China's Emissions Trading Scheme

Designing efficient allowance allocation

Abstract

In 2017, the People's Republic of China (hereafter, "China") decided to implement a national emissions trading scheme (ETS) to limit and reduce CO_2 emissions in a cost-effective manner. Set to start in 2020, the ETS will initially cover coal- and gas-fired power plants. It will allocate allowances (also known as permits), based on the plant's generation output, with a different benchmark for each fuel and technology. China's ETS, set to expand to seven other sectors, will be the world's largest by far, covering one-seventh of global CO_2 emissions from fossil-fuel combustion. The initial years of operation will be crucial to test the ETS's design and establish trust. Given the dominance of coal power in China's power sector and in its overall CO_2 emissions, how the country's fleet of coal-fired power plants is managed will be essential for China to meet its climate goals and other sustainable energy goals. The effect of the ETS on the operation of coal-fired power is worth examining because the ETS will co-exist with a suite of other policies, such as energy conservation standards, air pollution standards, power market reform and capacity retirement plans. This report weighs the implications of proposed benchmark options under the ETS for China's coal-fired power sector. It assesses how different options will affect allowance allocation to different types of plants, and considers the key elements that will determine whether generation units experience a deficit or a surplus of allowances. The report also looks at how these impacts will be distributed across provinces and companies. The report suggests how the ETS design could evolve to play a more central role in driving China's energy transition.

Table of contents

Executive summary

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China's emissions trading scheme, the world's largest

2020 is proving a watershed year for the development of China's energy system. The vital work of setting targets and priorities for the 14th Five-Year Plan (2021-25) would have been challenging enough, without the myriad impacts from the emergence of Covid-19. However, it is clear this has become an even more important moment for China's policy makers to embrace the expanded use of market mechanisms.

Calibrating and effectively co-ordinating the introduction of a nationwide emissions trading scheme (ETS) could prove to be a key factor in aiding China's recovery from the economic effects of coronavirus, while at the same time accelerating a clean energy revolution. In our ever more interconnected and interdependent world, the success of China's ETS has implications for us all.

China started the implementation phase of the national ETS in 2017 to limit and reduce CO_2 emissions in a cost-effective manner. The ETS could become a major climate policy tool to help China realise its Nationally Determined Contribution (NDC) to the Paris Agreement on climate change and its long-term low-carbon strategy. The first compliance period is expected to start in 2020.

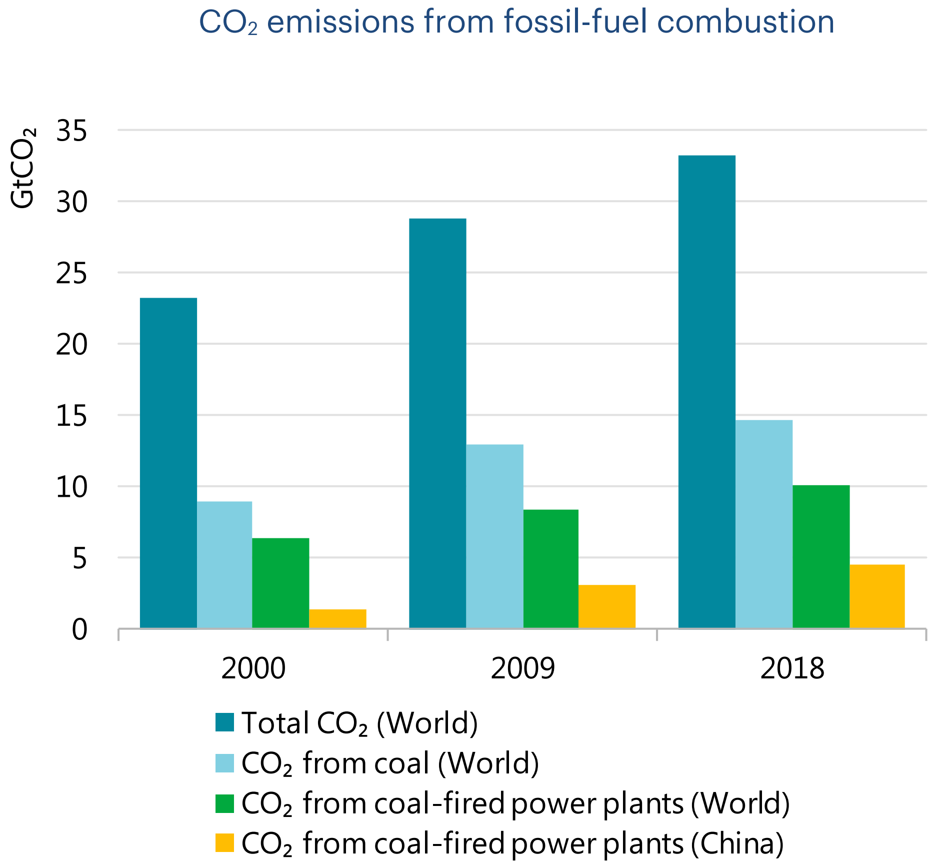
The national ETS will initially cover coal- and gas-fired power plants. Allowances to emit CO_2 (also known as permits) will be allocated based on each plant's generation output, with specific benchmarks for fuel and technology.

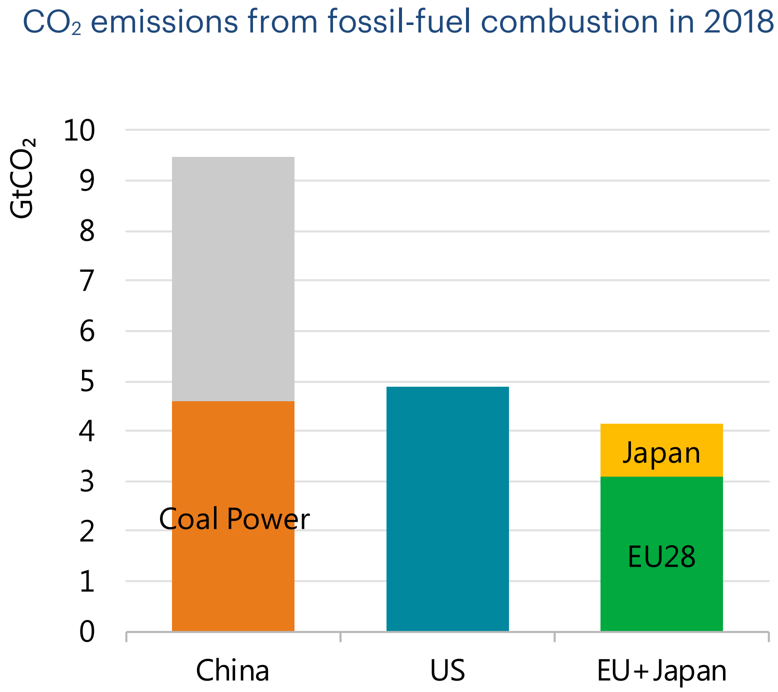
Coal-fired power plants account for almost half of China's CO_2 emissions from fossil-fuel combustion. Reducing emissions from coal-fired power plants will therefore be essential to reach China's low-carbon goals, and these plants will be the key sources covered by the ETS.

This report investigates the potential implications of the proposed ETS design for China's coal-fired power fleet. It is part of an ongoing project examining how the national ETS can contribute to China's clean energy transition. Supported by the IEA Clean Energy Transitions Programme, it will be followed by an in-depth analysis of the ETS, including effects on gas-fired power plants and the entire power sector to 2035.

The ETS will co-exist with current policies that directly affect coal-fired power plants in China. This reports begins by clarifying the institutions and policies regulating coal-fired plants, and by analysing coal-fired plant development trends. It then assesses the effect of the ETS design on coal-fired plants by sub-technology at national, provincial and company levels, and identifies key findings and recommendations.

China CO_2 emissions from coal-fired power plants increased between 2000 and 2018 to reach 4.6 $GtCO_2$





Sources: IEA (2019a), CO_2 Emissions from Fuel Combustion 2019 and IEA (2019b), World Energy Outlook 2019 for 2018 data

China's clean energy transition will rest heavily on its current coal-fired power fleet

China's coal-fired power sector has experienced remarkable growth over the past 18 years, guaranteeing energy security and affordability while keeping pace with growth in demand for power and heat. The key challenges now are reducing overcapacity and the environmental footprint of coal power.

Installed coal power capacity has quadrupled since 2000 from 222 gigawatts (GW) to 1 007 GW in 2018, mainly driven by the deployment of larger and more efficient supercritical and ultra-supercritical plants since 2005. As a result, average coal plant efficiency improved from 30% in 2000 to 39% in 2018, making China's coal fleet one of the world's most efficient.

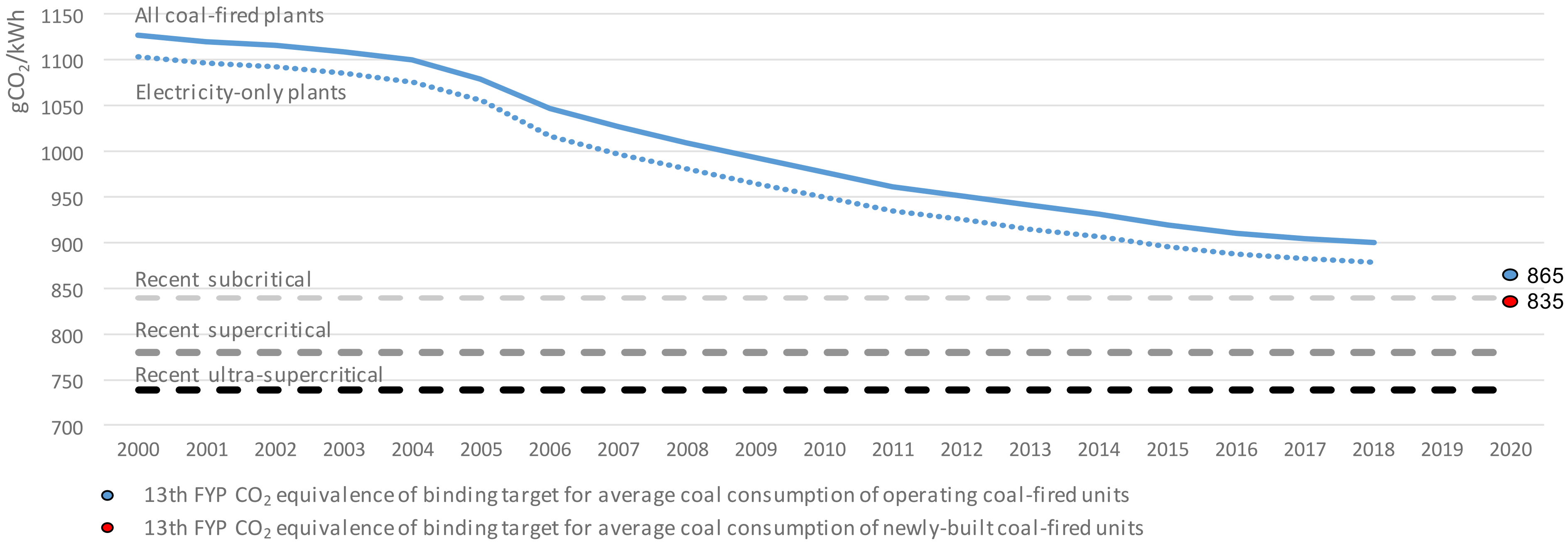
China also has the largest and one of the youngest coal power fleet. Nevertheless, subcritical plants still account for a large part of China's coal power capacity, of its power and heat generation, and of its CO_2 emissions. CO_2 intensity improvements have been slowing down in recent years and large amounts of CO_2 emissions may be locked in for decades.

CO_2 emissions from coal-fired power plants reached 4.6 gigatonnes (Gt) in 2018, surpassing the emissions from fossil-fuel combustion of the European Union and Japan combined. Ten of China's provinces account for two-thirds of the country's CO_2 emissions from coal-fired power plants and the "big five"[1] state-owned power companies by capacity account for 50%.

[1] CHN Energy, Huaneng, Huadian, Datang and State Power Investment Corporation.

Efficiency improvements rapidly decreased CO_2 intensity, though the trend has slowed recently

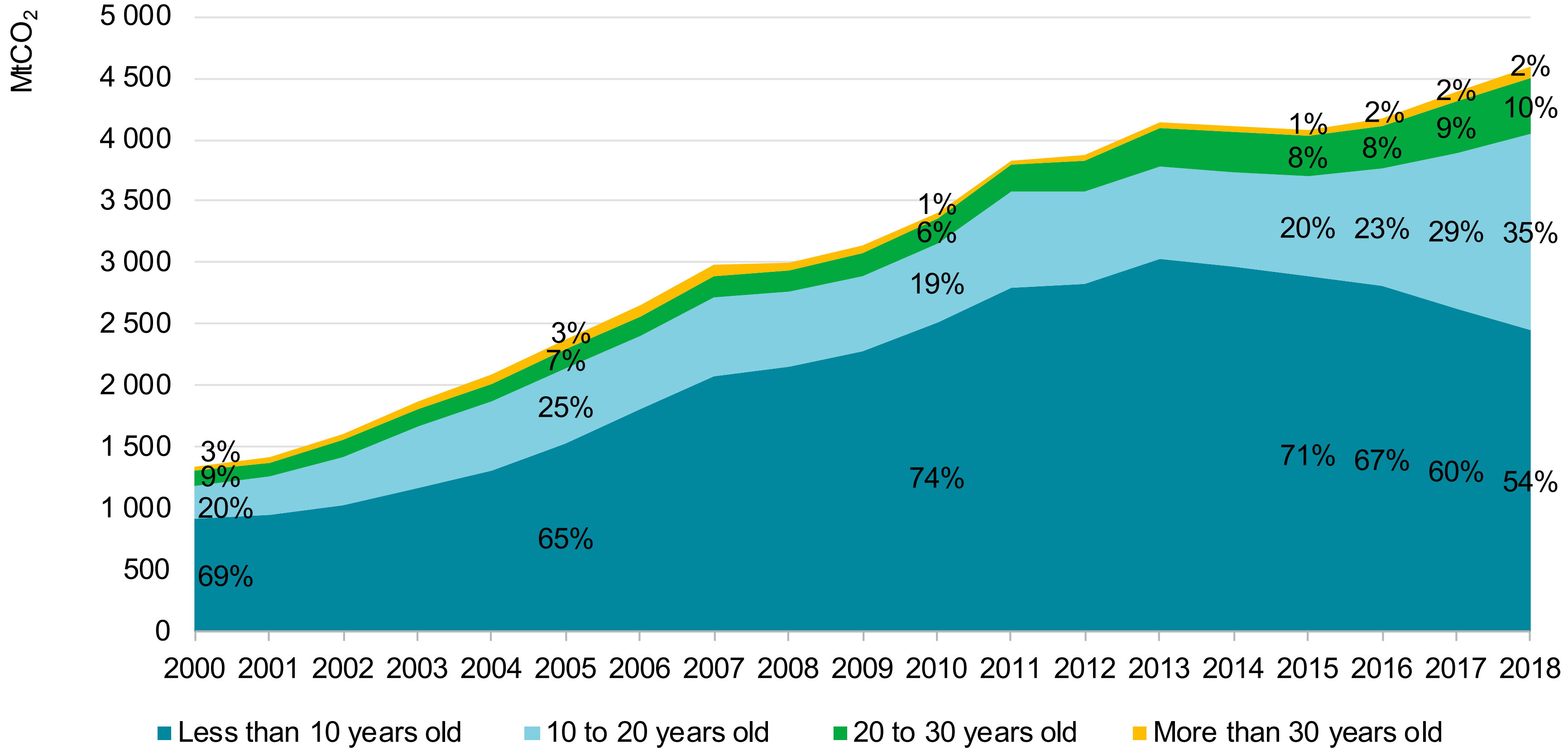
Average CO_2 intensity of power generation from coal power plants



Note: Heat generated from CHP plants is not taken into account in the 13th Five-Year Plan average coal consumption targets, which only cover power generation. The CHP fleet is older hence less efficient on average, which increases the average CO_2 intensity of power generation from coal-fired plants compared with the average CO_2 intensity of power generation from electricity-only units. CO_2 intensity target from the average coal consumption target for operated coal plants is stated in the 13th Five-Year Plan for Power Development, which corresponds to the use of the CO_2 fuel factor for "other bituminous coal" (i.e. 95 $kgCO_2/GJ$).

The low average age of China's coal power fleet potentially locks in large amounts of CO_2 emissions for the next decades

CO_2 from coal-fired power plants (segmented by plant age ranges)



Note: Age is defined as the weighted average age of capacity.

Repurposing, retrofitting and retiring coal capacity

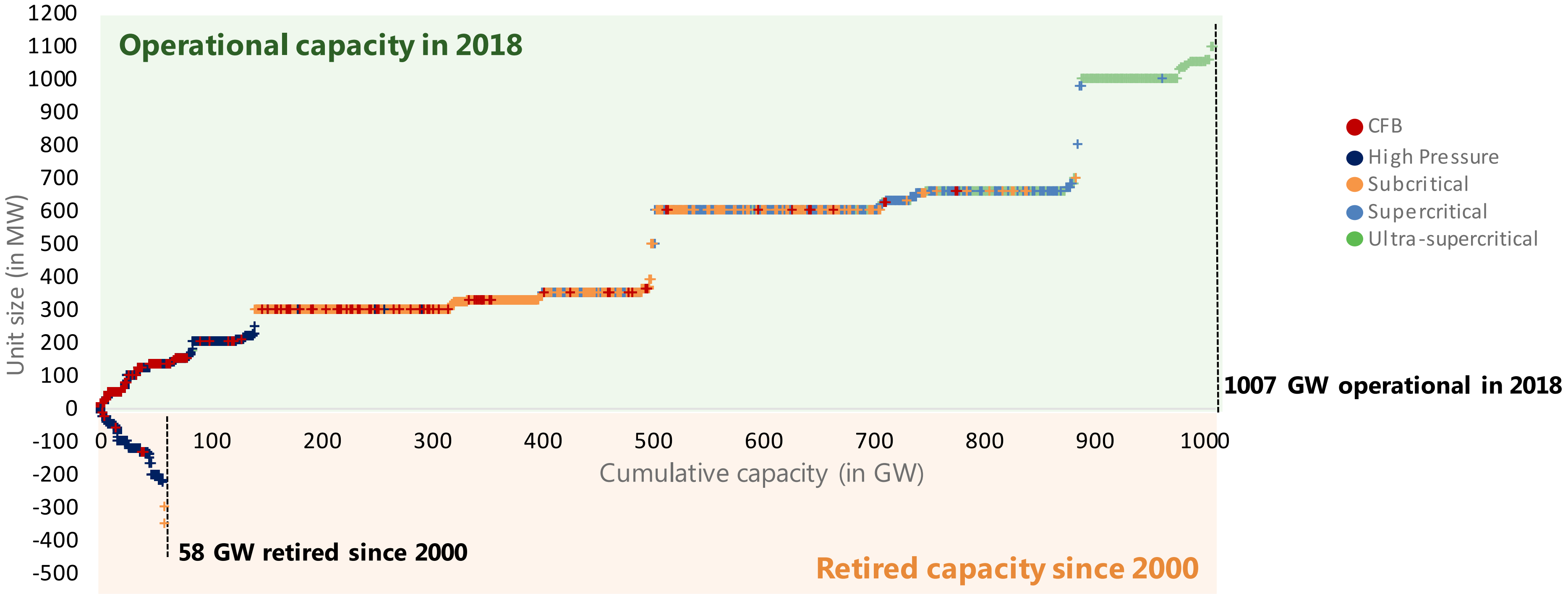
Managing the existing coal-fired power fleet to reduce emissions will be key to China's clean energy transition. Emissions could be reduced by managing plants better; retrofitting plants, including with carbon capture, utilisation and storage (CCUS); and retiring inefficient plants before the end of their expected lifetimes. Any newly built coal capacity will make a successful clean energy transition harder to achieve.

China is still planning to build new coal capacity for various reasons such as to provide jobs, increase local economic growth, provide flexibilty for greater integration of renewables, as well as satisfy heat demand while improving the efficiency of its existing fleet of combined heat and power (CHP) plants. One option to manage emissions reductions is to match each new coal capacity addition with a retirement plan for old and less efficient units, to keep a balance of zero net coal capacity additions.

Retirement of coal-fired power plants in China will have to move beyond small plants and increasingly focus on large, as well as aging, CHP plants. Repurposing existing efficient supercritical and ultra-supercritical electricity-only units to CHP could be an alternative way to avoid the construction of new CHP units.

To date only small and inefficient circulating fluidised bed (CFB), high pressure and subcritical units have been retired

Installed capacity in 2018 (top) and retired units since 2000 (bottom)



Accelerating the transformation of China's coal power with the support of the ETS

Regulation and market-based measures could be mutually supportive ways to reduce CO_2 emissions significantly in the medium to long term. China's national ETS, and particularly its monitoring rules, should dramatically improve the availability and quality of emissions data, which in turn can improve plant operation and emissions management overall. Based on experience elsewhere, covered companies will also build up carbon management capacity and integrate a carbon cost for their medium- to long-term decision making.

The chosen allowance allocation, output-based and relying on benchmarks, will create incentives to increase the efficiency of existing coal-fired power plants. In the short term, the ETS creates an incentive for high-emission coal plants to improve their CO_2 emission factor, for example by investing to improve efficiency or by burning higher-quality coal. It could also encourage companies to shift generation from less efficient to more efficient plants within their portfolio. In the longer term, the ETS will motivate companies to shift investments from subcritical (or even less efficient) plants to supercritical and ultra-supercritical plants. In addition, the ETS would favour the phase-out of smaller and less-efficient circulating fluidised bed (CFB), high pressure and subcritical coal plants.

The ETS draft allowance allocation plan may result in large overallocation

The CO_2 fuel factor (the amount of CO_2 emitted per unit of fuel) that is used for monitoring emissions from coal will be decisive for the stringency of the entire ETS given the dominance of coal-fired power plants. A high default factor is applied to plants that do not monitor their CO_2 fuel factor, which is a good incentive to improve monitoring. However, the more units are monitored, the higher the surplus of emissions allowances will be, as monitored fuel factors will be well below the default value.

Among the benchmark options currently considered by Chinese regulators, a single benchmark for conventional coal (Option 1) would result in a more stringent ETS than two benchmarks differentiated by plant size (Option 2). Moreover, two benchmarks may produce counterproductive outcomes by encouraging generation from less efficient plants covered by a weaker benchmark, rather than from more efficient ones covered by a more stringent benchmark.

The benchmark values are the most lenient for larger conventional coal-fired power plants, no matter the option or whether fuel factors are monitored. This results in an overall allowance surplus.

The more units are monitored, the higher the surplus

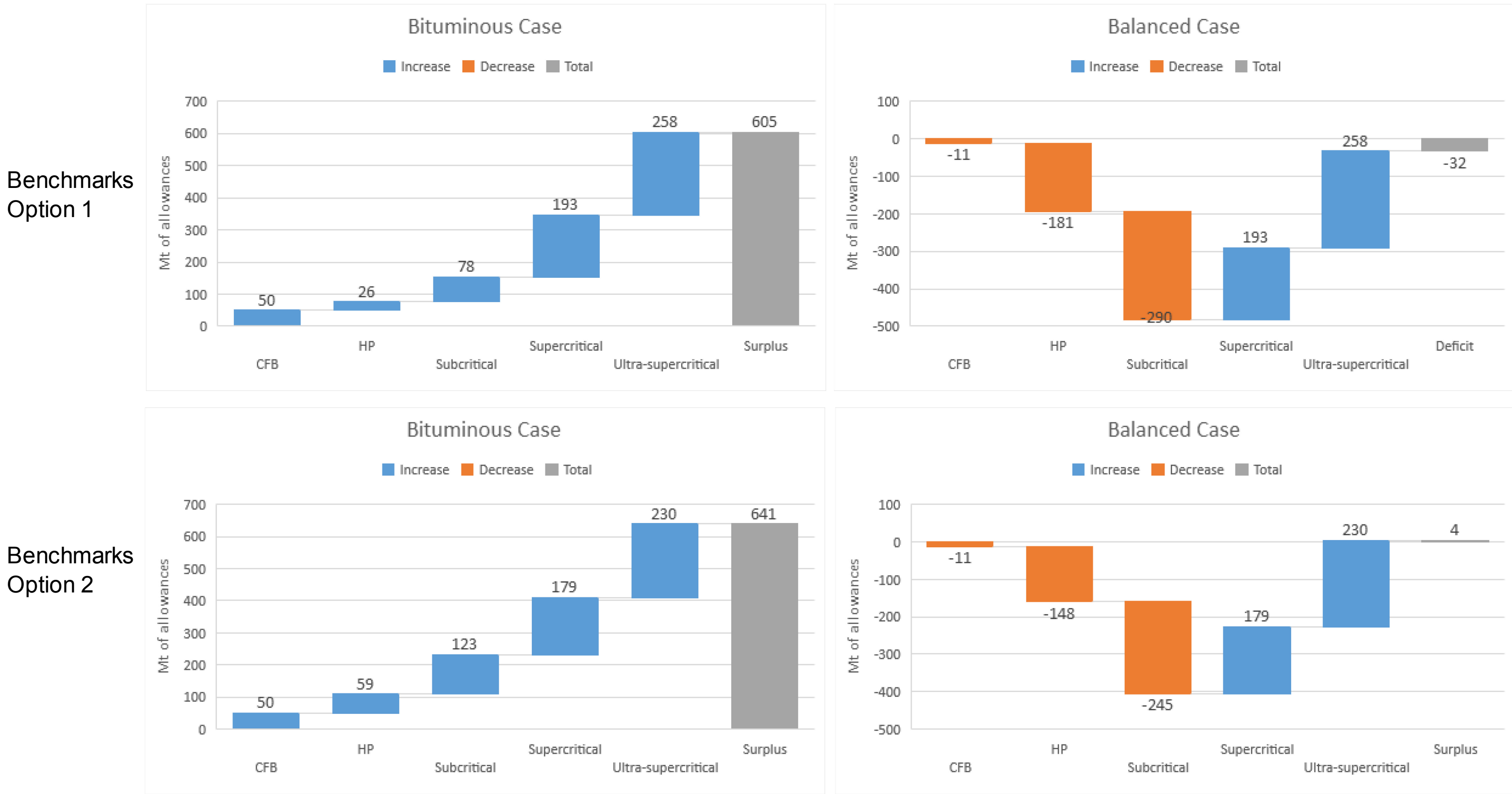
Surplus or deficit is sensitive to the share of units monitoring CO_2 fuel factor

Scenario cases	Number of unit	Power and heat generation (TWh)	Reported CO_2 emissions ($MtCO_2$)	Allowance allocation (Benchmark Option 1)			Allowance allocation (Benchmark Option 2)		
	Share	*Share*	*Share*	Net Balance			Net Balance		
Bituminous Case:						605			641
Monitored Factor: all units	*100%*	*100%*	*100%*	605			641		
Default Factor: none	*0%*	*0%*	*0%*		0			0	
Balanced Case (BC):						-32			4
Monitored Factor: super and ultra-supercritical units, subcritical and CFB **above 600 MW**	*27%*	*54%*	*47%*	487			433		
Default Factor: high pressure, and subcritical and CFB **below 600 MW**	*73%*	*46%*	*53%*		-519			-429	
Default Case:						-752			-716
Monitored Factor: none	*0%*	*0%*	*0%*	0			0		
Default Factor: all units	*100%*	*100%*	*100%*		-752			-716	

Notes: in green: Deficit; in red: Surplus. The IPCC 2006 guidelines for "other bituminous coal" of 95 $kgCO_2/GJ$ is taken as an average value for the monitored CO_2 fuel factor. For non-monitored units, the default factor set out in China ETS reporting rules of 123 $kgCO_2/GJ$ is applied.The scale of the surplus will depend on the average monitored value of the CO_2 fuel factor for the coal fleet, which may differ slightly from the assumed value.

Under the draft plan, one benchmark for conventional coal would be more stringent, though it remains lenient for larger plants

Allowance balance under different benchmark options and CO_2 fuel factors



Note: Ultra-supercritical and supercritical plants and units above 600 MW generate most of the surplus, confirming that the conventional coal benchmark above 300 MW is not very stringent – especially given the increasing share in power generation of such plants.

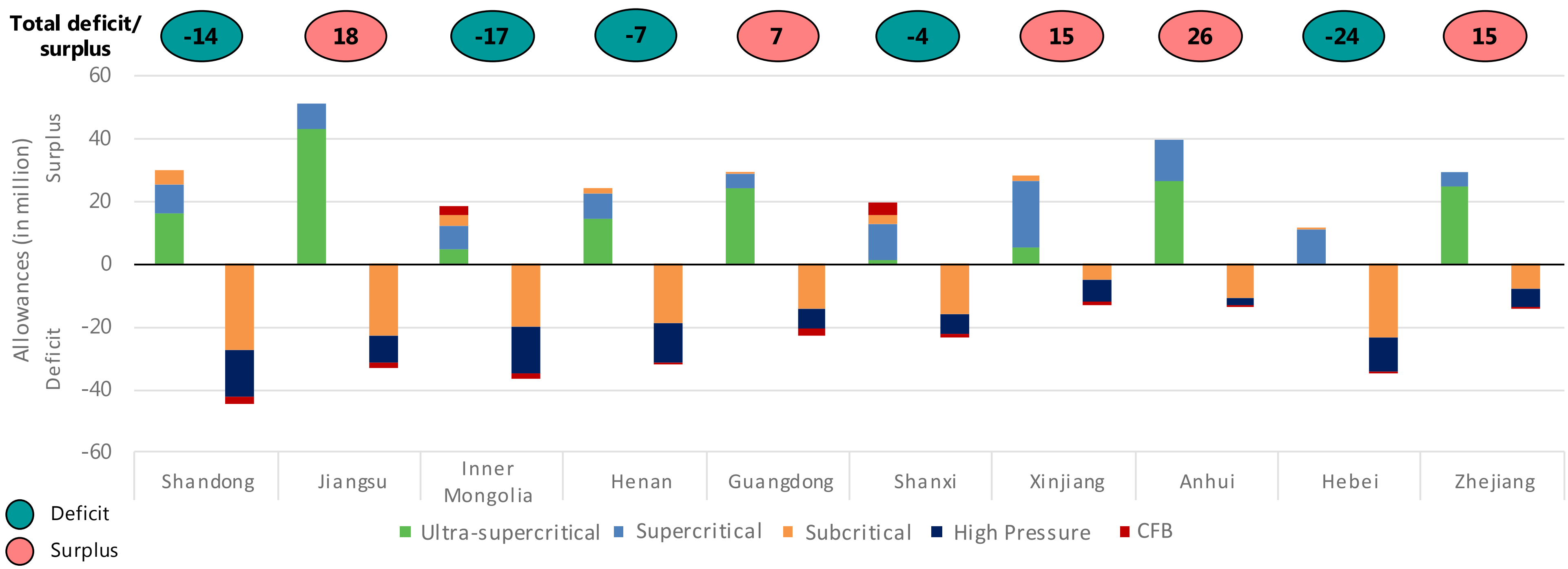
Addressing distributional effects and equity between provinces and companies

Distributional questions on a provincial level arise as units in some provinces generate large allowance surpluses, while others generate large deficits.This is especially true for three of the "big five" state-owned power companies that will generate monetised allowance surplus of CNY 1.75 billion (Yuan renminbi), while all other companies combined would face a carbon cost of CNY 1.5 billion in the Balanced Case, in which only a share of coal power units monitor their CO_2 fuel factor.

Policymakers should pay close attention to the large extremes of allowance surplus and deficits on a provincial and company level, especially for the ten provinces and five state-owned power companies with the largest coal-fired power capacity.

Five out of the ten largest provinces by coal power capacity will generate allowance surpluses, while other five generate deficits

Allowance balance by technology and province in the Balanced Case – Option 2



The ETS will need to be considered within the relevant policy landscape

The ETS needs to be designed so that it can be adjusted and adapted to policies that affect its functioning. For example, any rapid changes in the capacity mix – such as a plan to retire large amounts of coal-fired power capacity over a short period (e.g. by the end of 2021) – will increase the allowance surplus dramatically if this possibility is not taken into account in the benchmark setting.

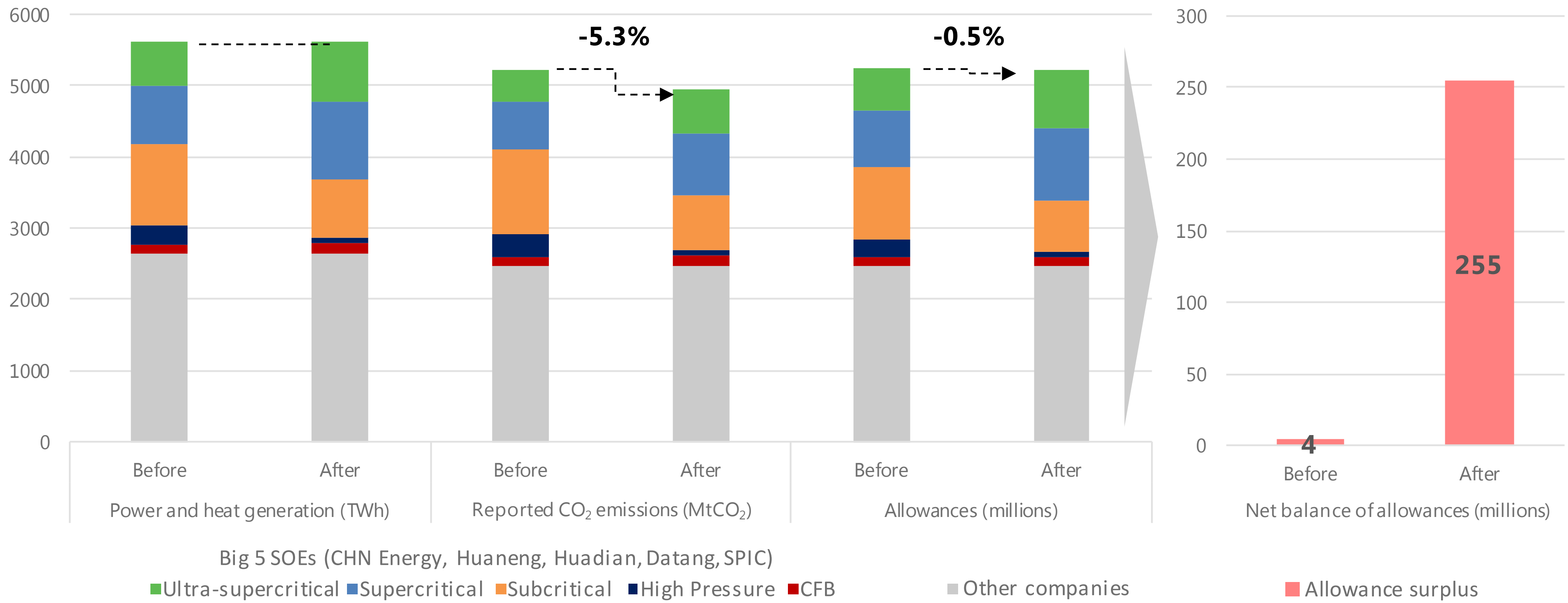
The effectiveness of the ETS will be closely related to progress with power market reform, in particular for power dispatch. Dispatch is currently governed by the "three equals system" that allocates each plant a defined full load hours by technology.

Without a reform of dispatch, the ETS will have a limited role in reducing power sector emissions, because coal-powered units will not be able to adjust their operation in response to the price signal stemming from the ETS allowance allocation.

A clean energy transition of the power sector will also require policies that support low-carbon energy generation. Since the current ETS covers only coal- and gas-fired power plants, it will have limited influence on reducing the share of coal power in the total generation mix. Entities can receive surplus allowances for their supercritical and ultra-supercritical plants, but currently receive no surplus by investing in low-carbon power technologies such as renewables. This situation may even have the perverse outcome of making the most efficient coal power plant more economically competitive than renewables.

If large-scale retirements are not considered in the ETS allowance allocation, a huge allowance surplus will be generated

Impact of retiring 150 GW for the five largest SOEs in the Balanced Case – Option 2 on power and heat generation, reported CO_2 emissions and allowances (left). Net balance of allowances in millions (right)



Note: Reported CO_2 emissions are sensitive to the CO_2 fuel factors used in reporting, thus do not necessarily correspond to actual emission levels.

Policy recommendations

Improving the current benchmarks

The benchmarks for coal-fired power plant CO_2 emissions should be enhanced to better reflect the expected policy ambitions regarding the existing coal plant fleet and to avoid significant overallocation of allowances, which would jeopardise the functioning of the ETS.

The high default CO_2 fuel factor, which is 20% higher than the worse type of coal in term of CO_2 emissions, is a good incentive for power entities to monitor their CO_2 fuel factors. However, it should not increase the value of the benchmark, which would result in an oversupply of allowances.

Implementing fewer benchmarks for different coal sub-technologies would result in higher effectiveness and greater equity with regard to the allowance allocation and reduction of CO_2 emissions. Multiple benchmarks are usually used to address distributional effects of allowance allocation between technologies. However, equity issues could be resolved by other means (e.g. financial support). Avoiding the use of multiple benchmarks would support power sector reform, since it would encourage reducing the use of less efficient plants and increasing operation of more efficient ones.

Options for ETS design

Introducing allowance auctions could create a new revenue stream that could be used to address equity issues between provinces and between entities. Before a full auction system is in place, earmarking funds generated from allowance surpluses for low-carbon investments can also help finance China's clean energy transition in various ways, including research and development (R&D), innovation, and labour force retraining and redeployment.

The ETS could be a central pillar of China's power sector transformation if designed differently. Merging coal and gas benchmarks, including with CCUS, and expanding the ETS to cover low-carbon energy sources, such as wind and solar photovoltaic (PV), could greatly reduce power sector CO_2 emissions, and could support or even substitute policies such as coal consumption targets or feed-in-tariffs for renewables.

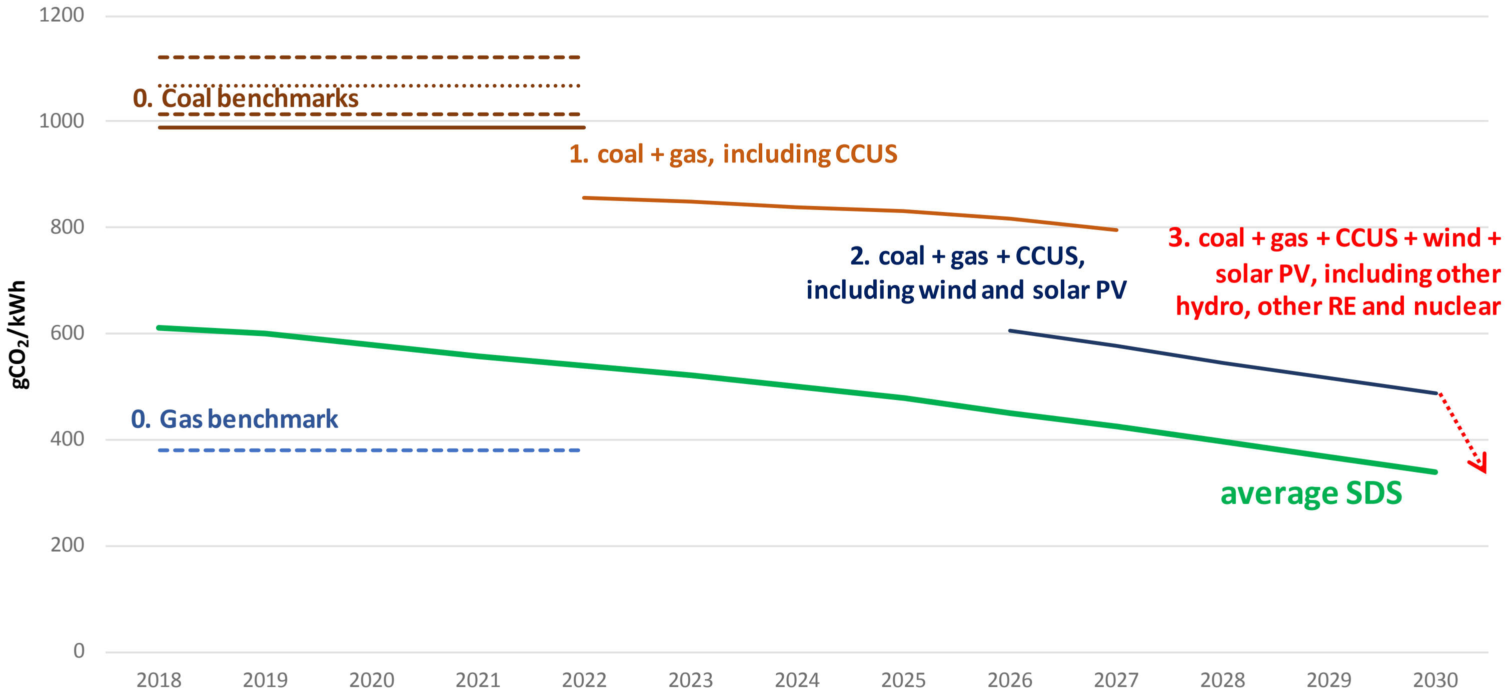
Using the current rate-based allowance allocation system when expanding the ETS to manufacturing sectors would increase complexity and therefore be more challenging. A system with an absolute cap and a mass-based allocation design could be considered as an alternative.

Suggested priorities for China's national ETS implementation

1. Launch the first compliance period of the ETS for the power sector in 2020, with more stringent benchmark levels and with a single benchmark for conventional coal (Option 1).
2. Collect unit-level data and encourage units to monitor their CO_2 fuel factors.
3. Adjust and strengthen the benchmark values, taking into consideration 2020 data, including changes in monitored units for the next compliance period.
4. Integrate auctioning to create a useful revenue stream, and use targeted measures to address distributional issues and to guarantee power and heat security and affordability.
5. Define the ETS role, and develop a roadmap and timeline for a multi-step approach to: merge benchmarks including other power technologies (CCUS, low-carbon and renewables); define CO_2 absolute cap trajectory; and integrate more advanced ETS flexibility mechanisms.

A clear roadmap for ETS evolution will support the implementation of a multi-step benchmark approach for the power sector

Multi-step approach: Merging benchmarks progressively to keep track with the power decarbonisation trajectory



Note: The IEA Sustainable Development Scenario (SDS) outlines a major transformation of the global energy system to deliver simultaneously on the three main energy-related Sustainable Development Goals (air pollution, energy access, climate change). In the SDS, China's energy system transforms significantly by 2050, to be aligned with China's "ecological civilisation" vision. The CO_2 intensity of the power sector in the SDS reaches 340 g/kWh in 2030, a 45% decrease from the 2018 level of 613 g/kWh.

Improving policy co-ordination

The 13th Five-Year Plan (2016-20) set average coal consumption targets of 310 grams of standard coal equivalent per kilowatt hour (gsce/kWh) for operating coal power plants and 300 gsce/kWh for newly built plants by 2020. These targets can also be translated into emissions intensity levels, which would act in parallel with the ETS allocation benchmarks. Achieving the energy conservation targets would result in an average CO_2 intensity for operating coal-fired power plants far below the benchmark levels for both allowance allocation options, thus increasing allowance surplus. Aligning the ETS benchmarks with the more stringent energy conservation targets would avoid this counterproductive effect. With the benchmarks aligned with coal consumption targets, the ETS could be a market-based means of achieving the binding Five-Year Plan targets.

Better plant management, retrofitting and retirement of less efficient plants will also be needed to achieve a clean energy transition. Complementary regulations and measures, such as ministry, industry or local government plans for retiring coal plants, will be required to avoid the potential lock-in of CO_2 emissions. However, these will always need to be taken into account in the ETS design.

The ETS and power market reform could – and should – be mutually supportive. Dispatch reform could enable and amplify the expected operation and investment impacts of the ETS, while ETS allocation design and any future use of auction revenues can support power market reform. These measures can accompany decreasing coal plant use by allowing plants to operate more flexibly and provide ancilliary services.

More co-ordination between the ETS and policies regulating the energy sector could be mutually supportive to achieve the most efficient and effective emissions reductions and distributional outcomes.

The 14th Five-Year Plan (2021-25) provides a great opportunity to guide coal power development in line with China's concept of ecological civilisation. Measures to be considered include more stringent energy consumption targets for the coal fleet in operation and for newly built units; large-scale retirement of old and less efficient high pressure and subcritical plants; defining goals and targets for the national ETS with more ambitious benchmarks; and accomplishing the power market reform. For example, a zero net coal capacity addition target by 2025, coupled with an inspirational long-term coal capacity vision for 2050, could provide a clear and stable signal to guide investment and operation decisions.

Introduction

Coal is at the core of China's power and heat generation

In 2018, CO_2 emissions from coal accounted for 44% of the world's total CO_2 emissions from fossil-fuel combustion (33 $GtCO_2$), with two-thirds emitted by coal-fired power plants alone (Figure 1). China has about half of the world's installed coal-fired capacity, with around 1 000 GW (Figure 2). Since 2000, China's CO_2 emissions from fossil-fuel combustion have more than tripled, reaching 9.5 $GtCO_2$ in 2018. CO_2 emissions in China may continue to increase slightly and should peak before 2030 to be in line with China's Nationally Determined Contribution to the Paris Agreement on climate change. CO_2 emissions from coal-fired power plants, including electricity only and CHP units, reached 4.6 $GtCO_2$ in 2018, which accounted for almost half of China's CO_2 emissions from fossil-fuel combustion. This represented around one-seventh of global emissions, surpassing the CO_2 emissions from fossil-fuel combustion of the European Union and Japan combined.

Coal also dominates heat generation in China. Since 2000, China's power and heat generation from coal-fired power plants has almost quadrupled. In 2018, coal-fired power plants generated 70% of China's power and heat and emitted 97% of China's CO_2 emissions from power and heat generation.

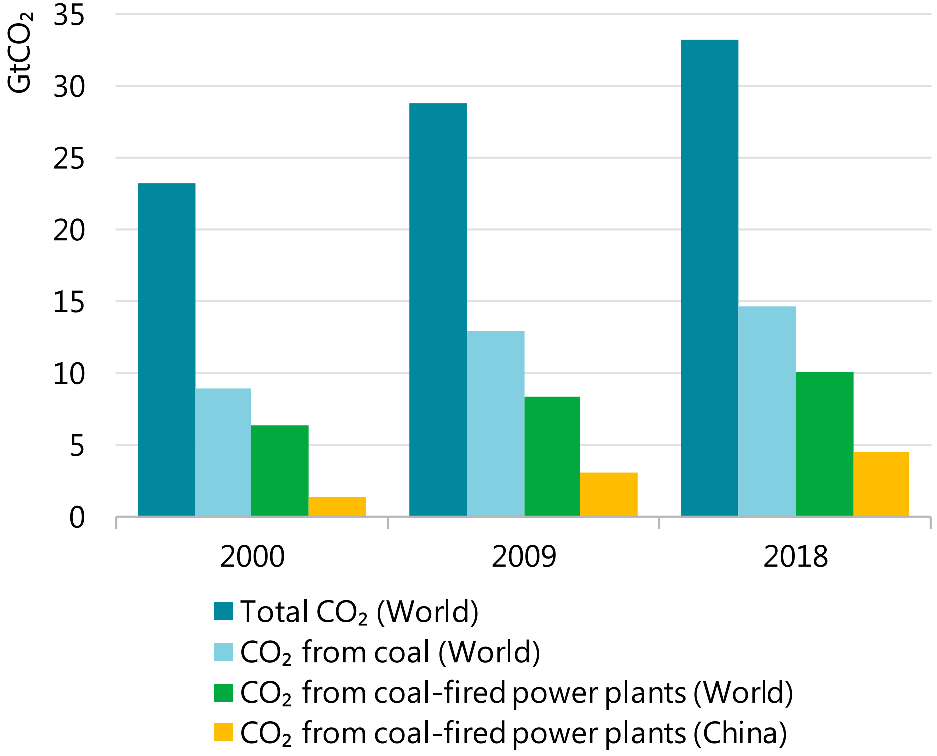
Although shares of low-carbon energy sources and gas in power generation are increasing, absolute generation from coal-fired plant continues to grow, because clean energy deployment alone still can not meet the growing power demand in China. Coal-fired power plants impose a major challenge to realise the "Beautiful China" vision put forward by President Xi Jinping. China needs ambitious policy and regulatory measures focusing on the coal-fired power plants to achieve its clean energy transition.

In its 13th Five-Year Plan (2016-20), China adopted the 2020 Energy Conservation Targets for both operating and newly built coal-fired units. As an important complement to these measures, in 2017 China decided to use a market-based policy instrument by implementing a national emissions trading scheme (ETS) to control and reduce its CO_2 emissions in a cost-effective manner. The first compliance period is expected to start in 2020. The national ETS will first cover coal- and gas-fired power plants (around 4.7 $GtCO_2$) with an output-based allowance allocation: plants will receive emissions allowances proportional to their current generation levels, relying on fuel- and technology-specific benchmarks. The design of China's ETS is to be finalised this year, and as such it is important to understand the impact and implications of current design discussions on coal-fired power in particular.

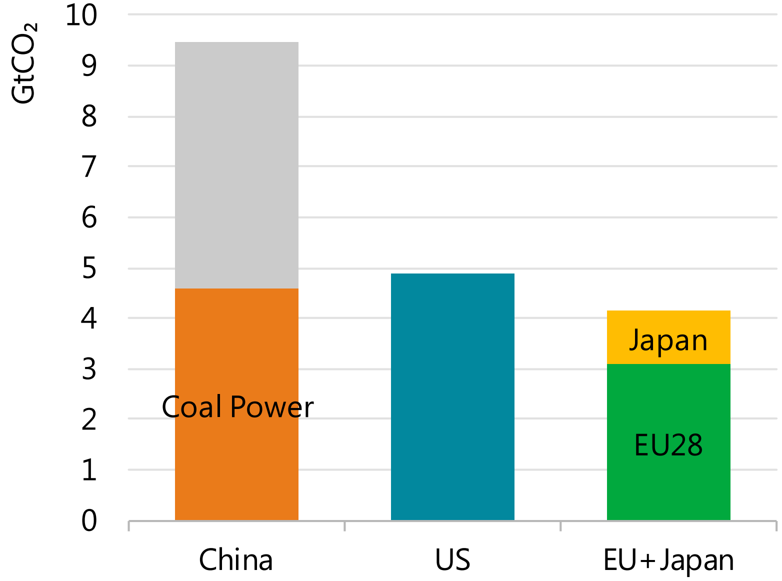
In this context, this paper first identifies the institutions and policies regulating coal power and analyses coal-fired power development trends. It then presents a preliminary assessment of how the current ETS draft design could affect coal-fired power plants by sub-technology at national, provincial and company levels. It concludes by identifying key findings and recommendations, as well as avenues for future analysis.

China CO_2 emissions from coal-fired power plants, including CHP, increased between 2000 and 2018 to reach 4.6 $GtCO_2$

Figure 1: CO_2 emissions from fossil-fuel combustion



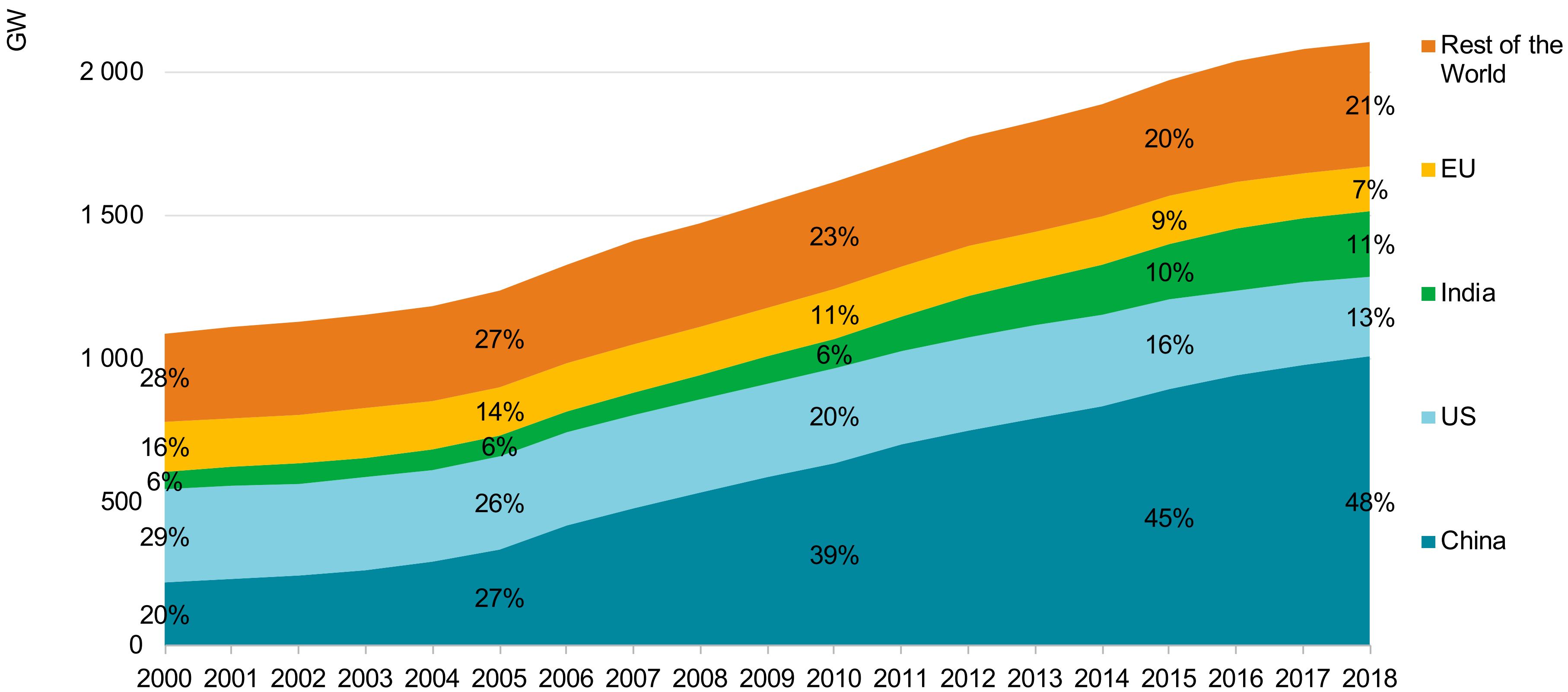
CO_2 emissions from fossil-fuel combustion in 2018



Sources: IEA (2019a), CO_2 Emissions from Fuel Combustion 2019 and IEA (2019b), World Energy Outlook 2019 for 2018 data.

Global installed coal capacity doubled to 2 100 GW between 2000 and 2018, mainly led by China

Figure 2: Installed coal-fired capacity



Sources: IEA (2019c), *World Energy Balances 2019*.

Energy and climate policymaking in China

Overview of China's energy and climate governance structure

Since taking office in 2013, President Xi Jinping has called for energy sector reform and pledged sustainable economic development. Driven by both domestic concerns and international commitments, China is pushing for a clean energy transition. Over the past two decades, the government has adopted numerous energy and climate policies and targets, including the internationally agreed climate targets set out by the Paris Agreement.

The development and implementation of China's energy and climate policies requires co-operation between ministries, commissions and state-owned enterprises (Figures 3 and 4). Within China's parallel Communist Party governance structure, these entities' competences are distributed from the national level down to the provincial and subordinate levels. The Communist Party appoints officials for the central and local governments, with each level supervised both by the party and higher-ranking government branch up to the State Council (which is supervised only by the party). The State Council, chaired by the premier, is the chief administrative authority in China. The State Council supervises commissions, ministries and organisations at national level and the subordinate provincial governments.

The key national agencies for energy and climate policies are the National Development and Reform Commission (NDRC), the Ministry of Ecology and Environment (MEE), the Ministry of Science and Technology (MOST), the Ministry of Finance (MOF), the Ministry of Foreign Affairs (MFA), the Ministry of Industry and Information Technology (MIIT) and the State-owned Assets Supervision and Administration Commission of the State Council (SASAC).

The NDRC is in charge of developing and implementing economic reform, which includes preparing China's national Five-Year Plan, leading power sector reform and approving infrastructure projects throughout China. The National Energy Administration (NEA), under the NDRC, plans and drafts China's strategy and policy governing the energy sector. The NDRC and the NEA are the major authorities that regulate the power sector in China.

The MEE is the national environmental policy and enforcement body, which monitors pollution, develops environmental plans, strategies and standards, including China's Nationally Determined Contribution (NDC) under the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement, and implements the national ETS. The MFA manages China's international relations and treaty agreements, and shares responsibilities with the MEE for climate negotiations.

The MOST drafts and implements science and technology policies, hosts the administrative Centre for China's Agenda 21 (ACCA21) and develops national R&D and innovation programmes. The MOF administers the national budget and manages taxes and the social security fund. The MIIT is responsible for the administration of China's industrial branches and information industry, which plays a key role in industry energy conservation and electric vehicle-related regulations and programmes. The SASAC supervises and manages state-owned enterprises, including large power, oil and gas companies, as well as the industry associations such as the China Electricity Council.

The provincial governments play an essential role in implementing policies from the central government and engaging in local policymaking. Their structure is similar to that of the central government, with parallel party and government supervision and departments that focus on different sectors. The provincial governments have the same rank as central government ministries, meaning that provincial governments and ministries are both directly supervised by the State Council and they collaborate in adopting and implementing polices with limited leeway.

Figure 3: Overview of major climate and energy policy organisations

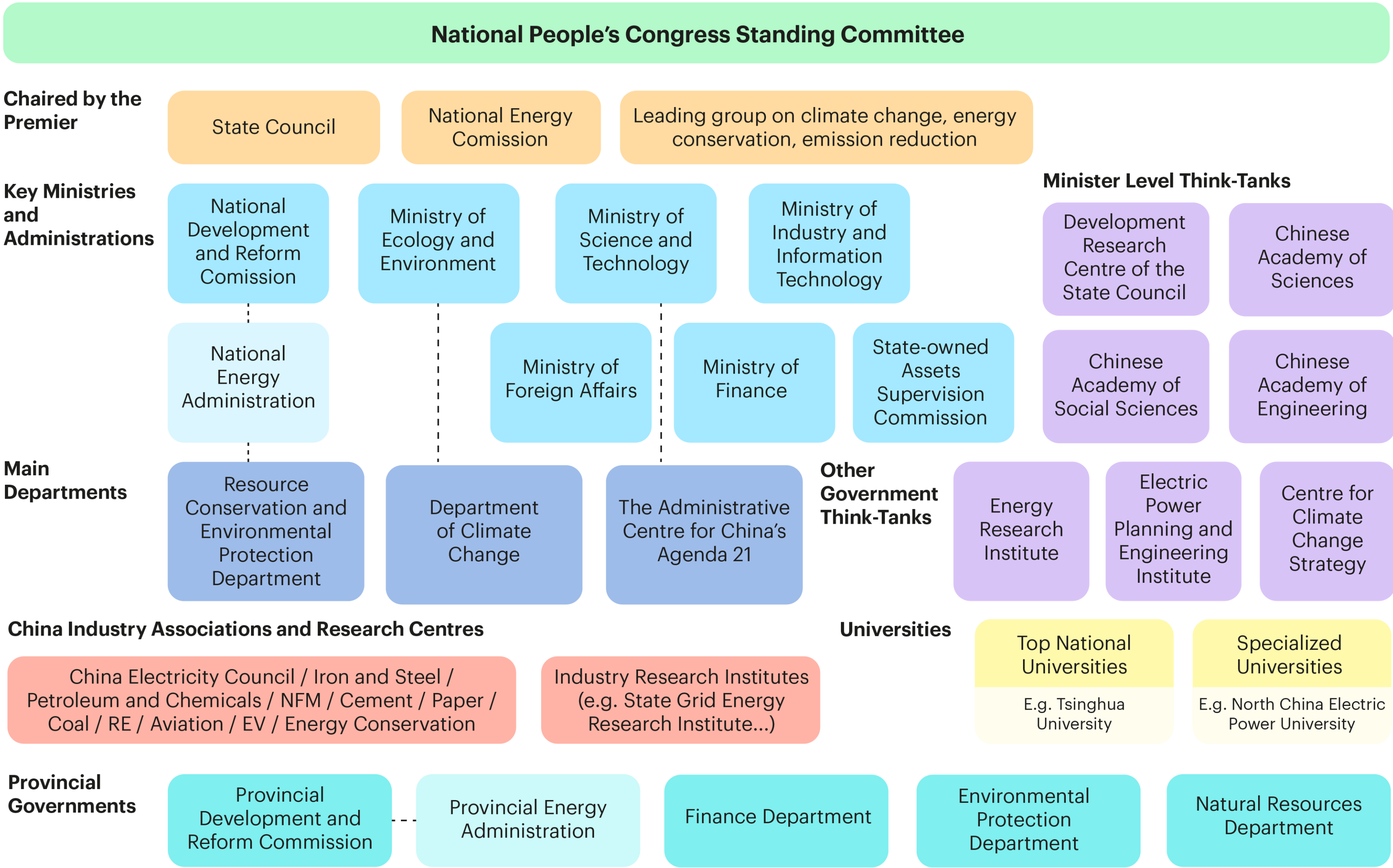
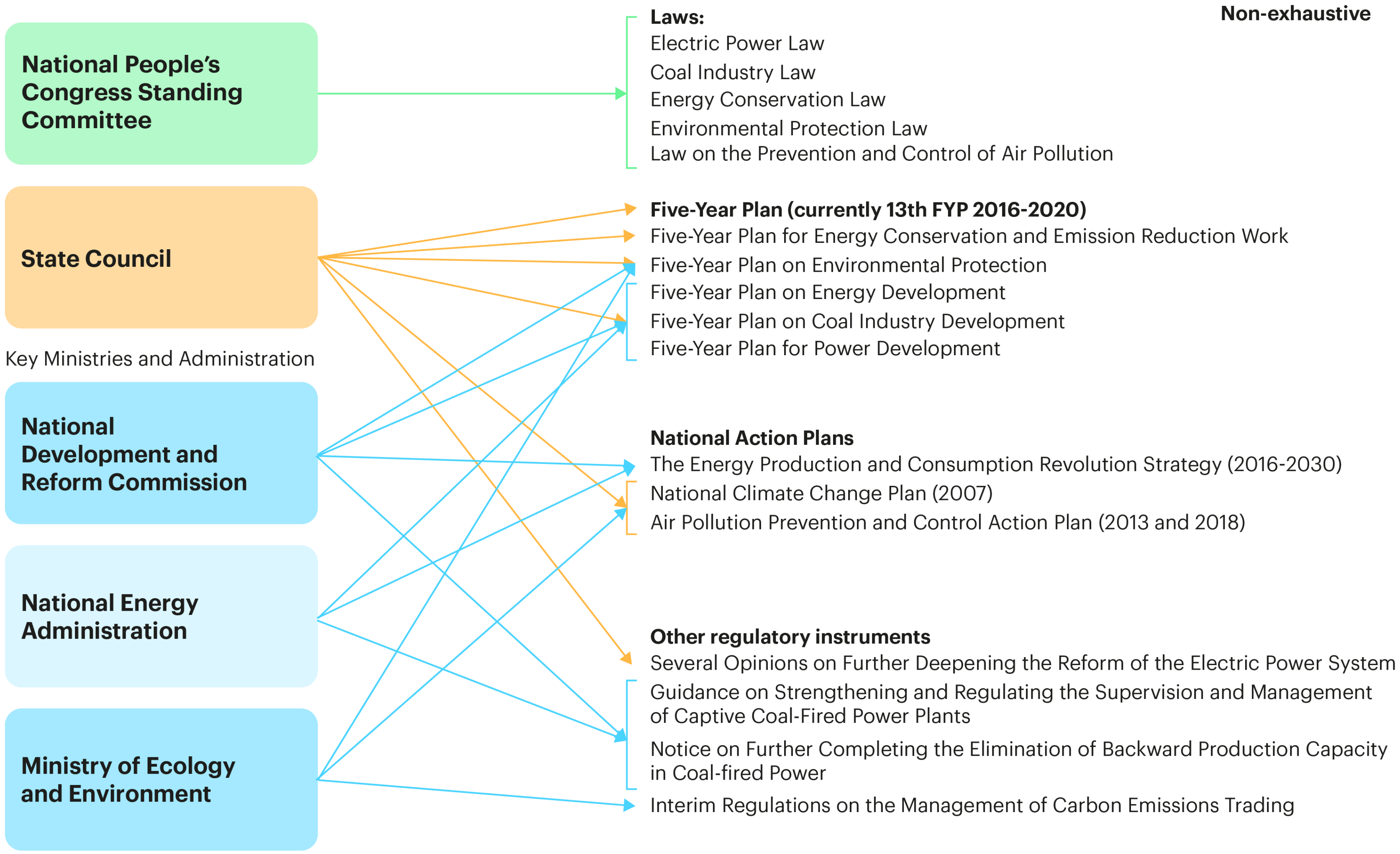


Figure 4: The planning authorities regulating China's power and heat sector and key policies concerning coal plants



Brief overview of the development of China's energy and climate policies

Policies and measures related to climate change mitigation or energy sector reform first emerged in China in the late 1980s. The first Environmental Protection Law was introduced and executed in 1989. Following the establishment of the Co-ordination Committee on climate change under the Environmental Protection Committee of the State Council in 1990, China joined the UNFCCC in 1992 and signed the Kyoto Protocol in 1998. During the 1990s, many energy and climate policies and measures were adopted, including the Law on the Prevention and Control of Air Pollution, the Electric Power Law, the Coal Industry Law, the Energy Conservation Law, the Ten-Point Strategy for China's Environment and Development, and China Agenda 21. Sustainable development was included in China's 9th Five-Year Plan (1996-2000) for the first time.

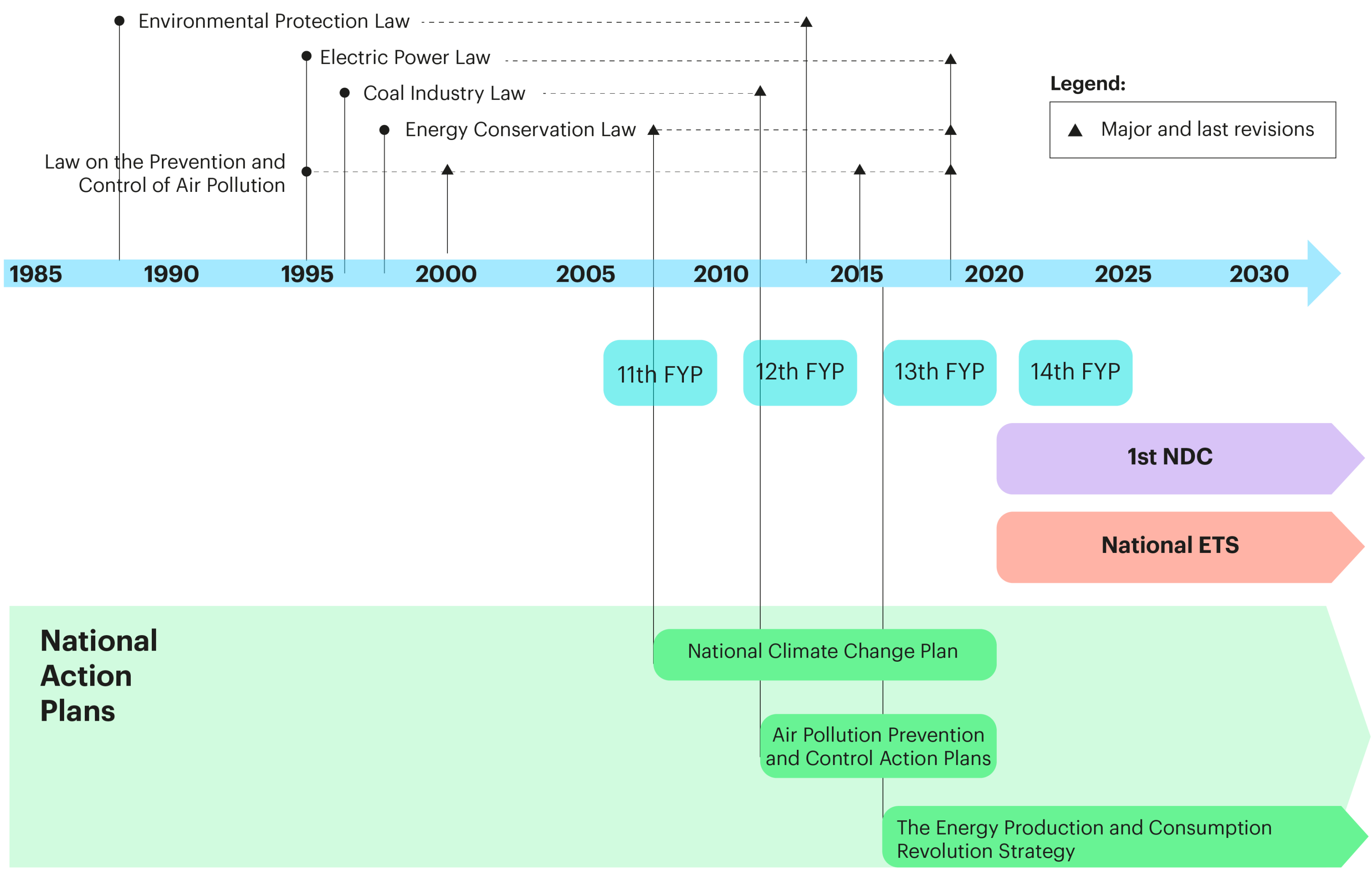
The Five-Year Plan is the main planning and policymaking system in China. In this process, the central government gathers and analyses information, establishes national targets, defines directions for the ministries and local government, and co-ordinates implementation and monitoring. Once the National Five-Year Plan is published, a multitude of sector- and technology-specific Five-Year Plans will be published by relevant ministries. Provincial Five-Year Plans will also be created to define the local contribution and implementation to achieve the national Five-Year Plan. A rich policy package with laws, regulations, yearly action plans and guidelines is introduced and adopted nationally and locally to achieve the target outlined by the Five-Year Plan. In addition to the Five-Year Plan, China also uses National Action Plans for long-term planning, generally covering 10 to 15 years. These long-term action plans guide and play important roles in ensuring coherence between Five-Year Plans and long-term visions.

Climate change was mentioned in the 10th Five-Year Plan, but not until the 11th Five-Year Plan (2006-10) were specific measures targeting climate change included (Figure 5). The 11th Five-Year Plan focused on promoting technology development and commercialisation of the renewable energy industry, and setting targets for energy efficiency. The 12th Five-Year Plan set targets to reduce energy intensity, increase non-fossil energy usage and reduce carbon intensity. The current 13th Five-Year Plan (2016- 20) sets updated goals, including a 15% share of non-fossil energy in the primary energy mix, society-wide energy conservation initiatives and grid modernisation. These measures came in the wake of President Xi Jinping's call for an "Energy Revolution" in 2014. The Energy Revolution targets reform in five areas: consumption, supply, science and technology, institutional systems and deepening international co-operation. Under this guidance, the NDRC and NEA released the Energy Production and Consumption Revolution Strategy (EPCRS) in 2017, which sets out key targets and strategies for China's energy sector in 2030. Its aim is to reduce coal use while increasing the share of non-fossil fuels in China's primary energy consumption and enhancing energy efficiency measures.

Regarding the future of coal, the 13th Five-Year Plan set national reduction targets for total coal consumption and caps on energy intensity and emission intensity for coal-fired power plants (Table 1). The subsequent 13th Five-Year Work Plan for Greenhouse Gas Emission Control reaffirmed the launch of China's national Emissions Trading Scheme (ETS) after an announcement from President Xi Jinping and finalised the ETS Legislation.

Since the 13th Five-Year Plan went into effect in March 2016, China has signed and ratified the Paris Agreement on climate change, including its own Nationally Determined Contribution (NDC), and successfully piloted carbon markets in seven regions. The 13th Five-Year Plan will end in 2020, and the final phase of the national ETS development and the NDC will take effect in 2020. The 14th Five-Year Plan (2021-25), with the post-Covid-19 stimulus response, will be critical for the success of China's clean energy transition. Co-ordinating energy and climate policymaking will be vital to implement effective policies but will also be complex and challenging.

Figure 5: Timeline of key policies and measures covering coal-fired plants



Note: The 14th Five-Year Plan (2021-25), with the post-Covid-19 stimulus response, will be critical for the success of China's clean energy transition.

Table 1: 13th Five-Year Plan's main targets affecting coal-fired power plants

Category	Target	2015	2020	Target attribute
Primary energy	Total coal consumption *(billion tonnes)*	3.96	4.1	Aspirational*
	Coal consumption *(%)*	64%	58%	**Binding***
Power structure	Coal-fired power share in power capacity mix *(%)*	59%	55%	Aspirational**
	Coal-fired power capacity *(terawatts)*	0.9	< 1.1	Aspirational*
	Thermal power capacity to retire *(gigawatts)*		20	Aspirational**
Energy conservation	Average coal consumption of operating coal-fired power units *(grams of standard coal equivalent/kWh)*	318	< 310	**Binding***
	Average coal consumption of newly-built coal-fired power units *(grams of standard coal equivalent/kWh)*		300	**Binding****
	CO_2 emission intensity of coal-fired power plants (gCO_2/kWh)		~865	Aspirational**

Sources: * NDRC and NEA (2016a), 能源发展“十三五”规划 [13th Five-Year Plan on Energy Development]; ** NDRC and NEA (2016b), 电力发展“十三五”规划 [13th Five-Year Plan for Power Development]; CEC (2018), 电力行业应对气候变化进展 (2017-2018) [Progress in the Power Sector's Response to Climate Change (2017-2018)].

China's power market regulations

China has also commenced sweeping power market reforms, starting with State Council Document #9: Deeping Power Sector reform.[2] This document laid out wide-ranging reforms aimed at improving system efficiency, reducing end customer prices, enhancing regulation of power sector entities, and increasing the role of market-based mechanisms in determining power sector operation. The National Energy Administration and the NDRC were responsible for executing many of these reforms and issued many of the subsequent policy documents.

Before these reforms, generation volumes and prices were set in negotiation with the government and were roughly the same across all units of a similar type (known as the "three equals system"). This policy was implemented to stimulate investments in generation during power shortages in the mid-2000s. The three equals system resulted in operation challenges. Less efficient plants would operate as much as efficient plants, increasing system costs and emissions, and grid operators struggled to fulfill all the volumes promised to units, so they often operated more expensive plants with higher emissions instead of efficient plants and renewables. The system also resulted in overcapacity, as the generous terms continued to drive investment even as power demand growth slowed.

To address these challenges, China began introducing markets that would move responsibility for pricing energy and setting operation volumes from governments to business. The major competitive energy markets that emerged were:

- medium- to long-term transactions, which allowed end customers to negotiate prices and volumes directly with power units or through retail companies
- spot markets, which helped identify and use the lowest-cost resources available in real-time to meet demand
- ancillary services markets, which helped identify least-cost options for flexibility to integrate renewables and maintain the grid.

These markets are already being piloted in many regions throughout China and have already influenced China's energy prices and power plant operations, reducing costs and increasing flexibility. These reforms are expected to continue to develop and expand to most provinces in China, and eventually operate through a unified market across entire grid regions after 2025.

[2] State Council of China (2015), 关于进一步深化电力体制改革的若干意见 (中发〔2015〕9 号) [Opinions on Further Deepening the Reform of Power System (Document No.9)]. Retrieved from http://www.ne21.com/news/show-64828.html.

China coal-fired power trend analysis

China's coal-fired power boom

The growth story of coal power in China

Driven by fast-growing demand for power and heat, China's coal-fired power capacity more than quadrupled from 222 GW in 2000 to 1 007 GW in 2018 (Figure 6). Capacity is still increasing, with around 200 GW under construction or planned.

China has two main type of boilers. Pulverised coal units, also called conventional coal, are separated in this report into high pressure[3], subcritical, supercritical and ultra-supercritical. Circulating fluidised bed (CFB) units are categorised as unconventional coal.

As of 2018, high pressure, subcritical and less-efficient CFB[4] plants still made up over half of China's coal power fleet. Since 2007, however, more efficient supercritical and ultra-supercritical plants have seen their share increase rapidly to 43% in 2018.

Annual capacity additions peaked in 2016 at 80 GW and have been decreasing since. In 2015, administrative changes in the approval processes resulted in a one-time resurgence of newly installed coal capacity. Since 2017, China has installed about 30 GW every year, mainly supercritical and ultra-supercritical plants.

Growth has been driven primarily by power demand. While heat remains important and installed CHP capacity more than doubled since 2000, CHP's share of total installed coal-fired capacity decreased significantly, reaching 38% in 2018.

The 13th Five-Year Plan capped the installed coal-fired power capacity to 1 100 GW. Thanks to the ban since 2016 on approval of new coal plants, China should stay below the Plan target by the end of 2020.

In 2020, the National Energy Administration loosened restrictions for new coal plant approvals.[5] Coal power was also listed in the massive investment package[6] to support the economic recovery from the Covid-19 crisis.

The 14th Five-Year Plan's coal cap target, currently under discussion, will fix the trends for the next five years of coal power capacity, and will be a major parameter in shaping China's energy transition trajectory.

[3] High pressure are small subcritical unit below 300 MW

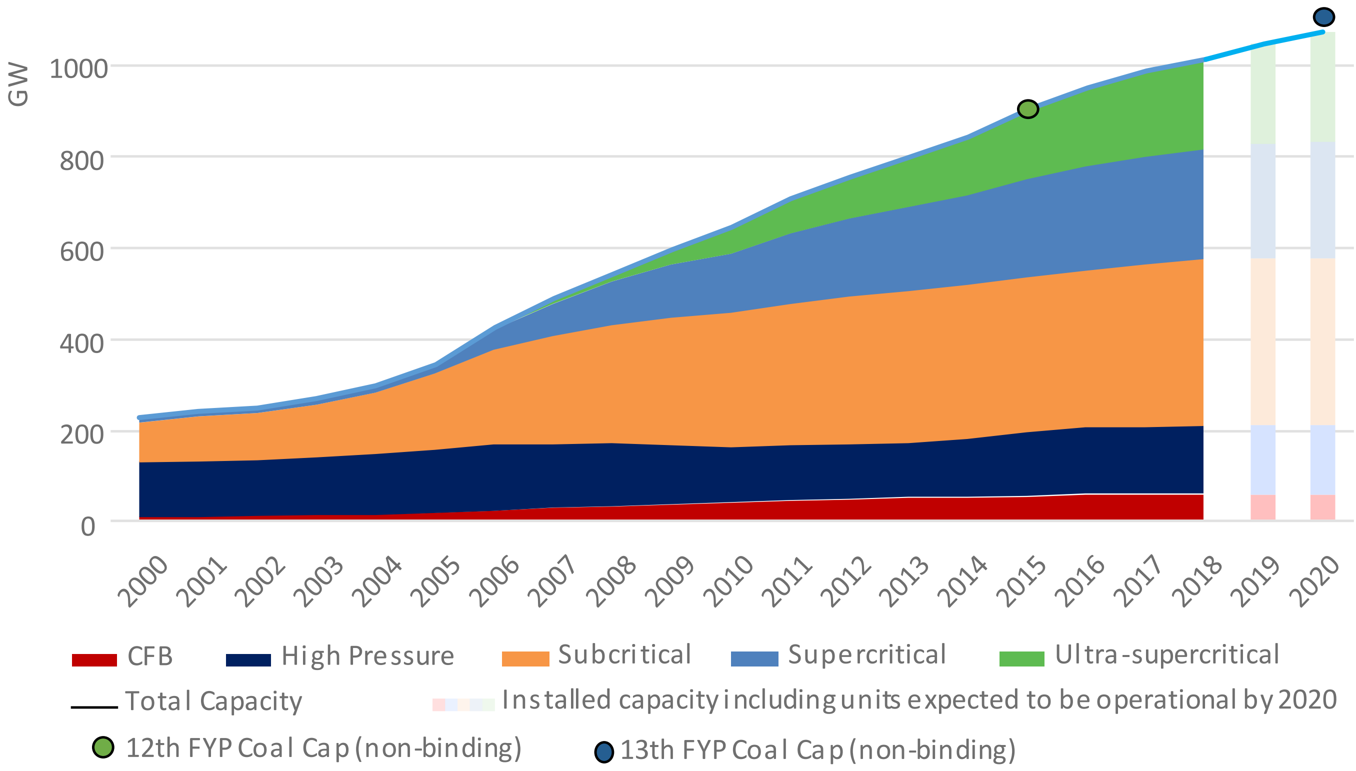
[4] From 2013, China installed around 6 GW of new supercritical and ultra-supercritical CFB capacity representing about 10% of operational CFB capacity in 2018.

[5] NEA (2020), 国家能源局关于发布 2023 年煤电规划建设风险预警的通知 [The NEA released notice for coal-fired power construction warning in 2023], http://www.nea.gov.cn/2020-02/26/c_138820419.htm

[6] Nengyuanjie (2020), 五大发电动作频多 煤电基建多个项目正在路上! [Activities from the Big Five power companies, multiple coal-fired power projects on the way], http://www.nengyuanjie.net/article/35157.html

China's coal power capacity increased more than four-fold from 2000 to reach around 1 000 GW in 2018

Figure 6: Installed coal-fired power capacity



Note: 2019 and 2020 data includes plants under construction expected to be commissioned. We used UDI World Electric Power Plants Database 2019 (S&P Global Platts, 2019) for coal unit level in China and adjusted the data to provincial statistics (CEC, 2019). About 50 GW of non-identified units has been added to fit CEC statistics over six provinces (Shangdong, Shanxi, Inner Mongolia, Anhui, Xinjiang and Zhejiang). Non-identified capacity has been considered to be small captive units of high pressure and subcritical capacity.

Power and heat generation from coal power plants increases faster than renewables combined

China's power generation increased fivefold and heat generation threefold from 2000 to 2018 (Figure 7). Coal-fired power plants were the major contributor, accounting for more than 60% of the increase in power generation and 85% of the rise in heat generation. In 2018, power[7] generation reached 4 630 TWh and heat[8] from CHP plants reached 980 TWh (equivalent to about 3 500 petajoules (PJ)).

While the share of coal in the power mix has significantly decreased, from 78% in 2000 to 66% in 2018, absolute power generation from coal-fired plants is still increasing. Coal's share in heat generation remains at around 85%, a level that has remained relatively stable since 2000.

A higher share of electricity-only power plants has been built since 2000 to satisfy faster power demand growth. This strong increase in demand for power has increased generation from all sources, including renewable power, alongside the increase in coal-fired power plants.

Nevertheless, the total increase in coal-based power generation from 2010 to 2018 (1 500 TWh) was 50% more than the increase in renewable-based generation over the same period (1 000 TWh) including hydro, wind and solar combined. **In 2018, the annual increase in power generation from coal was double that of generation from renewables.**

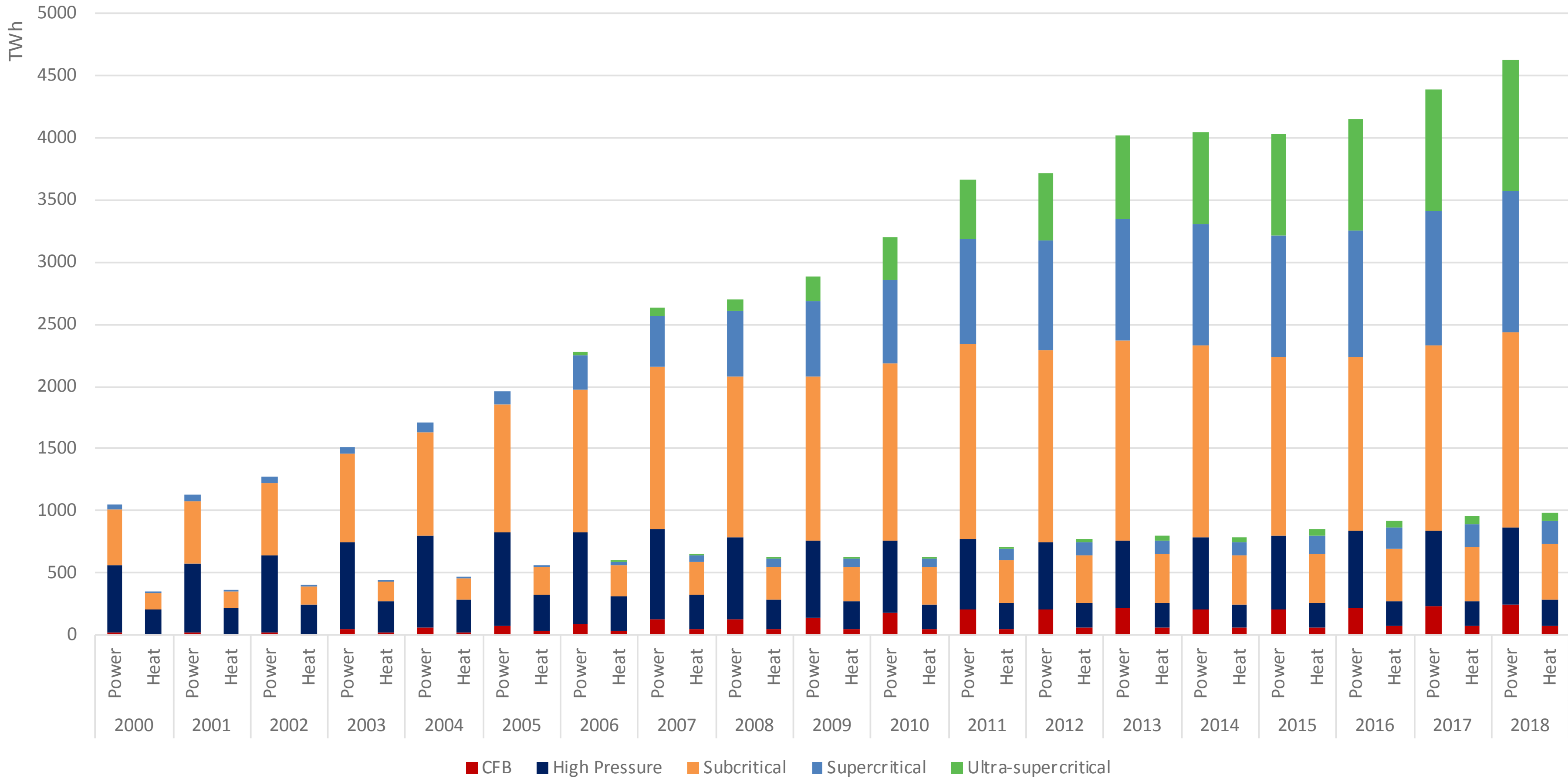
Recent and current growth in power generation from coal is driven by supercritical and ultra-supercritical plants, though subcritical plants remain the dominant source of power and heat generation. CHP remains important in China, as these plants contributed about 26% to power generated plus all the heat generation in 2018, most of which were subcritical plants.

[7] IEA (2019c) statistics from 2000 to 2017 for other bituminous coal. 2018 value adjusted from IEA (2019b), *World Energy Outlook 2019*.

[8] IEA (2019c) statistics from 2000 to 2017 for other bituminous coal. 2018 value estimated using 2017 CHP power/heat ratio.

Power and heat generation from coal have increased around 440% and 290% respectively

Figure 7: Coal-fired power and heat generation by technology



Note: 1 TWh = 3 600 TJ used to convert heat generation in TJ to TWh.

Efficiency and CO_2 intensity

Efficiency has increased significantly, while average full load hours have been decreasing

China has one of the most efficient coal-fired power fleets in the world, due to a large increase in construction over the past 15 years, particularly of more efficient supercritical and ultra-supercritical power plants.

Average operational efficiency of power generation for the coal fleet has reached 39% (Table 2), the level of the most efficient, most recently built subcritical plant, and **China's average operational efficiency for power generation is 2 percentage points above the rest of the world**. The average efficiency of the fleet could increase further, given that the most efficient coal-fired power plants reach about 46% efficiency if run at full capacity factor levels.

Table 2: Average operational efficiency of power generation for coal power plants and by coal technology (including CHP)

Coal technology	2000	2010	2018
Total coal power plants	**30.4%**	**35.4%**	**38.6%**
CFB	30.9%	34.7%	37.0%
Subcritical	30.3%	33.4%	35.2%
Supercritical	33.5%	38.3%	40.2%
Ultra-supercritical	-	41.4%	44.2%

Improved operational efficiency has decreased the average CO_2 intensity of power generation, from 1 128 gCO_2/kWh in 2000 to 900 gCO_2/kWh in 2018 (Figure 8), which avoided about 1 $GtCO_2$ from power generation in 2018.

The rate of decline in CO_2 intensity has slowed since 2010, primarily due to three factors: fewer newly built supercritical and ultra-supercritical units, limited potential to improve the most efficient technologies, and fewer retirements of small and inefficient units.

Binding average coal consumption targets for 2020 in China's 13th Five-Year Plan would effectively ban construction of subcritical and less efficient coal plants, which today represent over 50% of installed coal-fired power capacity. The equivalent informative target of 865 gCO_2/kWh for operating plants could be met by electricity-only plants, but given that the CHP fleet is older and less efficient, the average CO_2 intensity of coal-fired power plants overall is not on track to meet the 2020 coal consumption target. The Covid-19 crisis may also raise the risk of not achieving the 13th Five-Year Plan target for 2020, as efficiency decreases when units run at lower full load hours, which could be the case given lower demand in 2020.

While energy efficiency and CO_2 intensity have been improving, average full load hours have been decreasing. Average full load hours reached almost 6 000 hours in 2004 due to rapidly increasing power demand and installed power capacity shortage. Since then the average has been decreasing due to lower power demand growth and the growth of renewables. It reached its lowest level of 4 400 hours in 2016 before increasing again to 4 600 hours in 2018.

Reduced average full load hours are largely due to overcapacity. Coal power plant construction accelerated after approval for new plants shifted to provincial authorities in 2015, which has accentuated overcapacity. This also explains the recent consideration by the SASAC to retire quickly a significant amount of coal-fired power capacity.[9]

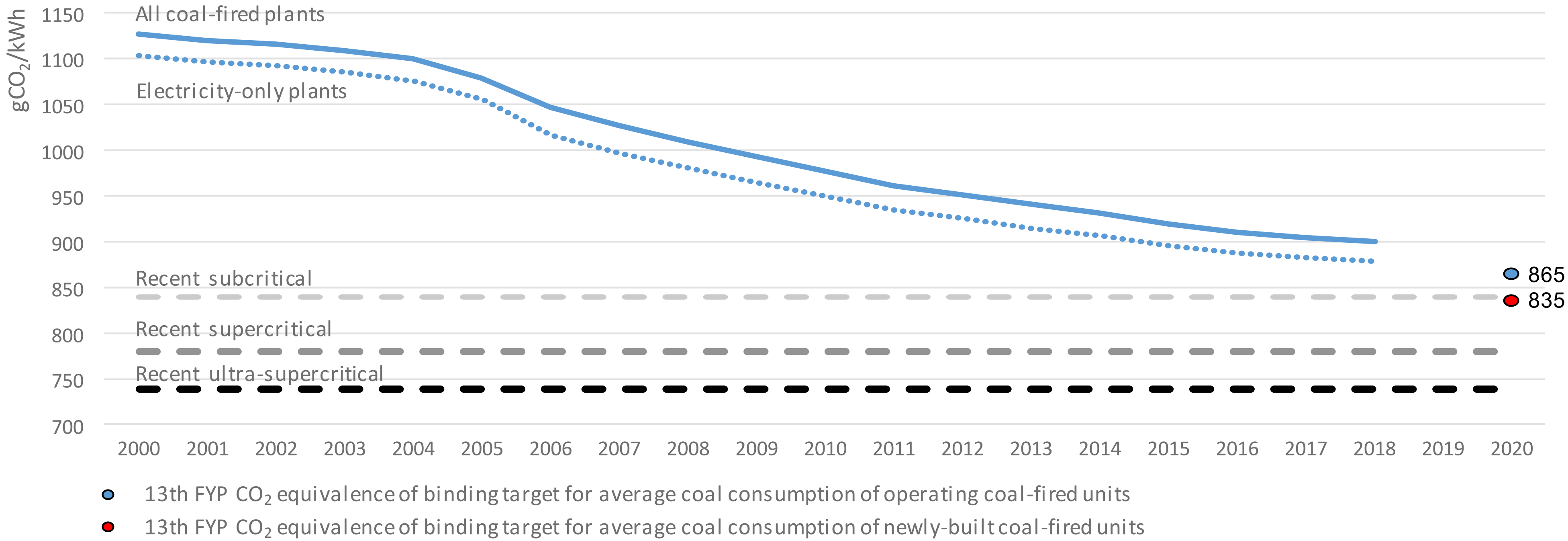
Reduced full load hours are also due to a change in the role of the existing coal fleet. Coal power is increasingly used as flexible generation to back up renewable power, given increasing shares of variable renewables and future targets to increase this share significantly.

If the installed coal-fired power plant fleet were run at 2006 levels (5 500 hours), which is the usual assumption taken for new coal capacity investment decisions, China would have been able to generate an additional 910 TWh in 2018. This equates to about 200 GW of coal capacity that could have been retired or not been built (e.g. China has about 200 GW coal capacity in the pipeline, under construction or planned).

[9] Tanjiaoyi (2019), 重磅！国资委发布《中央企业煤电资源区域整合试点方案》全文 [Headline! SASAC released the full text of the "Pilot Program for Regional Consolidation of Coal-fired Power Resources of SOEs"], http://www.tanjiaoyi.com/article-29645-1.html; Xinhua (2019), 五央企牵头煤电资源区域整合试点启动 [Five SOEs Lead the Pilot of Regional Consolidation of Coal-fired Power Resources], http://www.xinhuanet.com/fortune/2019-12/03/c_1125300602.htm

Efficiency improvements rapidly decreased CO_2 intensity, though the trend has slowed recently

Figure 8: Average CO_2 intensity of power generation from coal power plants



Note: Heat generated from CHP plants is not taken into account in the 13th Five-Year Plan average coal consumption targets, which only cover power generation. The CHP fleet is older hence less efficient on average, which increases the average CO_2 intensity of power generation from coal-fired plants compared with the average CO_2 intensity of power generation from electricity-only units. CO_2 intensity target from the average coal consumption target for operated coal plants is stated in the 13th Five-Year Plan for Power Development, which corresponds to the use of the CO_2 fuel factor for "other bituminous coal" (i.e. 95 $kgCO_2/GJ$).

Young coal fleet – a challenge for reducing CO_2 emissions

A large and young coal fleet makes rapid CO_2 emission reductions challenging

Over the past two decades, the global average age of coal-fired power plants has remained stable at about 20 years. Two-thirds of coal-fired capacity worldwide under 20 years is located in China. These plants also account for about 40% of total installed coal capacity worldwide.

To keep up with rapid power demand growth, intensive installation of new capacity in China from 2004 has meant China's coal-fired plant fleet remains very young; 85% of China's installed coal capacity has less than 20 years of operation (Table 3).

Table 3: Annual average age of China's coal-fired power plants, by technology (including CHP)

Coal technology	2000	2010	2018
Total coal power plants	**7.2**	**7.8**	**11.5**
CFB	2.2	4.9	10.3
Subcritical	7.5	9.8	14.9
Supercritical	4.1	4.3	8.9
Ultra-supercritical	-	2.1	6.3

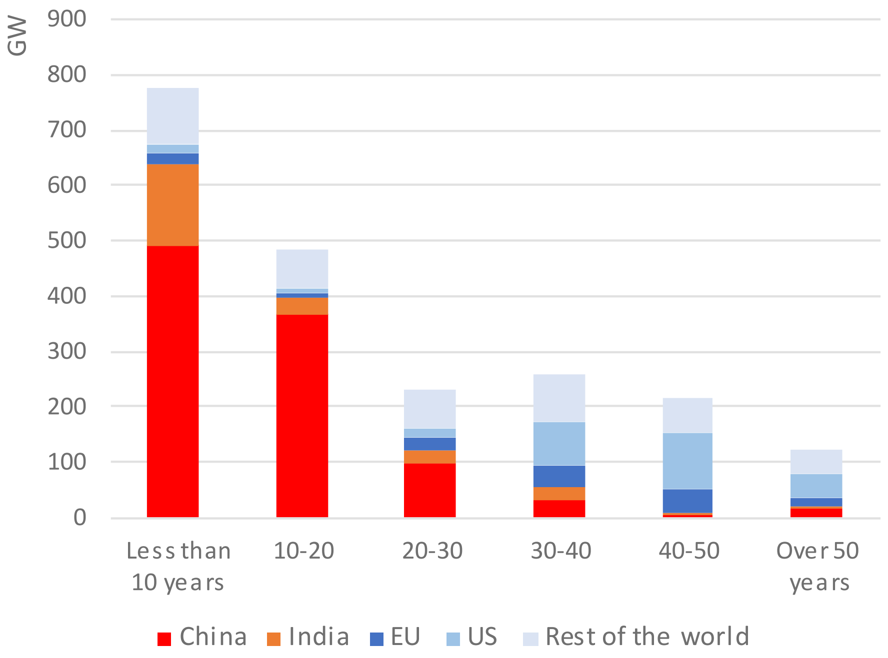
The average age of China's coal-fired power fleet reached 10 years only in 2016. At a little over 11 years in 2018, China's coal power fleet was still half the global average age and significantly below the EU or US average (Figure 9). **More than 88% of CO_2 emissions from coal-fired power plants in 2018 came from plants less than 20 years old.** Neverthless, CO_2 emissions from plants less than 10 years old are decreasing for the first time since 2013, mainly due to a slowdown in newly installed capacity.

In 2018, plants older than 20 years accounted for about 150 GW of capacity and represented only 12% of CO_2 emissions from power and heat generation. **The large share of emissions coming from remaining young coal-fired power plants presents a risk of locking in these emissions for decades (Figure 10).**

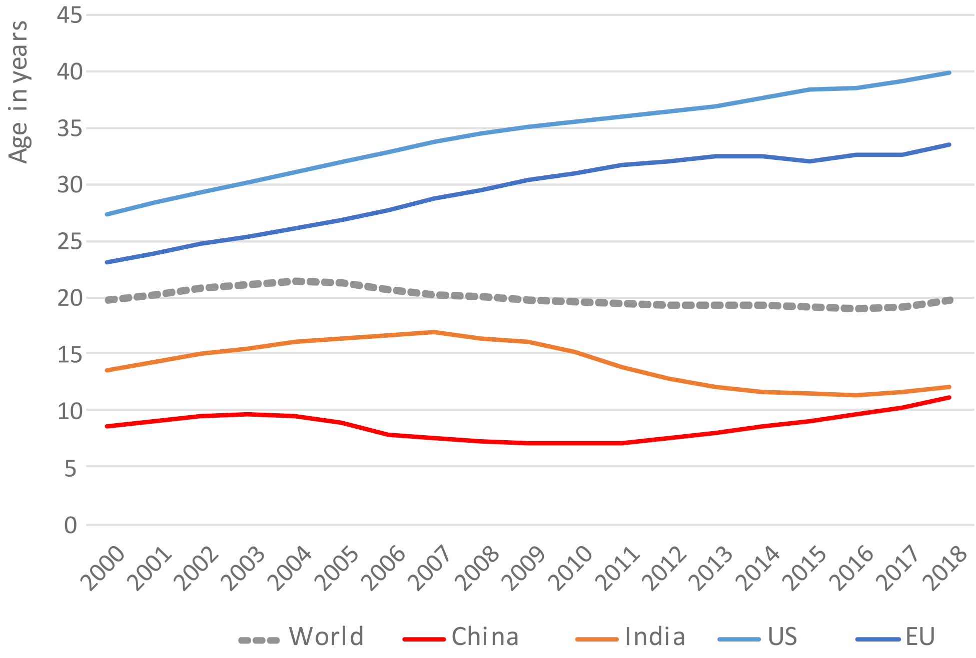
In addition, if these 150 GW were retired and replaced by increasing the average full load hours of the existing fleet or by building new coal power plants, this would significantly limit the gains in CO_2 emissions reduction. The major part of the gap in power generation could instead come from low-carbon power sources.

The average age of coal-fired plants in China is about half the world average...

Figure 9: Coal-fired power capacity by plant age, 2018



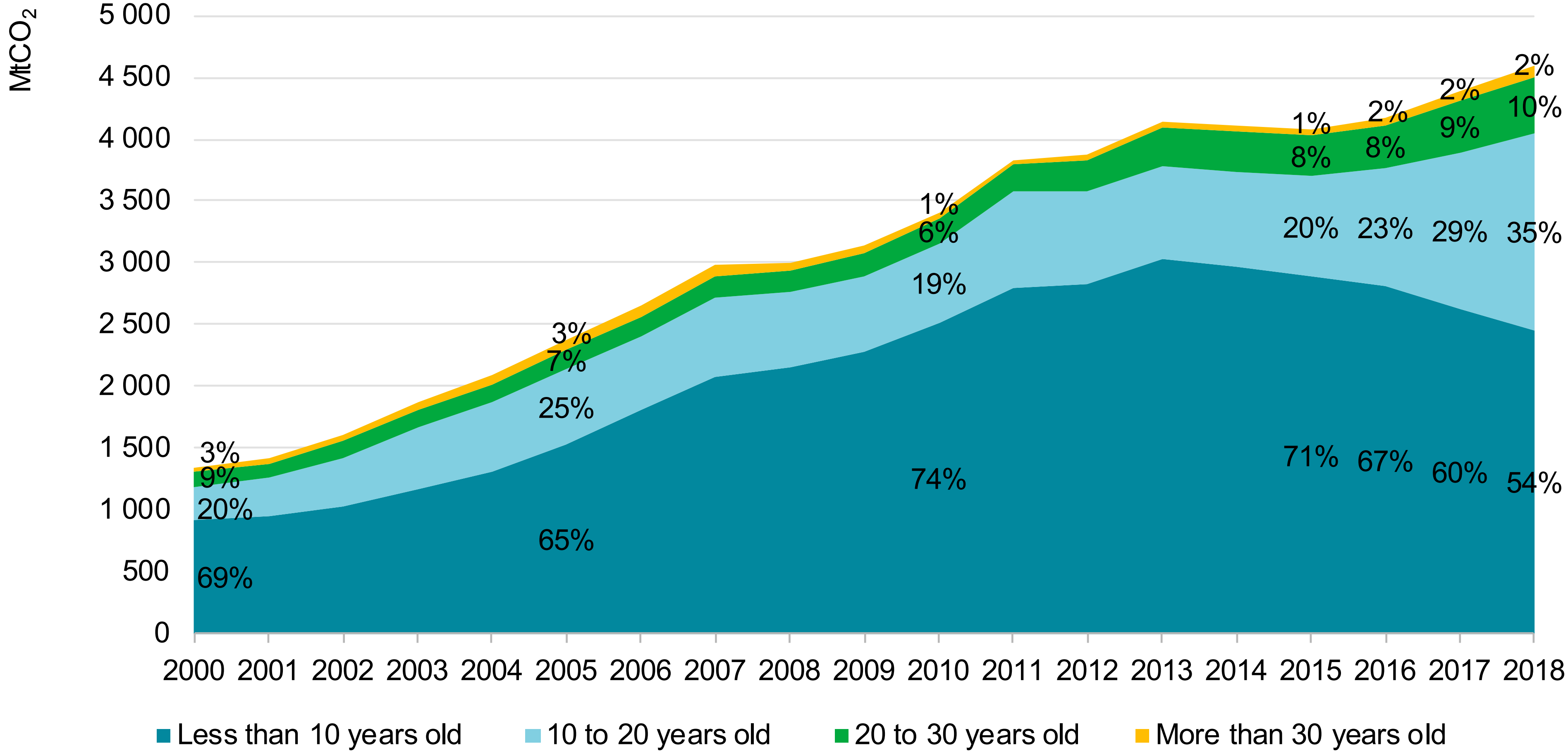
Annual average age of coal-fired power fleet from 2000 to 2018



Note: Average age is defined as the weighted average age of capacity.

... potentially locking in large amounts of CO_2 emissions for the next decades

Figure 10: CO_2 from coal-fired power plants (segmented by plant age ranges)



Note: Age is defined as the weighted average age of capacity.

Accelerating repurposing and retirement would support faster CO_2 emissions reduction

Since 2000, China has retired about 60 GW of coal-fired power capacity (representing 6% of total coal capacity), with a sharp drop in retirements since 2013 (Figure 11). In contrast to the world average of around 40 years, the average age of retired plants in China was 20 years.

The large majority of retired coal-fired units in China have been small and inefficient high pressure plants. China retired about 900 units, all less than 225 MW (the average size was less than 60 MW) except for four subcritical 300 MW units. Only very few small and inefficient CFB units have been retired, out of a total capacity of 2 GW. These retirements were part of a "shut down small and open large" campaign, aimed at fighting pollution and reducing overcapacity.

To tackle air pollution and overcapacity, the 20 GW retirement target in China's 13th Five-Year Plan will require significant acceleration of retirement, given only 3 GW was retired by the end of 2018.

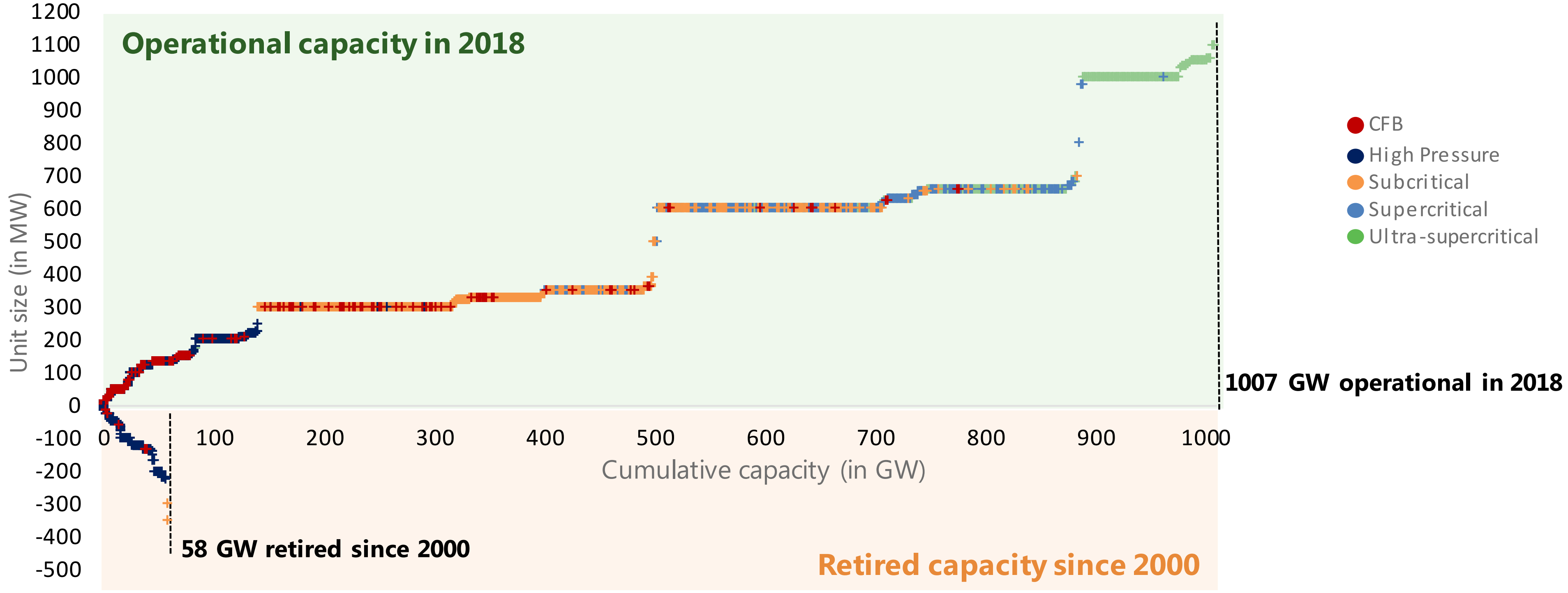
The challenge in particular will be progressively retiring, retrofitting (including with CCUS) and repurposing 570 GW of less efficient CFB, high pressure and subcritical capacity – of which 50% is CHP capacity – while meeting power and heat demand.

This is especially true for the 163 GW capacity (65% CHP) built before 2000 that has now reached or already exceeded China's historic average retirement age of 20 years. Fifty-seven percent of this capacity is owned by China's five largest utilities, which are state-owned enterprises.

How to meet heat demand in the short term should therefore be one of the key questions for any retirement plan. Few alternatives to coal exist for heat supply in China. The main ones are gas, biomass and electricity, but gas and biomass prices are much higher than coal prices, and electricity-based boilers are not yet efficient enough to supply heat for energy-intensive industrial uses.

To date only small and inefficient CFB, high pressure and subcritical units have been retired

Figure 11: Installed capacity in 2018 (top) and retired units since 2000 (bottom)



The ten provinces with the largest installed coal-fired capacity

Spotlight on the ten provinces with the largest coal-fired capacity

The top ten provinces by capacity (out of 31 provinces[10]) are responsible for 3 $GtCO_2$ annually, up from 810 $MtCO_2$ in 2000 (Figure 12). These provinces represented 64% of China's coal-fired power capacity and 48% of China's population in 2018.

Jiangsu, Zhejiang, Guangdong and Shangdong are more developed and industrialised provinces located along the east coastal area. The four provinces generated 35% of China's gross domestic product (GDP) and emitted almost 30% of CO_2 emissions from coal power plants.

The other six provinces are located next to developed coastal provinces or in the north or northwest of China. They are less developed, still industrialising, often more rural and host mines, such as Shanxi, Inner Mongolia and Xinjiang, where power plants are often still run to manage peat waste during coal extraction.

The top three provinces by capacity (Shandong, Jiangsu, Inner Mongolia) make up almost 30% of China's coal power CO_2 emissions. Jiangsu has slightly more capacity but Inner Mongolia emits 20% more due to the dominance of subcritical plants. Given its rapid economic expansion, Xinjiang has the fastest-growing CO_2 emissions.

In 2017, the NEA[11] restricted new coal plant approval with the establishment of a traffic light system by province that suspended the construction or approval of about 120 GW. However, CHP plants were exempt from these rules. In February 2020, the NEA[12] announced a loosening of this system, which could lead to new investment in coal plants. This may increase the risk of slowing down the clean power transition, particularly in the top 10 coal-capacity provinces.

Given the heterogeneous provincial distribution of coal power plants, national policies could usefully be complemented with specific provincial policies. The 14th Five-Year Plan could be the opportunity to define clean power transition pilots to manage the environmental and economic risks of having large or growing coal power fleets in selected provinces.

[10] Provincial-level administrative divisions, including provinces, municipalities and autonomous regions. The two Special Administrative Regions (Hong Kong and Macau) and Chinese Taipei are not included in this analysis.

[11] NEA (2017), 国家能源局关于发布 2020 年煤电规划建设风险预警的通知 [The NEA released notice for coal-fired power construction warning in 2020], http://sdb.nea.gov.cn/new/2017-5/2017510150252.htm

[12] NEA (2020), 国家能源局关于发布 2023 年煤电规划建设风险预警的通知 [The NEA released notice for coal-fired power construction warning in 2023], http://www.nea.gov.cn/2020-02/26/c_138820419.htm

Top ten provinces by coal capacity had 645 GW in 2018, almost as much as the US, the EU and India combined

Table 4: Top ten provinces by coal capacity and key indicators in 2018

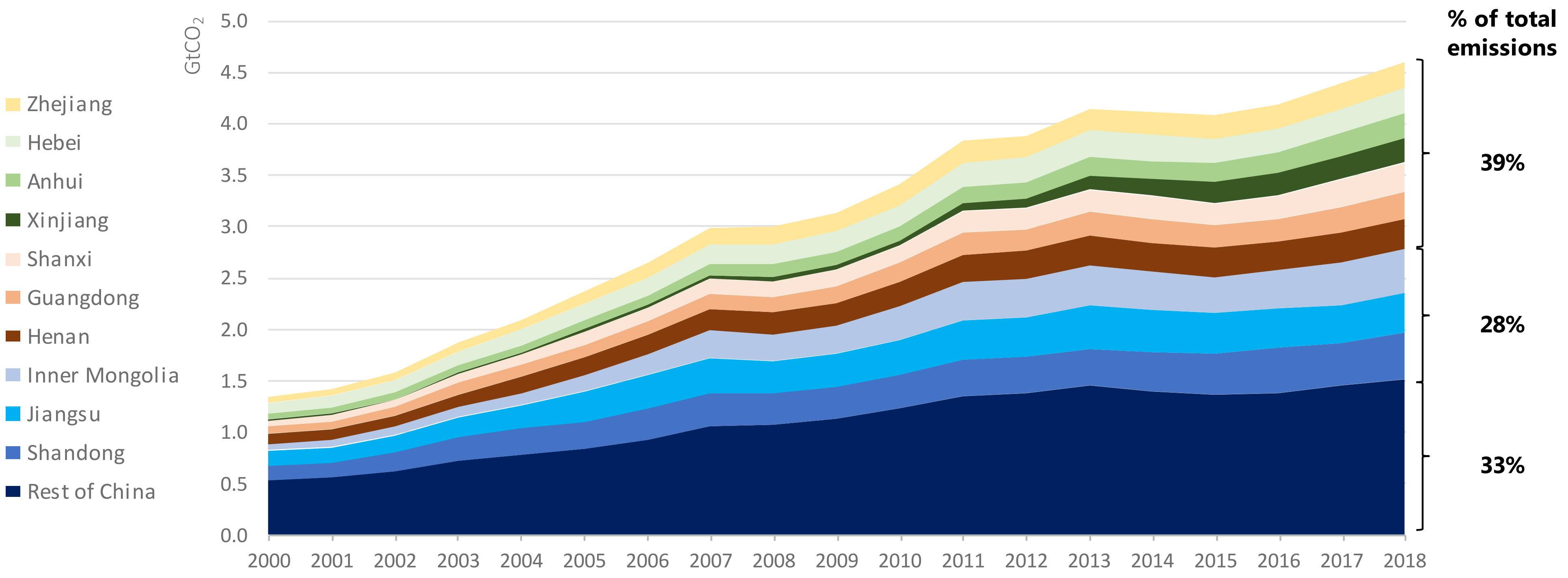
Province	Capacity	CO_2 emissions	Population	GDP	GDP/capita
	(% of total)	(% of total)	(% of total)	(% of total)	(% compared with national average)
Shandong	9.5%	9.8%	7.2%	8.4%	116.2%
Jiangsu	8.1%	8.1%	5.8%	10.1%	175.6%
Inner Mongolia	8.0%	9.7%	1.8%	1.9%	104.2%
Henan	6.8%	6.3%	6.9%	5.3%	76.4%
Guangdong	6.1%	5.7%	8.1%	10.6%	130.9%
Shanxi	6.1%	6.0%	2.7%	1.8%	69.1%
Xinjiang	5.1%	5.2%	1.8%	1.3%	74.9%
Anhui	5.0%	5.5%	4.5%	3.3%	72.4%
Hebei	4.6%	5.4%	5.4%	3.9%	72.8%
Zhejiang	4.6%	5.4%	4.1%	6.1%	149.6%
Rest of China	**36.0%**	**32.9%**	**51.7%**	**47.2%**	**91.2%**

GDP/Capita compared with national average : Higher Lower

Sources: NBS (2019) for population and GDP, IEA for capacity and CO_2 emissions.

Coal power plants in China's top ten provinces emitted a third more CO_2 emissions than India's total CO_2 emissions from fossil-fuel combustion in 2018

Figure 12: CO_2 emissions from Coal-fired power plants by province



Note: Coal power plants in China's top 10 provinces by capacity emitted about 3 $GtCO_2$ in 2018, 30% more than the total CO_2 emissions from fossil-fuel combustion in India, the world's third-largest emitter (2.2 $GtCO_2$). China's top three provinces emitted around 1.2 $GtCO_2$, more than Japan, the fifth largest emitter in 2018 (1 $GtCO_2$) (IEA, 2019c).

The coal capacity mix varies by provincial development, resources and geography

The high shares of subcritical, high pressure and CFB plants in some provinces is due to abundant and cheap local coal resources (Inner Mongolia, Shanxi, Xinjiang and Hebei), while in Shandong it is due to the high number of captive plants encouraged by a "self-ownership" policy at the province level. Xinjiang also has a similar self-ownership policy.

The presence of CFB plants is driven by the availability of local low-quality coal and provincial geography that makes high-quality coal imports more expensive (e.g. Inner Mongolia and Shanxi).

Less efficient subcritical capacity increased especially in Shandong, Inner Mongolia, Shanxi and Hebei, while supercritical and ultra-supercritical capacity increased steeply in Jiangsu, Henan, Guangdong and Anhui. The colder northeastern provinces of Shandong, Shanxi and Hebei in particular have a higher share of CHP (ranging from 46% to 62%) than the national average (38%). Highly industrialised provinces like Guangdong and Jiangsu have high CHP shares for industrial use, at 72% and 53% respectively. While not among the top ten provinces, the northeastern province of Liaoning has significant CHP capacity with around 29 GW, dominated by subcritical and high pressure CHP plants.

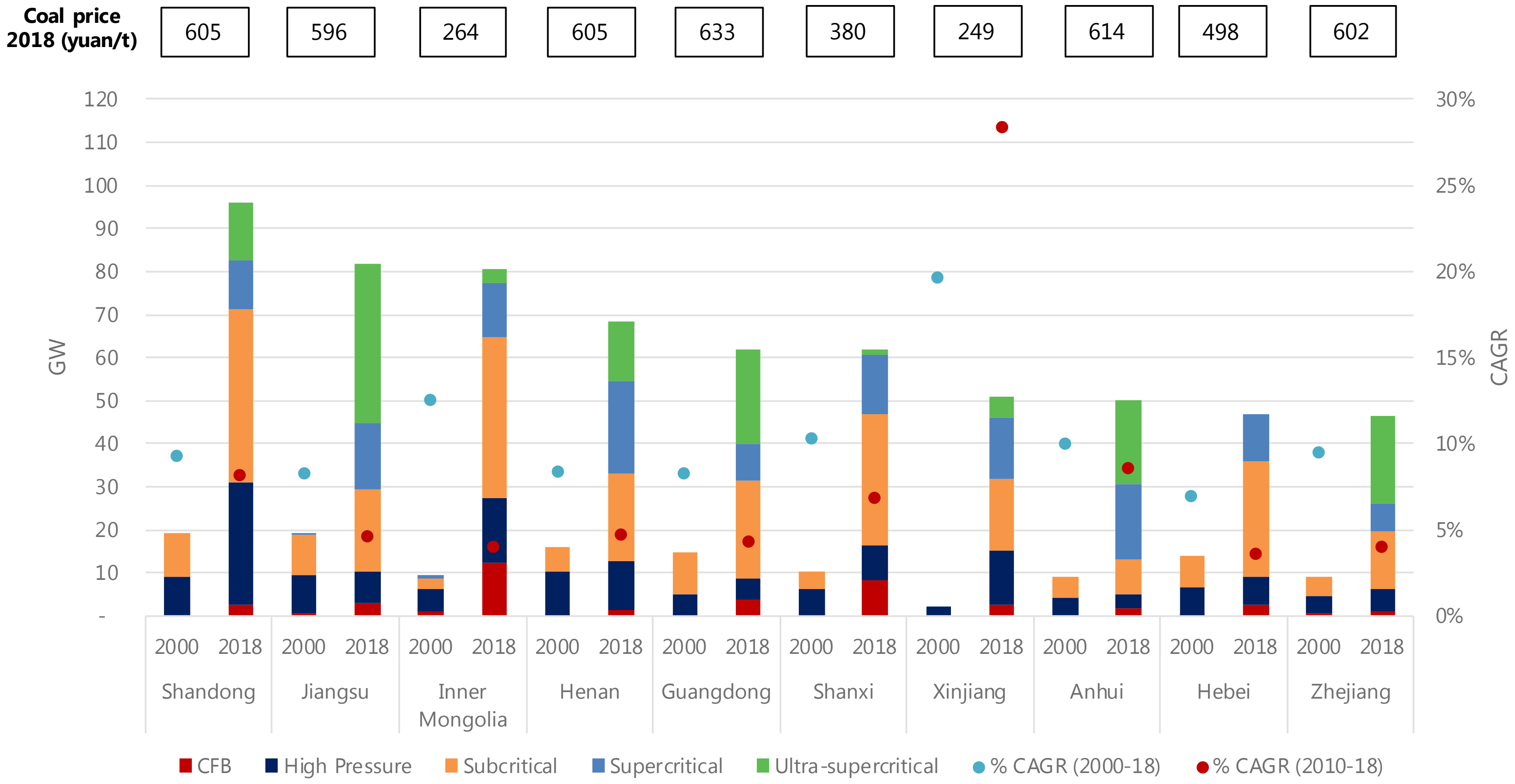
Xinjiang had the highest growth rate in coal capacity between 2000 and 2018; the compound annual growth rate (CAGR) was 20%, while the national average reached 9% (Figure 13). Xinjiang's CAGR from 2010-18 was 30%, while the rate declined for the nine other provinces over this period. This is due to Xinjiang's still early stage of development and very cheap coal prices. As a result, Xinjiang has the youngest coal fleet with an average age of five years in 2018. In contrast, Hebei has the oldest fleet at almost 15 years. Hebei, part of the Jing-Jin-Ji Megalopolis with Beijing and Tianjin, developed its coal fleet earlier and new coal plant construction is limited due to measures to fight air pollution.

The average age of coal-fired power plants varies by province mainly because of varying economic development status. CHP plants are on average older than electricity-only plants – in some provinces significantly – posing a challenge for potential early retirement while securing heat supply (Figure 14).

A combination of factors need to be taken into account when defining policies and targets to regulate coal plants, such as local coal prices, geographical situation, economic development stage, and coal power technology mix, efficiency and age.

The top ten provinces increased their capacity by an average of 10% per year from 2000 to 2018

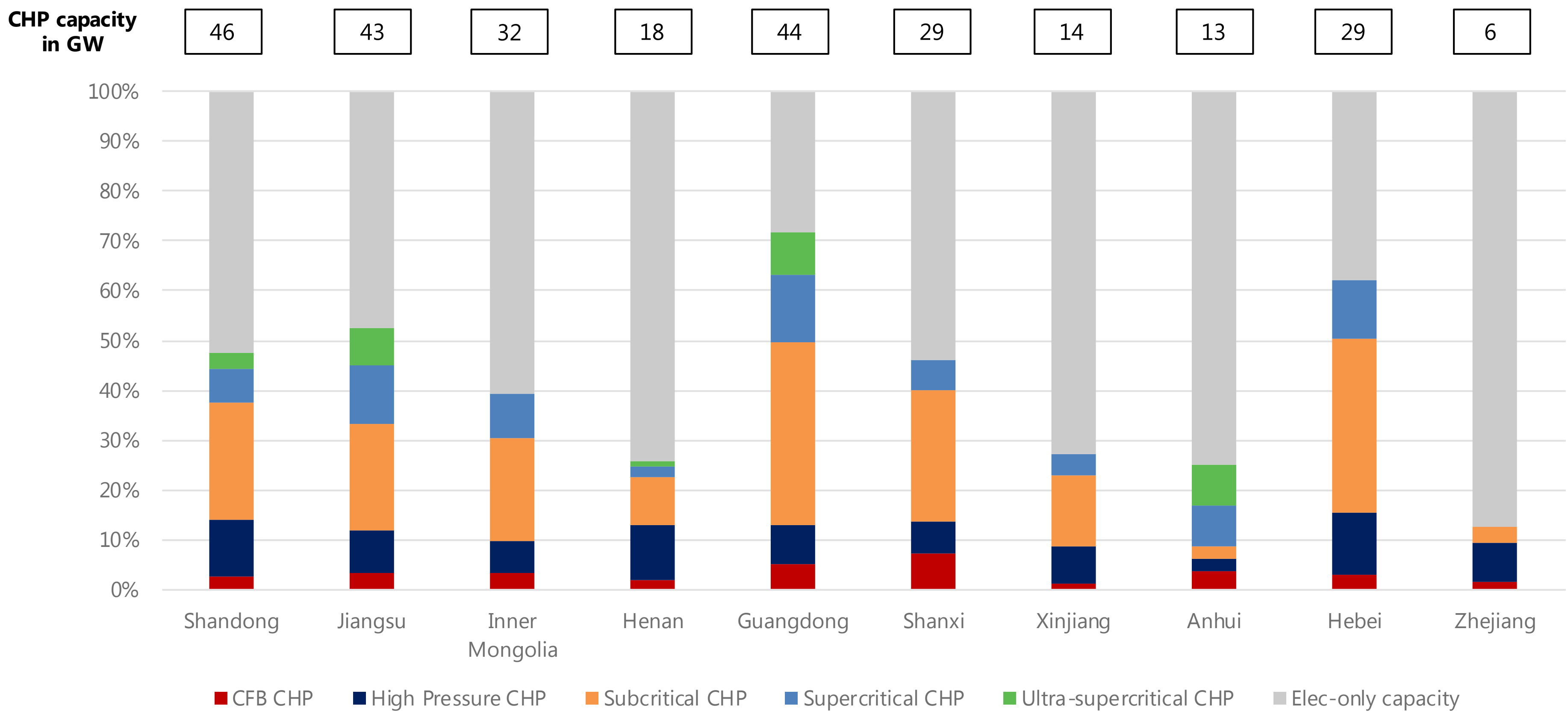
Figure 13: Coal-fired power capacity and CAGR by province



Note: Compound Annual Growth Rate (CAGR).

CHP capacity is dominated by older and subcritical plants, mainly in the north and east

Figure 14: Share of CHP capacity by technology in 2018



China's five largest state-owned power companies

Spotlight on China's five largest state-owned power companies

The power sector in China is dominated by large state-owned entreprises (SOEs), which also play a central role in the deployment and operation of coal-fired power and heat generation.

The five biggest state-owned power companies were created in 2002 when the former State Electric Power Corporation was unbundled. In 2017, China Guodian and Shenhua merged into CHN Energy, which became the world's largest power company by capacity. Today, the five biggest state-owned power companies make up more than half of China's installed coal capacity: CHN Energy, Huaneng Group, Huadian Group, Datang Corporation and State Power Investment Corporation (Figure 15). Their status as SOEs means that they are supported by the government through preferential access to bank capital, lower rate loans, lower tax and other policies, as well as state capital injection when needed.

The SASAC owns the SOEs, while the Chinese Communist Party nominates the key management teams of these SOEs. This vests SOEs with important political influence, sometimes comparable to that of certain Ministries.

These five biggest state-owned power companies produced around 2 500 TWh of power and 1 670 PJ of heat from coal plants in China in 2018, which is almost equivalent to the combined power generation of Japan (1 069 TWh) and India (1 618 TWh).

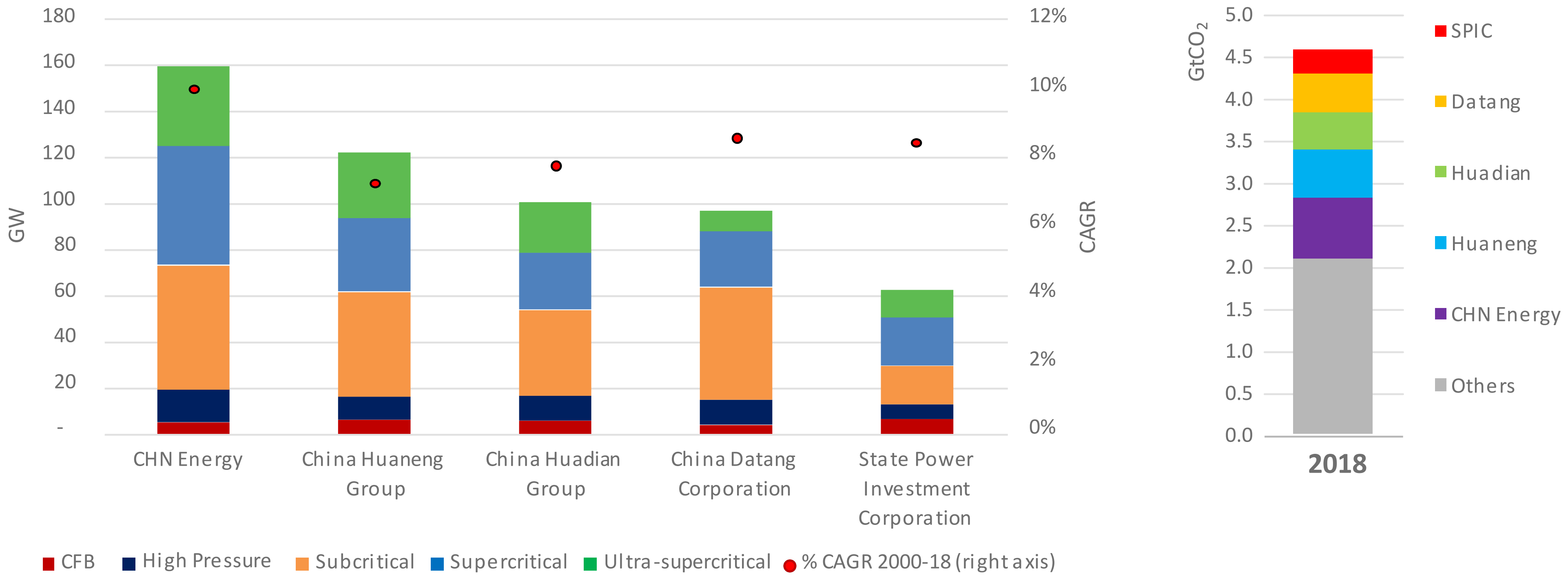
CHN Energy has the largest and fastest-growing coal-fired power fleet. Supercritical and ultra-supercritical plants make up more than half of its coal-fired capacity. Datang, with a long history in coal-fired generation, has by far the highest share in subcritical plants (51%) and the lowest share in ultra-supercritical plants (9%).

These companies emitted about 2.5 GtCO_2 from their coal-fired plants in 2018, representing more than 50% of annual emissions from China's entire coal-fired power fleet.

Due to their size and political influence level, provinces often face challenges in regulating central SOEs. Policy enforcement from China's ministries is usually needed. There is thus an opportunity for the central government to guide the low-carbon transformation of its SOEs, which in turn would drive China's power transformation given the dominance of these SOEs.

Over half of installed coal-fired power capacity owned by top five companies, emitting 2.5 $GtCO_2$

Figure 15: Coal-fired capacity (left) and CO_2 emissions (right) of China's top five coal-fired power companies (2018)



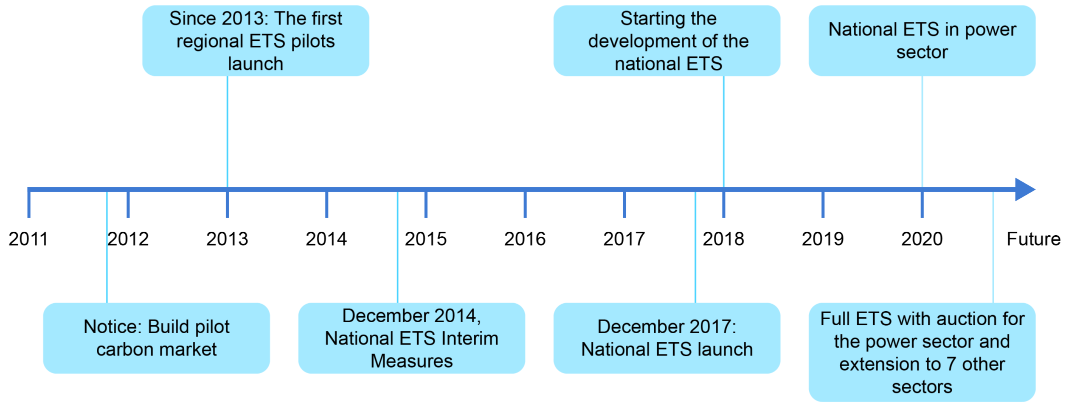
China ETS regulation

Timeline of emissions trading in China

On 19 December 2017, China officially launched the development of its national ETS. As the largest CO_2 emitter in the world, with emissions dominated by power generation and energy-intensive industries, China has great potential to reduce emissions. **As China's ETS will be the largest carbon market in the world, its experience could shape other carbon markets and set an example for other emerging economies.**

The design of China's national ETS is based on over a decade of experience with other carbon markets. Since 2005, China has participated in the Clean Development Mechanism (CDM), which is a global carbon market under the United Nations Framework Convention on Climate Change (UNFCCC). After gaining experience and knowledge from participating in the CDM, China announced the plan for seven regional ETS pilots in 2011 and launched the first pilot in 2013.

In 2015, President Xi Jinping announced China's plan to start its national ETS in 2017 during a meeting with then President Barack Obama of the United States. Subsequently, the NDRC drafted and released the official guidelines for constructing the national ETS after approval from the State Council. The work plan consists of a gradual transition to a full ETS over three phases. The first phase focuses on constructing market infrastructure. The second phase is a trial run for the power sector to test out the ETS. The third phase (post-2020) is the launch of the full ETS with auctioning of allowances for the power sector, while gradually extending to other sectors.



Overview of China's ETS

The goal of China's national ETS is to reduce carbon emissions cost-effectively while using the market to direct resource allocation. The current phase of the national ETS has limited sectoral coverage, emission coverage and threshold for participation.

Only the power sector, including cogeneration, is covered at the beginning, but China has already planned to extend coverage gradually to seven other sectors: petrochemicals, chemicals, building materials, iron and steel, non-ferrous metals, paper and domestic aviation.

Direct CO_2 emissions from fossil-fuel combustion from coal and gas power plants including CHP are included. Indirect emissions from power consumption will be included once the ETS integrates other sectors, as well as direct CO_2 emissions from fossil-fuel combustion from these sectors. Possible expansion to other greenhouse gases (GHG) has not been considered yet.

Compliance is mandatory for entities[13] with annual emissions over 26 000 tCO_2, a level that covers all coal-fired power plants in China (e.g. a unit of 6 MW running at 2018 average full load hours reaches the threshold).

The design of the national ETS is based on China's past experience with emissions trading and tailored to fit China's current economic, industrial and political circumstances. In contrast with the cap-and-trade model used in the European Union and North America, China's ETS uses an output-based allocation.

Allowances are freely allocated using a CO_2 emissions intensity benchmark to ensure flexibility in operation and reduction in overall emission intensity. Output-based allocation is less likely to restrain energy demand growth, which is still high in China, given continued economic development and industrial capacity expansion.

If a cap-and-trade model were used, allowance caps would need to be constantly adjusted to reflect fairly and effectively the changing demand and efficiency level of individual covered entities. Otherwise the economic growth assumption used to define the cap trajectory could result in a weak cap while increasing the risk

[13] An entity is a company that can own one or many coal and gas-fired power plants which are composed by one or several power units.

of a cap overestimation that would jeopardise the effectiveness of the ETS, similarly to the EU-ETS Phase 1 and 2 experiences.

As it has been the case for other existing ETS, the power sector receives free allowances. There is limited scope for windfall profits as the CO_2 cost passed-on to consumer is limited in China because power and heat prices are centrally controlled.

The transition from regional pilots supervisored by local officials to a single national scheme supervised by the central government could make it challenging to maintain the same level of enforcement while keeping the flexibility to negotiate with individual participating entities and to make adjustments. In addition, the jump in scale of the ETS could seriously test the effectiveness of entities' current measurement, reporting and verification (MRV) systems.

To date, neither the duration of the first ETS phase nor the CO_2 emissions reduction targets (absolute nor intensity) have been defined. These key parameters should to be defined as soon as possible to shape the overall goal and ensure the coherence of the policy with China's climate governance.

Allowance allocation and benchmarks for the power sector

In May 2017, the draft CO_2 allowance allocation plan for power, cement, and electrolytic aluminium was developed and the trial allocation work was carried out in two provinces. The draft plan[14] proposed 11 benchmarks for the power sector, nine of which were for coal-fired plants and the rest for gas-powered technologies. In September 2019, the Ministry of Ecology and Environment released an updated trial plan[15] for the power sector (including captive power plants and cogeneration) seeking comments from provincial Departments of Ecology and Environment and major entities that will be covered by the ETS.

For the trial, allowance allocation will be using output-based benchmarks in tCO_2/MWh for power generation and tCO_2/gigajoules (GJ) for heat generation. Two allowance allocation options are proposed, which only differ by the number of benchmarks for conventional coal-fired power plants (Table 5). Only one of the two options will be chosen for the official ETS.

Conventional coal-fired power plants include all pulverised coal boilers, i.e. high pressure, subcritical, supercritical and ultra-supercritical coal power units. Option 1 has one benchmark for conventional coal while Option 2 has two benchmarks differentiated by the unit size. Ultra-supercritical, and large supercritical and subcritical units belong to the category of conventional coal over 300 MW capacity benchmark. Small supercritical and subcritical as well as all high pressure belong to the category of conventional coal at and below 300 MW capacity benchmark. Allowance allocation options are identical for unconventional coal-fired plants, which include CFB and integrated gasification combined cycle (IGCC)[16] units, and for gas-fired plants[17].

The allowance allocation and compliance period are annual. Entities will receive allowances equivalent to their total electricity and heat generation multiplied by the corresponding emission

[14] ETS in China (2017), NDRC Issued Internal Draft Allowance Allocation Plans for Three Sectors, https://ets-china.org/news/ndrc-internally-issued-the-draft-allowance-allocation-plans-for-three-sectors/

[15] MEE (2019a), 2019 年发电行业重点排放单位（含自备电厂、热电联产）二氧化碳排放配额分配实施方案（试算版） [2019 Implementation Plan of Carbon Dioxide Emission Quota Allocation for Key Emission Units of Power Generation Sector (Trial)].

[16] China has only one IGCC unit in operation in 2018. This unit has been including in CFB technology in this study.

[17] This study focuses on coal-fired power plants and does not assess the ETS allowance allocation options on gas-fired plants.

benchmark. Electricity-only units will receive allowances equal to their electricity output multiplied by corresponding power benchmarks while CHP units will receive allowance based on both the electricity and the heat component.

Units in surplus can sell allowances, thus generating financial incomes from their allowance surplus. Power units in deficit will have to purchase allowances from others, within the same entity or on the carbon market. Due to high gas prices and China's political will to increase the share of gas in power and heat generation, gas-fired power generation will not have to procure additional allowances if in deficit, limiting the additional burden from the ETS.

Over the last two months of 2019, China conducted Allowance Allocation and Management Training Series that trained several thousand experts, utilities and policy makers in different cities. The training also provided an opportunity to test with a large number of power representatives the two proposed allowance allocation options.

The transition to fewer benchmarks have been a constructive step forward in the construction of China National ETS during the last years. China is now in the phase to finalise the benchmark stringency levels before defining their gradual tightening trajectories.

Table 5: Proposed ETS allowance allocation and CO_2 intensity benchmarks

Option 1 → **Benchmarks for three technology categories**

Technology	Benchmark	
	Electricity (tCO_2/MWh)	Heat (tCO_2/GJ)
Conventional coal-fired plants *High pressure, subcritical, supercritical and ultra-supercritical power units*	1.015	0.135
Unconventional coal-fired plants *CFB units*	1.12	0.135
Gas-fired plants	0.382	0.059

Option 2 → **Benchmarks for four technology categories**

Technology	Benchmark	
	Electricity (tCO_2/MWh)	Heat (tCO_2/GJ)
Conventional coal-fired plants over 300 MW capacity *Ultra-supercritical, supercritical 600 MW and subcritical 600 MW power units*	0.989	0.135
Conventional coal-fired plants at and below 300 MW capacity *High pressure, subcritical 300MW and supercritical 300MW units*	1.068	0.135
Unconventional coal-fired plants *CFB units*	1.12	0.135
Gas-fired plants	0.382	0.059

Source: MEE (2019a), 2019 年发电行业重点排放单位（含自备电厂、热电联产）二氧化碳排放配额分配实施方案（试算版） [2019 Implementation Plan of Carbon Dioxide Emission Quota Allocation for Key Emission Units of Power Generation Sector (Trial)], http://www.mee.gov.cn/xxgk2018/xxgk/xxgk06/201909/W020190930789281533906.pdf

Measuring and reporting emissions is pivotal for a robust ETS

A well functioning ETS relies on robust data. China has learned this from the seven ETS pilots plus its experiences in Fujian province, which launched its ETS in late 2016. However, data at national level remains sparse due to the lack of capacity among the covered entities to report CO_2 emissions. In recent years, China has required entities to self-report key parameters that are necessary to calculate their reported CO_2 emissions, such as fuel consumption and, when possible, the CO_2 fuel factor, which represents the quality of the fuel burned.

One tonne of reported CO_2 emissions is equivalent to one allowance. Entities have to submit every year for compliance the number of allowances that corresponds to their annual reported CO_2 emissions. Fuel consumption data are generally known and robust. However, **data on the CO_2 fuel factor, which is also an important parameter as it determines the CO_2 intensity of a power unit and thus the quantity of allowances to be submitted for compliance, are much less robust**. International and domestic guidelines provide CO_2 fuel factor values for different types of fuels (Table 6).

Reported CO_2 emissions =
fuel consumption x CO_2 fuel factor
CO_2 fuel factor = carbon content x carbon oxidation factor
x C/CO_2 molecular weight ratio*

In China, CFB coal power units are burning low-quality domestic coal, mainly lignite. The rest, around 95% of installed coal capacity, use bituminus coal or a blend of "other bituminous coal" with sub-bituminous coal. Due to the dominance of bituminous coal in China's coal power sector, and for simplification, guidelines from the Intergovernmental Panel on Climate Change (IPCC) for other bituminous coal of 95 $kgCO_2/GJ$ have been used for units that monitored their CO_2 fuel factor[18].

By imposing a default value of 123 $kgCO_2/GJ$ for units that do not monitor their CO_2 fuel factor, the ETS reporting guidelines encourage plants to monitor their CO_2 fuel factors by implementing specific measures. The default value is much higher than the real one, thus penalising the plants by requiring them to report higher CO_2 emissions for compliance, which result in higher CO_2 intensity. **To date, the number of plants that have been monitored remains unknown, leading to high uncertainty regarding the stringency of the ETS benchmarks.**

[18] In reality, the unit-level CO_2 fuel factor would differ by unit based on the coal type used. On average the CO_2 fuel factor should be close to the value of other bituminous coal. However, more bottom-up data at unit level would be needed to improve the estimation of the unit's CO_2 fuel factor.

*The CO_2/C molecular weight ratio is 44/12.

ETS default CO_2 fuel factor of 123 $kgCO_2/GJ$ is at least 20% higher than factors for all other type of coal from international and domestic guidelines.

Table 6: CO_2 parameters per coal type by source

Coal type	Default carbon content (kgC/GJ)	Default carbon oxidation factor	CO_2 fuel factor ($kgCO_2/GJ$)
Values from IPCC 2006			
Anthracite	26.8	100%	98
Coking coal	25.8	100%	95
Other bituminous coal	**25.8**	**100%**	**95**
Sub-bituminous coal	26.2	100%	96
Lignite	27.6	100%	101
Brown coal briquettes	26.6	100%	98
Coke	29.2	100%	107
China's provincial GHG inventory guideline			
Anthracite	27.4	94%	94
Bituminous coal	26.1	93%	89
Lignite	28	96%	99
Coking coal	25.4	98%	91
Coal briquette	33.6	90%	111
Coke	29.5	93%	101
China ETS reporting rules			
Default value	**33.56**	**100%**	**123**

Sources: IPCC (2006), 2006 IPCC Guidelines for National Greenhouse Gas Inventories; NDRC (2011), 省级温室气体清单编制指南（试行）[Provincial GHG Inventory Guideline (Trial)]; MEE (2019b), 关于做好 2019 年度碳排放报告与核查及发电行业重点排放单位名单报送相关工作的通知 [Notice on the Work Related to the 2019 Carbon Emissions Reporting and Verification and the Submission of the List of Key Emission Units in the Power Generation Sector].

ETS analysis for coal plants

Overview of unit-level analysis

Overview of the analysis

Based on an in-depth analysis at unit level of China's coal power plants in 2018, this report defines six cases to assess the effects of two key design parameters of the national ETS:

- allowance allocation using output-based benchmarks
- monitoring of the CO_2 fuel factor to calculate "reported CO_2 emissions" from coal power units.

The **six cases explore the implications of the two allowance allocation options** stated in the Ministry of Ecology and Environment draft plan[19]. The two options differ by the number of benchmarks for conventional coal power units (one or two benchmarks) (Figure 16). This affects the distribution of allowances between units, resulting in different levels of stringency and burden for units, depending on their size.

The CO_2 fuel factor depends mainly on the coal type burned in the unit and could vary substantially. Units are encouraged to monitor their CO_2 fuel factor. If they do not monitor it, they are required to use a default factor of 123 $kgCO_2/GJ$. This default factor penalises units by resulting in higher reported CO_2 emissions than if the fuel factor had been monitored and more accurately reflected the carbon content of the coal.

For each allowance allocation option, **three cases examine different possible CO_2 fuel factors** applied to coal power units for their emissions monitoring.

- **Default Case**: No coal power units monitor their CO_2 fuel factor and the default factor is applied for all. This is the least probable case with highest reported CO_2 emissions, and the worst case not only for units but also for the quality of the ETS measurement, reporting and verification (MRV) system.
- **Bituminous Case**: All units monitor their CO_2 fuel factor. Since the consumption of other bituminous coal is dominant in China's coal power plants, the IPCC 2006 guidelines for "other bituminous coal" of 95 $kgCO_2/GJ$ is taken as an average value for the monitored CO_2 fuel factor[20]. While not all the units can monitor fuel factors immediately, due to capacity constraints, they will increasingly do so. This case could become the most probable one before the end of the 14th Five-Year Plan.

[19] MEE (2019a), 2019 年发电行业重点排放单位（含自备电厂、热电联产）二氧化碳排放配额分配实施方案（试算版）[2019 Implementation Plan of Carbon Dioxide Emission Quota Allocation for Key Emission Units of Power Generation Sector (Trial)].

[20] Coal power plants in China use different type of coal ranging from low-to high-quality coal in term of calorific value. The CO_2 fuel factor used in the Bituminous Case may be slightly lower than the real average coal factor of China's coal power fleet, but the difference should be minor given the dominance of bituminous coal in China's coal power fleet.

- **Balanced Case**: Only a share of coal power units monitor their CO_2 fuel factor. The assumption is that small units (CFB, high pressure and subcritical units below 600 MW) will use the default CO_2 fuel factor due to a lack of MRV capacity. Supercritical and ultra-supercritical units, as well as large subcritical units over 600 MW, monitor their CO_2 fuel factor and the IPCC 95 kgCO_2/GJ value is applied. This is considered the most likely case at present.

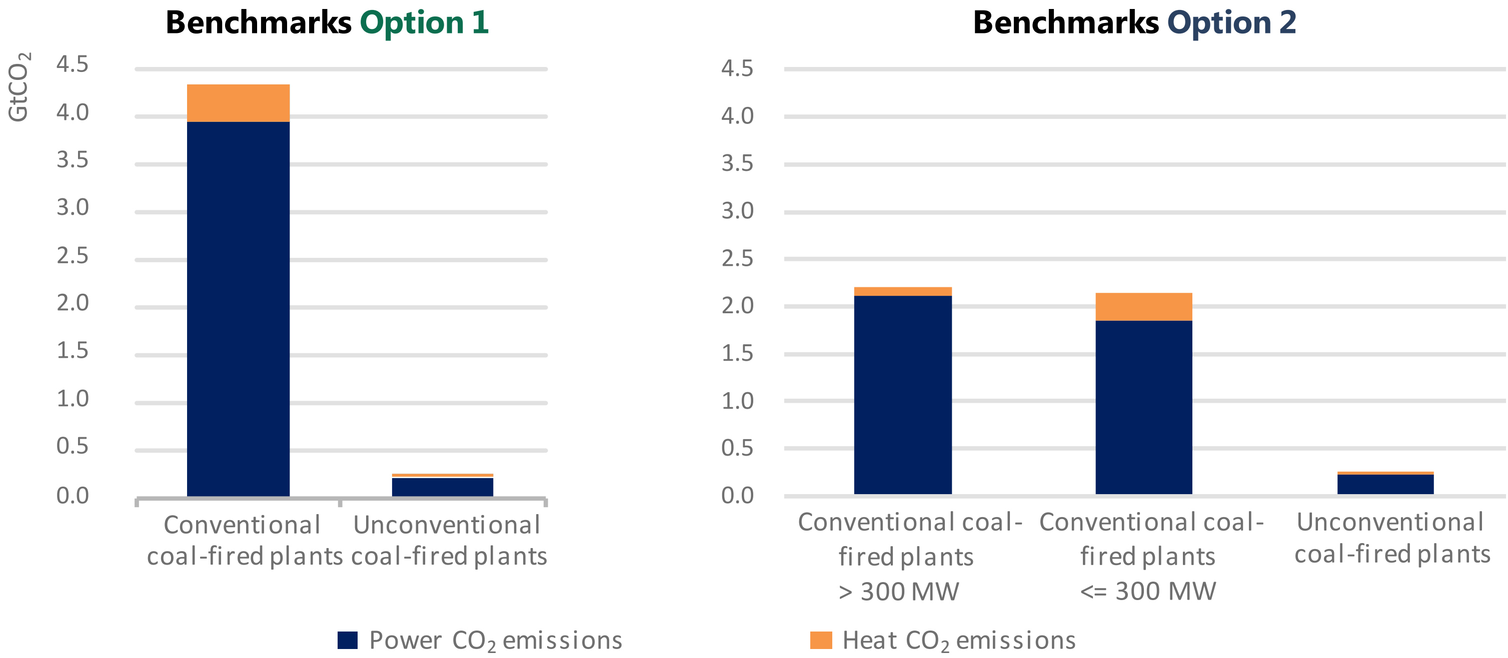
This unit-level analysis presents results of the overall allowance balance for the ETS in the six cases, then provides a detailed analysis for the Balanced Case with allowance allocation Option 2 (two benchmarks for conventional coal). Finally, the analysis explores possible future evolution of China's ETS, and its role in accelerating power sector decarbonisation.

Cases	Bituminous Case	Balanced Case	Default Case
Coal CO_2 fuel factor applied	All technologies: 95 kgCO_2/GJ*	Supercritical and ultra-supercritical: 95 kgCO_2/GJ* CFB and subcritical >=600MW: 95 kgCO_2/GJ* HP, other CFB and subcritical: 123 kgCO_2/GJ**	All technologies: 123 kgCO_2/GJ**
Allocation design: Option 1	Bituminous-Option 1	Balanced-Option 1	Default-Option 1
Allocation design: Option 2	Bituminous-Option 2	Balanced-Option 2	Default-Option 2

* IPCC 2006 value for bituminous coal; ** China's default value applied to non-monitoring units

Different benchmark options would break down covered CO_2 emissions differently

Figure 16: CO_2 emissions[21] for different benchmarks



Note: In Option 1, conventional coal-fired plants would consist of ultra-supercritical, supercritical and subcritical as well as high pressure plants. Unconventional would cover CFB power plants. Option 2 divides the conventional plants into above and below 300 MW capacity, resulting in one onventional benchmark for larger ultra-supercritical, supercritical and subcritical plants and another for smaller mainly supercritical and subcritical as well as high pressure plants. The unconventional benchmark remains unchanged.

[21] Unless specified, CO_2 emissions presented in this study are calculated using the IPCC (2006) "other bituminous coal" CO_2 fuel factor. These are different from the "reported CO_2 emissions" presented in the different cases under the ETS policy analysis; in that analysis, the CO_2 emissions presented here are equal to "reported CO_2 emissions" for the Bituminous Case.

CO_2 fuel factor monitoring, benchmark design and ETS effectiveness

ETS effectiveness will depend on the share of units that monitor their CO_2 fuel factor

If entities monitor their CO_2 fuel factor, ETS allocation benchmark levels would likely not be stringent (Bituminous Case). The average CO_2 intensity of all coal plant types would be below their corresponding allowance allocation benchmark, thus generating a surplus. Supercritical and ultra-supercritical units would receive the largest surplus. Demand for allowances from less efficient coal units would be too low to balance the units in surplus. **The Bituminous Case would generate an annual surplus of more than 600 $MtCO_2$ in allowances, equivalent to 13% of reported CO_2 emissions**. The resulting lack of a price signal would jeopardise the effectiveness of the ETS.

In 2018, the average CO_2 intensity of power generation in the Bituminous Case (0.900 tCO_2/MWh) is consistent with the actual average CO_2 intensity of 0.865 tCO_2/MWh, which matches the 13th Five-Year Plan average coal consumption target for operating coal-fired power plants by 2020 (310 gsce/kWh). Both allowance allocation options have benchmarks at levels far above the 2018 average CO_2 intensity. **With the current allocation options, coal consumption targets will have counterproductive effects on the ETS by increasing allowance surplus**. Current ETS benchmark levels are also not stringent enough to support the achievement of the average coal consumption target for coal-fired power plants.

However, if entities do not monitor their CO_2 fuel factor, the higher factor will be applied (Default Case). The average CO_2 intensity for most coal power technologies would be above the benchmark, except for some supercritical and ultra-supercritical units. The penalty implied by the default factor is intended to encourage units to monitor their CO_2 fuel factor. The Default Case would lead to much more stringency, though this case is the least probable.

In the Balanced Case, smaller or older units use the default CO_2 fuel factor while large and supercritical and ultra-supercritical ones monitor their CO_2 fuel factor. Those that monitor receive a higher surplus of allowances, while those that do not monitor experience a larger deficit of allowances. The Balanced Case would result in an equilibrium between allowance surplus and deficit.

Table 7: Power generation allowance allocation benchmarks and average CO_2 intensity by technology (tCO_2/MWh)

	Average CO_2 intensity			Benchmarks	
Technology	Bituminous Case	Balanced Case	Default Case	Option 1	Option 2
Unconventional coal: CFB	0.933	1.147	1.208	1.120	1.120
Conventional coal	0.899	1.012	1.164	1.015	-
at and below 300 MW	0.968	1.229	1.254	-	1.068
High pressure	0.990	1.282	1.282	1.015	1.068
Subcritical 300 MW	0.986	1.277	1.277	1.015	1.068
Supercritical 300 MW	0.804	0.804	1.042	1.015	1.068
above 300 MW	0.846	0.846	1.096	-	0.989
Subcritical 600 MW	0.961	0.961	1.245	1.015	0.989
Supercritical 600 MW	0.865	0.865	1.120	1.015	0.989
Ultra-supercritical	0.776	0.776	1.005	1.015	0.989

Heat generation allowance allocation benchmark and average CO_2 intensity by technology (tCO_2/GJ)

	Average CO_2 intensity			Benchmarks
Technology	Bituminous Case	Balanced Case	Default Case	Option 1 & 2
Coal	0.121	0.145	0.156	0.135

With the current allowance allocation design, the effectiveness of the ETS will thus be directly dependent on the number of units that monitor their CO_2 fuel factor.

In the Balanced Case, the assumption about how many units would monitor their CO_2 fuel factor is based on coal technology and on capacity size. These represent only a quarter of coal-fired power units but generated 54% of the power and heat and 47% of CO_2 emissions from coal-fired power plants in 2018.

Most of China's coal power units, even at 300 MW and below, have been successfully retrofitted with other emissions controls and reporting protocols on SO_2, NO_x and other air pollutants. The ETS could therefore probably rapidly achieve similar outcomes for monitoring of the CO_2 fuel factor. **The more units are monitored, the higher the surplus (Table 8)**. If all units at and above 300 MW monitor their CO_2 fuel factor, monitoring would cover 56% of coal units and around 80% of power and heat generation. The net balance of allowances would lead to a surplus of about 400 $MtCO_2$.

The more units are monitored, the higher the surplus

Table 8: Surplus or deficit is sensitive to the share of units monitoring CO_2 fuel factor

Scenario cases	Number of unit	Power and heat generation (TWh)	Reported CO_2 emissions ($MtCO_2$)	Allowance allocation (Benchmark Option 1)			Allowance allocation (Benchmark Option 2)		
	Share	*Share*	*Share*	Net Balance			Net Balance		
Bituminous Case:						605			641
Monitored Factor: all units	*100%*	*100%*	*100%*	605			641		
Default Factor: none	*0%*	*0%*	*0%*		0			0	
Alternative Case:						374			411
Monitored Factor: super- and ultra-supercritical, subcritical and CFB **above 300 MW**	*56%*	*83%*	*79%*	568			572		
Default Factor: high pressure and CFB **below 300 MW**	*44%*	*17%*	*21%*		-194			-161	
Balanced Case (BC):						-32			4
Monitored Factor: super and ultra-supercritical units, subcritical and CFB **above 600 MW**	*27%*	*54%*	*47%*	487			433		
Default Factor: high pressure, and subcritical and CFB **below 600 MW**	*73%*	*46%*	*53%*		-519			-429	
Alternative Case:						-193			-156
Monitored Factor: only super and ultra-supercritical units	*22%*	*44%*	*35%*	451			409		
Default Factor: high pressure, subcritical and CFB	*78%*	*56%*	*65%*		-643			-565	
Default Case:						-752			-716
Monitored Factor: none	*0%*	*0%*	*0%*	0			0		
Default Factor: all units	*100%*	*100%*	*100%*		-752			-716	

Note: In green: Deficit; in red: Surplus. The scale of the surplus will depend on the average monitored value of the CO_2 fuel factor for the coal fleet, which may differ slightly from the assumed value (IPCC 2006 guidelines for other bituminous coal).

Number of benchmarks distributes allowances differently between technologies

Depending on the benchmark option, the allowance distribution between technologies as well as the overall balance would vary. Under the current draft plan, Option 1 (one benchmark for all conventional coal plants) is more stringent than Option 2 (separating plants below and above 300 MW) (Figure 17).

All cases under Option 2 have more overall surplus, fewer allowances distributed to supercritical and ultra-supercritical units, and more allowances for high pressure and subcritical units. The benchmark for units below 300 MW is less stringent than that for units above 300 MW relative to the single benchmark option.

In Option 1, larger conventional coal plants receive more allowances while smaller ones receive much fewer, compared with the situation under Option 2 (Figure 17). This disadvantages smaller, less efficient units. However, the ETS allocation design should be intended to benefit more efficient units. More benchmarks distribute mitigation effort differently for different technologies, which is the reason for maintaining a separate unconventional coal benchmark. However, this tends to slow mitigation actions and keep less-efficient technologies running longer. While a single benchmark for all coal technologies would be best, considering the draft allocation plan, **Option 1 with a single benchmark for conventional coal would be simpler, more equitable and more effective**. More benchmarks increase the risk of favouring certain technologies, increasing lobbying and locking in CO_2 emissions.

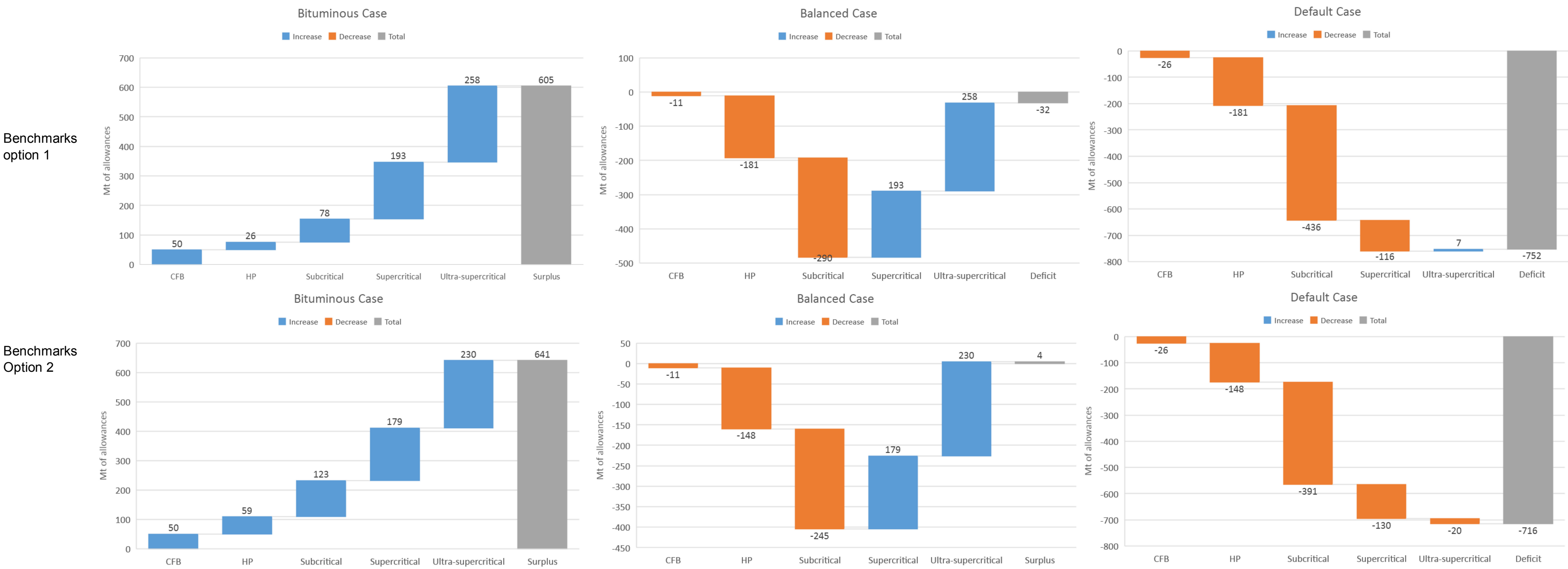
Except for the Default Case (no units monitor the CO_2 fuel factor), benchmarks for conventional coal become very lenient for large and most efficient coal technologies under both benchmarking options. The vast majority of recent and large plants will monitor their CO_2 fuel factor and have a CO_2 intensity significantly below the benchmark value, accumulating surplus allowances. In the Balanced Case, conventional coal plants generating almost 60% of power would have their CO_2 fuel factor below the benchmark, while coal plants generating more than 40% of power would need to purchase allowances (Figure 18).

In 2019, China required power units to self-report their 2018 emissions data. Improving robust data collection at unit level is key for the benchmark definition, and ideally should not be affected by default CO_2 fuel factor rules. However, given that the share of units with monitored CO_2 fuel factors is still uncertain, **benchmarks should be updated annually to integrate changes in the coal fleet and increased monitoring of CO_2 fuel factors**.

Communicating how benchmark formulation will evolve can also help participants plan for purchasing allowances and enhance ETS efficiency.

Under the draft plan, one benchmark for conventional coal would be more stringent…

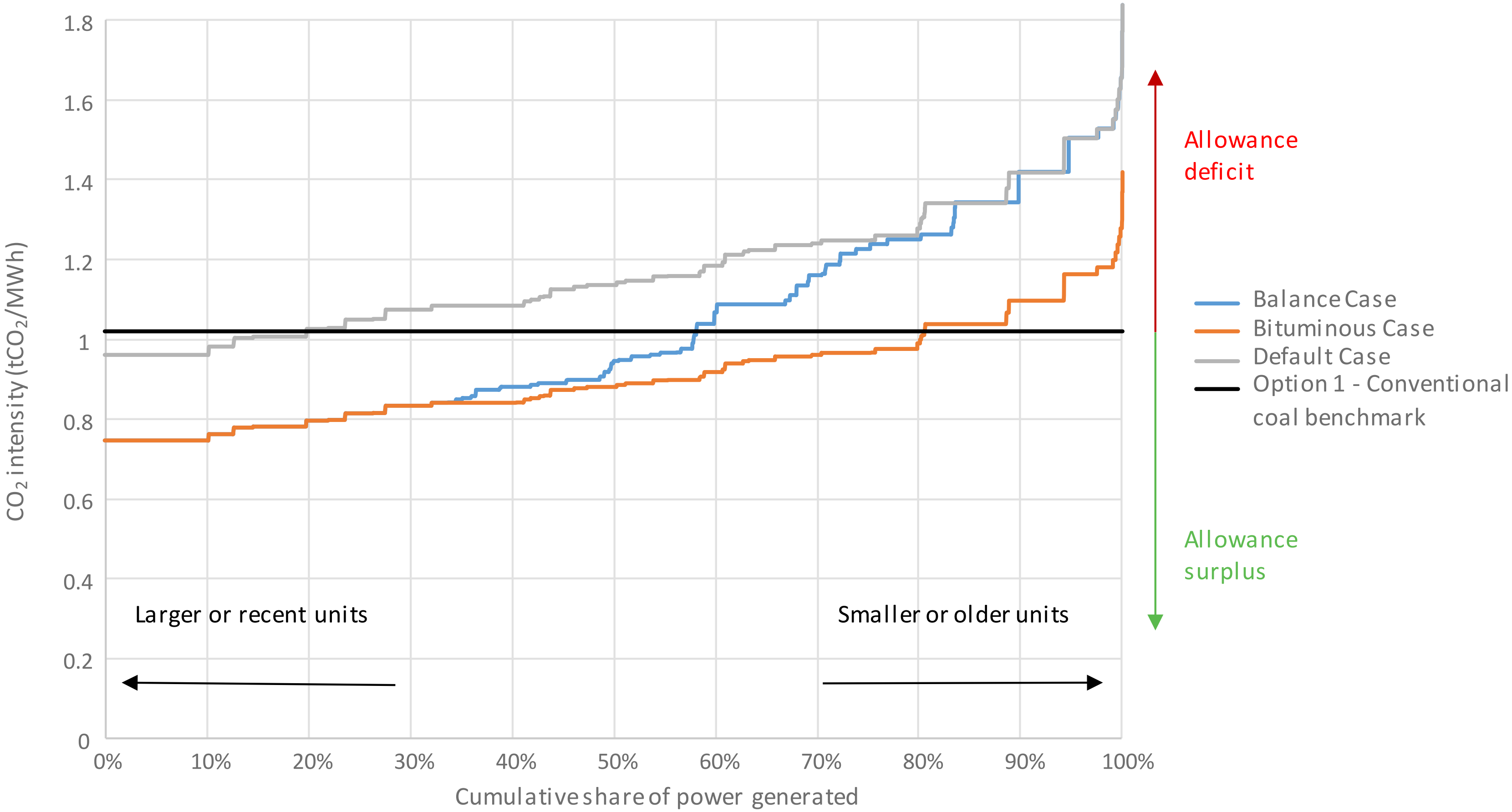
Figure 17: Allowance balance under different benchmark options and CO_2 fuel factors



Note: Ultra-supercritical and supercritical plants and units above 600 MW generate most of the surplus, confirming that the conventional coal benchmark above 300 MW is not very stringent – especially given the increasing share in power generation of such plants.

...though it remains lenient for larger plants relative to current CO_2 intensity levels

Figure 18: CO_2 intensity for each unit of power generated



One benchmark for conventional coal would support the ongoing power market reform

Ongoing power market reform will increasingly allow units to adjust their power generation to the grid according to their costs of production. The ETS allowance allocation design will provide incentives for more efficient units, mainly supercritical and ultra-supercritical units, to run more and to increase their average full load hours. This will increase the share of power generation from units with lower CO_2 intensity than the benchmark and reduce the share from units with higher CO_2 intensity. Less efficient units would logically run less. This would accentuate the overall allocation surplus in the ETS and support the argument for more ambitious benchmark levels that decrease over time.

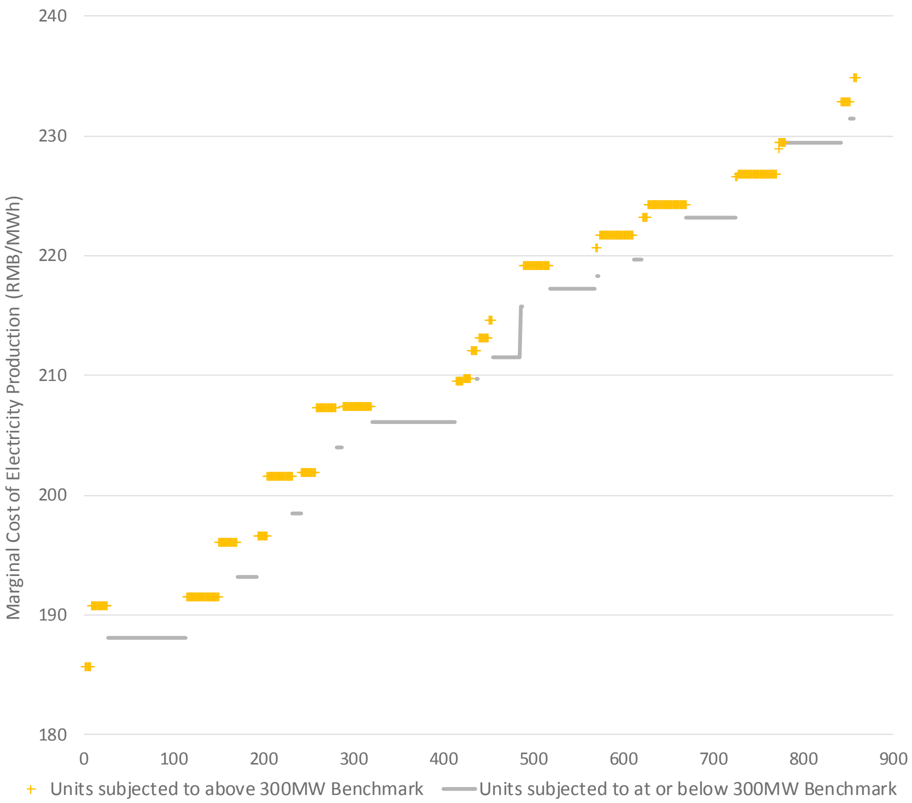
The two benchmarks for conventional coal plants in Option 2 would create further discord with the ongoing power market reforms if the allowance price became substantial. The least efficient plants under the more efficient benchmark would need to buy allowances, which may be sold by plants under the less efficient benchmark. This would allow some less efficient plants to offer lower prices in spot markets, while more efficient plants would need to raise their price in spot markets to pay for allowances. This could lead to spot markets selecting more inefficient, more polluting plants over others due to the impact of the ETS allocation on allowance distribution and pricing.

Figure 19 shows, in orange, plants that are subject to the more stringent benchmark for units over 300 MW. The grey line shows power units at or below 300 MW. Any discontinuities in the line show points where the ETS has caused units that are less efficient (therefore more costly and higher emitting) to move earlier in the merit order, thereby increasing their operation volumes over more efficient units. This means that maintaining **two benchmarks for conventional coal has a "cross-over" effect that undermines the power market reform objectives of least cost, merit order dispatch and could drive up emissions during power system operation**.

This counter-productive phenomenon will not occur in the early phase of the ETS due to surplus allocations, but could occur if the two-benchmark system persists as allocations are ratcheted down. At the same time, removing the second benchmark will become more challenging the longer the system operates.

Two benchmarks may give less-efficient power plants lower production costs

Figure 19: Zoom on the "cross-over" effect of the merit order curve under two benchmarks for conventional coal power plants



Note: The horizontal axis orders power units sequenced by their true efficiency (the ideal outcome of marginal cost dispatch in spot markets). The vertical axis displays the marginal cost of each unit including the marginal cost due to the ETS. This "cross-over" effect occurs at levels as low as CNY 2 per tonne of CO_2 abated. The chart assumes CNY 43/tCO_2 (Slater et al. (2019), 2019 China Carbon Pricing Survey price expectation by 2022).

Allowance allocation and equity

Allowance allocation disparity by province raises equity issues

Surplus and deficits in allowances are very unevenly spread; provinces that have larger shares of ultra-supercritical and supercritical plants benefit disproportionately. This poses serious questions about distributional effects under either benchmarking option and no matter what level of monitored coverage of units' CO_2 fuel factor.

In the Balanced Case, with the allowance allocation design Option 2, the ETS overall would generate a limited allowance surplus of 4.5 million at the national level. Units with CO_2 intensity below the benchmark, mainly supercritical and ultra-supercritical units, will accumulate a surplus of 445 million allowances. The others will be in deficit of 440 million allowances. Most subcritical units, including high pressure units, will be in deficit. Only few recent and larger subcritical units could gain some surplus.

At provincial level, around half of China's 31 provinces will have a net surplus of allowances. Out of the top ten provinces by capacity, Anhui, Jiangsu, Xinjiang, and Zhejiang will generate the most surplus (Table 9 and Figure 20). This poses distributional questions, especially for provinces in deficit. Other provinces with a larger share of subcritical units in their mix will be in deficit, such as Heibei, Inner Mongolia, Northeastern and Shangdong provinces.

In addition, if more units within a province monitor their CO_2 fuel factors, the province will have larger surplus and smaller deficits. This could encourage provinces to support monitoring of units, thus increasing the distributional effect of the allowance allocations and raising equity issue between provinces with higher monitoring capacities than others.

An allowance has a monetised value corresponding to the ETS market price, making surpluses and deficits economic incentives primarily for units, but also for provinces. The 2019 China Carbon Pricing Survey,[22] led by China Carbon Forum, estimated a price expectation of CNY 43/tCO_2 by 2022, based on wide consultation of stakeholders in carbon markets in China. Using this allowance price estimation, Anhui, Jiangsu, Xinjiang and Zhejiang could receive a monetised surplus of more than CNY 500 million from the ETS for their coal plants.

[22] Price expectation of 43 CNY/tCO_2 from Slater et al. (2019), 2019 China Carbon Pricing Survey, http://www.chinacarbon.info/wp-content/uploads/2019/12/2019-China-Carbon-Pricing-Survey-Report.pdf

Table 9: Overview of the ETS allowance allocation draft plan by province

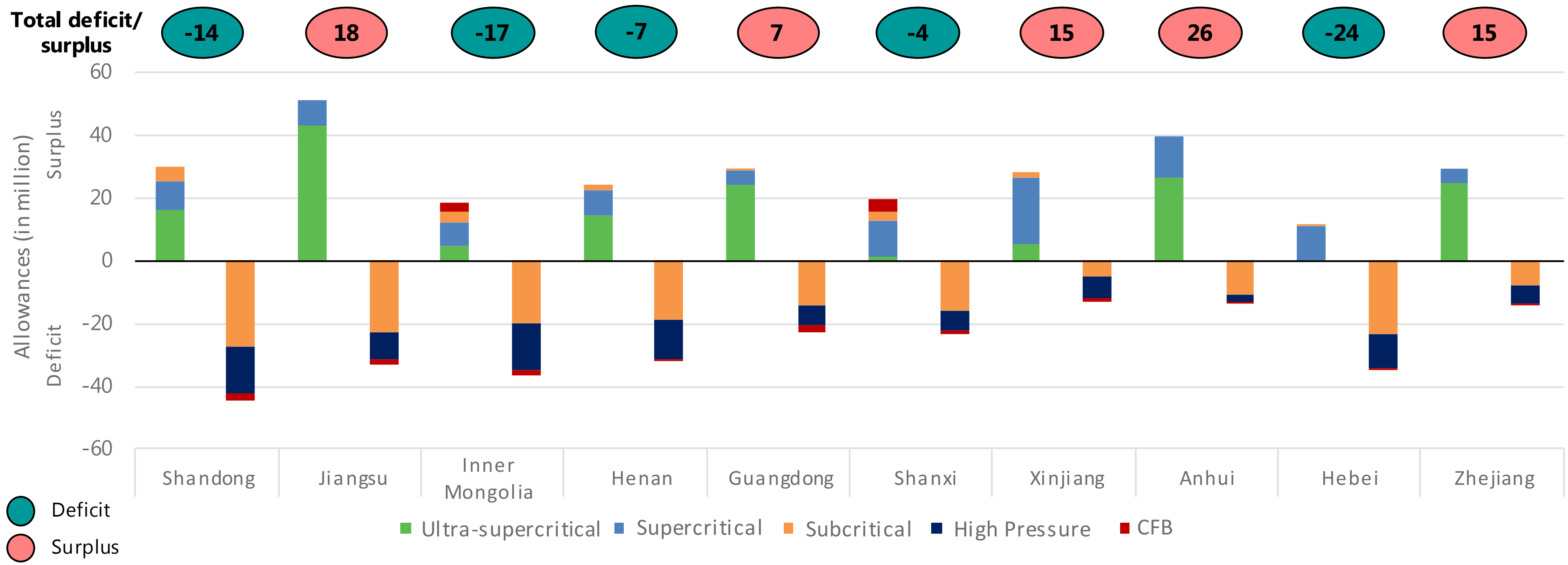
Net balance (million of allowances) and estimated value (millions of CNY) by province in the Balanced Case – Option 2

Province	Net balance Surplus	Estimated value
Anhui	26.4	1137
Jiangsu	18.4	793
Xinjiang	15.1	648
Zhejiang	15.1	648
Jiangxi	9.1	393
Guangdong	7.2	310
Fujian	6.4	277
Guizhou	4.1	178
Guangxi	3.2	135
Chongqing	1.9	81
Qinghai	0.8	34
Hainan	0.7	29
Ningxia	0.5	22
Tibet	0	0

Province	Net balance Deficit	Estimated value
Tianjin	-0.3	-12
Henan	-1	-42
Hubei	-1.3	-58
Yunnan	-1.5	-65
Sichuan	-2.1	-89
Shaanxi	-2.4	-103
Hunan	-2.9	-127
Shanxi	-3.5	-152
Shanghai	-4.6	-198
Gansu	-5.2	-222
Heilongjiang	-7.1	-307
Jilin	-7.3	-313
Liaoning	-9.9	-427
Shandong	-14.2	-612
Inner Mongolia	-17.5	-752
Hebei	-23.6	-1014

Five out of the ten largest provinces by coal power capacity will generate allowance surpluses

Figure 20: Allowance balance by technology and province in the Balanced Case – Option 2



Three of the top five power SOEs would receive an allowance surplus in the Balanced Case, opening the possibility of windfall profits

At the company level, allowance surpluses are even more concentrated: three of the top five state-owned coal power companies would receive an allowance surplus in the Balanced Case (Figure 21).

These three SOEs would generate an allowance surplus of 40.6 million, with the remaining companies – including Huaneng and Datang – facing greater stringency with a deficit of CNY 36.2 million.

This equates to a monetised allowance surplus for the three SOEs of CNY 1.75 billion, including CNY 1.28 billion for CHN Energy – and a carbon cost of CNY 1.55 billion for the rest. Datang would experience a high deficit due to its large share of subcritical power plants. The ETS could thus encourage mergers and acquisitions between power companies.

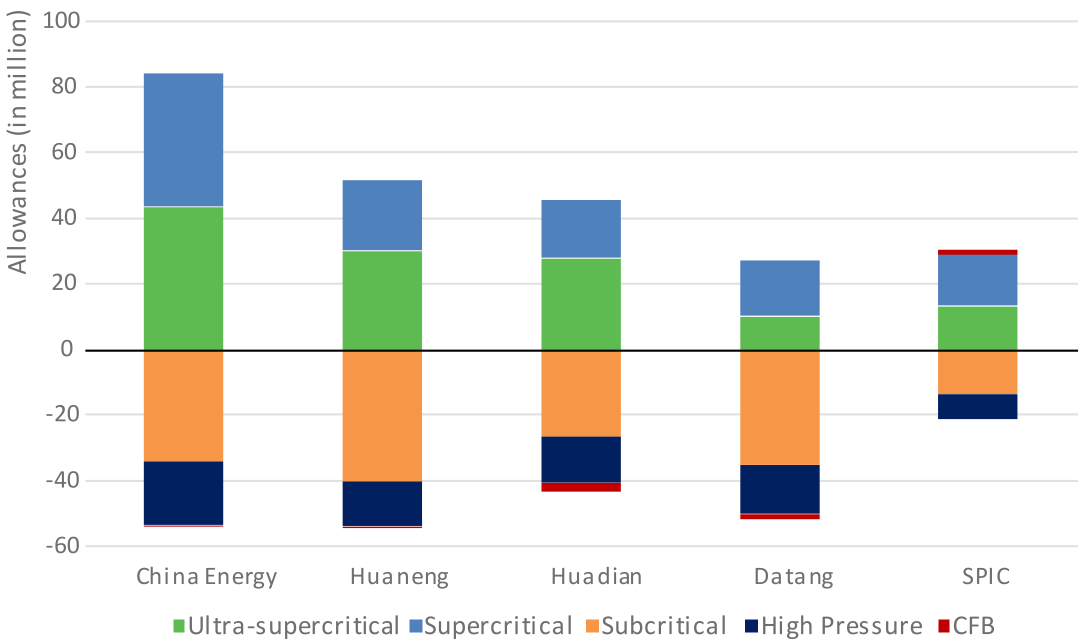
Even in the conservative Balanced Case, the ETS allocation surplus for some companies would result in positive financial incomes without substantial efforts to improve plant CO_2 intensity. **Since low-carbon power technologies are currently not included in the ETS design, companies are left with limited options to reduce the CO_2 intensity of their fleet.** These could be limited to retrofits and operational or management changes, which may not be aligned with broader energy transition objectives. For example, a simple change in management could increase the allocation surplus by shifting power generation from the least to the most efficient plants owned by the company. For companies with an allowance surplus, the ETS could improve their competitiveness against gas-fired and renewables-based power plants – the opposite of what would be expected from an ETS.

The current draft allowance allocation plan would use free allocation and explore possible future use of auctions. Since power and heat generation is not sensitive to international competitiveness, auctioning allowances would reduce the implicit subsidy created by a surplus of free allowances. Moreover, it would create revenues that could be used to support innovation and R&D, as well as to compensate certain companies or provinces according to technology.

Auctioning could be introduced progressively, even when free allocation is dominant. Setting aside funds generated from allowance surplus for low-carbon investments can support China's clean energy transition in various ways, including labour force retraining and redeployment.

Companies with a larger share of supercritical and ultra-supercritical plants will receive allowances in surplus, others will be in deficit

Figure 21: Allowance balance by technology and company in the Balanced Case – Option 2



Company	Allowance Balance (million)	Value (million CNY)
China Energy	29.8	1 283
SPIC	9.2	397
Huadian	1.6	68
Huaneng	-2.9	-126
Datang	-25.2	-1 082
Other companies	-8.1	-347

Policy interactions and effects on ETS

Policy interactions need to be considered – retiring plants to reduce overcapacity will have important effects on the ETS

In order to reduce air pollution and overcapacity, China is considering large-scale retirement of less efficient coal-fired power plants. In 2019, SASAC was considering a retirement plan[23] for SOEs in five pilot provinces by the end of 2021: Gansu, Ningxia, Qinghai, Shaanxi and Xinjiang.

If such a retirement plan were extended to all provinces, the implications for the ETS allowance allocation are striking. Retiring 25% to 33% of coal-fired capacity from the top five SOEs would remove around 150 GW of capacity.

This would require the retirement of all plants 15 years or older (Figure 22). This represents almost 600 units of an average size of 250 MW, equivalent to about half of the units in operation but only about 29% of the total capacity of their joint fleet. Of the retired plants, 60% would be CHP, which in 2018 generated more than 40% of the heat from the five SOEs and 25% of the power. Filling the heat generation gap is thus more challenging than the power gap for the remaining coal fleet. Assuming that the loss of power and heat generation is compensated by running the rest of their coal power fleet more often (using 2018 data), there would be technical challenges in satisfying the increase in both power and heat generation. This is essential to consider in any large retirement plan for China, particularly regarding the CHP fleet and the heat demand.

The vast majority of these retired units would be less efficient high pressure and subcritical plants with a CO_2 intensity of power generation ranging from 1.2 to 1.6 tCO_2/MWh. If no distribution constraint is defined between SOEs or provinces, most would be retired by China Energy, Huaneng and Datang in the Shandong, Inner Mongolia and Hebei provinces.

In the Balanced Case, this retirement plan would reduce emissions by 275 $MtCO_2$, a 5.3% reduction in CO_2 emissions from coal power plants. However, if not taken into account in the ETS allowance allocation design, even with the proposed output-based allocation, **this retirement of capacity would increase the net**

[23] Tanjiaoyi (2019), http://www.tanjiaoyi.com/article-29645-1.html; Xinhua (2019), http://www.xinhuanet.com/fortune/2019-12/03/c_1125300602.htm

annual allowance surplus almost 50 times, to about 255 $MtCO_2$ (Figure 23). The surplus would be considerably higher if more units monitored their CO_2 fuel factors, that is once most of the plants have opted for monitoring their emissions (e.g. Bituminous Case). With no adjustment to the benchmark level, two effects would increase the allowance surplus. First, less power will be generated by units that would need to buy additional allowances to meet the benchmark. Second, power not generated by the retired units will be generated by more efficient ones with CO_2 intensity lower than the benchmark, which creates additional surplus.

Several technical elements could help the ETS manage a relatively rapid change in the coal power fleet technology mix, such as through a large-scale retirement plan:

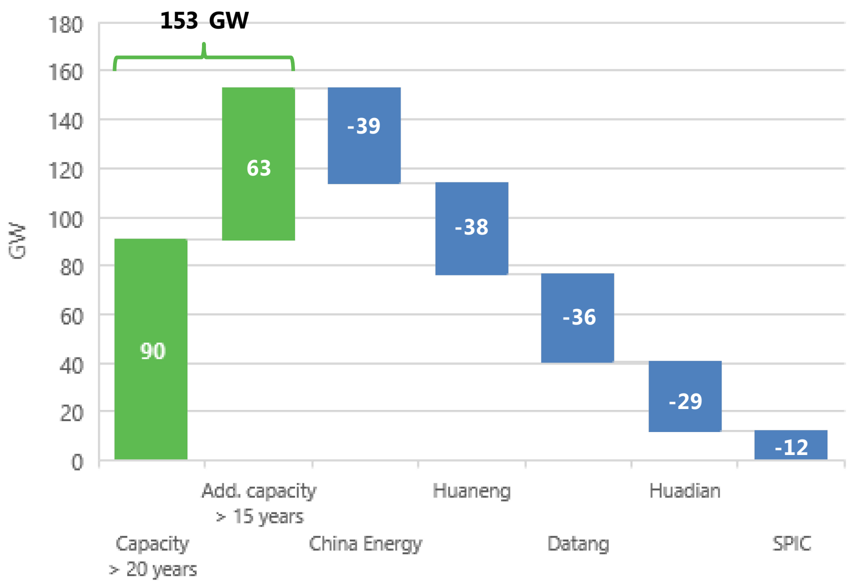
- Accounting for the impact of the change, e.g. retirement, ex-ante in the benchmark setting. Since the benchmark will evolve, it could adjusted to align with a retirement plan. In the Balanced Case, reducing the benchmarks by 5.4% would have avoided the 251 $MtCO_2$ additional surplus otherwise created by the retirement plan.
- Introducing an adjustment mechanism in China's ETS that can absorb surplus allowances in the face of various shocks or changes.

Having a mechanism that allows the ETS to adapt to changes and shocks is important, as illustrated by the example of a large-scale retirement plan. The coal-fired power mix can be affected by a range of policies, such as power market reform, coal capacity caps, environmental and energy conservation standards, and renewable performance standards. Knowing these will lead to changes in the power mix should be considered when designing the technical parameters of China's ETS.

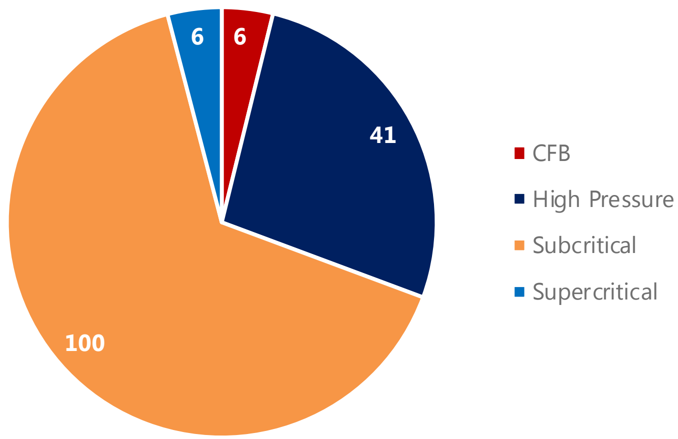
Ideally, adjustment mechanisms can also reduce the impact of shocks in the power system such as as an economic or health crisis. In terms of designing these mechanisms, there is no perfect ETS design. All existing ETS have had to learn by doing, and improve their policy through successive reforms.

Retirement of 150 GW would require the retirement of all coal-fired plants in their fleets that are 15 years or older

Figure 22: Breakdown of capacity to be retired by end 2021

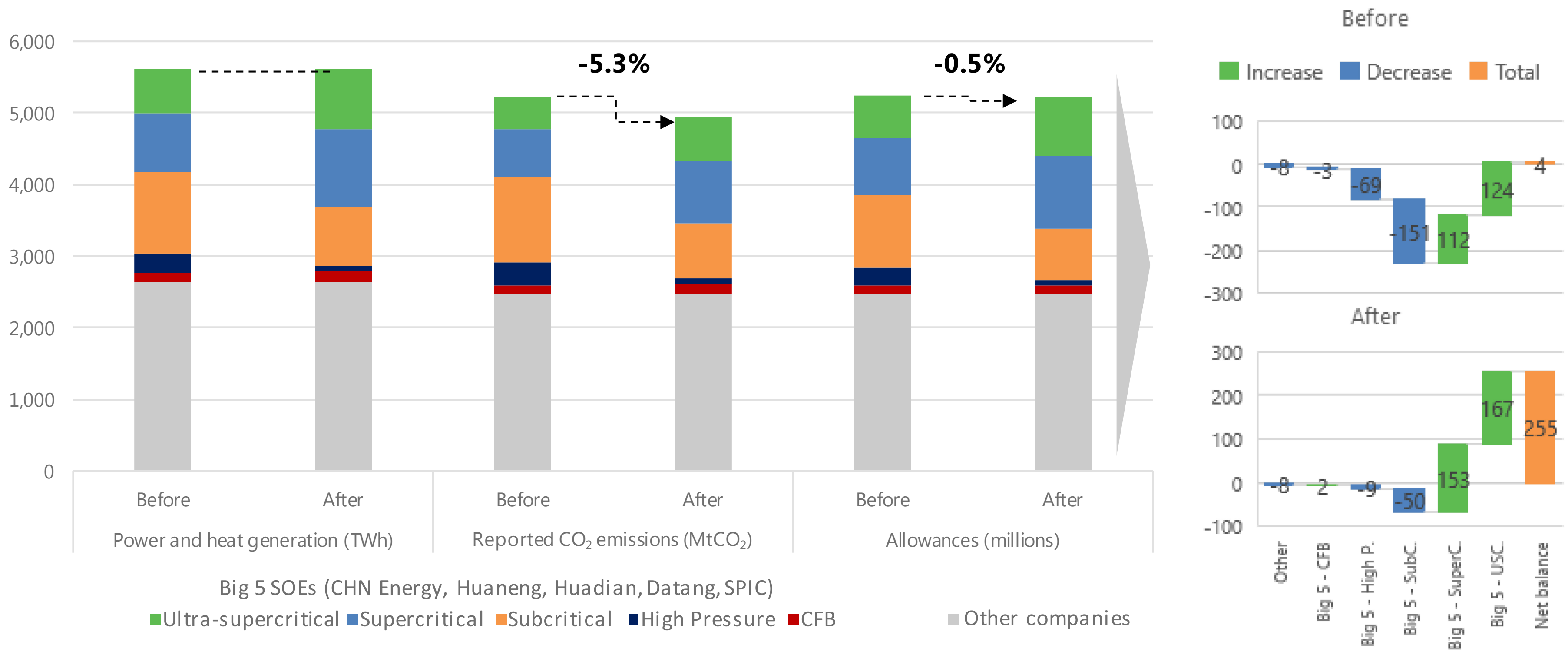


To be retired plants by technology (in GW)



If retirements are not considered in the ETS allowance allocation, a huge allowance surplus will be generated

Figure 23: Impact of retiring 150 GW for the five largest SOEs in the Balanced Case – Option 2 on power and heat generation, reported CO_2 emissions and allowances (left). Net balance of allowances in millions (right)



Note: In the Net balance of allowances in millions (right) figure, High P.=High Pressure, SubC.=Subcritical, SuperC.=Supercritical, USC.=Ultra-supercritical. Reported CO_2 emissions are sensitive to the CO_2 fuel factors used in reporting, thus do not necessarily correspond to actual emission levels.

Overview of power market reform interactions with ETS

Substantial reforms in the Chinese power sector are being implemented in parallel with the ETS, and will similarly drive increased utilisation of efficient, low-emission and least-cost resources. While most are aligned with the overall objectives of ETS, the timing of their rollout may complicate allocation methodologies, setting benchmarks, and forecasting availability of allocations in the ETS, especially in a multi-benchmark system. The table below describes key power sector reforms, their impact on power system operation, and their interaction with the ETS.

	Policy	Impact to units	Interaction with ETS
Mid- to long-term power contracts	Shifts from a model of government allocating roughly equal annual volumes to each plant, to a model where each unit signs contracts with end-users at negotiated volumes and prices.	Shifts bulk generation and revenues to the most efficient plants, since they can offer lower prices and attract more customers. This improves fleetwide emissions factors.	Will increase the availability of allocations in the ETS. If allocations are traded at a positive price, ETS will further improve the economics of efficient plants, and end-customers will be increasingly likely to purchase from efficient plants.
Spot markets and ancillary service markets	Creates a real-time market that prioritises the lowest marginal cost generation and flexibility to meet demand and integrate renewables.	This will shift more generation to efficient plants and renewables, but revenues will likely not change since those are guaranteed by mid- to long-term contracts. Mid-merit plants and high-cost plants will also operate more flexibly.	Will increase the availability of allocations in the ETS by using more efficient generation. For plants operating flexibly, their emissions per MWh will increase. Therefore, the ETS will drive up the cost of flexibility, and may make renewable integration seem more expensive.
Closures of old plants	Mandated closure of inefficient plants without adequate pollution controls, including industrial facilities, to manage air quality and overcapacity.	Will shift generation into the power market and will likely accumulate to the most efficient units.	Inefficient plants in the ETS will be closed, further improving fleetwide efficiency and creating surplus credits.
Coal consumption caps	Provinces in populous regions with air quality issues have caps on annual coal consumption.	Causes provinces and power companies to prioritise contracts with lower emitting resources. Restricts future investment in coal, driving provinces to import more, and build natural gas, nuclear or renewables.	Shifts towards more efficient generation, creating surplus ETS unless these restrictions are considered in benchmark setting for these regions. These provinces, usually wealthier, will have surplus allocation that they may sell to inefficient regions that are poorer, creating adverse wealth transfers.

Discussions on possible ETS evolutions in China

The ETS allowance allocation design should evolve with the changing role of the ETS

China's national ETS will co-exist with a suite of complex policies and regulations that aim to achieve diverse objectives, such as energy security and affordability, environmental protection, and socio-economic and climate change objectives. The ETS allowance allocation design could also serve these different objectives, while controlling and reducing emissions.

The in-depth static analysis of the ETS allowance allocation draft plan in previous sections of this report identifies important findings and recommendations. However, the ETS will be evolving in a dynamic environment. Its objective is to remain in place over time while becoming a major climate policy to support emissions reductions in CO_2-intensive sectors such as power and industry.

The role and function of the ETS should thus be carefully considered and reflected in its design. Learning by doing will be inevitable, as has been the case for all other existing ETS.[24] Policy interactions are broad and diverse, with risks of undesirable effects and chances of positive synergies. It is important to take into account these policies and their evolution in the design and the necessary evolution of the ETS.

Power will be the first sector to be covered. **The ETS will have to adjust to evolutions within the power sector.** This includes the major ongoing power market reform,[25] in particular of dispatch, which today is still administratively defined based on equal share dispatching rules in most provinces. The ETS will also have to respond to other policies such as overcapacity reduction programmes, energy conservation and air pollutant standards, and renewable portfolio standards.

This section explores principles, particularly of allowance allocation design, that could be considered for the ETS to take on a primary role in reducing power sector emissions over time.

The current ETS allocation benchmarks are a good starting point, allowing China to gain experience and to improve monitoring and data quality. Nevertheless, further action is needed to reach a continuous decrease of CO_2 intensity.

[24] See IEA (forthcoming), *Implementing Effective Emissions Trading Systems to Reduce GHG Emissions*.

[25] See IEA (2018), *Power Sector Reform in China* for more details.

China's ETS could play a key role in supporting power system transformation

In an ETS where allowances are allocated based on emissions intensity, as in China, the variation of power demand – whether due to GDP growth, economic structure shift, or energy efficiency measures – has limited impact on CO_2 intensity of the power sector.

The main factors influencing CO_2 intensity of the power sector will be efficiency improvements of different fossil-fuel generation technologies, coal-to-gas switching and, of course, increasing the share of low-carbon generation such as renewables and nuclear, and of CCUS. Since 2010, the deployment of low-carbon sources, particularly hydro, has been the main factor reducing the CO_2 intensity of power.

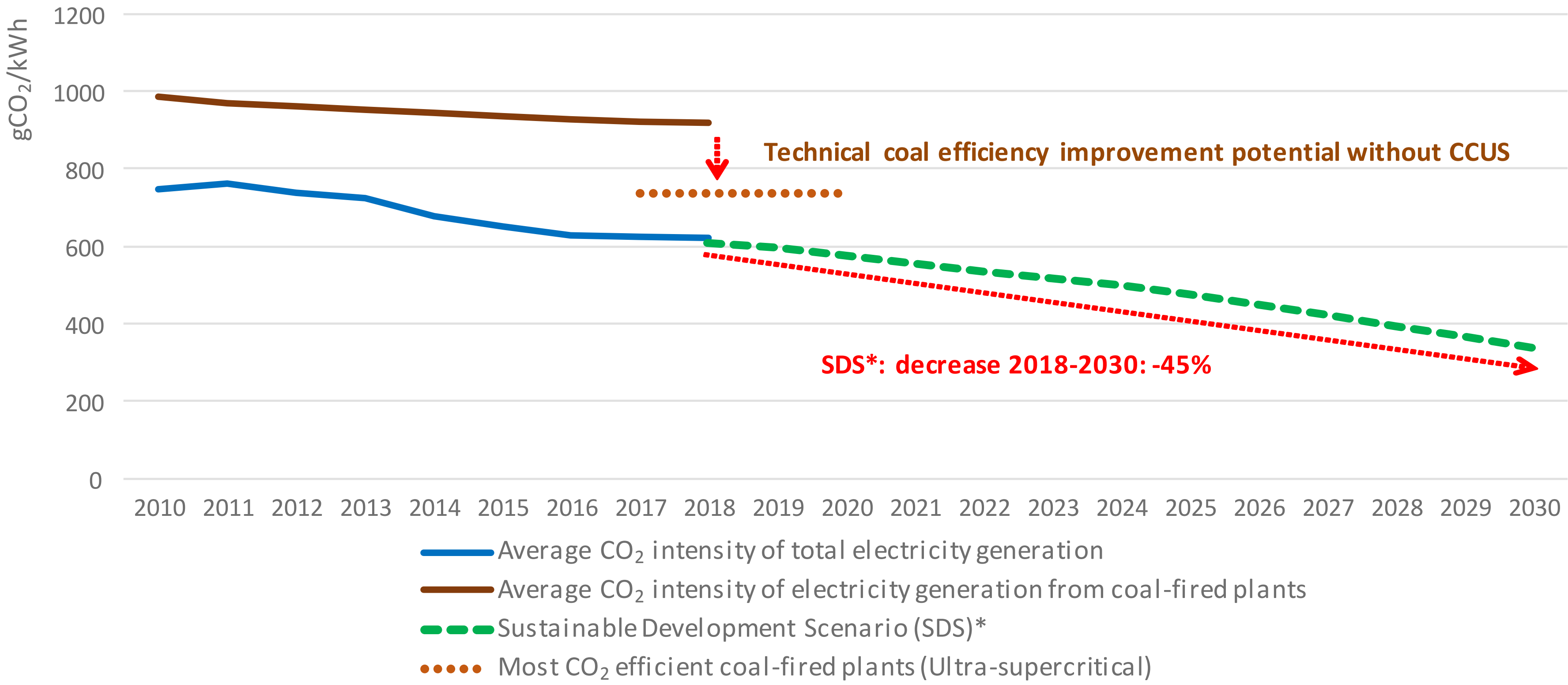
In China, the share of low-carbon generation is set to increase due to support policies for renewables and nuclear, including capacity-based targets. Coupled with lower growth in power demand, these will strongly decrease the overall CO_2 intensity of power generation, even without coal-to-gas switching or improved efficiency. With the current ETS allowance allocation draft plan, deployment of low-carbon technologies takes place independently of the ETS. Nevertheless, **the ETS can play an important role in reducing carbon intensity and transforming the power sector**.

Combined with power market reform, the ETS can increase the efficiency of coal plants. There remains a significant gap between the average CO_2 intensity of coal plants at 900 gCO_2/kWh, and that of the most efficient ultra-supercritical units at 740 gCO_2/kWh (at full capacity factor levels). The ETS could help narrow the gap with more stringent benchmarks, and by encouraging changes in operation from less efficient to more efficient units. However, this would require a change in current power dispatching rules. Decided ex-ante annually and based on equal share dispatching, current rules restrain the ability of units to adjust their operation.

With different allocation design, the ETS can support the shift from coal to low-carbon technologies (Figure 24). By providing a meaningful price signal, the ETS could directly support the shift from coal to low-carbon technologies, in particular to wind and solar PV, while supporting gas and CCUS deployment. Changes in the ETS allowance allocation design would be needed, such as having fewer benchmarks, and eventually having a single one covering all power generation technologies. The ETS could then become a major driver of power sector decarbonisation.

Improvement potential of coal efficiency is limited: change in the generation mix will become the key driver of CO_2 intensity reduction

Figure 24: Average CO_2 intensity trends (2010-2018) and SDS* projections (2018-2030)



* The IEA Sustainable Development Scenario (SDS) (IEA, 2019b) outlines a major transformation of the global energy system to deliver simultaneously on the three main energy-related Sustainable Development Goals (air pollution, energy access, climate change). In the SDS, China's energy system transforms significantly by 2050, to be aligned with China's "ecological civilisation" vision. The CO_2 intensity of the power sector in the SDS reaches 340 g/kWh in 2030, a 45% decrease from the 2018 level of 613 g/kWh.

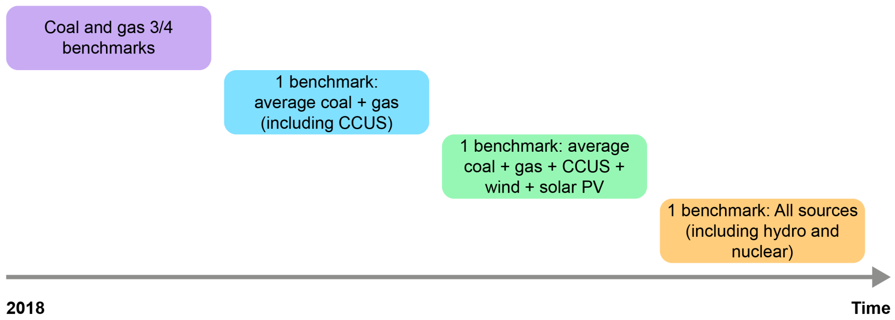
A multi-step approach would encourage fuel and technology switch

Research has shown that a single benchmark would be the most efficient and effective output-based design for the power sector.[26] However, there could be strong resistance to convergence towards a single benchmark from covered entities in the absence of a clear roadmap for the evolution of the ETS.

A multi-step approach would enable the technology benchmarks to converge towards a single power-sector benchmark in successive phases, with clarity on the timing and phases (Figure 25). The multi-step approach could progressively merge benchmarks for coal and gas, including units equipped with CCUS, then include wind and solar PV, and finally integrate all renewables and nuclear. The surplus allocation for CO_2-intensive power technologies would progressively disappear, and fossil-fuel technologies would experience larger deficits while low-carbon technologies would receive a surplus.

Such an approach integrates and optimises the "three pillars" for decarbonisation: fossil fuel efficiency, fossil-fuel mix, and deployment of low-carbon technologies. It also helps **identify the policies that could be substituted or be supported by an ETS** (e.g. coal consumption standards and reduction of subcritical coal power plants, renewable support policies) and provide a clear signal for CCUS investments and deployment.

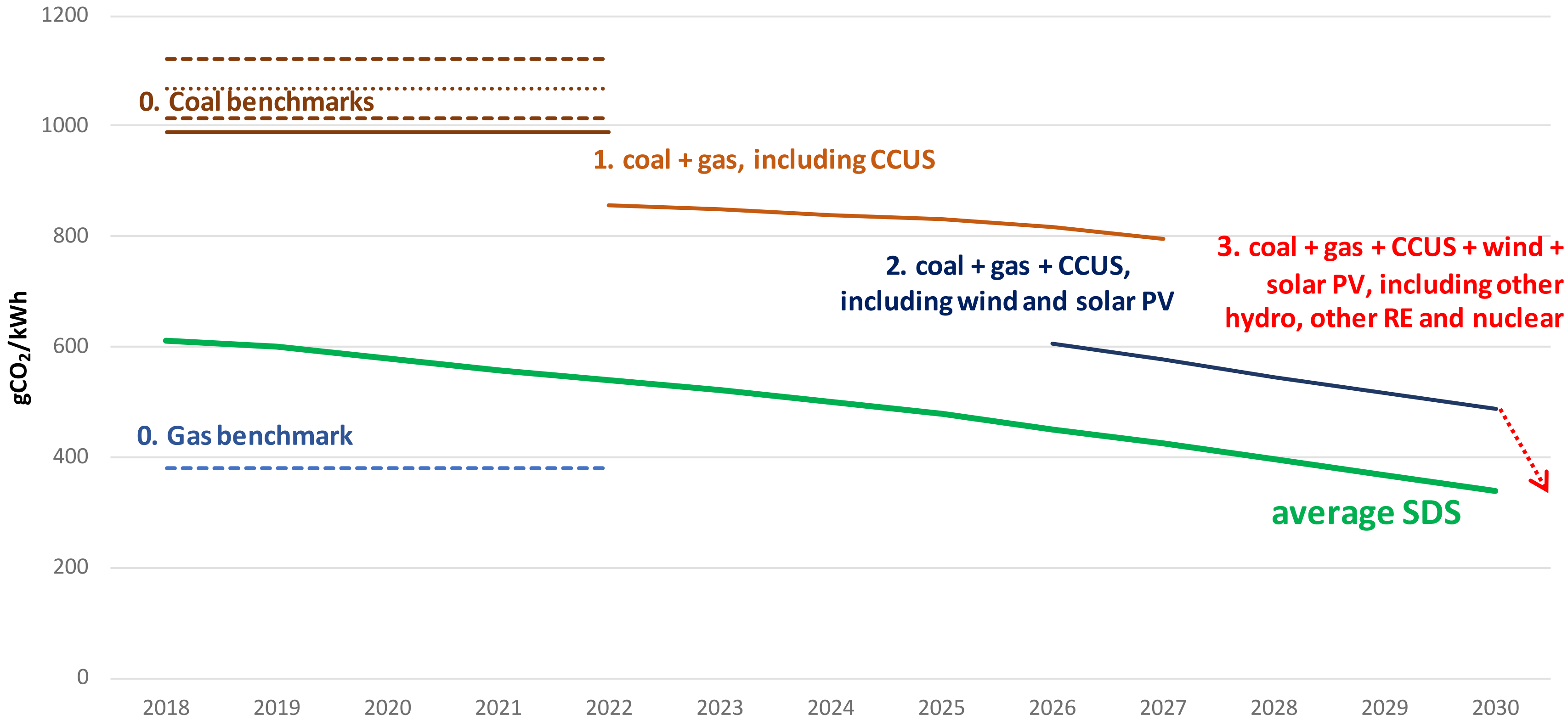
Conceptualizing a multi-step approach – climbing down the ladder



[26] Goulder and Morgenstern (2018), China's Rate-Based Approach to Reducing CO_2 Emissions: Strengths, Limitations, and Alternatives, https://doi.org/10.1257/pandp.20181028.

A clear roadmap for ETS evolution will support the implementation of a multi-step benchmark approach for the power sector

Figure 25: Multi-step approach: Merging benchmarks progressively to keep track with the power decarbonisation trajectory



The ETS could provide support for CCUS deployment

Given China's large and young coal power fleet and power system structure, a rapid coal phase-out is unrealistic today.

CCUS would allow deep power decarbonisation,[27] but R&D and economic incentives are needed to reduce its costs and support large-scale deployment. A 2016 IEA report[28] concluded that over 300 GW of existing coal-fired power plants met a basic set of criteria to be suitable for retrofit (access to CO_2 storage, age, size, load factor, and type and location of fuel source).

Several pilot and test CCUS facilities are operational in China, such as the Shanghai Shidongkou Carbon Capture Demonstration Project, a Huazhong University project and the Haifeng Carbon Capture Test Platform.[29] In addition, several large-scale CCUS projects are being developed, such as Huaneng in Tianjin, a 400 MW IGCC CCUS project with a capture capacity of 2 $MtCO_2$ per year, and Xinjiang has been proposed as a potential CCUS hub.

The ETS can help provide the right incentives to support CCUS deployment in two ways:

1. Coal and gas units equipped with CCUS technology should be covered under the same benchmark as other coal and gas units. Monetised value of allowances received in surplus will help reduce their costs of production.

2. Auctioning of allowances will create a new revenue stream that could be used to support CCUS deployment or retrofit.

A mix of regulations and market-based policy instruments could also be mutually supportive. For example, the 14th Five-Year Plan could fix a maximum life-time for unabated[30] coal power plants and require new coal plants to be CCUS-equiped by 2025. All unabated installed coal plants will thus be able to operate until they reach 30 years. The ETS – and its revenues – could act as a subsidy for CCUS deployment in new coal construction or retrofit of young and large units already in operation.

[27] MOST (2019), 中国碳捕集利用与封存技术发展路线图 (2019) [CCUS Roadmap for China (2019)].
[28] IEA (2016), *Ready for CCS Retrofit*, https://www.iea.org/reports/ready-for-ccs-retrofit
[29] Global CCS Institute (n.d.), Global CCS Facilities Database, https://co2re.co/FacilityData, accessed 20 May 2020.
[30] Unabated coal power generation refers to the coal-fired power generation without any technology to substantially reduce its CO_2 emissions, such as carbon capture utilisation and storage (CCUS).

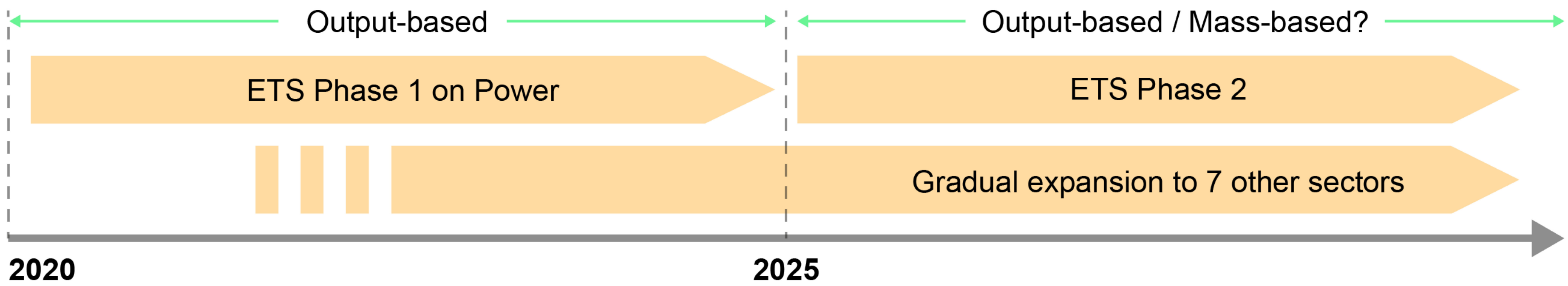
Capping CO_2 emissions in China's ETS by moving to mass-based allocation and extending sector coverage

China plans to expand its national ETS to seven other sectors (petrochemicals, chemicals, building materials, steel, nonferrous metals, paper and domestic aviation).

Output-based allowance allocation based on benchmarks would become increasingly complex when expanding to other sectors. Moreover, ensuring equity for emissions reduction efforts between covered entities from different economic sectors may become more challenging.

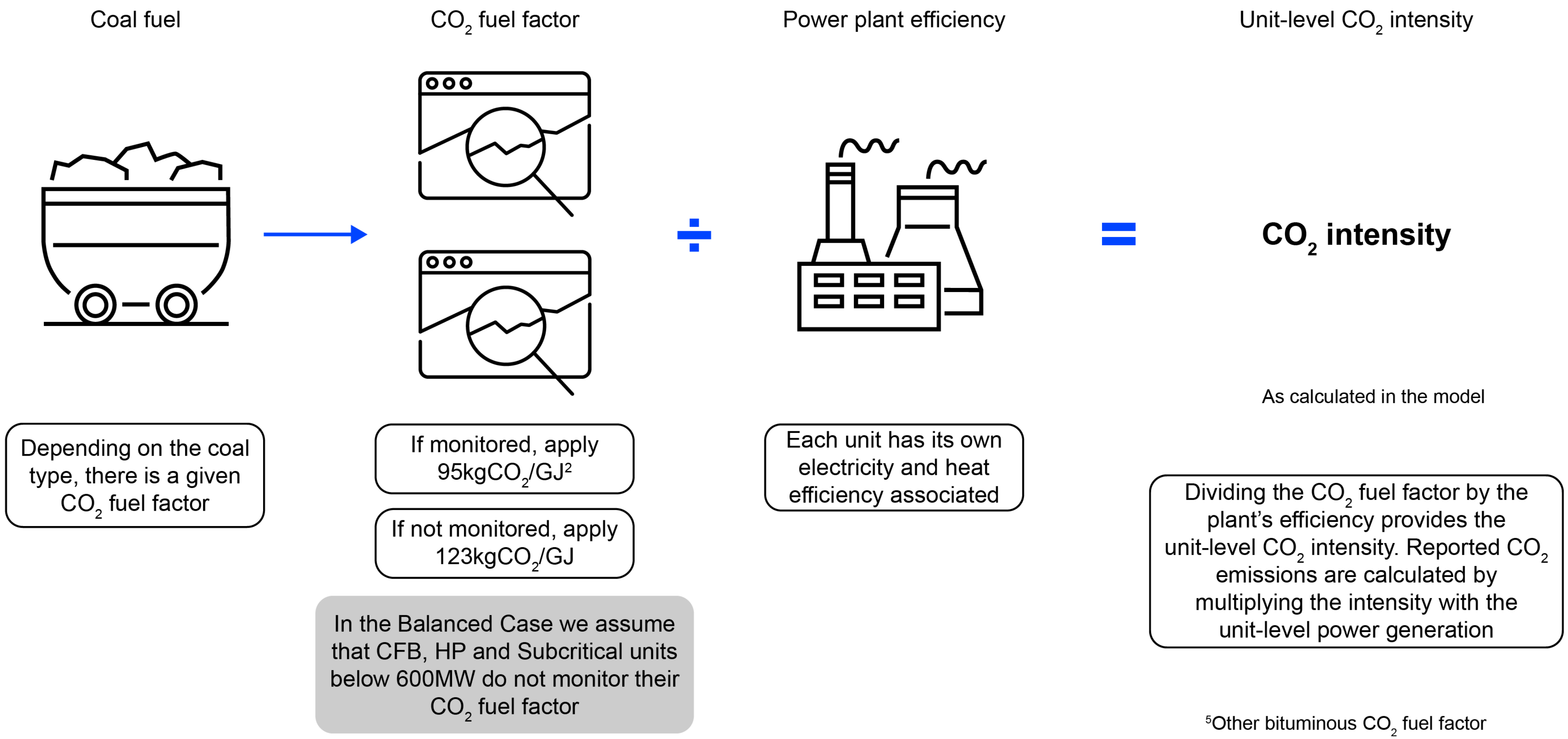
Thus, the ETS expansion to other sectors could result in a second phase with a new ETS design, for example by moving from an output-based to a mass-based ETS similar to the EU-ETS.

This ETS change would require a significant reform of the policy. However, experience from the first phase and the ETS pilots, improved data quality and enhanced capacity of covered entities to monitor their emissions could facilitate and support the reform.



General annex

Figure 26: Calculation of unit-level CO_2 intensity in the database used



Abbreviations and acronyms

ACCA21	Administrative Centre for China's Agenda 21
CAGR	compound annual growth rate
CCUS	carbon capture, utilisation and storage
CDM	Clean Development Mechanism
CEC	China Electricity Council
CFB	circulating fluidised bed
CHP	combined heat and power
C	carbon
CO_2	carbon dioxide
ECC	IEA Environment and Climate Change Unit
EPCRS	Energy Production and Consumption Revolution Strategy
ETS	Emissions Trading Scheme
EU	European Union
FYP	Five-Year Plan
GDP	gross domestic product
GHG	greenhouse gas
HP	high pressure
IEA	International Energy Agency
IGCC	integrated gasification combined cycle
IPCC	Intergovernmental Panel on Climate Change
MEE	Ministry of Ecology and Environment
MFA	Ministry of Foreign Affairs
MIIT	Ministry of Industry and Information Technology
MOF	Ministry of Finance
MOST	Ministry of Science and Technology
MRV	monitoring, reporting and verification
NBS	National Bureau of Statistics
NDC	Nationally Determined Contribution
NDRC	National Development and Reform Commission
NEA	National Energy Administration
NO_x	nitrogen oxides
PV	photovoltaic
R&D	research and development
RE	renewable energy
SASAC	State-owned Assets Supervision and Administration Commission of the State Council
SDS	Sustainable Development Scenario
SO_2	sulfur dioxide
SOE	state-owned enterprise
SPIC	State Power Investment Corporation
UNFCCC	United Nations Framework Convention on Climate Change

Glossary

CNY	Chinese Yuan renminbi
g	gram
GJ	gigajoule
gsce	gram of standard coal equivalent
Gt	gigatonne
GW	gigawatt
kg	kilogram
kWh	kilowatt hour
Mt	million tonnes
MW	megawatt
MWh	megawatt hour
PJ	petajoule
t	tonne
TJ	terajoule
TWh	terawatt hour

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