,022.7
	Scenario 2 No generation from coal; about 70% from natural gas; about 25% from zero carbon energy.	0.074	70	3.3	2,639.7

2.10.1 Hong Kong's Greenhouse Gas Inventory of 1994

In 1994, Hong Kong's net total GHG emissions (including land-use change and forestry) amounted to about $3,516.35\times10^4$ t CO_2 eq. Amongst which carbon dioxide, methane, nitrous oxide and fluorinated gas accounted for 94.16%,4.41%, 1.07% and 0.36% respectively; the carbon sink from land-use change and forestry amounted to about 46.16×10^4 t CO_2 eq. When excluding land-use change and forestry, Hong Kong's total GHG emissions in 1994 stood at about $3,562.52\times10^4$ t CO_2 eq, amongst which carbon dioxide, methane, nitrous oxide and fluorinated gas

[1] Chain volume measures of GDP for 2015.

accounted for 94.24%, 4.35%, 1.05% and 0.36% respectively. (Table 7-6)

Table 7-6 Hong Kong's GHG Emissions by Gas in 1994

GHG	Excluding land-use change and forestry		Including land-use change and forestry	
	CO_2 eq. (10^4t)	Percentage (%)	CO_2 eq. (10^4t)	Percentage (%)
Carbon dioxide	3,357.22	94.24	3,310.9	94.16
Methane	155.04	4.35	155.04	4.41
Nitrous oxide	37.51	1.05	37.64	1.07
Fluorinated Gas	12.75	0.36	12.75	0.36
Total	3,562.52		3,516.35	

2.10.2 Hong Kong's Greenhouse Gas Inventory of 2005

In 2005, Hong Kong's net total GHG emissions (including land-use change and forestry) amounted to about $4{,}081.23 \times 10^4$ t CO_2 eq. Amongst which carbon dioxide, methane, nitrous oxide and fluorinated gas accounted for 91.60%, 5.34%, 0.93% and 2.12% respectively; the carbon sink from land-use change and forestry amounted to about 40.52×10^4 t CO_2 eq. Therefore, when excluding land-use change and forestry, Hong Kong's total GHG emissions in 2005 stood at about $4{,}121.76 \times 10^4$ t CO_2 eq, amongst which carbon dioxide, methane, nitrous oxide and fluorinated gas accounted for 91.69%, 5.29%, 0.92% and 2.10% respectively (Table 7-7) .

Table 7-7 Hong Kong's GHG emissions by Gas in 2005

GHG	Excluding land-use change and forestry		Including land-use change and forestry	
	CO_2 eq. (10^4t)	Percentage (%)	CO_2 eq. (10^4t)	Percentage (%)
Carbon dioxide	3,779.07	91.69	3,738.41	91.60
Methane	218.02	5.29	218.02	5.34
Nitrous oxide	37.96	0.92	38.10	0.93
Fluorinated gas	86.71	2.10	86.71	2.12
Total	4,121.76		4,081.23	

2.10.3 Hong Kong's Greenhouse Gas Inventory of 2012

In 2012, Hong Kong's net total GHG emissions (including land-use change and forestry) amounted to about $4{,}253.33\times10^4$ t CO_2 eq. Amongst which carbon dioxide, methane, nitrous oxide and fluorinated gas accounted for 91.51%, 5.18%, 0.81% and 2.49% respectively; the carbon sink from land-use change and forestry amounted to about 45.85×10^4 t CO_2 eq. Therefore, when excluding land-use change and forestry, Hong Kong's total GHG emissions in 2012 stood at about $4{,}299.18\times10^4$ t CO_2 eq, amongst which carbon dioxide, methane, nitrous oxide and fluorinated gas accounted for 91.60%, 5.13%, 0.80% and 2.47% respectively. (Table 7-8)

Table 7-8 Hong Kong's GHG emissions by gas in 2012

GHG	Excluding land-use change and forestry		Including land-use change and forestry	
	CO_2 eq. (10^4t)	Percentage (%)	CO_2 eq. (10^4t)	Percentage (%)
Carbon dioxide	3,938.19	91.60	3,892.21	91.51
Methane	220.51	5.13	220.51	5.18
Nitrous oxide	34.48	0.80	34.62	0.81
Fluorinated Gas	106.00	2.47	106.00	2.49
Total	4,299.18		4,253.33	

Chapter 3 Impacts of and Adaptation to Climate Change

According to prevailing 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. Hong Kong 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 trend of climate change in Hong Kong is basically in line with the overall global trend. The Hong Kong Observatory (HKO) began to make systematic observations of meteorological parameters in the 1880s (Figure 7-3). As shown in the trend of temperature change, the annual mean temperature increased at the rate of 0.12°C per decade on average from 1885 to 2016. The rate of increase became faster from 1987 to 2016, reaching 0.15°C per decade.

Regarding the trend of the rise of the sea level, there was an obvious rise of the sea level in the Victoria Harbour from 1954 to 2016, and the rate was 3.1 mm per year on average. 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 day per decade from 1947 to 2016, and the annual number of thunderstorm days increased at an average rate of 2.0 days per decade during the same period.

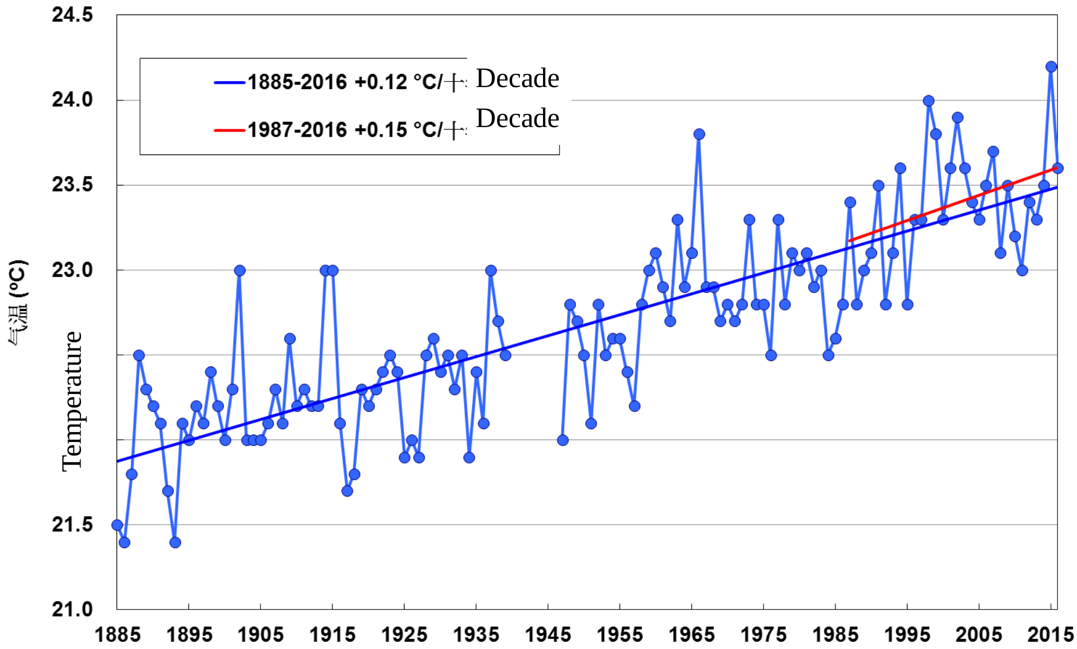

Figure 7-3 Annual Mean Temperature Recorded at the Hong Kong Observatory Headquarters (1885-2016)

3.1.2 Future Trends in Climate Change

HKO uses the IPCC global climate model results obtained under different GHG concentration scenarios, together with the past temperature and rainfall records of Hong Kong, to project Hong Kong's future temperature and rainfall trends by adopting the downscaling methodology. The temperature projections have also taken into account the impact of urban heat island effect. The projections under high GHG concentration scenario[1] are as follows: Firstly, the annual average temperature is expected to rise by 3°C - 6°C in 2091 - 2100, when compared with the average temperature of 23.3°C in 1986 - 2005. Secondly, the numbers of hot nights (days with a minimum temperature of 28°C or above) and very hot days (days with a maximum temperature of 33°C or above) are expected to increase significantly, while the number of cold days (days with a minimum temperature of 12°C or below) is expected to continue to decrease. Thirdly, the annual average rainfall in 2091 - 2100 is expected to rise by about 180 mm when compared to the annual average rainfall of 2,400 mm in 1986 - 2005. Moreover, the number of extremely wet years (with annual rainfall over 3,168 mm) is expected to increase substantially from 3 years for the period between 1885 and 2005 to 12 years for

[1] For projections under other GHG concentration scenarios, please refer to: https://www.hko.gov.hk/climate_change/future_climate_e.htm.

the period between 2006 and 2100, while the number of extremely dry years (with annual rainfall less than 1,289 mm) will remain at 2 years. In addition, the average rain intensity will also increase. Fourthly, the mean sea level in Hong Kong and its adjacent waters for 2081-2100 is expected to rise by 0.63 m - 1.07 m from the mean level for 1986-2005[1], and the extreme water level caused by the rising sea level will also go up 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 to climate change. Currently, progress has been made in a number of areas:

3.2.1 Biodiversity

Enhancing the vegetation diversity in urban areas is a priority in the 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 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 livability 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 DJ water from Guangdong province. The annual supply ceiling in the current DJ water supply agreement is set at 820 million m^3[2] (mcm). In 2018, Hong Kong consumed a total of 1,292 mcm of water, of which, around 57% was imported DJ water from the Guangdong province, 21%

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1 Included the effects caused by vertical movement of the crust.

came from the rainwater collected from local catchment, and the remaining 22% was seawater for toilet flushing. In view of the influence of climate change, the increase in water demand with population and economic growth, as well as the keen demand for water resources in the Pearl River Delta region, the Government promulgated its Total Water Management Strategy since 2008 to ensure water security and support sustainable development in Hong Kong. Besides taking forward some measures on the hardware front (such as using flow controllers), the Water Supplies Department (WSD) has also launched publicity programmes to promote water conservation and implemented initiatives to reduce water loss in the networks. It has also been introducing seawater desalination for potable use and developing the use of reclaimed water, treated grey water and harvested rainwater for non-potable purposes, and exploring efficient ways to utilize local water resources.

3.2.3 Hygiene and Health

Vector-borne diseases and heat-related diseases caused by climate change have become serious health problems. The Department of Health has been promoting relevant health messages through various channels, including enhancing public awareness of mosquito-borne diseases and the preventive measures to avoid mosquito bites. In addition, the Department of Health collaborates with HKO to issue press releases timely to remind members of the public to take heed of hot weather conditions and to take appropriate measures against heat stroke and ultraviolet radiation.

The impacts of climate change on food safety include food adulterated with pollutants, chemical residues in food, foodborne diseases, etc. The Centre for Food Safety (CFS) under the Food and Environmental Hygiene Department operates a routine and 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 assess the Food Surveillance Programme regularly to ensure that the food sold in the market is fit for consumption and complies with other legal requirements in Hong Kong. In addition, the CFS organizes publicity and educational activities with a view to preventing and controlling foodborne diseases relating to climate change.

3.2.4 Infrastructure

To combat the impact of climate change on Hong Kong's infrastructure, the HKSAR

Government has formed – a Climate Change Working Group on Infrastructure (CCWGI) in June 2016 to co-ordinate the strategies for tackling the impact of climate change on infrastructure in a more holistic approach. The CCWGI chaired by the Civil Engineering and Development Department (CEDD) with current 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). Relevant departments of the HKSAR Government have taken various measures to cope with climate change.

CEDD has made reference to the Fifth Assessment Report (AR 5) published by the Intergovernmental Panel on Climate Change (IPCC) and updated the Port Works Design Manual in January 2018, incorporating projections of rise in mean sea levels and increase in wind speed due to climate change. In addition, CEDD is now conducting study to compile a list of existing critical infrastructures in Hong Kong and examine the scopes of enhancement works necessary for strengthening the resilience of the critical infrastructures. CEDD also implemented a Landslip Prevention and Mitigation Programme to deal with landslide risks arising from both man-made slopes and natural hillsides.

Since 2008, DSD has been conducting comprehensive reviews on the drainage capacity of the existing drainage systems. Taking into account, inter alia, climate change effects and sustainable urban developments, the Department has formulated both short-term and long-term drainage proposals and carried out drainage improvement works to address the increasing flood risk. Meanwhile, DSD is conducting comprehensive condition survey of the existing drainage systems in phases for the timely identification of aging storm water drains and sewers with high risk of failure; and rehabilitation of those aging storm-water drains and sewers. In order to promote greening, enhance biodiversity, beautify the environment and meet the public demand for water friendly activities while achieving effective drainage performance, DSD commenced a consultancy study in December 2015 with a view to putting forward feasible proposals that apply the concept of revitalizing water bodies to nullahs. Furthermore, the HKSAR Government is actively exploring the feasibility of applying the concept of "floodable area" to improve the flood resilience of the city, alleviate the pressure on the conventional drainage systems and reduce the socio-economic losses.

Designated areas will be flooded in a controlled manner under extreme weather events so as to reduce the flood damages to the massive areas or areas with critical infrastructure.

WSD is progressively establishing the Water Intelligent Network (WIN) by setting up District Metering Areas (DMAs) in the fresh water supply distribution network, under which fresh water supply distribution network performance is monitored continuously in a holistic manner and network data is analyzed, with a view to determining the priorities and the most effective measures to tackle the water loss in individual DMAs (including (i) water pressure management; (ii) active leakage detection and control; (iii) quality and speedy repair of water mains burst and leaks; (iv) provisioning of water mains beyond economic repair). Under the WIN, the whole fresh water supply distribution network will be divided into more than 2 000 DMAs in Hong Kong. Up to end December 2018, WSD has established about 1 260 DMAs and anticipates that the remaining DMAs will be established by 2023.

Hong Kong Electric has been progressively phasing out overhead cables since 2012. Its transmission and distribution network mainly comprises cable tunnels and underground cables to guard against storms. The Hong Kong Electric Co., Ltd and CLP Power Hong Kong Limited have deployed advanced cable diagnostic techniques to identify and replace weak components and reduce the risk of power blackout.

3.2.5 Resilience

To reduce the impacts of severe weather such as tropical cyclones and rainstorms, the HKSAR Government has formulated long-standing and effective contingency plans, which include strengthening the research on forecasting extreme weather and related issues; establishing good communication system, including the weather warning and alert systems operated by HKO, and the early storm surge alert systems for low-lying areas prone to sea flooding jointly established by DSD, HKO and Home Affairs Department (HAD); formulating contingency plans for the financial regulators to ensure important financial infrastructure, the settlement system and the securities and futures trading markets will function in an orderly manner and minimize any impact on the financial industry arising from emergencies including extreme climate events; formulating solutions for the electricity systems to withstand extreme weather, including improving the structure of high-risk buildings and pylons, installing intelligent switch equipment, setting up flood forecasting and prevention mechanisms, as well as enhancing equipment specifications to withstand the higher operating temperature. The emergency procedures and manpower deployment plans are also formulated, complemented by regular drills, to get people well prepared for emergency incidents.

The Emergency Support Unit of the Security Bureau oversees the Contingency Plan for Natural Disasters, amongst others, to ensure the relevant plans are in coordination with each other. The Development Bureau has set up the Interdepartmental Task Force on Emergency Preparedness to enhance public awareness of potential natural hazards, and facilitate central monitoring and management of incidents. Under the HKSAR Government Emergency Response System, HAD coordinates the relief work at the district level through the Headquarters Emergency Coordination Centre of HAD and the District Emergency Coordination Centers of the 18 District Offices with the cooperation of other government departments. Meanwhile, various contingency plans are in place under different departments to cater for the climate change impacts.

Under the influence of extreme weather, multiple disasters may occur, which means incidents of flooding, fallen trees and landslides, etc. may happen concurrently. A "Common Operational Picture (COP)" is currently under development by CEDD to enhance the emergency information sharing and support for dealing with the concurrence of multiple hazards. COP is a platform based on the Geographic Information System (GIS) for sharing real-time emergency information by various departments. It will incorporate related information such as weather information and the latest status of temporary shelters to provide a comprehensive platform for emergency responses.

3.3 Measures to be taken to Adapt to Climate Change

To further enhance climate change adaptation, the HKSAR Government will further expand the scope of surveys and studies, strengthen its systems and mechanisms, and reinforce publicity and education.

The scope of surveys and studies will be expanded. In-depth studies on vulnerable areas and industries will be conducted to assess their potential risks and identify key measures to adapt to climate change, so as to prioritize various improvement measures;

The existing systems and mechanisms will be strengthened. The current systems and mechanisms will be improved, and the monitoring and auditing systems will be revised, so as to enhance the capability of institutions to adapt to climate change;

Publicity and education will be enhanced. The HKSAR Government will continue to distribute leaflets, broadcast Announcements in the Public Interest on television and radio, display posters and set up a new climate change website to raise public concern over climate change adaptation and publicize the Government's response measures. In addition, the Environment and Conservation Fund of the HKSAR Government will subsidize non-profit-making organizations to organize publicity and education activities on climate change adaptation. The HKSAR Government will also continue to organize a series of climate-related education and publicity activities in the form of thematic and roving exhibitions, public consultation meetings, seminars, talks, competitions, carnivals, charter schemes, and awards ceremonies, etc.

Chapter 4 Climate Change Mitigation Policies and Measures

Being an international city, Hong Kong has all along attached much importance to the issue of climate change. To echo with the Central Government, Hong Kong has spared no efforts in controlling the GHG emissions effectively through various policies and measures, including reforming energy structure, improving energy efficiency, developing low-carbon transport system, promoting green and low-carbon communities, and tree-planting.

4.1 Policies and Targets

The HKSAR Government has been continuing to implement various policies and measures to mitigate GHG emissions since 2010. A quantitative GHG emission reduction target was first set in Hong Kong's Climate Change Strategy and Action Agenda published in 2014 to reduce carbon intensity by 50% to 60% by 2020 as compared with the 2005 level. Hong Kong has made significant advances in controlling GHG emissions by adopting multi-faceted measures: in 2010 - 2016, Hong Kong's population growth was 4.4% and the real GDP growth was 2.9%, but the carbon dioxide emissions per unit GDP dropped around 29% and the GHG emissions per capita in 2016 maintained at around 5.7 tons of carbon dioxide equivalent (t CO_2 eq).

In 2016, through consulting various stakeholders and the public, the Steering Committee on Climate Change suggested to set Hong Kong's target for reducing carbon emissions by 2030: reduce carbon intensity by 65% to 70% using 2005 as the base, which is equivalent to an absolute carbon emission reduction of 26% to 36% and a reduction to 3.3 to 3.8 tones on a per capita basis from the 2005 level. In January 2017, the HKSAR Government announced "Hong Kong's Climate Action Plan 2030+"[1], setting out various major policies and measures to achieve the carbon emissions reduction target for 2030.

4.2 Energy Industry

Phasing down of coal-fired electricity generation. As electricity generation accounts for around 70% of Hong Kong's carbon emissions, the most effective vehicle for reducing carbon emission will come from changing its fuel mix. As the existing two power companies will install new gas-fired generating units to replace coal-fired generating units in the next few years, it is anticipated that Hong Kong will be able to substantially reduce its carbon intensity by 2020, with the carbon emission peaking before 2020 as a result. To further reduce carbon emission and achieve the carbon reduction target of 2030, Hong Kong will further reduce coal-fired electricity generation, i.e. phase down the majority of the coal-fired generation units and replace them by lower carbon energy sources by 2030.

Promotion of Renewable Energy (RE). In April 2017, the HKSAR Government entered into the post-2018 Scheme of Control Agreements with the two power companies. Promotion of renewable energy is one of the foci of the agreements. The relevant measures include the introduction of Feed-in Tariff (FiT) to encourage the private sector and the community to invest in distributed RE as the power generated can be sold at a rate higher than the normal electricity tariff rate to the power companies to cover the cost of their investments in the distributed RE systems and generation. At the same time, RE certificates will be sold by the power companies for electricity generated from RE sources such that buyers can show their support for RE. The revenue from the sale of RE certificates will be used to alleviate the overall tariff impact of the FiT scheme. The Government has also reached agreements with the two power companies which will facilitate grid connection of distributed RE systems. In addition, the Government will encourage

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[1] http://www.enb.gov.hk/sites/default/files/pdf/ClimateActionPlanEng.pdf.

the two power companies to develop RE.

4.3 Building Industry

Enhancing buildings energy efficiency. The Buildings Energy Efficiency Ordinance was implemented in 2012. It requires central building services installations in newly constructed buildings and buildings undergoing major renovation to meet the energy efficiency standards stipulated in the Code of Practice for Energy Efficiency of Building Services Installation. The aforementioned Code standards are reviewed once every three years to reflect the development of international standards and latest technological advancement. The second review completed in 2018 and the new standards, which is up to 18% higher than the 2012 standard, will take effect in 2019. With the new standards, there would be an estimated accumulative energy saving of 27 billion kilowatt hours (kWh) in all new and existing buildings in Hong Kong by 2028, equivalent to a reduction in carbon dioxide emissions of about 19000000 tones. The Ordinance also requires owners of commercial buildings to carry out energy audit for central building services installations in accordance with the Code of Practice for Building Energy Audit (hereinafter "EAC") once every 10 years. The EAC is also reviewed regularly. Taking the lead to set specific electricity reduction targets for government buildings, the HKSAR Government is now working towards the target of achieving 5% saving in the electricity consumption of government buildings in the five financial years from 2015-2016 to 2019-2020, under comparable operating conditions in 2013-2014. At present, the HKSAR Government has completed energy audits for about 340 major government buildings. To assist the relevant bureaus and departments to implement the energy saving measures identified in the energy audits, the Government has earmarked at least $900 million to take forward the relevant measures progressively. The HKSAR Government will also encourage the relevant bureaus and departments to strengthen energy saving efforts through appointing green managers and energy wardens, adopt better housekeeping measures and implement electricity saving projects. After implementation of these measures, government buildings have saved 4.9% of electricity consumption in the first three years.

Enhancing energy efficiency of electrical appliances. With the enactment of the Energy Efficiency (Labelling of Products) Ordinance in 2008, the HKSAR

Government has implemented the Mandatory Energy Efficiency Labelling Scheme (MEELS). New energy efficiency grading standards were introduced in October 2014 and were fully implemented in November 2015. The upgraded standards are estimated to bring about an annual electricity saving of 300 million kWh and an annual reduction of carbon dioxide emissions by about 210000 tones. Besides, the HKSAR Government also amended the subsidiary legislation of the Energy Efficiency (Labelling of Products) Ordinance to cover five additional types of products in the MEELS, namely televisions, electric storage water heaters, induction cookers, washing machines (with a washing capacity greater than 7 kg but less than 10 kg), and room air conditioners with both heating and cooling functions. The estimated annual electricity saving would be about 150 million kWh and an annual reduction of carbon dioxide emissions by about 105000 tones. The relevant work was completed in mid-2018. The HKSAR Government will continue to include more electrical appliances into the MEELS and tighten the energy efficiency grading standards in phases.

Conducting GHG emission audit on buildings. The HKSAR Government published the "Guidelines to Account for and Report on Greenhouse Gas Emissions and Removals for Buildings (Commercial, Residential or Institutional Purposes) in Hong Kong" (the Guidelines) in 2008. Users and managers of buildings may follow the Guidelines in assessing the carbon emissions of their buildings and drawing up emission reduction measures. The HKSAR Government is committed to promoting carbon audit and has taken the lead in conducting carbon audits on government buildings and public facilities. Starting from 2017-2018, bureaux and departments are required to conduct annual carbon audits on major government buildings with annual electricity consumption of more than 500 000 kWh and disclose their carbon audit findings. EPD has organised a number of carbon audit training workshops to provide further support to the departments in conducting carbon audits.

Improving efficiency in district development. To support low-carbon development in the Kai Tak Development, the HKSAR Government has established a district cooling system (DCS) for providing chilled water to buildings in the area for air-conditioning purposes. The system commenced operation in early 2013. The DCS consumes 35% and 20% less electricity as compared with traditional air-cooled air-conditioning systems and individual water-cooled air-conditioning systems using cooling towers respectively. With a higher energy efficiency, the DCS will achieve an estimated annual electricity saving of 85 million kilowatt-hour and an annual reduction of carbon dioxide emissions by 59,500 tones. The HKSAR Government plans to continue providing DCS in suitable new development or redevelopment areas to promote low-carbon development.

4.4 Transport

Expanding the railway network. Hong Kong's railway development has progressed rapidly over the past few years. The West Island Line, the Kwun Tong Line Extension, the South Island Line (East) and the Hong Kong section of the Guangzhou-Shenzhen-Hong Kong Express Rail Link were commissioned successively. The Shatin to Central Link project is being implemented steadily. After the Shatin to Central Link project has been completed, the total length of Hong Kong's railways will increase to more than 270km, bringing more than 70% of the local population into the railway catchment area. The rail share of local public transport will then increase to 43%. Having regard to transport demand, cost-effectiveness and the development needs of new development areas and other new development projects, as well as the potential housing supply that may be brought about by railway development, the Government will implement the new railway projects recommended in the Railway Development Strategy 2014 in a timely manner. The railway network is targeted to serve areas inhabited by about 75% of the local population and about 85% of job opportunities.

Promoting the wider use of electric vehicles. To promote the use of Electric Vehicles (EV), the HKSAR Government set up the Steering Committee on the Promotion of Electric Vehicles, chaired by the Financial Secretary with members drawn from various sectors, to give relevant policy suggestions, including the following key measures:

(a) Waiving the First Registration Tax for EV (until end of March 2017);

(b) Allowing enterprises that procured environmentally friendly vehicles, including EV, to have full profits tax deduction for the capital expenditure in the first year of procurement;

(c) Establishing a HK$300 million Pilot Green Transport Fund in March 2011 to encourage the public transport sector, goods vehicle operators and non-profit organizations to try out green, innovative and low-carbon transport technologies (including EV);

(d) Subsidizing 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 under local conditions;

(e) Granting concessions on gross floor area for car parks in new private buildings with EV charging-enabling infrastructure to encourage developers to put in place the necessary EV charging-enabling infrastructure, including provision of sufficient power supply, cabling and conduits for all parking spaces in the buildings concerned, to facilitate the installation of chargers to meet the needs in the future;

(f) Establishing a dedicated team and a hotline within the HKSAR Government to provide 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.

Taking forward other related measures. The HKSAR Government will continue to take appropriate measures to manage the private car fleet size, improve coordination of different modes of public transport to alleviate road traffic congestion and better match passenger demand. The HKSAR Government has also been promoting "Walk in Hong Kong" and fostering a pedestrian-friendly environment, and shall continue to 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 purpose.

4.5 Waste Management

Supporting waste reduction. The HKSAR Government has promoted source-separation of waste, and has provided waste separation facilities at source to facilitate residents to practise source-separation. The Government has also advocated waste reduction, recovery and recycling. In 2016, 34% of municipal solid waste generated in Hong Kong was recovered.

Promoting waste-to-energy. All operating strategic landfills in Hong Kong utilize landfill gas to generate electricity for use by their own infrastructural facilities and heat for use by their leachate treatment plants. Methane gas generated in the four large-scale secondary sewage treatment plants in Hong Kong is used for electricity and heat generation for use by the plant facilities, the sludge will be sent to the sludge incineration facility for treatment and turned into energy. There is also an organic resource recycling center in Hong Kong that converts food waste into biogas by anaerobic digestion technology.

Enhancing recycling of waste. ENB and EPD commissioned a consultancy study on planning of future environmental infrastructure facilities for waste treatment and transfer in Hong Kong in September 2015. The study will identify and determine additional waste treatment facilities and technologies to be required up to 2041 to meet Hong Kong's future waste management needs. The chosen facilities should meet the following four criteria:

(a) Maximizing resources recovery from waste;

(b) Optimizing synergy of waste management technologies and land use;

(c) Minimizing disposal of untreated or unsorted solid waste at landfills; and

(d) Minimizing the need of vehicular traffic for transportation of waste.

4.6 Tree-planting and Urban Greening

From 2010 - 2017, about 54 million trees and shrubs were planted in Hong Kong and about 6 million of them were trees. The HKSAR Government adopts a comprehensive and sustainable approach in implementing landscape and tree management initiatives, including the formulation and implementation of Greening Master Plans having regard to district characteristics and species suitability according to the principle of "Right Tree, Right Place", as well as the introduction of green infrastructure measures such as the use of vertical landscape, rooftop landscape, permeable paving materials and rainwater harvesting, etc. By early 2017, Hong Kong has designated a total of 24 country parks and 22 special areas, and the total area was as large as 443 square kilometers, representing around 40% of the land in Hong Kong. Such protected land, apart from beneficial to the rich biodiversity in Hong Kong, can further enhance Hong Kong's carbon dioxide removal capacity.

4.7 Measurement, Reporting and Verification of Mitigation Actions

Regarding Hong Kong's mitigation actions, the Secretariat of the Interdepartmental Working Group on Climate Change has consolidated and recorded the progress of mitigation actions taken by bureaus and relevant departments. The HKSAR Government organized a seminar in the first quarter of 2016 to enhance the understanding of bureaus and relevant departments on the measurement, reporting and verification of mitigation actions.

To facilitate the development of GHG certification and verification, Hong Kong introduced the accreditation service for GHG certification/verification providers in December 2012. Accredited organizations are permitted to verify GHG emission reports in accordance with ISO14064 certification standard.

The HKSAR Government has worked with the Hong Kong Exchanges and Clearing Limited to introduce and promote the website on Carbon Footprint Repository for Listed Companies in Hong Kong that was launched by the Government in December 2014. As in 2018, more than 80 listed companies participated in this carbon disclosure initiative by disclosing their carbon management information on the website.

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, publicity and capacity building on climate change; encouraging public engagement; enhancing public awareness on climate change; and developing co-operations and exchanges with counterparts in the country and abroad.

5.1 Monitoring of and Research on Weather Systems

HKO undertakes to monitor and conduct research on climate change in Hong Kong. The main services of HKO include issuing weather forecasts and warnings, providing real-time weather information, tropical cyclone information, weather maps, radar and satellite imageries, etc. In addition, HKO also conducts research on climate change, analyses the impacts of weather and climate on society, and forecasts annual rainfall and yearly number of tropical cyclones affecting Hong Kong. It has updated the projections of Hong Kong's annual temperature, rainfall and extreme weather events by making use of the latest IPCC global climate model data. HKO completed a Hong Kong-specific climate projection study on extremely warm-and-humid days in the 21st century. The annual number of extremely warm-and-humid days and the annual maximum number of consecutive extremely warm-and-humid days in Hong Kong are expected to increase in the 21st century.

5.2 Education, Publicity and Public Awareness

HKO enhances public awareness on climate change through various channels, including school talks, open days, social media, thematic webpages on climate topics, short online video, etc. It also collaborates with the Radio Television Hong Kong to produce and broadcast a radio programme named "Climate Watcher" in order to motivate citizens to take proactive action to face the challenges brought about by climate change. It also publishes the latest global developments and research findings on climate change. In 2016, HKO published the second edition of the "Hong Kong in a Warming World" pamphlet on climate change and updated the climate projections for Hong Kong and worked with relevant government departments and other organizations to organize the "Climate Change· Our Response" Roving Exhibition.

To raise public awareness of the importance of combating climate change, and to highlight the key measures that the HKSAR Government will introduce to combat climate change, ENB released a leaflet, an Announcement in the Public Interest, short videos, a poster and a new climate change website[1] in January 2017. In addition, the Environment and Conservation Fund Committee has set aside $10 million in February 2017 for subsidizing non-profit-making organizations to launch public education activities and projects with the theme of climate change.

The Education Bureau (EDB) launched an Inter-school Cross-curricular Project Competition on Climate Change between October 2016 and May 2017. As a follow-up event to the Competition and to enhance teachers' and students' awareness of climate change, EDB is planning to invite local and overseas experts, government departments, green groups and local schools to organize a series of seminars, workshops, visits and field studies on climate change. EDB is also planning to provide climate change learning and teaching resources for Hong Kong schools. Moreover, EDB issued a circular on "Environmental Policy and Energy Saving Measures in Schools" to all schools in April 2017 to remind schools of the importance of formulating a school-based environmental policy and implementing measures for energy saving, and provide updates on the related information and resources.

In 2015, ENB and EMSD launched the Energy Saving for All Campaign to promote energy saving for combating climate change. In 2016, activities including Energy

[1] https://www.climateready.gov.hk.

Saving Charter and Energy Saving Championship Scheme continued to be implemented. To commemorate the World Environment Day, the Environmental Campaign Committee set up by the HKSAR Government launched its first ever outdoor Zero Carbon Fun Fair in June 2017. The event, with the theme "Climate Ready and Low Carbon Living", was a conglomerate of local communal activities related to low carbon and about 40 non-government organizations, green groups, public utilities and schools jointly promoted low carbon awareness among the public.

5.3 Strengthening Regional Co-operation

Effort has been made to conduct researches on regional strategies for developing clean energy and renewable energy and promoting their development and application; support energy saving and emission reduction at enterprises; enhance exchanges on scientific researches related to combating climate change, development and application of technologies, education and fundamental capacity building, etc.

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 combat climate change. The Hong Kong-Guangdong Joint Liaison Group on Combating Climate Change, co-chaired by the Secretary for the Environment of the HKSAR Government and the Director General of the Guangdong Development and Reform Commission, was set up in 2011 to negotiate and co-ordinate issues on combating climate change, promote active collaboration and exchanges on relevant scientific research, technological development and application, publicity as well as education etc. for controlling GHG emissions of both sides.

5.4 Finance, Technology and Capacity-Building Needs

5.4.1 Needs for Funding

Major needs for funding include those for compilation of GHG inventories, organization of seminars and workshops on capacity building, implementation of mitigation and adaptation measures, and participation in international conferences and training, etc.

5.4.2 Needs for Technologies

Major needs for technologies for mitigating climate change include those on energy saving products in buildings , new wall materials, hybrid and electric vehicles (including large buses), high efficiency fast recharging facilities for electric vehicles, high efficiency batteries and materials, renewable energy (in particular building-integrated photovoltaics (BIPV) system), waste-to-energy, etc.

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

5.4.3 Capacity Building

Major requirements of capacity building include strengthening the team and capacity building for enhancing information exchange and compiling the GHG emissions inventory; 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.

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 mild climate, limited natural resources, high population density and well-developed gaming 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 in the west side of the estuary of the Pearl River Delta on the South China coast, bordering the Zhuhai City of the Guangdong Province in the north, overlooking the Hong Kong SAR which is located in the east side of the Pearl River's estuary, facing the South China Sea to the south, being separated by seawater from the adjacent Wanzai and the Hengqin islands of the Zhuhai City to the west. With its three sides being engulfed by sea, Macao mainly consists of 4 components: Macao Peninsula, Taipa and Coloane islands as well as Cotai land area reclaimed from sea.

Under the subtropical marine climate, Macao is significantly influenced by monsoon. Macao has a mild climate. According to climate materials of 1981 to 2010, the annual mean temperature of Macao is 22.6°C. January is the coldest month with the monthly mean temperature of 15.1°C; and July is the warmest month with the monthly mean temperature of 28.6°C. Its annual average precipitation is 2,058.1 mm with significant seasonal differences. Macao's rainy 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 include subtropical cyclones and associated storm surges, strong monsoons, rainstorms and thunderstorms. About 5 to 6 subtropical cyclones impact Macao on annual average, among which 1 to 2 may bring high 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 2016, its total land area was 30.5 km^2, an increase by 0.7% relative to 2014. In 2009, the central government approved a proposal a 361.65 ha land reclamation project for construction of a new urban zone. On July 20, 2013, the new campus of the University of Macau (UM) on Hengqin Island was handed over to Macao government. The campus has a terrestrial area of about 1.4 square kilometers.

The local water storage facilities in Macao are insufficient, and over 96% of its drinking water needs to be introduced from Guangdong Province. In 2016, Macao's total water consumption was up to 86.7 million m^3, of which the business sector and industries accounted for 51%, followed by the household water consumption accounting for 43%, and the remaining 6% were consumed by governmental and other facilities.

1.2 Population and Society

Macao is among the most densely populated regions in the world. In 2016, Macao's total population was 645 thousand, increasing by 1.4% compared to 2014, and its density was approximately 21 thousand persons per square kilometer. The estimated total labour force in Macao was about 397 thousand, of which 390 thousand were employed population. The employed population in the primary industry accounted for only 0.1% of the total labor force, and that in the secondary and tertiary industries accounted for 13.7% and 86.2% respectively.

Based on the educational statistics for 2016-2017 by Education and Youth Affairs Bureau, the total number of schools in Macao was 74, with 74.4 thousand students receiving regular education. There were also 10 tertiary education schools with about 33,000 students, of whom the resident ones accounted for 54.7%, and the non-resident for 45.3%.

In 2016, there were 1,726 doctors, 2,342 nurses and 1,591 hospital beds in Macao. The spending on hospitals totaled 7.0 billion Patacas in 2016, accounting for 10.3% of the total expenditure of the SAR government, which was equivalent to 1.9% of Macao's GDP.

1.3 Economic Development

With rapid economic development, in 2016 the GDP (based on current price, the same below) was about 362.3 billion Patacas, and the per capita GDP was 561 thousand Patacas. The GDP has continued to grow for a decade with an average annual growth rate of 5.5%. In Macao's GDP, the contribution from the primary industry was barely null, but that from the secondary and tertiary industries accounted for 6.6% and 93.2% respectively. The gaming industry, a pillar of Macao's economy, accounted for 47.2%; in addition, real estate, banking, wholesaling/retailing and construction were also very important industries in Macao, accounting for 10.6%, 5.5%, 5.3% and 5.3% respectively. Tourism played an important role in the economic development. In 2016, the number of visitors to Macao was 30.95 million, most of whom were from China's mainland, accounting for 66.1% of the total.

In 2016, Macao's total energy consumption was 0.819 Mtce, of which light diesel accounted for 31.2%, and heavy oils, kerosene, gasoline, petroleum gas and natural gas accounted for 25.7%, 19.5%, 13.7%, 8.3% and 1.6% respectively of the total energy consumption. From the perspective of industries and sectors, energy transformation accounted for 26.1%, road transportation accounted for 23.5%, air transportation accounted for 19.1%, waterway transportation accounted for 12.7%, commercial, catering and hotel sector accounted for 9.7%, industry and construction accounted for 5.8%, residents life accounted for 2.8% and others accounted for 0.3%.

Macao's power consumption is dominated by electricity import from the Guangdong Province, which is supplemented by local power generation by heavy oils and natural gas. Since 2007, the local power generation has been continuously decreased with increasing electricity import. In 2016, Macao's total electricity import was 4.31 billion kWh, while the local power generation was only 990 million kWh.

The transportation system in Macao consists of 3 components: land roads, waterway and aviation. In 2016, the total road length in Macao was 427 km, with 250 thousand vehicles and 140 thousand passenger ferry trips. The commercial flights by destinations to and from the Macao International Airport totaled 27 thousand.

The basic information of Macao in 2016 is shown in Table 8-1.

Table 8-1 Basic Information of the Macao in 2016

Indicators	2016
Population (in 10,000 at year end)	64.5
Land area (km^2)	30.5
GDP (in 100 million US$ by expenditure approach, 1 US$ = 7.9948 Patacas)	453.1
Per capita GDP (in US dollars by expenditure approach)	70,160
Proportion of industrial value added among GDP (by production approach) (%)①	6.6
Proportion of service value added among GDP (by production approach) (%)	93.2
Proportion of agricultural value added among GDP (by production approach) (%)	0
Farmland area (km^2)	0
Percentage share of urban population in total (%)	100
Cattle (head)	5
Horse (head)	446
Pig (head)	3
Sheep (head)	8
Forest area (km^2)②	5.34
Poverty population (in 10,000 persons)③	1.6
Life expectancy at birth (year)	80.2 (Male); 86.4 (Female)
Literacy rate (%) ④	96.5

Note: 1. The industrial sectors here include mining, manufacturing, water, electricity and gas production and supply, as well as construction that belong to the secondary industry;

2. The data is based on the results of Macao SAR green land general survey completed in 2017;

3. The data here refer to employed people with low income (an average monthly income of less than 4,000 Patacas);

4. The data are based on the literacy rate of population aged over 15 shown in the census of Macao in accordance with mid-2016 population by-census data.

1.4 Institutional Arrangements for Addressing Climate Change

The government of the Macao has always attached great importance to climate change issues. In order to effectively manage and coordinate the efforts in response to climate change, Macao has established an Inter-departmental Working Group on Climate Change (hereafter referred to as the Working Group), which is responsible for coordinating the arrangements relating to the implementation of the United Nations Framework Convention on Climate Change, including the development of “measurable, reportable and verifiable” mitigation actions, and for promoting the mitigation and adaptation efforts within the private sectors and the general public for mobilizing the public to involve in addressing climate change.

The Working Group, led by the Secretariat for Transport and Public Works, has organized a total of 14 governmental departments to address climate change in synergy, including Municipal Affairs Bureau (the former IACM), Economic Bureau, Statistics and Census Bureau (Statistics and Census Service), Health Bureau, Education and Youth Affairs Bureau, Tourist Office, Marine and Water Bureau, Housing Bureau, Environmental Protection Bureau, Civil Aviation Authority, Transport Bureau, Office for the Development of the Energy Sector, Transportation Infrastructure Office and Meteorological and Geophysical Bureau. Among them, Macao 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 2010

To prepare the Macao's GHG Inventory of 2010, the methodologies recommended by the *Revised 1996 IPCC Guidelines* and *IPCC GPG 2000* have been mainly used with some parameters and default emission factors from *2006 IPCC Guidelines*. According to the actual circumstances and the availability of related data, the reporting scope of Macao's GHG Inventory of 2010 mainly covers GHG emissions from energy and waste sectors. The estimated GHGs cover CO_2, CH_4 and N_2O.

2.1 Overview

Due to Macao's geographical characteristics, the only emissions in its administrative division are those from energy and waste sector. In 2010, Macao's total GHG emission was 1,193 kt CO_2 eq (Table 8-2 and 8-3), of which the emission from energy accounted for 98.3%, and the emission from waste 1.7% (See Figure 8-1). In 2010, the total emissions of CO_2, CH_4 and N_2O were 1,159 kt, 4 kt CO_2 eq and 30 kt CO_2 eq, accounting for 97.2%, 0.3% and 2.5% of the total GHG emission respectively (See Figure 8-2).

Table 8-2 2010 Macao's Total GHG Emissions (10,000 metric tons of CO_2 eq)

	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Total
Energy	115.6	0.4	1.3				117.3
Industrial processes	NO	NO	NO	NE	NO	NO	NE/NO
Agriculture		NO	NO				NO
Waste	0.3	0.0	1.7				2.0
LUCF	NE	NO	NE				NE/NO
Total (excl. LUCF)	115.9	0.4	3.0	NE	NO	NO	119.3
Total (incl. LUCF)	115.9	0.4	3.0	NE	NO	NO	119.3

Note: 1. Due to rounding, the aggregation of various items may have slight difference with the total;

2. NO (Not Occurring) for activities or processes that do not occur for a particular gas or source/sink category within Macao. NE (Not Estimated) for existing emissions and removals which have not been estimated.

Table 8-3 Macao's CO_2, CH_4 and N_2O Emissions in 2010 (100 tons)

Source/Sink categories	CO_2	CH_4	N_2O
Total (excl. LUCF)	11,593.4	1.7	0.9
1. Energy	11,561.6	1.7	0.4
—Fuel combustion	11,561.6	1.7	0.4
♦Energy industries	6,103.4	0.3	0.0
♦Manufacturing industries and construction	725.8	0.0	0.0
♦Transport	2,830.5	1.1	0.3
♦Other sectors	1,902.0	0.3	0.0
—Fugitive emission from fuels		NE	
2. Industrial processes	NO	NO	NO
3. Agriculture		NO	NO
4. Land-use change and forestry	NE	NO	NE
5. Waste	31.8	0.0	0.5
—Solid waste disposal on land	31.8	NO	0.0
—Wastewater handling		0.0	0.5
Memo items			
—Special regional aviation	2,609.7	0.0	0.1
—Special regional waterborne-navigation	1,849.3	0.0	0.0
—International aviation	1,832.0	0.0	0.1
—International waterborne-navigation	NO	NO	NO

Source/Sink categories	CO_2	CH_4	N_2O
—Biomass burning	557.4		

Note: 1. Due to rounding, the aggregation of various items may have slight difference with the total;

2. NO (Not Occurring) for activities or processes that do not occur for a particular gas or source/sink category within Macao. NE (Not Estimated) for existing emissions and removals which 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 totals;

4. Fugitive emissions from fuels and LUCF cannot be estimated due to the in-progress statistics system;

5. Memo Items are not counted in the total emissions. CO_2 emissions from biomass combustion only include those from biogenic waste incineration;

6. Special regional waterborne-navigation and aviation refer to shipping and airplanes between Macao and mainland China (including Hong Kong and Taiwan).

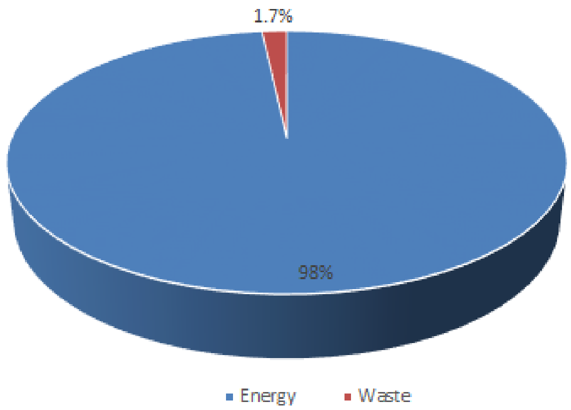

Figure 8-1 GHG Emissions by Sector in Macao in 2010

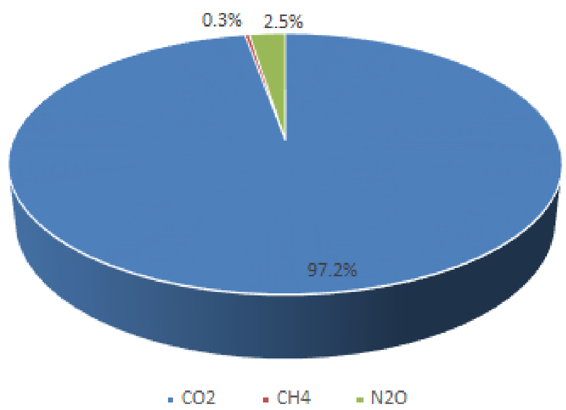

Figure 8-2 GHG Emissions by Sector in Macao in 2010

In 2010 the total emission from international aviation and special regional aviation in Macao was 449 kt CO_2 eq, and that from special regional waterborne-navigation was 185 kt CO_2 eq. The emissions from the above sources, which are separately provided as Memo items. Besides, CO_2 emissions from the biomass burning of urban waste were about 56 kt are also listed in the Memo items. The total GHG emissions from above activities were about 690 kt CO_2 eq which were not counted into the total emissions of Macao.

2.2 Energy

2.2.1 Scope

For energy activities, the reporting scope of the Macao's GHG Inventory of 2012 mainly covers the CO_2, CH_4 and N_2O emissions from fossil fuel combustion in energy industries, manufacturing industries and construction, road transport and other sectors. Considering the fact that incineration is the major approach for waste handling, and the power generation from waste incineration delivers to Macao's power grid, therefore the GHG emissions from fossil components (like cloth and plastic) combustion are counted into energy activities, while CO_2 emissions from biomass combustion of urban waste are not counted into the total emissions but only listed as a Memo item.

2.2.2 Methodologies

For the GHG inventory for energy activities, Tier 1 method recommended in the *Revised 1996 IPCC Guidelines* has been applied for CO_2, CH_4 and N_2O emissions caused by fossil fuel combustion from energy industries, manufacturing industries and construction, other sectors as well as special regional marine, while for those from the road transport, international and special regional aviation, the Tier 2 method recommended in the *Revised 1996 IPCC Guidelines* was used.

The activity data were the statistical and sectoral data that have been publicized in Macao. Both sector and fuel categories are basically the same as those given in the *Revised 1996 IPCC Guidelines*.

The emission factors were mainly from the *Revised 1996 IPCC Guidelines*, while for those unavailable, the default values were taken from *2006 IPCC Guidelines*.

2.2.3 GHG Emission

Macao's GHG emissions from energy sector in 2010 were about 1,173 kt CO_2 eq (1,156 kt for CO_2, 4 kt for CH_4 and 13 kt for N_2O), accounting for 98.3% of its total emissions. CO_2 emissions from energy sector accounted for 99.7% of the total CO_2 emissions of Macao.

In 2010, among Macao's total GHG emission from energy sector, 612 kt CO_2 eq was from the energy transformation, accounting for 52.2%; 296 kt CO_2 eq from road transport, for 25.2%; 192 kt CO_2 eq from other industries (including the commercial business, restaurants, hotels and residential), for 16.4%; and 73 kt CO_2 eq from manufacturing and construction, accounting for 6.2%.

2.3 Waste

2.3.1 Scope

The reporting scope of Macao's GHG inventory for waste sector mainly covers CH_4 and N_2O emissions from urban sewage treatment, and CO_2 and N_2O emissions from solid waste disposal. The Inventory only reports CH_4 emissions from industrial sewage treatment as Macao's urban sewage is treated with aerobe.

2.3.2 Methodologies

Methodologies given in the *Revised 1996 IPCC Guidelines* have been used.

Activity data of N_2O emissions from wastewater handling were based on the total population provided by the Statistics and Census Bureau (DSEC) and Macao's per capita annual protein consumption in 2010 from the Food and Agriculture Organization of the United Nations, and N_2O emission factors are based on IPCC default values; CO_2 and N_2O emissions from solid waste disposal were estimated using the activity data provided by DSEC and IPCC recommended default emission factors.

2.3.3 GHG Emission

In 2010, Macao's total GHG emission from waste disposal was 20 kt CO_2 eq, accounting for 1.7% of the total emission of Macao, of which emissions from wastewater handling and waste incineration were 16 kt CO_2 eq and 4 kt CO_2 eq, accounting for 80.0% and 20.0% of the total respectively.

2.4 Quality Assurance and Quality Control

2.4.1 Efforts to Reduce Uncertainties

To reduce uncertainties of the inventory, from methodological perspective, methodologies from *Revised 1996 IPCC Guidelines* and *IPCC GPG 2000 Guidelines* have been used while taking into account the approaches from *2006 IPCC Guidelines* to ensure that the methodologies were scientific, comparable and consistent. The institutions engaged in the preparation of the inventory in Macao have selected the higher-tier methods as many as condition allows. For instance, Tier 2 method has been used for road transport, international aviation and special regional aviation. As for activity data, the institutions have used the data verified by Macao SAR governmental departments such as Statistics and Census Bureau, Civil Aviation Authority, Environmental Protection Bureau, Transport Bureau and other governmental departments as much as possible to ensure the authority of the activity data. The national inventory team was invited to review the Macao GHG Inventory during the preparation process as independent third party expert.

2.4.2 Uncertainty Analysis

Although the great efforts have been made in reporting scope, methodology and quality by the Macao Inventory team in the preparation of its 2010 GHG Inventory, some uncertainties still exist.

Tier 1 method from *IPCC GPG 2000* has been used to calculate uncertainties, taking into account the emission factor uncertainty approach in *Revised 1996 IPCC Guidelines* and *2006 IPCC Guidelines*. The overall uncertainty of Macao's GHG emissions in 2010 was about 3.4%, and 3.4% and 17.8% for energy and waste sectors respectively. See Table 8-4.

Table 8-4 Results of Uncertainty Analysis of Macao Greenhouse Gas Inventory of 2010

	Emissions (10,000t CO_2 eq)	Uncertainty (%)
Energy	117.3	3.4
Waste	2.0	17.8
Total uncertainty		3.4

2.5 Inventory for Previous Submission Years

In the Second National Communication, Macao reported its 2005 GHG inventory. The total GHG emission of Macao was 1,803 kt CO_2 eq. Macao's total GHG emissions in 2010 reduced by 33.8% (about 610 kt CO_2 eq) over 2005. The main reason was that the increase of imported electric power reduced the emission from energy sector.

The Macao's 2010 and 2005 Inventories were the same in methodologies and GHG categories, What's different is that, the CO_2 emissions from biomass burning among urban wastes were included under the Memo items.

2.6 GHG Emissions Change Trends of Macao

2.6.1 Analysis Method and Scenario Assumptions

To analyze the future change trends of CO_2 emissions from energy sector in Macao, in this report we have adopted the scenario analysis method and developed three scenarios, those are, baseline scenario, policy scenario and enhanced low carbon scenario, all of which are based on the assumption that future economic development maintains at an annual growth of around 5.67%. And emissions from imported electricity are included in the calculation of the three scenarios.

In the baseline scenario, according to the change trends of the energy structure of Macao and its socio-economic development trends after returning to China, without making more changes, we have analyzed Macao's future energy demands based on its existing trends.

In the policy scenario, on the basis of the baseline scenario, we have added recent existing relevant plans such as increasing the proportion of natural-gas-fueled buses in the public transportation priority policy issued in 2010, the Hong Kong-Zhuhai-Macao Bridge opened on October 2018, the light rail to be completed in 2019, and policy impacts that are currently not written in relevant plans but can be easily realized recently, such as encouraging households and large public buildings to change to energy-saving lighting devices.

In the enhanced low carbon scenario, on the basis of the policy scenario, we have enhanced some existing energy conservation policies, advance efforts of energy conservation and added some relevant policy impacts that currently do not exist, such as vigorously promoting the use of electric vehicle, replacing the lighting system and air conditioning and cooling system in large hotels on a large scale.

2.6.2 Analysis of Simulation Results

Under the baseline scenario, Macao's demands for primary energy including imported electricity rise from 1.5 Mtce in 2010 to 3.8 Mtce in 2030, and the energy consumption per unit of GDP decreases by 33% from 2010. Under the policy scenario, Macao's demands for primary energy drop to 3.08 Mtce in 2030, and the energy consumption per unit of GDP decreases by 46% from 2010. Under the enhanced low carbon scenario, Macao's demands for primary energy is further controlled at 2.41 Mtce in 2030, and the energy consumption per unit of GDP decreases by 63% from 2010.

Under the baseline scenario and the policy scenario, the CO_2 emissions from energy sector including imported electricity in Macao will peak in 2029. Under the enhanced low carbon scenario, the CO_2 emissions will peak in 2019. In 2030, the CO_2 emissions from energy sector in Macao will reach 6.46 Mt under the baseline scenario, and will reduce to 5.26 Mt under the policy scenario and to 3.77 Mt under the enhanced low carbon scenario, down 19% and 42% respectively from that under the baseline scenario, while the proportions of CO_2 emissions from imported electricity in total CO_2 emissions under the three scenarios are 73%, 70% and 58% respectively. In 2030, the CO_2 emissions per unit of GDP of Macao under the baseline scenario, the policy scenario and the enhanced low carbon scenario will decrease by 51%, 60% and 71% from 2010 respectively.

Chapter 3 Climate Change Impact and Adaptation

Macao has organized relevant department and relevant research unit to monitor and assess the impacts of climate change on water resources, terrestrial ecosystem, etc., making preparations for the development of mitigation and adaptation policies on climate change. Moreover, by making use of Macao's historical climatological observation data and global climate model simulation data, Macao has organized research on assessment and prediction of 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 2016, and has predicted future climate change in Macao with the multi-model ensemble assessment method using the GHG emission scenarios and global climate model simulation data adopted in the IPCC 5th 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 2016, the characteristics of climate change in Macao are as follows:

The temperature changes in Macao in the past 116 years are basically consistent with global average temperature changes. The linear warming trend in 100 years is 0.76°C, and the warming rate after the 1970s increased. Of the 10 warmest years in the 116 years, 5 are in the 21st century. The temperatures in different seasons in Macao all increased, of which spring saw the biggest rise, which is about 0.095°C per 10 years, followed by winter (about 0.081°C per 10 years) and autumn (about 0.077°C per 10 years), while summer had the smallest rise of about 0.055°C per 10 years. Both the daily maximum temperature and the daily minimum temperature in Macao showed a rising trend, and the former showed clear interannual variations.

The precipitation in Macao showed clear interannual variations. In the 20th century, the whole was on the rise. Precipitation increment in every 10 years was about 41.9mm. The 1970s saw the maximum precipitation, and summer saw the most significant precipitation increase, while other seasons didn't see clear changes. According to the definitions of the Expert Team on Climate Change Detection and Indices (ETCCDMI), Macao Meteorological and Geophysical Bureau has calculated climate change indices (see Table 8-5). The overall changes have reflected the warming trend. Meanwhile, precipitation intensity and maximum continuous precipitation of 5 days also showed a clear rising trend.

There were clear interannual variations in the hot days with a daily maximum temperature of 33 °C, but there's no significant increase in the number of hot days. Regarding the cold nights (with a minimum temperature of 12 °C or below) and hot nights (with a minimum temperature of 27°C or above), there was a significant and continuous change trend. Cold nights decreased by about 1.2 days per 10 years, while hot nights increased by about 1.8 days per 10 years. Moreover, the frequencies of heavy rain (over 50mm per day) and rainstorm (over 100mm per day) also increased. The linear trends of the two in 100 years were 3.3 days and 1.7 days, respectively.

Table 8-5 Index Table about Macao Climate Change (Based on Information between 1901 and 2016)

Index	Concept	Change per ten years
ID12	Cold day	-0.076 days
CD12	Cold night	-1.20 nights
SU33	Hot day	0.32 days
TR27	Hot night	1.8 nights
TXx	Annual maximum temperature	0.049°C
TNx	The highest record of the lowest daytime temperature for a whole year	0.047°C
TXn	The lowest record of the highest daytime temperature for a whole year	0.036°C
TNn	Annual temperature Min.	0.061°C
SDII	Daily average precipitation intensity	0.48 mm/day
Rx5day	Maximum consecutive 5-day precipitation	9.40 mm

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 average temperature in Macao will continue to rise. Research shows that under all scenarios, by the middle of the century (2050-2059), the temperature will rise 1.4°C to 2.2°C compared to the average temperature in 1956-2005; by the end of the century (2090-2099), the temperature will rise 1.4°C to 3.9°C (Table 8-6); and by the end of the century, the temperatures in all seasons will also rise (Table 8-7).

Table 8-6 Multi-model Evaluation of Future Climate Change of Macao (Compared with the Period between 1956-2005)

Greenhouse gas emission scenario	Temperature （°C）	
	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 Climate Change in Different Seasons of Macao (Compared with the Period between 1956-2005)

Greenhouse gas emission scenario	Temperature (°C) (2090-2099)			
	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

Research results also indicate that the precipitation intensity in rainy season in Macao will also increase by the middle and end of the century, with the highest rise of 14%.

3.3 Main Vulnerable Areas of Macao

3.3.1 Water Resources

Over 96% of the water supply in Macao is 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 analysis of the runoff observation results of the main rivers in mainland China in the past 40 years, even though the decline in the runoff of the Pearl River is very small, due to the rapid economic development of Macao, in the 20 years from 1998 to 2017, its water consumption had increased to more than 1.6 times; in addition to the sea level rise of the South China Sea, in recent years, every time when there was a spring tide during the winter dry season, seawater intrusion into the Pearl River basin had directly threatened the water supply safety of a number of metropolitans including Macao.

Even though it's predicted that the runoff of the Pearl River basin may increase by 5%-10% in the middle and later periods of the century, it's still difficult to meet the increasing demands for water resources as a result of rapid urbanization and population growth in the Pearl River Delta. In addition, precipitation in South China is likely to concentrate in summer and autumn in future and precipitation in winter and spring will continue to decrease. Under the general background of global warming and sea level rise, the possibility of occurrence of salt tides during winter and spring dry seasons will increase in future. It is thus especially important to properly store and utilize the precipitation in summer and autumn with frequent rainfall.

3.3.2 Land Ecosystem

According to observation, in the past several decades, the subtropical liana in the forest vegetation in Macao has grown faster. In addition to the increase in alien invasive plants, they have affected the stand structure and the normal growth of other plants. In the meantime, individual cases of plant diseases and insect pests in forest are on the rise. Through preliminary assessment, it's believed that it may have something to do with CO_2 concentration increase and temperature rise. However, it's 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, besides establishing special natural conservation areas, the Macao, together with domestic scientific research institutes, has continuously conducted basic survey of animals and periodical monitoring and research of plants and animals sensitive to meteorological conditions since 2011, so as to establish more comprehensive data to make preparations for assessment of future climate change.

3.3.3 Sea Level Change and Coastal Zone Ecosystem

According to the analysis of the tide station data in Macao from 1925 to 2017, the sea level in Macao rose at a rate of 1.6 mm per year, and the rise rate had increased in the past 20 years, which was about 2.4 mm per year. Macao is a coastal city. The west coast of the Macao Peninsula, the lowest in terrain, is the area affected the most by sea level rise. Every time when a relatively subtropical cyclone approaches or lands the coast along the Pearl River Estuary, it can cause a storm surge. If there is an astronomical tide, it can cause serious inwelling and large-area flooding. In the past 100 years, Macao was seriously affected by 14 storm surges, of which 6 occurred in the past 20 years. It is projected that the degree and frequency of being affected by inwelling and flooding in Macao will increase, so will the probability of being affected by strong storm surges.

3.4 Adaptation Measures Already Adopted

Macao actively deals with the impacts brought by climate change and is organizing forces from all sectors to develop adaptation measures. However, relevant research is still in the early stage and there is no complete strategy. Some of the measures and actions that Macao has adopted to adapt to climate change in recent years have shown certain effect.

3.4.1 Water Resources

To stabilize water resource supply and reduce salt tides in Macao, water resource adaptation measures are mainly to strengthen water resource management and build a water-saving society. The measures and actions that Macao has adopted: 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 future; in 2009, Macao allocated 800 million yuan to support the resettlement of inhabitants, water and soil conservation and environmental governance of the Guangxi Dateng Valley Water Control Project; in 2009 Macao trusted a research unit to complete Overall Water-saving Plan Research Report of Macao; in 2010, Macao prepared Outline of Water-saving Plan of Macao, determining the development direction of Macao's water-saving work in the next 15 years; through prepayment of increasing water rates, Macao provided an interest-free loan of 450 million yuan to the Zhuyin Water Resource Project in Guangdong, and Macao received about 16 million m^3 or 40% of the total operating water volume after the Zhuyin Reservoir was completed in 2011; in 2015, Macao completed the Macao Dashuitang Water Plant Project, increasing Macao's daily water supply capacity from 330 thousand m^3 to 390 thousand m^3; in 2016, Macao began the construction of the fourth Zhuhai-to-Macao Raw Water Pipeline to increase water supply system efficiency; in 2018 Macao began the construction of ColoaneShek Pai Wan Water Purification Plant to develop reclaimed water and make it the second water source of Macao.

3.4.2 Land Ecosystem

In 2001 the Macao SAR built the first ecological reserve on the wetland in the west of the Cotai Reclamation Zone, with a total area of about 55 ha, protecting over 100 species of plant and animal. Moreover, Macao strictly restricts tree cutting.

3.4.3 Sea Level and Coastal Zone

Macao government has taken various measures to reduce the damage caused by flooding due to storm surges and astronomical tides to economic development and urban operation. Specifically, in 2018 the flood-proof standard for electric power facilities in buildings is about to be completed, which specifies that newly built electric power facilities such as transformer rooms, line distribution boxes and ammeters should be installed above the "flood-proof elevation"; in 2017 Macao studied the building of a tide gate on the Wan Chai Waterway to reduce flooding in low-lying areas caused by storm surges and astronomical tides; in 2018 Macao optimized the storm surge warning system and improved the prevention and coping capacity of governmental departments and citizens. Moreover, Macao has conducted periodical monitoring and protection of mangrove forest, and has collected the fruits and plumular axis of mangrove plants native to Macao by phases so as to transplant them to appropriate places at appropriate time to ensure diversity of species of the mud flat ecosystem.

3.5 Adaptation Measures to be Adopted in Future

Macao needs to expand and strengthen continuous monitoring and data collection work relating to climate change so as to establish a complete database to provide sufficient, credible data sources for preparation of relevant reports, research programs and policies in future. In the meantime, with respect to the vulnerable areas, Macao should put forward scientific climate change adaptation strategies, and assess them periodically and make proper adjustment and improvement. Macao should also strengthen existing natural disaster warning and emergency response mechanisms to cope with possible aggravated extreme and severe weather events caused by climate change, shortage of water resources and other issues; include climate change impact and adaptation measures in economic and social development plans and improve the city's overall capacity to address climate change.

Chapter 4 Policies and Actions for Climate Change Mitigation

Macao has always attached great importance to climate change mitigation, and has been dedicated to building a low-carbon economy and society by taking policies and measures on energy mix optimization, energy conservation, energy efficiency improvement, as well as urban landscaping and preference to public transport.

4.1 Policies and Targets for GHG Emission Control

In 2010, in its administrative report, Macao proposed a concept of 'building a low-carbon Macao, creating green living together' to ensure its sustainable development, to actively support and cooperate with national policies and actions in addressing climate change, to develop low-carbon products and technologies, to promote the development of green and low-carbon industries, and to accelerate transition toward a low-emission and low-consumption economic development model. Macao prepared *Macao Five-Year Development Plan (2016-2020)* in 2016, making it clear to actively support national green development strategy and vigorously promote a civilized and healthy mode of life that pursues green, low carbon and emission reduction. Macao's target for GHG emission control is to reduce GHG emissions per unit of GDP by 40%-45% relative to 2005 level by 2020.

For the purpose of systematic protection of Macao's environment, 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 which will be implemented in three stages, that is near-term (2010-2012), medium-term (2013-2015) and long-term (2016-2020), is aimed to improve the living environment and protect the health of the people. To supervise the implementation of the plan, Macao issued the *Near-Term Implementation and Effect Assessment of the Environmental Protection Plan of Macao (2010-2020)* and the Medium-Term Implementation and Effect Assessment of the *Environmental Protection Plan of Macao (2010-2020)* in 2014 and 2016 respectively, assessed the near-term effect and the medium-term effect of the plan, and reviewed the fulfillment of the ecological targets in the plan and the action plans.

4.2 Mitigation Actions

4.2.1 Energy Industry

Gradually increase the share of natural gas power generation. With the socio-economic development and the increase in electricity demands, Macao purchased more and more electricity from the Mainland China. In addition, to reduce electricity-related emissions, Macao introduced much natural gas to replace heavy oil and formally realized power generation with natural gas in 2008. According to the *Statistics of Electricity and Natural Gas in the 4th Quarter of 2017*, the proportion of the electricity generated with natural gas increased from 30.9% in 2008 to 52.9% in 2017, which led to a significant reduction of power generation-related GHG emissions; Macao would further increase the proportion of the power generation with natural gas to mitigate climate change. Besides, the government launched the project for the construction of public natural gas pipe networks in 2012, and gradually supplied natural gas to residents to improve its energy consumption structure. In 2013, the Coloane gas pressure reduction station was formally started to operate and supply gas to the public housing on Coloane and the new campus of the University of Macao on Hengqin Island. Now the construction of urban natural gas pipe network is underway. By 2017, 96% of the main pipeline network in Cotai Island has been constructed, which laid as a foundation for providing diversified clean energy.

Promote renewable energy including photovoltaic power generation. Macao has been promoting the application of renewable energy. To make effective utilization of household refuse for power generation, Macao built the old plant and the new plant for the waste incineration center in 1992 and 2008 respectively. Its power generation system, besides meeting its own need, can deliver 21.7 MWh electricity to the public grid. In 2010, the *Guide for the Application of Solar Water Heating in Macao* was formulated to promote the application of this technology. The Office for the Development of the Energy Sector carried out test programs of solar water heating system and PV system in many public departments and the residential houses to make clear the feasibility of its application. With *Regulations on Solar Photovoltaic Grid Connection Safety and Installation* coming into effect in January 2015, Macao has not only provided the industry with the technical specifications, but also developed a feed-in-tariff system to encourage investors to install a photovoltaic system. Further, the Office for the Development of the Energy Sector and Institute for Tourism Studies developed the residual heat recovery technology for central air conditioning systems.

4.2.2 Transport

Implement "Public Transport Priority". In 2010, Macao promulgated the General Policy Framework for *Transit and Land Transportation in Macao (2010-2020)*, formulated transportation policies that give priority to public transportation, optimized the road network, improved the public transportation system, established a rail transit based public transportation network, improved the energy efficiency of public transportation and the construction of its transportation network in light of the development of the New Urban Zone, thus to exercise reasonable control of the growth and use of vehicles, and reduce the energy consumption and exhaust pollution from congestion. In 2017, the 9.3-kilometers overpass and the 11 stations for the Light Rapid Transit Taipa line were connected, train system equipment was being installed, and the line was expected to put into operation in 2019; its one-way peak transportation capacity per hour would be 7,800 person-times in the beginning, and would gradually increase to 14,100 person-times by 2020.

Promote the use of environmentally friendly and energy conservation vehicles. In 2016, Macao formulated the *Short-Term, Medium-Term and Long-Term Plans for the Introduction and Promotion of Eco-Friendly Vehicles in Macao*. The first batch of natural gas buses was put into operation from 2013, and a total of 69 natural gas buses were operating in 2017. By 2016, Macao had introduced 465 environment-friendly buses accumulatively that meet Euro IV or V standards, 50% more than 2015. Meanwhile, charging and parking spaces were set up in public parking lots, and the scope of the eco-friendly vehicles entitled to tax preference was revised in 2015. In order to eliminate heavy-polluting vehicles, the government formulated the *Finance Plan in 2017 to Eliminate Large-Capacity and Small-Capacity Two-Stroke Motorcycles*, and successfully eliminated over 5,000 of such motorcycles. To control vehicle exhaust emissions in a more efficient manner, from 2017, Macao started to implement the administrative regulations, including the *Standard on Unleaded Gasoline and Light Diesel for Vehicles*, and *Emission Limits and Measurement Methods of the Pollutants in the Exhaust Emissions of Vehicles in Use*, and shortened the compulsory vehicle inspection interval.

Participate in "Airport Carbon Accreditation Program". In 2014, Macao International Airport became accredited at the 'Reduction' level of Airport Carbon Accreditation, a program launched by Airports Council International, and continued to implemented various measures from 2015 to 2017, including gradual replacing of the lighting system with energy saving lights, replacing of vehicles in the airport convoy with environmentally-friendly ones, adjusting of air conditioner temperature and lighting time according to the schedule. With these measures implemented, the airport has reached and even exceeded its intended target, namely reducing the carbon emissions from every flight by 20% by 2018 over that in 2012.

4.2.3 Energy Conservation and Efficiency Improvement

Energy conservation in public sectors and institutions. In 2007, Macao piloted the energy management plan, established energy databases and set energy conservation targets; in 2011, it officially started the implementation of the energy management mechanism, formulated department energy conservation plans, supervised and managed the use of energy to improve the energy benefit of the public sector, with more than 50 departments or institutions participating in the program; Macao aimed to reduce the participants' annual energy consumption by 5%. In 2015, it implemented a plan on energy efficiency assessment for public sectors and institutions in 2015, developed an energy consumption capping standard appropriate to Macao based on sectoral per capita electricity consumption, so as to continuously improve and optimize energy management.

Energy conservation in public outdoor lighting systems. In 2008, the *Guide to the Design of Public Outdoor Lighting in Macao* was formulated to promote the application of LED lamps. LED street lamps were applied in Seac Pai Van and Zona Nova de Aterros do Porto Exterior respectively in 2013 and 2016, and more than 1,600 LED street lamps were installed in various regions in 2016 and 2017. Macao Port Management District for the artificial island of the Hong Kong-Zhuhai-Macao Bridge and the New Urban Zone would also use LED street lamps; the LED Lamp Replacement Plan was being implemented to replace about 14,000 high-pressure sodium vapor street lamps with LED lamps.

4.2.4 Hotels and Tourism

Promoting emission reduction in the hospitality industry. Since 2007, Macao has held the "Green Hotel Award" every year to promote the hotel and related industries in an environmentally-friendly, low-carbon and clean mode. Since the establishment of the award plan, the review standards were being optimized and perfected, with an increasing number of hotels participated in the plan; Since the establishment of the award plan, the review standards were being optimized and perfected, with an increasing number of hotels participated in the plan; up to 2018, the number of environmentally friendly hotels increased from 8 in the first session to 51, and over 27,000 rooms were covered by the plan. It successfully encouraged hotels to install energy-saving LED lamps, optimize ventilation and air conditioning systems, and reduce vehicle emissions, thereby producing marked effects in waste reduction and energy conservation. Besides, Macao planned to conduct carbon audit on hotels and tourism in 2018 to promote hotels' participation in energy conservation and emission reduction.

4.2.5 Urban Greening

Increase green coverage. Macao continued planting new trees, actively increased green coverage, and planted trees in parks, rest areas and pavements each year; from 2015 to 2017, along the coastal rest area of Taipa, more than 10 thousand mangrove saplings were planted, the forests on Coloane was transformed, and over 4,000 trees were planted. Macao organized the event of "Macao Green Week", and various forms of greening publicity campaigns every year to encourage all citizens to contribute to the greening of Macao; among other things, during the annual "Parade and Tree-Planting in Macao Green Week", over 1,000 saplings were planted.

Greening more spaces. To reach the green city targets and green more spaces, Macao widened the scope of greening to cover public garbage chambers, piers of overpasses, the roofs and facades of stands since 2011; between 2015 and 2017, pergolas were set up for plazas and streets, road slopes and medians were greened, and overhead green corridors were planned so as to better green roads, roofs and other places for more green spaces in Macao.

Chapter 5 Other Relevant Information

Macao has initiated a series of activities to enhance climate system observations and relevant research, to conduct a series of activities concerning education, outreach and training on climate change, encouragement of public participation, and raising awareness of climate change.

5.1 China's Climate System Observation

Despite its small size, Macao has a rather dense atmospheric and ocean observation network, including 14 automatic weather stations, 1 climate observation station, 1 atmospheric radiation monitoring station, 6 air quality monitoring stations, 2 tide monitoring stations and 1 sea wave monitoring station. Also, to address seawater encroachment caused by storm tide and astronomical tide, Macao has built 17 automatic water level monitoring stations to monitor coastal water level changes and submerge situation in Macao.

5.2 Climate Change Research

Macao's long history of meteorological observation has left it systematic and detailed records. By compiling these data, the Macao Meteorological and Geophysical Bureau has created a 100-year data set (1901-2000) and provided a solid foundation for climate change and related research and received high-level research results. Besides continuing to strengthen routine monitoring, analysis and researches on meteorological condition and sea level, Macao also stepped up ecological monitoring in areas that have relatively fewer data and smaller monitoring windows, and implemented monitoring of migratory birds and in-depth basement investigations of various plants.

Macao studied and compiled relevant action plans for addressing climate change. To this end, multiple fundamental and special researches are needed to support policy making. Major researches include: to organize meteorological materials accumulated since 1901; to introduce multiple global climate change models, and assess climate change impacts on Macao with downscaling analysis, particularly its impacts on water resource; to study climate change impacts on extreme weather events including typhoon and strong rainfall, assess risks of disastrous weather, particularly the possible losses caused to Macao's society and economy by storm tide accompanying typhoons.

5.3 Education, Outreach and Public Awareness

Macao SAR attached great importance to the outreach and education on climate change to raise the public awareness in this regard and advocated to jointly protect global climate environment. Since 2008, the Macao government held the Macao International Environmental Cooperation Forum and Exhibition (MIECF) annually, which received welcome and recognition by all. During outreach and education activities on climate change, priorities were given to fostering correct concepts and behaviors among primary school students. In formal education area, Macao government incorporated "knowing the nature and environmental protection education" into the natural science education part from 1995-1996 school year, and made it a legislative requirement in 2014 and 2015 that schools should set up relevant subjects in every education stage, regulated and led schools to include environmental protection contents in such subjects, which enabled students to gradually understand the contents and influences of environmental education since their childhood.

Relevant departments and groups in Macao have promoted energy efficiency and emission reduction through TV, the Internet, newspaper and multiple other media. Besides these efforts, they have also been following and reporting on international negotiations related to the Paris Agreement, aiming to raise the public awareness on climate change. A wide range of outreach materials on climate change have also been prepared and published, e.g. *Let's Care about Climate Change and Start from Me for Emission Reduction and Energy Conservation*, *Together We Tackle Climate*

Change, *Newsletter on Energy Conservation Campus* among other brochures. A cartoon entitled Carbon Family has also been co-published in Hong Kong and Macao.

The Macao government has also advocated for and promoted high-profile public outreach and education activities. It has actively supported a series of activities, e.g. Earth Day, World Environment Day, World Car Free Day, World Meteorological Day, Earth Hour, Macao Energy Conservation Week, "energy efficiency education promotional activities", "school energy saving culture series", and Green Businesses Companionship. Also, the Carnival for Application of the *Kyoto Protocol* to Macao in 2007, Essay Contest on Climate Change in 2008, Photography Contest themed on "Our Climate" in 2009, and Macao Student Drawing Competition - 'Unite! We Combat Climate Change' in 2010, "Summer Casual Outfit for Energy Conservation" design contest in 2012, "5% Energy Conservation Action" since 2015, and "Climate Change and the Paris Agreement Effective Day" workshop in 2016 all delivered climate change-related information to the public from various angles.

Besides what mentioned, Macao government is also committed to deliver water conservation messages to the public. To raise water conservation awareness among students, relevant departments kicked off "Campus Water Conservation Outreach Program". In the meantime, it compiled 2010-2013 Water Resources Condition Report and 2014-2016 Macao Water Resources and Water Supply, and publications such as Introducing Water Conservation Apparatus and Water Efficiency Label, which delivered more information on water resources and water conservation to the public. Activities such as Hotel Water Conservation Program and Business Tower Water Conservation Program were also rolled out among hotels and businesses in an effort to strengthen public awareness on water resources shortage issue.

5.4 Technology and Capacity-Building Needs

Macao highly values the technologies and capacity building in regard of climate change. It founded the "Environmental Protection and Energy Conservation Fund" to support the medium and small-sized businesses, social communities and other organizations and institutions to boost up their participation in environmental protection and energy conservation, broaden the space for development of environmental protection and energy conservation industries, and facilitate the diversified development in these industries. In the meantime, all departments have made necessary finance arrangement in their respective budgets to conduct researches and implement climate change-related activities. Despite all the policies and actions taken in addressing climate change by the Macao, insufficient technological capacity has been holding back the progresses in many sectors.

For climate change mitigation, Macao has been actively enhancing energy efficiency and utilization of renewable energies, therefore main technologies in demand include: highly efficient lighting system, building energy conservation technologies, highly efficient solar power utilization technologies, and waste recycling and reuse technologies, etc.

For climate change adaptation, Macao is in urgent demands to strengthen prevention and protection along coastal areas, therefore main technologies needed include: technologies for utilizing reclaimed water, technologies for forecasting and assessing sea level rise, highly efficient flood prevention technologies, ecosystem restoration and reconstruction technologies, as well as methods and measures in assessing disastrous climate caused by climate change, etc.

For capacity building, it needs to establish a nonlinear dynamic model of coupling "Energy-Economy-Environment-Population" for assessing future energy demands in Macao; enhance the executive capabilities of governmental institutions to push forward education and outreach on climate change, so as to raise the public awareness in this regard and to accelerate the construction of a low-carbon social economy.

It is Macao's hope to engage in broad cooperation, enhance technological development and build up capacities and contribute to jointly addressing climate change.