Regional Knowledge Sharing Event:
Air Quality and Climate Benefits of Energy Policies

CLEAN AIR ASIA
亚洲清洁空气中心

Key Indicators and Policies on Air Quality, Carbon Emission and Energy in Asia

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亚洲视角下的清洁空气与气候变化领域关键指标

Clean air and climate change - Asian perspective and key indicators

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Region	Country
East Asia	China
	Japan
	Republic of Korea
	Mongolia
South Asia	India
	Pakistan
	Bangladesh
	Sri Lanka
	Nepal
Southeast Asia	Singapore
	Republic of the Philippines
	Malaysia
	Thailand
	Viet Nam
	Indonesia
	Cambodia
	Myanmar
America	United States (US)
Europe	United Kingdom (UK)
	Germany

* Comparisons between countries in the report are made within the above-mentioned countries unless otherwise specified.

The report covers key indicators of clean air and climate change status and progress, including air quality, air pollutant emissions, greenhouse gas emissions, energy sector, transport sector and key industrial sectors.

Air quality

Air pollutant emissions

Greenhouse gas emissions

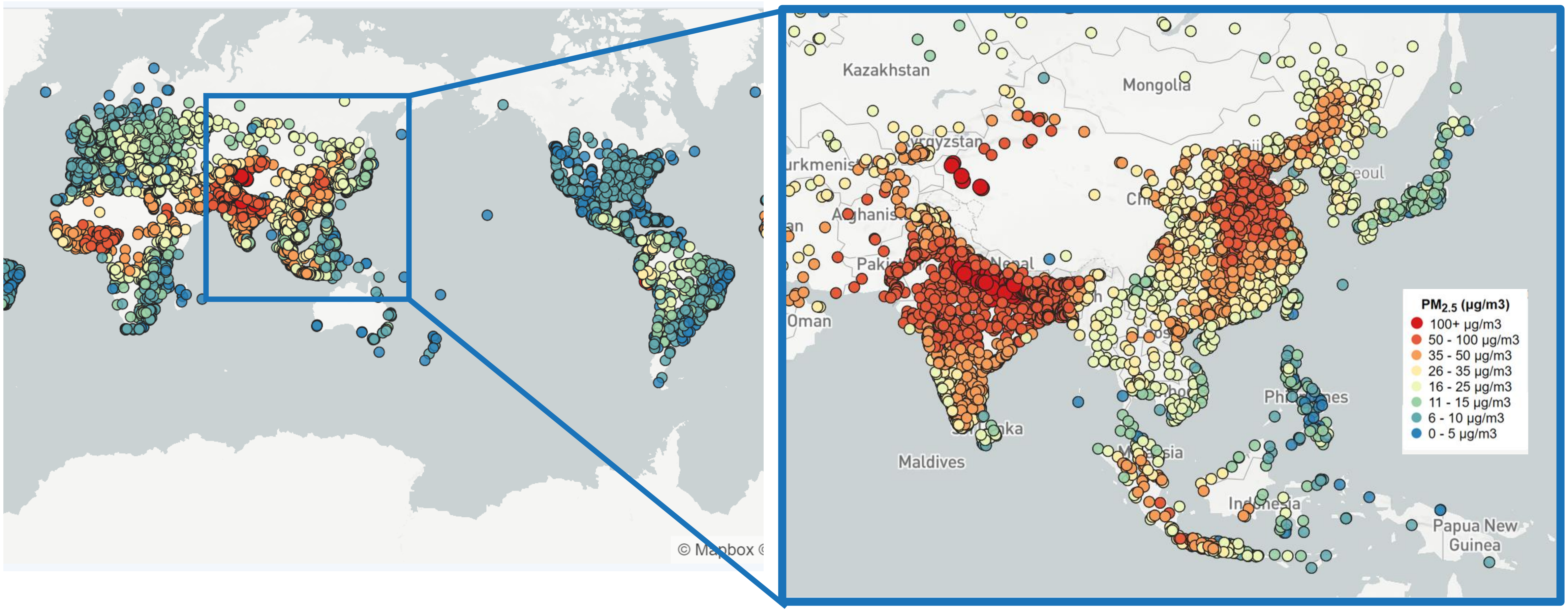
Energy sector

Transport sector

Key industrial sectors

空气污染仍然是全球普遍面临的问题，亚洲首当其冲需要采取行动

Air pollution is a common issue for all，Asia needs to take stronger action



Source: HEI,2022

Figure Population-weighted annual average $PM_{2.5}$ concentrations in cities in 2019

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Air pollution is a common issue for all，Asia needs to take stronger action

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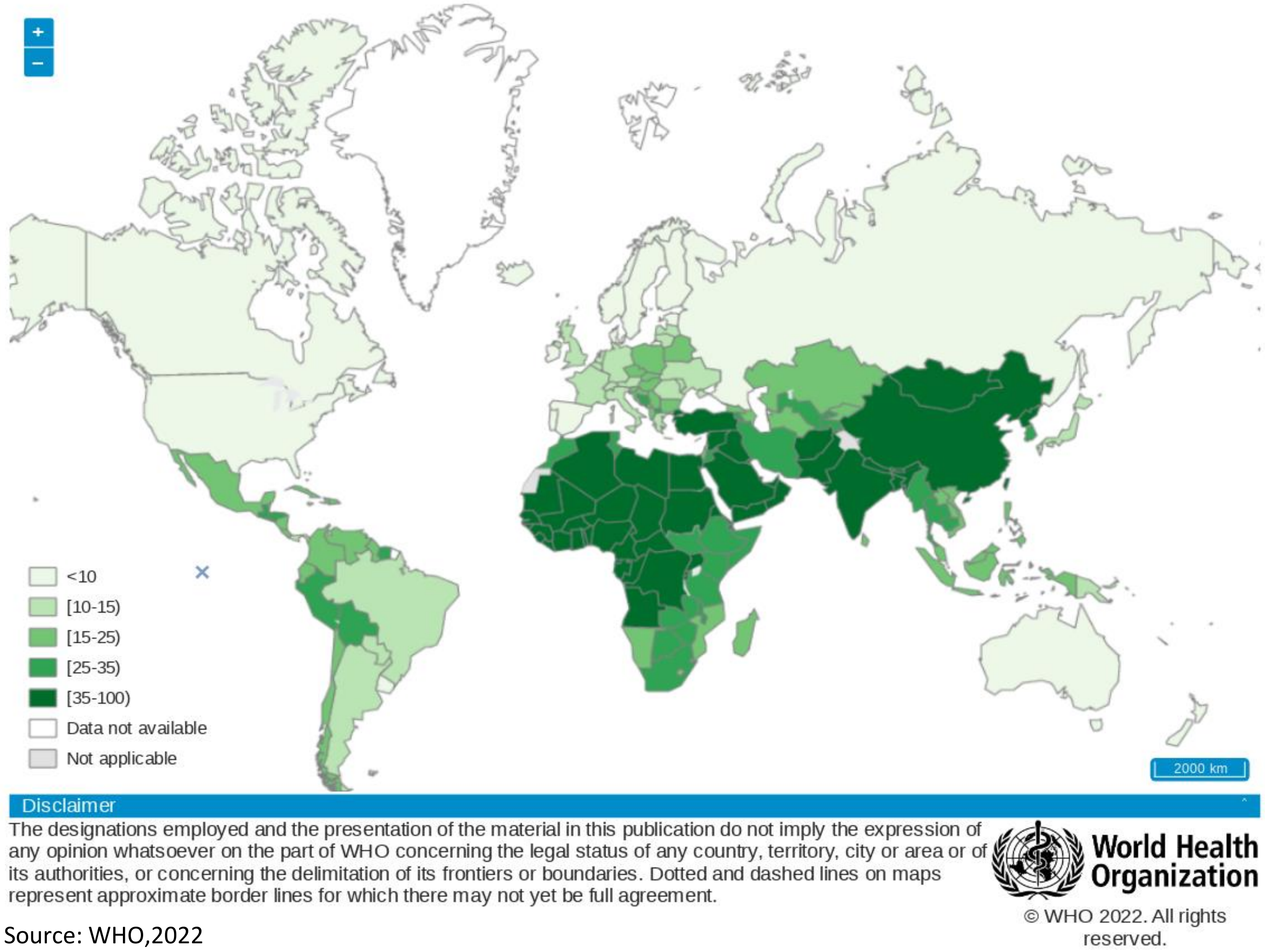


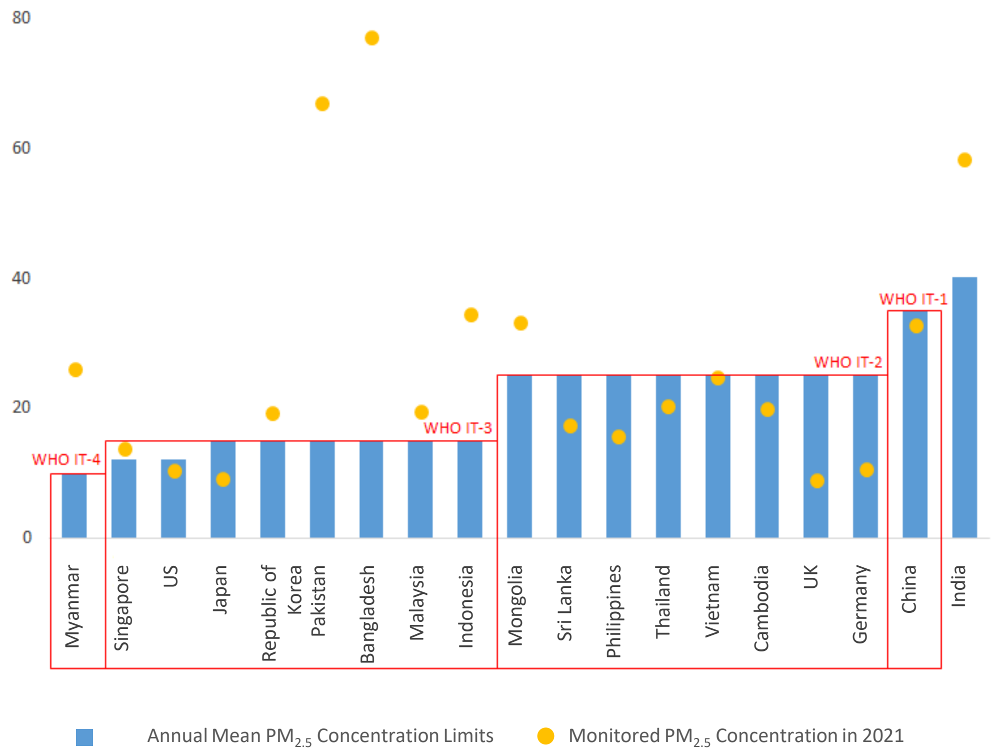
Source: WHO,2022

One of the most important changes in the World Health Organization's 2021 updated Global Air Quality Guidelines is that the guideline level for $PM_{2.5}$ has been significantly tightened based on the accumulation of scientific evidence, reducing the recommended annual average value of $PM_{2.5}$ from 10µg/m^3 to 5µg/m^3.

Based on monitoring data from over 6,000 cities in 117 countries, almost all of the global population (99%) is exposed to air that fails to meet the new guideline (5µg/m^3); the population-weighted annual average $PM_{2.5}$ concentration in South Asia, East Asia and West Africa is at or above the interim target 1 specified in the new guidelines (WHO IT-1, 35µg/m^3).

标准距离WHO新指导值差距较大，需要进一步提标保护公众健康

WHO AQGs and emerging needs for further public health protection



Pollutant	Averaging time	Interim target				AQG level
		1	2	3	4	
$PM_{2.5}$, μg/m³	Annual	35	25	15	10	5
	24-hour[a]	75	50	37.5	25	15

Figure Annual Mean $PM_{2.5}$ Concentration Limits and Monitored Concentration Levels in 2021 of Each Country

Source： see report references for details.

- China's annual $PM_{2.5}$ concentration limit in the NAAQS is the same as WHO IT-1, the most lenient one.
- The monitoring data in cities showed annual average $PM_{2.5}$ concentration was about 30μg/m³ in 2021, lower than the standard requirement. **Beijing: from 89.5 to 30 ug/m3**.
- Current air quality in nearly half of the Asian countries does not meet local standards. Some countries with relatively strict limits (with reference to WHO IT-3 and IT-4) still have poor air quality.
- **Upgrading the standards and continuous improvement in air quality can further protect the health of the public** (especially vulnerable groups such as the elderly and children), which is crucial for many Asian countries including China as the population is aging.

中国的空气质量快速改善，实现环境、经济“双赢”

Rapid air quality improvement and win-win situation in China

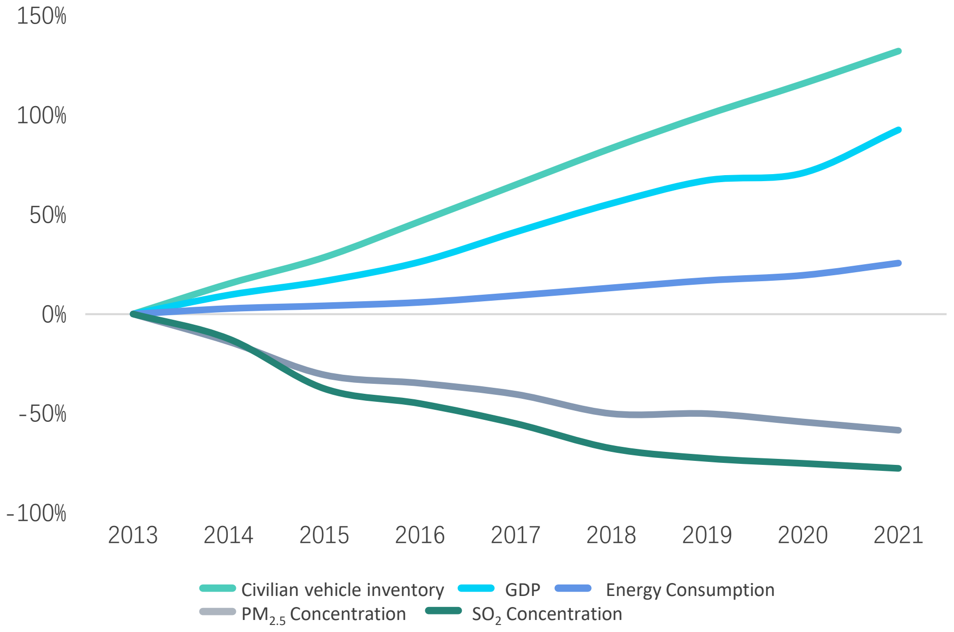


Figure Changes in China's GDP, Energy Consumption, Civilian Vehicle Inventory, and Air Pollutant Concentration, 2013-2021

Source： China Statistical Yearbook, 2014-2022

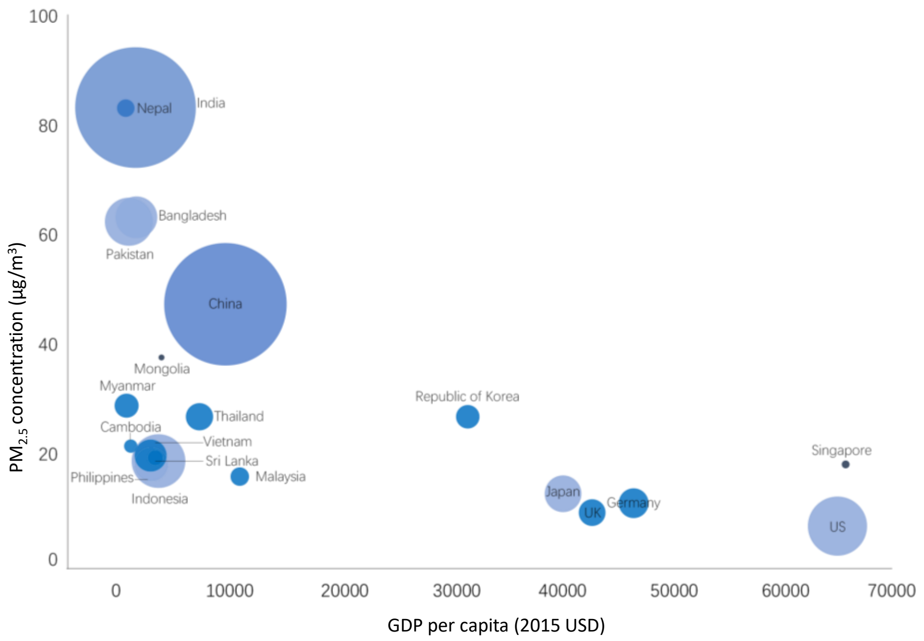


Figure $PM_{2.5}$ and GDP per Capita by Country, 2019

Note： GDP per capita is measured in 2019 US dollars; the size of the bubbles corresponds to the population of each country.

Source： Global Burden of Disease Study 2019, World Development Indicators

- From 2013–2021, China's overall annual average $PM_{2.5}$ and SO_2 concentrations have fallen by approximately 56% and 78%, respectively.
- China's GDP maintained a high average growth rate of 6.6%—nearly twice the average growth rate of developing economies.
- China's GDP per capita has exceeded the $10,000 threshold, crossed the "turning point" and successfully broken the connection between economic development and air quality deterioration.
- Energy consumption and the number of civilian vehicles increased by 25.7% and 132.2%, respectively.

大气污染物排放总量与单位GDP排放趋势

Emission trends of key air pollutants

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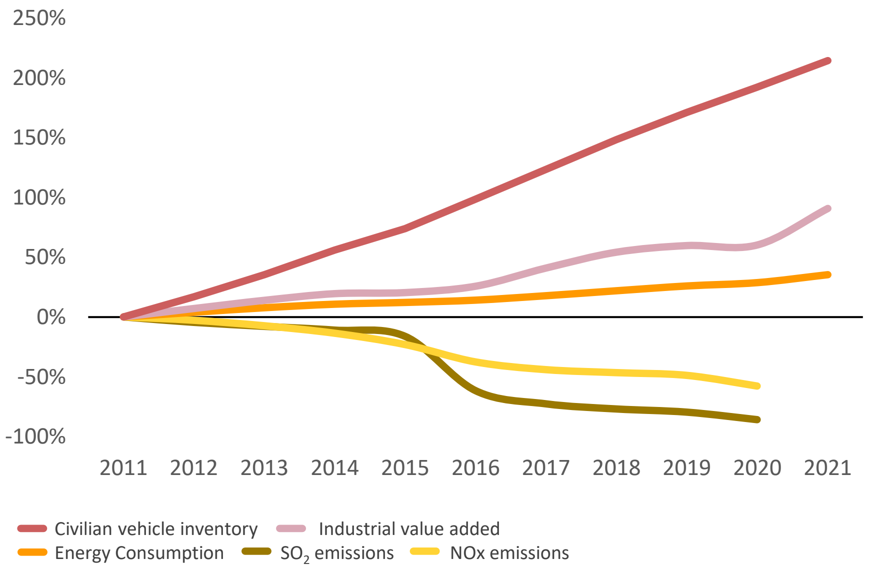
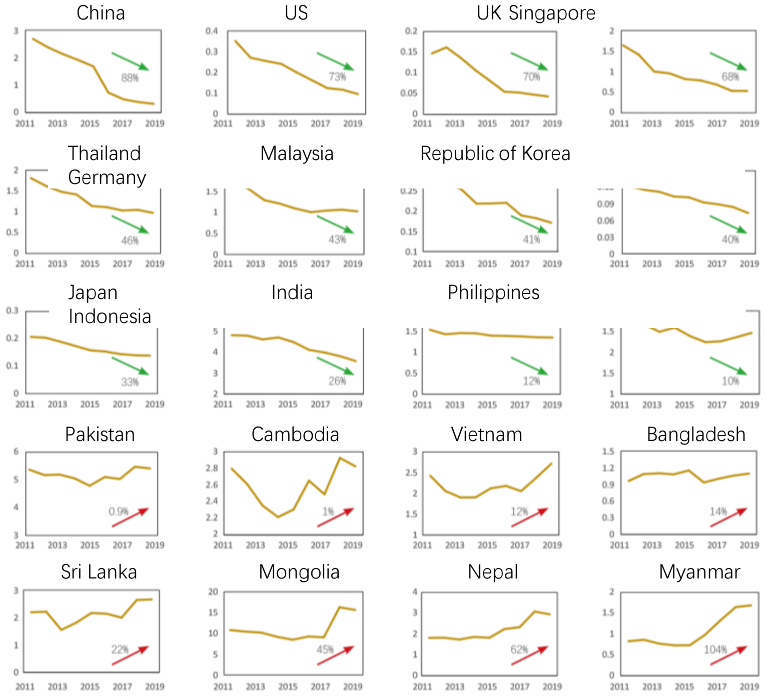


Figure Changes in China's Industrial Value Added, Energy Consumption Inventory, Civilian Vehicle Inventory, and Air Pollutant Emission, 2011-2021

Source： China Statistical Yearbook, 2012-2022



Unit： kg/1,000 (2015 USD)

Figure Changes in SO_2 Emission per Unit of GDP of Various Countries, 2011-2019

Source： Community Emissions Data System (CEDS) ， World Development Indicators

- China's energy consumption, industrial value added, and the number of vehicle had a steady growth of 35%, 91%, and 214%, respectively.
- **China's emissions of SO_2 and NOx, both major air pollutants, rapidly declined.** SO_2 emission decreased by 86%, from 22.179 million tons to 3.182 million tons, while NOx emission decreased by 58%, from 24.043 million tons to 10.197 million tons.
- From 2011–2019, **SO_2 emission per unit of GDP in China dropped by 88%.**

标准修订推动了中国空气质量管理体系的升级

Revision of NAAQS started the AQM framework upgrading in China

2012
- February — The revised Ambient Air Quality Standards was released

2013
- January — As the index of heavy smog went off the scale, the Premier pledged to take action
- June — The Ten Measures of the State Council released
- September — Action Plan on Air Pollution Prevention and Control was released

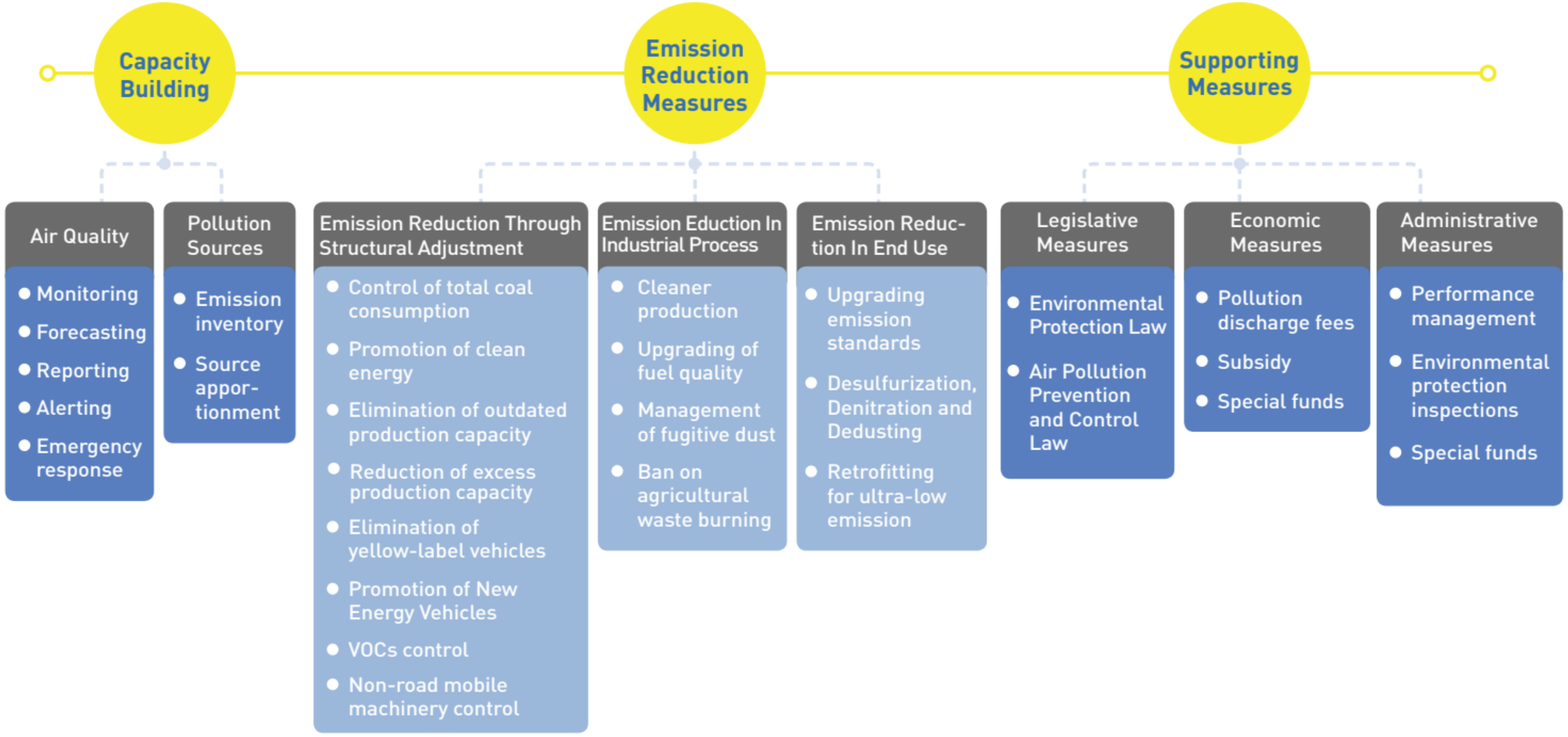
2014
- September — Implementation plan for the elimination of yellow-label vehicles

2015
- March — Pilots of development of air pollutant emissions inventory were launched
- May — The upgrading of fuel quality was accelerated
- October — Pilots for VOCs discharge fees began
- December — Implementation plan for vessel emission control zones was issued
- Ultra low emission and energy efficient retrofit of coal-fired power plants were accelerated

2016
- January — The amended Air Pollution Prevention and Control Law came into force
- September — The Limits for Exhaust Pollutants from Marine Engines was issued for the first time
- Pilot for provincial environmental protection departments to uniformly manage the environmental inspection and monitoring functions of cities and counties
- November — Implementation plan for the pollutants discharge permit system was released
- Two air quality indicators were established as compulsory indicators in the 13th Five-year Plan

2017
- January — China Ⅴ standards gasoline and diesel had been supplied nationwide
- March — The "Blue Skies" plan was proposed for the first time
- April — A year-long intensive inspection of air pollution prevention and control in the "2+26" cities was launched

China's Policy Framework for Air Pollution Prevention and Control



Milestones of China's AQM and Policy Framework

Source： Clean Air Asia. 2018. BREAKTHROUGHS: CHINA'S PATH TO CLEAN AIR 2013-2017

空气质量监测网络跨越式发展，站点密度和类别仍待提升

Leap-frogging of monitoring stations and needs for more comprehensive network

City	No. of continuous monitoring stations	Ranking by No. of stations per million habitants	Ranking by No. of stations per 1,000 sq km^2	$PM_{2.5}$	PM_{10}	SO_2	NO_2	CO	O_3	NO	Ox	NH_3	TSP	PM_1
London, UK	129	2	2	✓	✓	✓	✓	✓	✓					
Tokyo, Japan	82	14	6	✓	✓	✓	✓	✓		✓	✓			
Bangkok, Thailand	64	3	5	✓	✓		✓	✓	✓					
Guangzhou, China	52	10	16	✓	✓	✓	✓	✓	✓					
Seoul, South Korea	51	4	1	✓	✓	✓	✓	✓	✓	✓				
Xi’an, China	41	9	17	✓	✓	✓	✓	✓	✓					
Delhi, India	40	18	8	✓	✓	✓	✓	✓	✓	✓		✓		
Beijing, China	35	16	22	✓	✓	✓	✓	✓	✓					
Hangzhou, China	33	11	23	✓	✓	✓	✓	✓	✓					
Mumbai, India	30	15	4	✓	✓	✓	✓	✓	✓	✓		✓		
Singapore	22	7	7	✓	✓		✓	✓	✓					
Wuhan, China	22	17	21	✓	✓	✓	✓	✓	✓					
Shanghai, China	19	22	20	✓	✓	✓	✓	✓	✓					
Hong Kong, China	18	12	10	✓	✓	✓	✓	✓	✓					
Berlin, Germany	17	5	9	✓	✓		✓	✓	✓					
Los Angeles, USA	15	6	12	✓	✓	✓	✓	✓	✓					
Shenzhen, China	15	23	15	✓	✓	✓	✓	✓	✓					
Ulaanbaatar, Mongolia	15	1	18	✓	✓	✓	✓	✓	✓	✓				
Chengdu, China	14	24	25	✓	✓	✓	✓	✓	✓					
Nanjing, China	11	19	24	✓	✓	✓	✓	✓	✓					
Hanoi, Vietnam	10	20	19	✓	✓	✓	✓	✓	✓					
Jakarta, Indonesia	9	21	11	✓	✓	✓	✓	✓	✓					
Kathmandu, Nepal	7	13	14	✓	✓								✓	✓
Dacca, Bangladesh	3	25	13	✓	✓	✓	✓	✓	✓					
Colombo, Sri Lanka	2	8	3	✓	✓	✓	✓	✓	✓	✓				

- Prior to 2012, China's national ambient air quality monitoring network covered only 113 key cities with 661 state-controlled sites monitored PM_{10}, SO_2, and NO_2.
- In 2021, the number of state-controlled monitoring sites for ambientair quality in 339 cities of China was 1734, monitoring $PM_{2.5}$,PM_{10}, O_3, SO_2, NO_2 and CO.

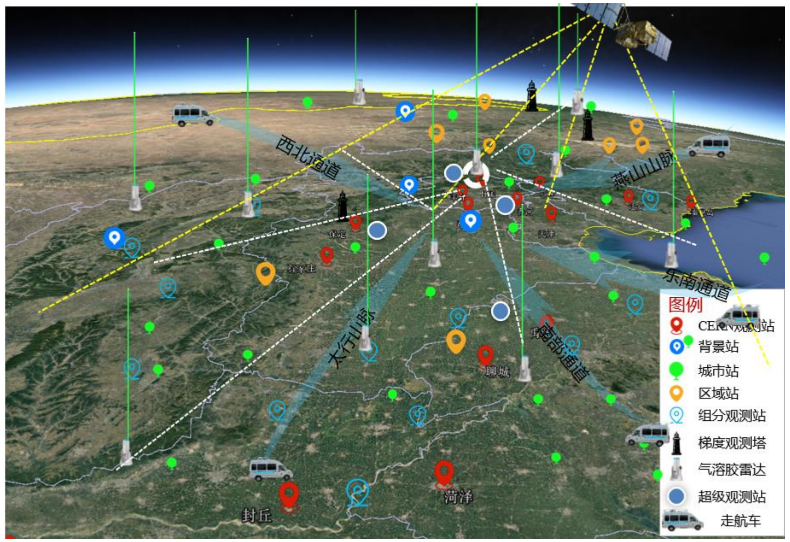


Figure Integrated ground-air-space stereo observation network in BTH 2+26 cities

Source： CRAES, 2021

亚洲大城市PM2.5污染的贡献来源

Primary contributors to PM2.5 pollution in mega cities

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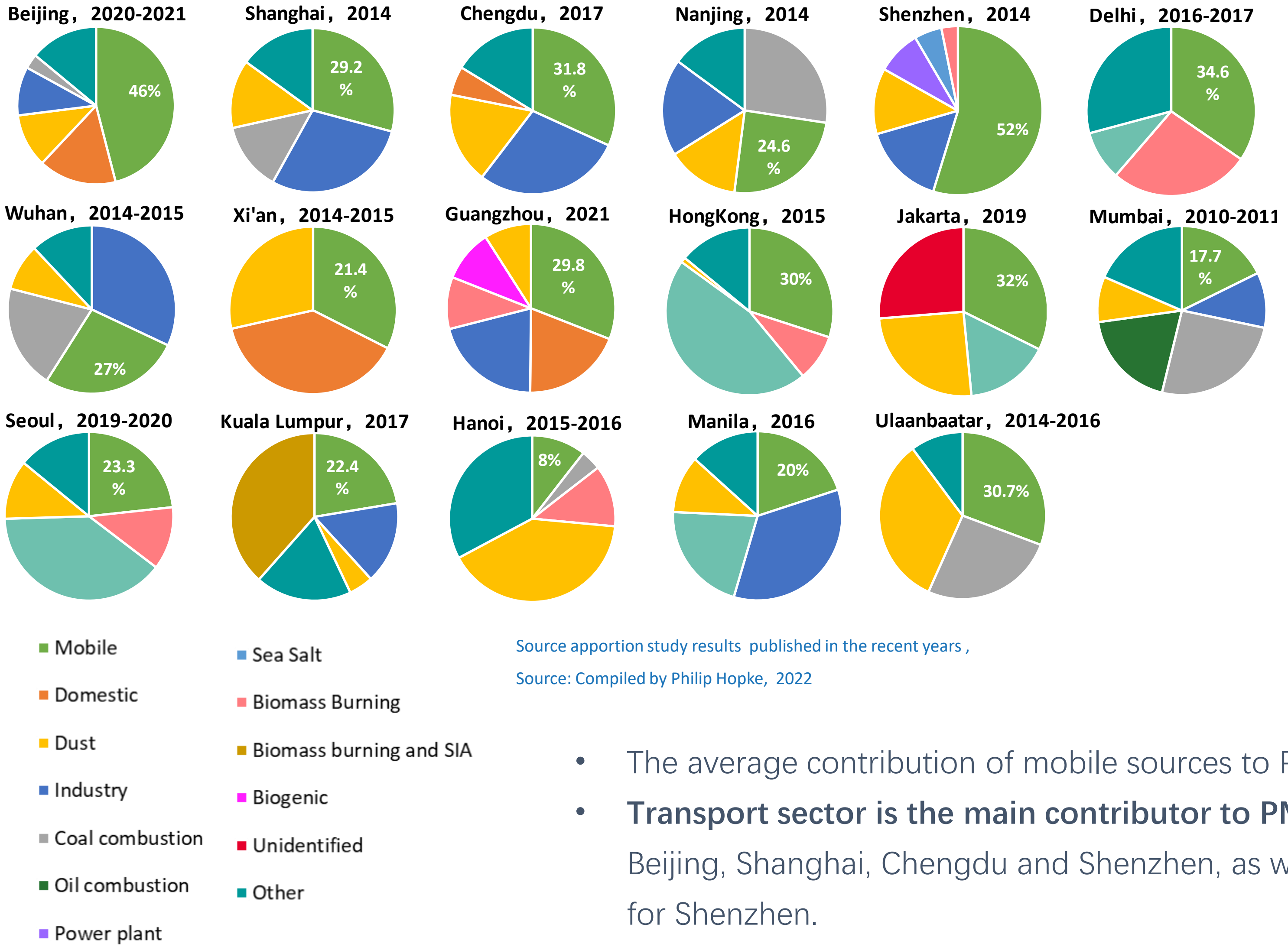
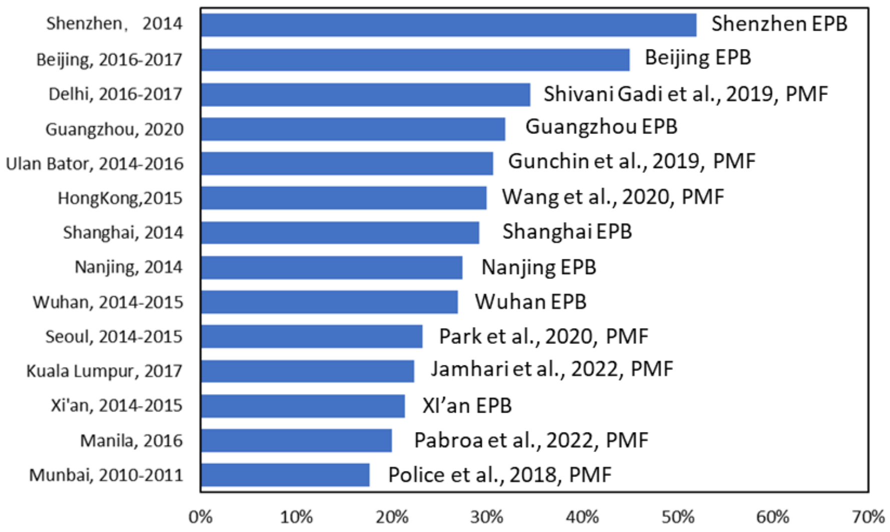




Source apportion study results published in the recent years ,

Source: Compiled by Philip Hopke, 2022

- The average contribution of mobile sources to PM2.5 in major Asian cities is about 30%.
- **Transport sector is the main contributor to PM2.5 in most cities**, including Chinese cities such as Beijing, Shanghai, Chengdu and Shenzhen, as well as Delhi and Jakarta, with the highest ratio over 50% for Shenzhen.

中国空气质量改善的主要贡献措施

Drivers of Improved PM2.5 Air Quality in China from 2013 to 2017

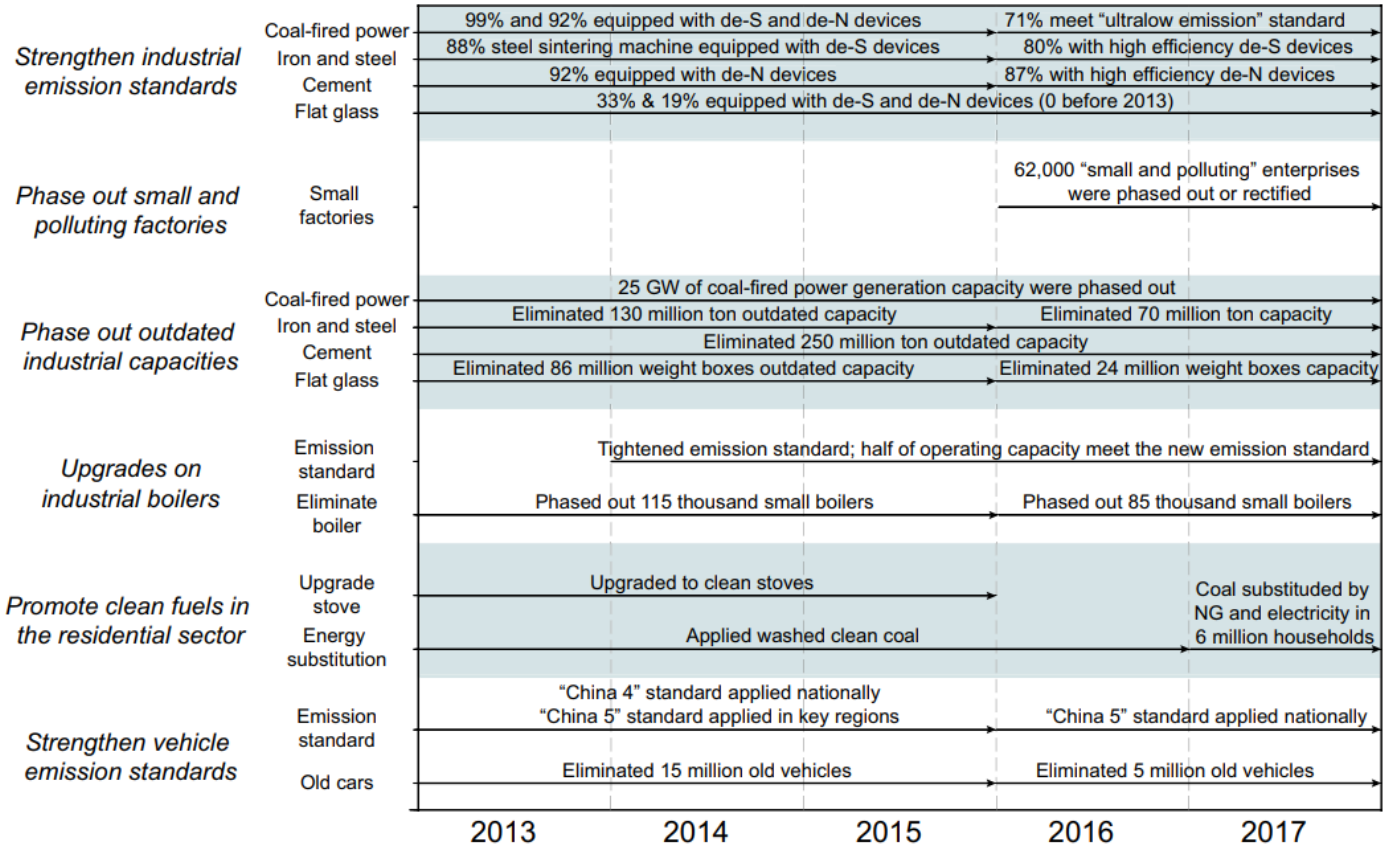
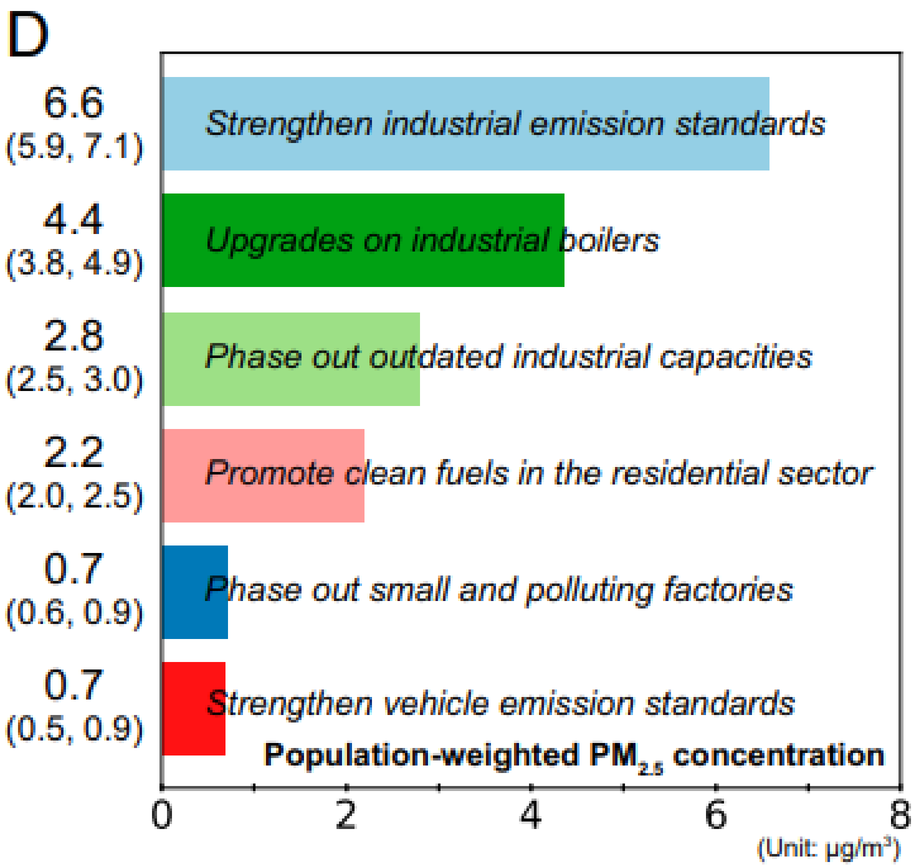


Fig. 1. Summary of major air pollution control measures taken between 2013 and 2017. De-S, desulfurization; De-N, denitrification; NG, natural gas.



Source: Zhang et al. PNAS 2019

中国电力行业排放控制力度空前，排放标准全球最严

China upgraded the emission control standards of coal-fired power plants to most stringent levels

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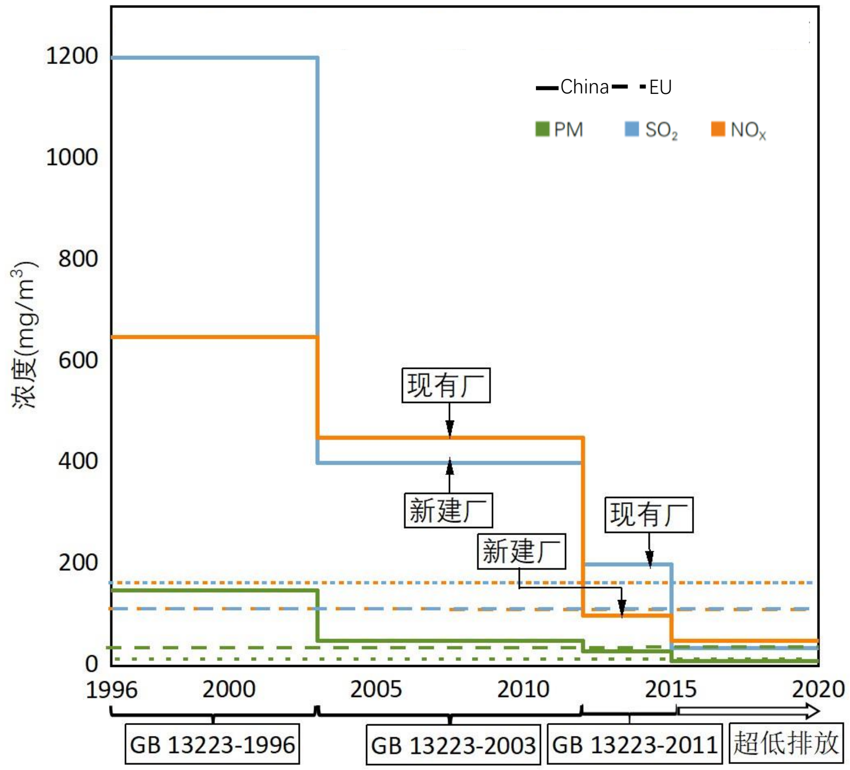


Figure Couse of Upgrades for the Power Sector’s Emission Standards in China

Source: see report references for details

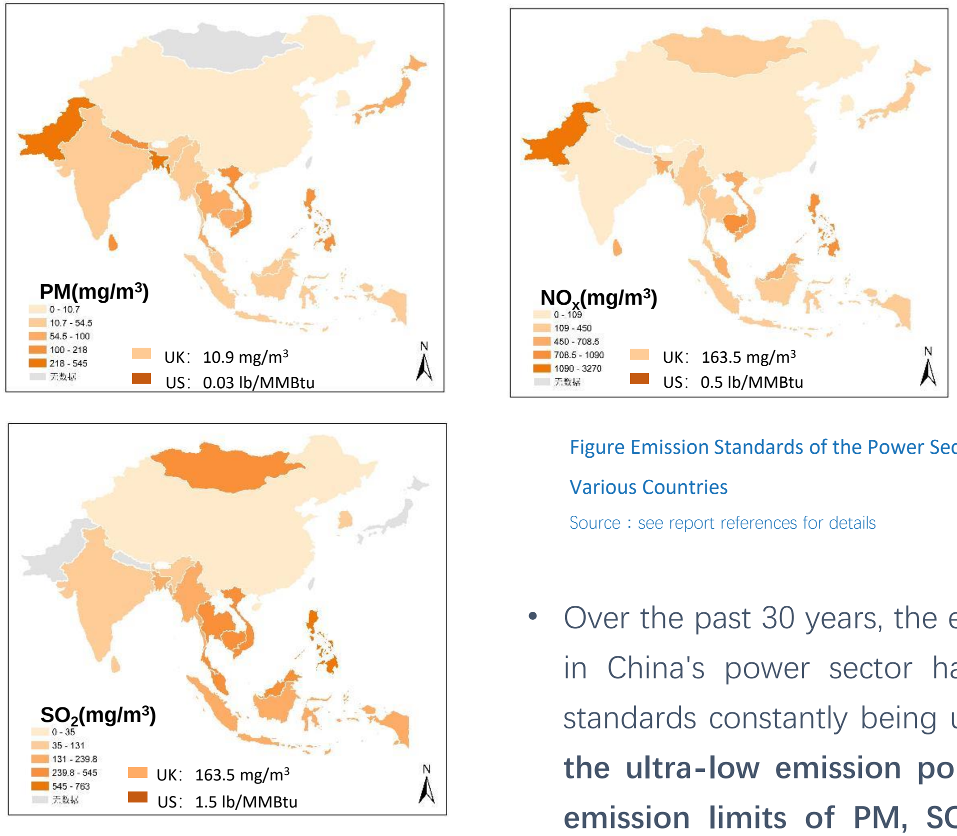


Figure Emission Standards of the Power Sector in Various Countries

Source：see report references for details

- Over the past 30 years, the emission control of air pollutants in China's power sector has developed rapidly, with the standards constantly being upgraded and tightened. **Under the ultra-low emission policy requirements, the current emission limits of PM, SO_2, and NOx are 10, 35, and 50mg/m^3**, respectively, which are stricter than the original standard limits in 1996 (by 93%, 97%, and 92%, respectively).
- The emission limits of SO_2 and NOx are 1/5 and 1/3 of the European Union (EU) standard, respectively.

能源消耗趋势趋势

Energy Consumption Trends

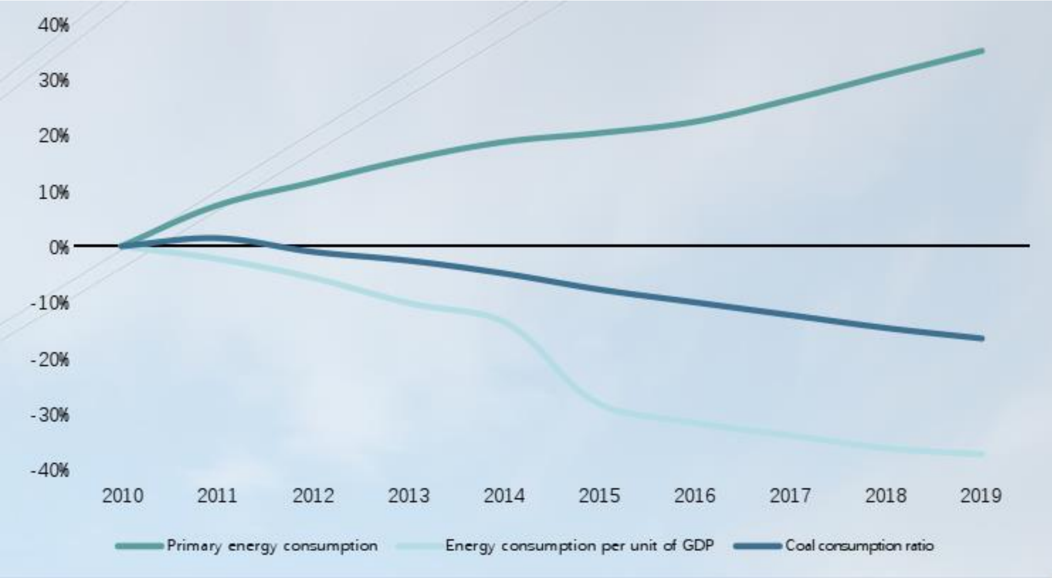
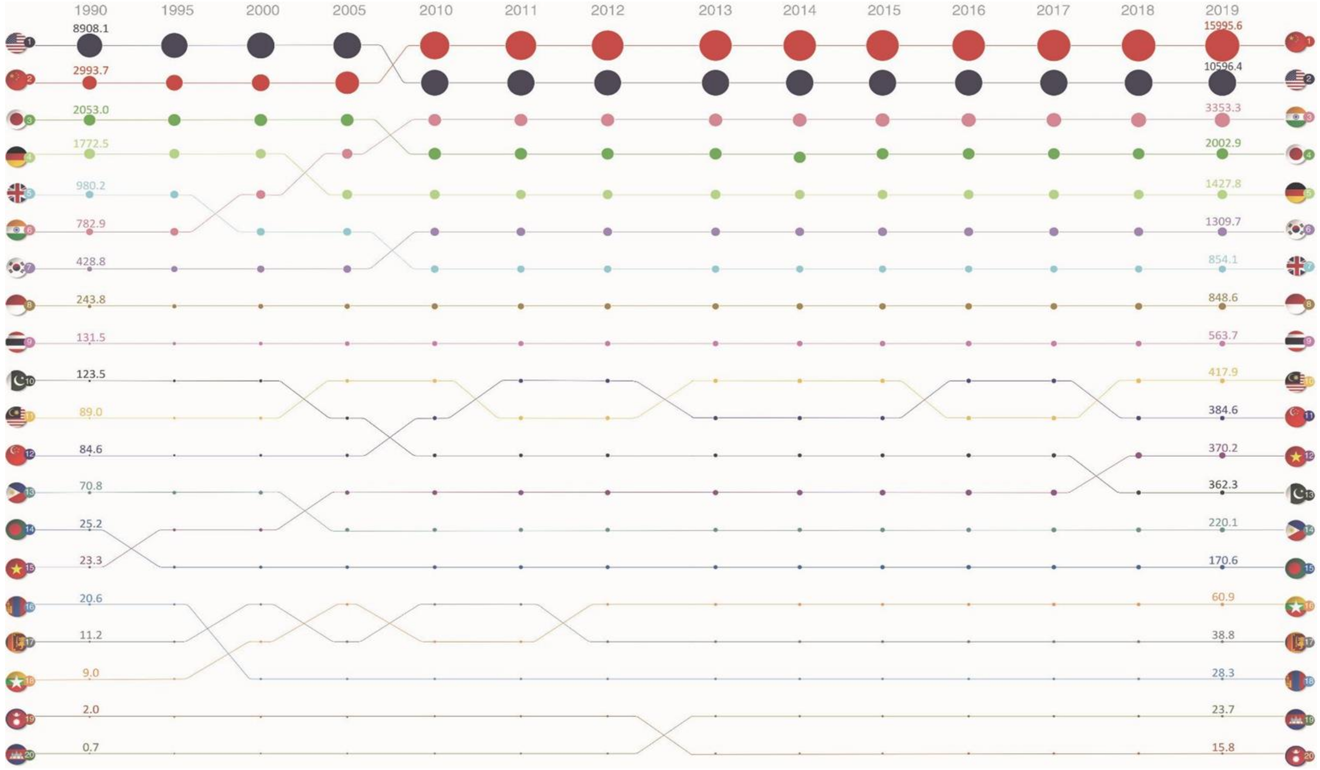


Figure 4.1 Changes in China's Primary Energy Consumption, Energy Consumption per Unit of GDP, and Coal Consumption Ratio, 2010-2019

Source: China Statistical Yearbook, 2011–2020



- In the last 30 years, most Asian countries have seen a rapidly increasing trend in energy consumption. Most countries' energy consumption growth slowed down after 2010.
- At present, China's total energy consumption is the highest. While the country' s energy consumption continues to grow, China' s energy consumption structure has been improving.
- As the largest coal consumer globally, China's coal consumption ratio in energy consumption structure has seen a downward trend, decreasing from 62.2% in 2010 to 57.7% in 2019.

亚洲国家化石能源依赖度较高，中国煤炭消费比重仍超过一半

Fossil fuel is the main energy for Asia, coal still domains energy consumption and production in China

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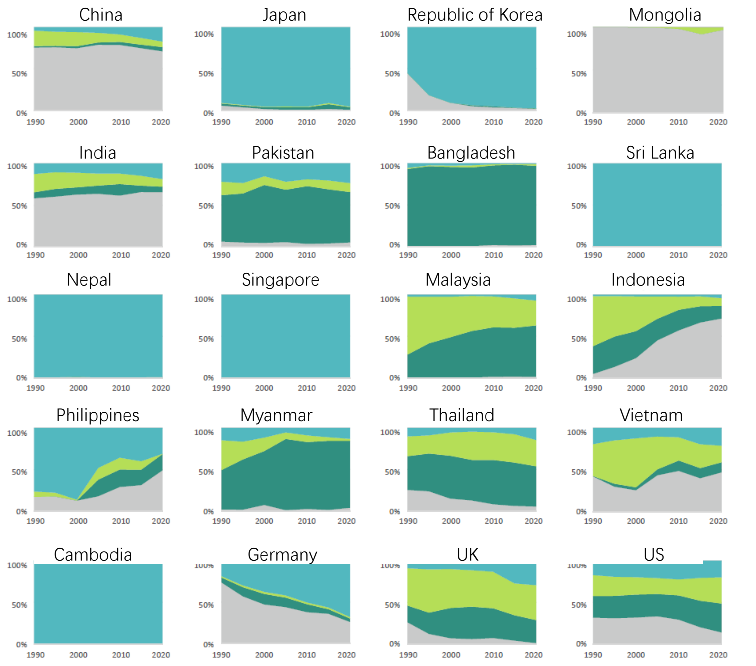

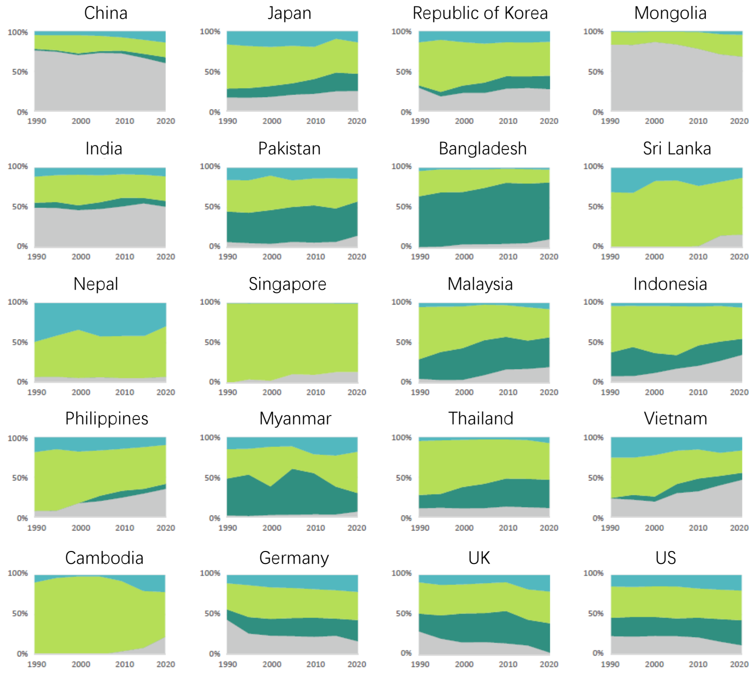

Renewable and nuclear　Oil　Natural gas　Coal

Figure Changes in the Energy Production Structure of Various Countries, 1990-2019

Source: U.S. Energy Information Administration

Figure Changes in the Energy Consumption Structure of Various Countries, 1990-2019

Source: U.S. Energy Information Administration

- Compared with typical countries in Europe and America, which gradually shift to a cleaner and more balanced energy structure, most Asian countries have a higher dependence on fossil energy.
- Because of China's "rich in coal, lacking in oil, and short in gas" resource endowment characteristics, **coal holds an important position in its energy production and consumption, but its proportion is gradually declining**.

亚洲迈向脱碳目标，将为清洁空气提供动能

Decarbonization of Asia will bring driving forces and co-benefits to clean air

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- As the world moves towards carbon neutrality and net-zero emission, many Asian countries have announced their decarbonization goals. Moving towards "carbon neutrality" will provide momentum for continuous improvement of air quality and fundamentally solve the air pollution problem.
- However, approximately 1/3 of the world's energy consumption and 1/2 of the world's CO2 emission comes from Asia, making the task of emission reduction for developing Asian countries challenging.
- China has promised to achieve carbon neutrality from peak CO2 emissions in about 30 years, much shorter than that promised by developed countries. It will take great efforts to achieve this with the "China speed".

Country	2020 CO_2 emissions (million tons)	Year	Goal
1 China	11,680.4	2060	Carbon neutral
2 US	4,535.3	2050	Net zero
3 India	2,411.7	2070	Net zero
4 Japan	1,061.8	2050	Net zero
5 Germany	636.9	2045	GHG neutral
6 Republic of Korea	621.5	2050	Net zero
7 Indonesia	568.3	2060	Net zero
8 Vietnam	321.9	2050	Net zero
9 UK	313.7	2050	Net zero
10 Malaysia	262.2	2050	Carbon neutral
11 Thailand	255.5	2050	Net zero
12 Pakistan	217.0	2050	Net zero
13 Philippines	139.2		
14 Bangladesh	108.5		
15 Singapore	56.1	2050	Net zero
16 Mongolia	38.2		
17 Myanmar	37.7	2050	Net zero
18 Sri Lanka	23.7	2060	Carbon neutral
19 Nepal	17.9	2045	Net zero
20 Cambodia	15.8	2050	Net zero

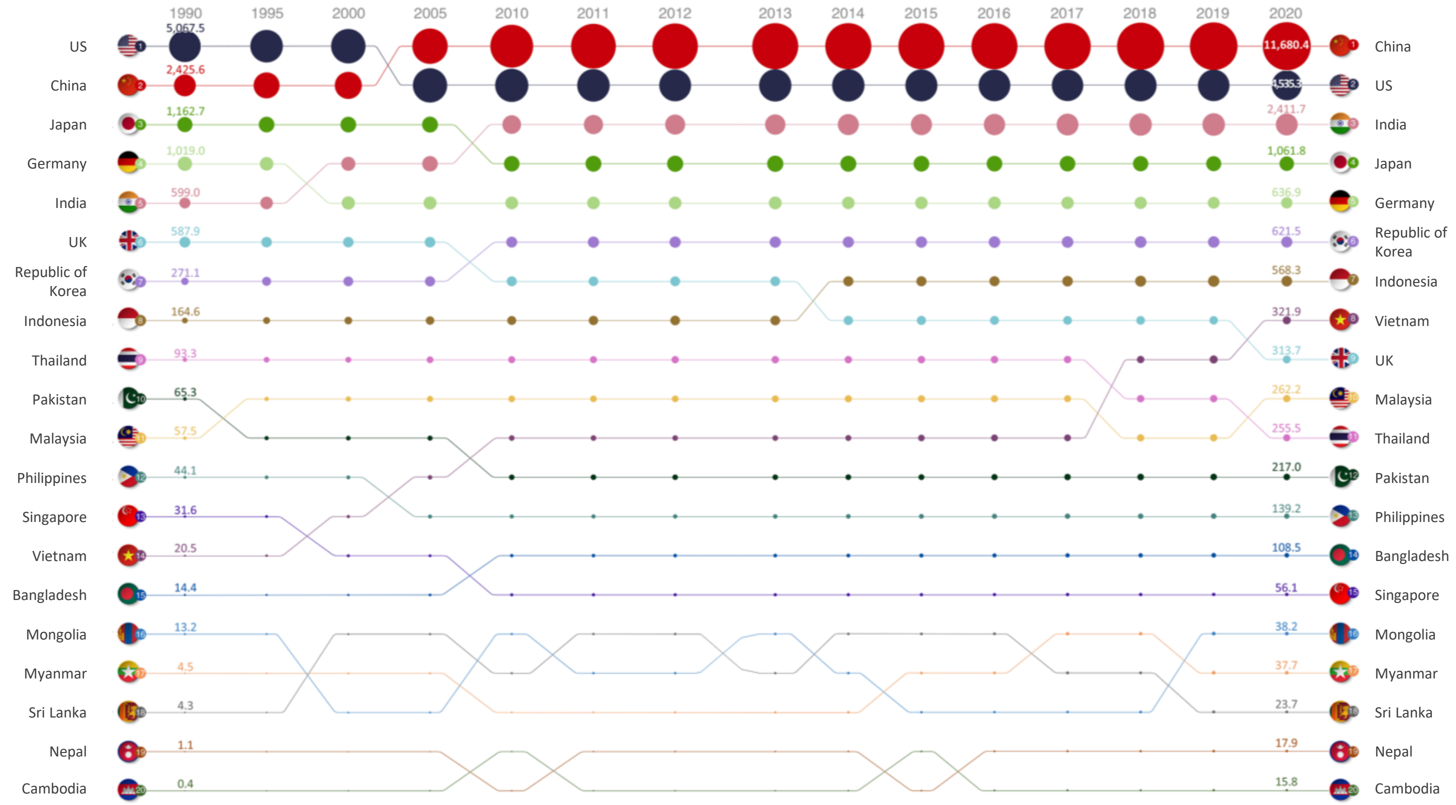
Figure Carbon Reduction Goals of Various Countries

Note： Empty cells mean that the country haven't announced carbon neutral or net zero related goal.

Source： Zerotracker

中国碳排放总量大于其它亚洲国家总和，近十年增速放缓

China contributed major CO_2 emission of Asia, a slowing-down appeared in the last decade



- Figure CO_2 Emissions and Ranking by Country, 1990-2020

- Unit：million tons
- Source：Emissions Database for Global Atmospheric Research

- Germany, Japan, the UK, and the US have achieved peak CO_2 emissions, while **Asian developing countries including China are still “climbing the hill.”**
- Over the past 10 years, China has taken various climate change mitigation actions to control greenhouse gas emissions, **slowing down the growth rate of carbon emission**.
- However, China has ranked as the highest emitter globally since 2015. Currently, China accounts for one-third of global CO_2 emissions, exceeding the sum of all other Asian countries.

中国碳排放强度十年降幅超1/3，排放结构电力为主

China's carbon emission per unit GDP has dropped more than 1/3 in the last decade

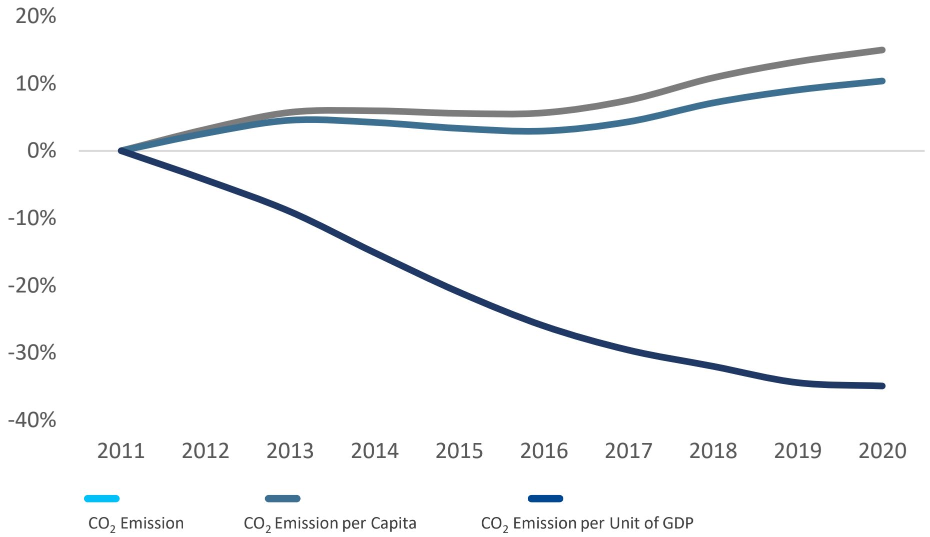


Figure Changes in China's CO_2 Emission, Emission per Capita, and Emission per Unit of GDP, 2011-2020

Source: Emissions Database for Global Atmospheric Research

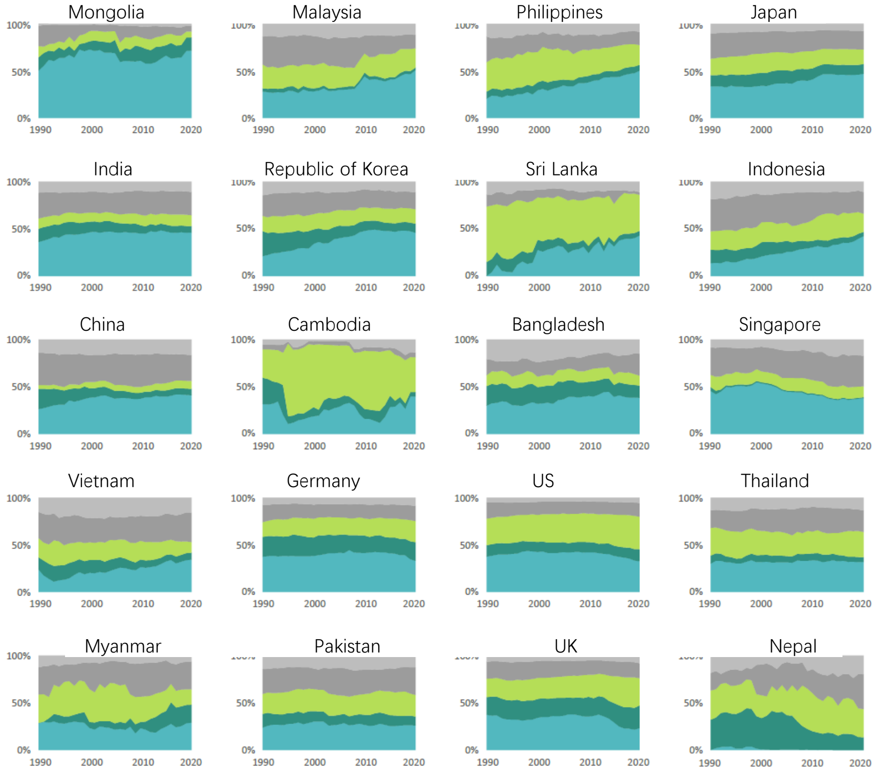


Figure Changes in CO_2 Emission Structure by Sector in Various Countries, 1990-2020

Source: Emissions Database for Global Atmospheric Research

- From 2011–2020, following rapid economic development and an increase in energy consumption, China's total CO_2 emission continued to increase. Meanwhile, China is gradually moving from an "intensive" economic development model to a greener development model, with **CO_2 emission per unit of GDP decreasing by 34.4% in 2020 compared to 2011.**
- Currently, power and industry are the highest carbon-emitting sectors in China, accounting for nearly 70% of the country's total emissions. The transportation sector will be the key sector to peak in the last, and face more difficulties to achieve carbon neutrality.

报告总结
Take-home messages

- *China has achieved rapid air quality improvement in the past decade through science-based management, comprehensive measures and strict standards etc.*

- *Currently, the end-of-pipe control measure are very strict, further emission reduction need to be done through a shift to cleaner structure of energy, transport and industries.*

- *China's experience will be useful for Asian countries facing with similar challenges to combat air pollution and climate change together.*

Report Team

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