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China Energy Transition Status Report 2020

Sino-German Energy Transition Project

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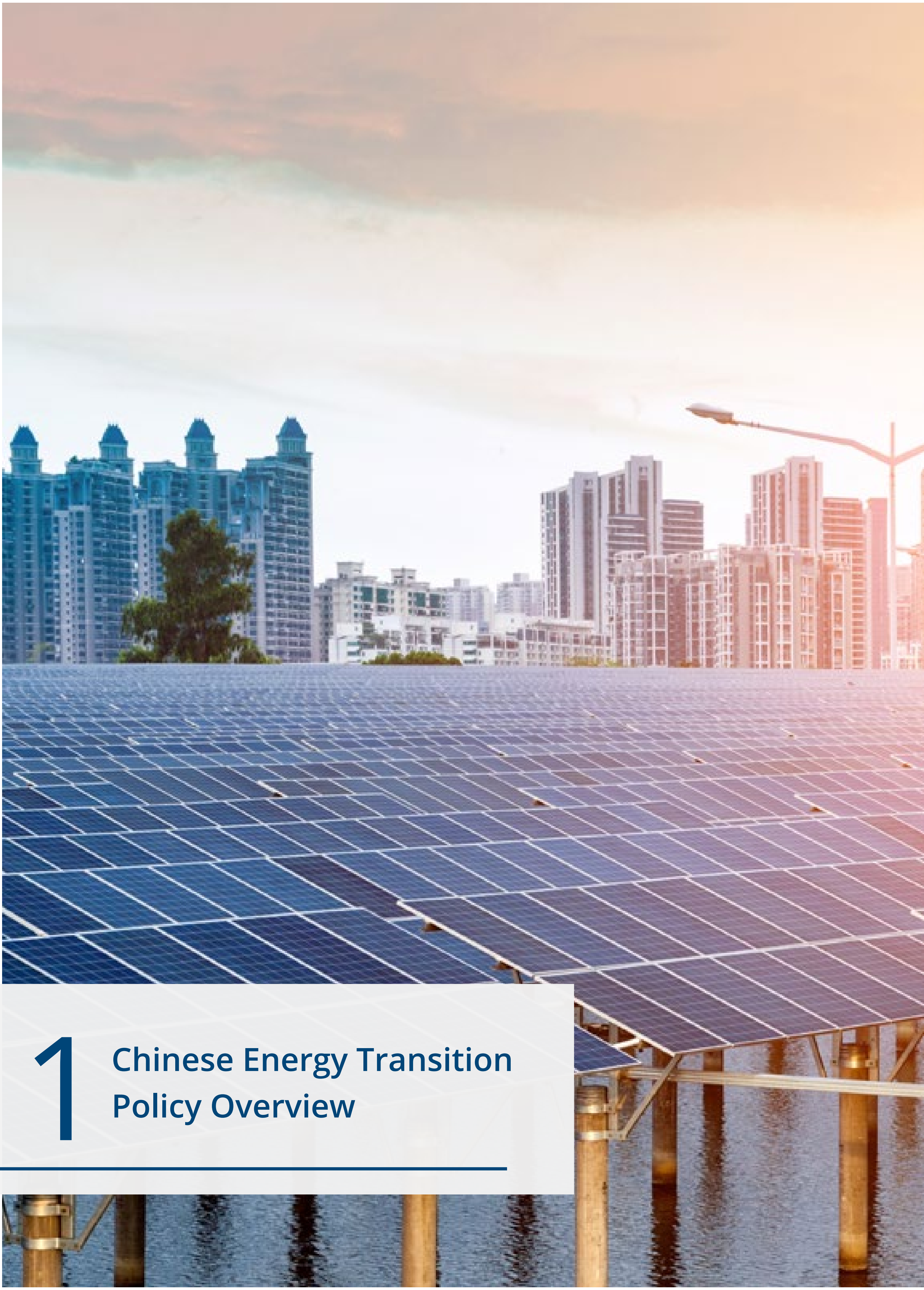


1 Chinese Energy Transition Policy Overview

1. Chinese Energy Transition Policy Overview

Introduction

2019 marked a shift in China's energy transition and energy transition policy environment, as the country's rapid growth in clean energy and clean energy technologies slowed due to efforts to scale back subsidies and shift towards market- and governance-based incentives.

Policy makers had signalled the need for such a shift for years. Critics had called out subsidy policies as rigid, costly and inefficient. At the same time, it is important to recognize these subsidies have been fundamental to China's swift rise as a leader and pioneer of wind, solar, electric vehicle, and battery technology—and the world's energy transition has benefited from China's clean energy scale-up.

The removal and scaling back of subsidies was anticipated and necessary, but nevertheless painful. It seems clear that market reforms in the electricity sector, such as spot markets, will have a positive effect on the transition by enabling greater uptake of existing renewable energy in the absence of subsidies. After EV subsidies scale off, incentives such as license plate policies and quotas are likely to sustain the growth of cleaner transportation, along with a push at the city level to encourage electrification of the logistics sector.

2020 is the final year of the 13th Five-Year Plan, and the preparations of the next plan must carry forward reforms in the above areas. The 14th Five-Year Plan period (2021-2025) represents a critical time for determining the speed of China's energy and economic transitions. Originally, 2020 was supposed to be a major year for climate negotiations where countries were expected to increase the ambitions for their nationally-determined contribution (NDC) to climate change agreements. The postponement of climate negotiations comes at an inauspicious time in China's five-year planning process, and it remains to be seen whether the schedule of carbon markets and clean energy policies could be further delayed.

Before the coronavirus hit, 2020 was already shaping up to be a year of transition in energy and climate policy. The worldwide economic disruption of 2020 adds significant uncertainty about both fields. The collapse in world oil prices could reduce urgency around limiting oil and gas imports, but at the same time renders domestic oil and gas production less competitive, calling into question whether China should continue to invest heavily in domestic production. Historically, China has relied heavily on infrastructure-based stimulus projects to ride out economic downturns, and China has already proposed a New Infrastructure plan for 2020 that includes items such as high-speed rail and 5G networks. Many observers have expressed worry that China could prioritize traditional building projects to absorb overcapacity production of steel, cement, and coal, which would represent a setback for both shifting away from energy-intensive industry towards cleaner sectors, but could also negatively affect air quality and carbon emissions.

President Xi addressed this issue in a March speech, noting that China will prioritize green growth.[1] (This report includes a section about Green Stimulus ideas that are currently circulating in various countries that could be applicable in China—see page 5-6) In past 2-3 years, China has pursued a middle course, bolstering fossil fuel or energy-intensive industries while also seeking to stabilize clean energy markets and find new ways to promote new technologies without incurring major new subsidy obligations. Renewable energy investment and reducing carbon emissions have been lower priorities recently, and the coronavirus and postponement of the Glasgow COP seem likely to reinforce that trend, but it also appears safe to predict there will be no dramatic turn back to coal.

Major progress

China made progress on energy transition policy in 2019:

Energy mix

The country's fuel mix continued to evolve. Non-fossil energy provided 14.9% of the country's energy production, versus 14.3% the prior year. Non-fossil sources provided 31% of electricity consumption. Combined, wind and solar accounted for 8.6% of electricity production, up from 7.8% the prior year[2]. This is approximately in line with the global average, but below some countries and regions such as Germany, with 33.6% of electricity from wind and solar in 2019 and all renewables accounting for 46.1% of electricity generation.[3]

Power reform

Spot power market pilots continued to develop, as did trading of electricity between provinces. As a result, the integration of renewable wind and solar electricity improved, and wind and solar curtailment fell below 5%, a target level considered acceptable by policy makers. This trend substantially improves the competitiveness in wind and solar versus coal across the country. Cross provincial power trading and more flexible coal power dispatch have also helped.

Energy efficiency:

The economy grew by 6.1% with an expected reduction in energy intensity of about 3%. Progress in energy efficiency over the last decade has relied on a mix of measures such as mandates on large energy consuming industries and gradually tightening efficiency requirements for new buildings. Between 2010 and 2018, China's energy intensity fell by approximately 30%, both as a result of efficiency measures, as well as through productivity gains and changes in the economic structure.

Carbon market:

China's Ministry of Ecology and Environment published final market rules, specifying power sector efficiency benchmarks, which will be the basis for allowance allocation. Following the official launch of China's national carbon market in 2017, implementation has proceeded cautiously, with national trading set to start in 2020, though the coronavirus could affect this schedule.

Air quality:

Improvements in air quality continues, particularly in Beijing, where average annual PM2.5 levels have fallen from a high of over 100 micrograms per cubic meter in 2013 to under 50 in 2019.[4] Other regions have seen improvements as well. China is midway through implementation of the Blue Sky Protection Plan, which set ambient air quality targets and implementation actions for a number of major regions. Air quality remains an ongoing concern, and a key driver of clean energy policy.

Electric vehicles:

50% of EV cars sold globally were in sold in China. Yet, the domestic market for EVs declined 4% in 2019 to 1.2 million vehicles, with most of the decline in the second half of the year following cuts to vehicle purchase subsidies. Subsidy cuts should help rebalance the market to longer-range EVs and favour companies using more advanced batteries—both trends which could benefit international carmakers. China continued rapid growth in EV charging infrastructure, reaching over 500,000 public charging points, up over 50% from the prior year.

Low-carbon 2022 Winter Olympics:

2019 saw significant progress towards realizing the vision of a low carbon 2022 Winter Olympic Games, which will take place in Zhangjiakou and Beijing. All Olympic venues will be powered by renewable energy, and Chongli district in Zhangjiakou will be mainly renewable-powered. Many 2008 Olympic venues will be reused, and several venues are repurposed industrial sites, including a former Shougang blast furnace in Beijing.[5]

Challenges remain

While energy reforms and clean energy policies are advancing, the overall energy transition in China remains challenged.

- Carbon emissions rose 1.9% in 2019, [6] which was down from the increase in 2019, but comes after several years when it had seemed that carbon emissions in China may have already peaked or flat-lined. [7]

- Slowing renewable additions: As subsidies scale off, the renewable sector has contracted. PV has slowed considerably since a mid-2019 subsidy quota cut. In 2019, China added 30 GW of solar PV, down by 25% from the prior year, though China remains the largest solar market in the world. Wind installations rose 30% to 26 GW, still below their peak. According to the China Renewable Energy Outlook, there is a need to raise renewable energy additions to around 150 GW each of wind and solar to meet the goals of the Paris climate agreement.[8] The reduction in subsidies, along with project delays caused by the coronavirus pandemic, will likely challenge renewable energy installations in 2020. However, since wind and solar are already economically competitive for many new projects without subsidies, the main factors affecting growth in future years remain project approvals, land use policies, and whether electricity market reforms continue to promote integration of renewable energy and favour dispatch of low-marginal cost energy sources.

- Coal power capacity and output continue to rise. In 2019, thermal electricity production rose 2.4%, accounting for the largest increase in output, even though other sources combined accounted for the majority of production increases.[9] China's coal fired power plants operate at low utilization,[10] and most operate at a loss. The National Energy Administration has given more provinces the green light for building new coal plants.[11] (See chapter 3 for more details.) RMI and ERI have suggested that existing coal-fired capacity and renewables can meet all of China's electricity demand growth.[12] However, organizations such as the power industry group China Electricity Council have called for China's coal power capacity to grow: CEC suggests a target of 1,300 GW by 2030 (implying 200-300 GW of new coal capacity) to meet rising peak load.[13] Economic weakness may strengthen calls for more coal investment and additional ways to help the SOE coal industry.

- Currently, the government has signalled the priority is on energy security,[14] which for the moment many policy makers appear to equate with increasing domestic fossil fuel production. Domestic renewable energy, along with energy storage and electric vehicles, contribute to energy security as well, and in the long run may offer better economic returns. Notwithstanding government commitments to a stable market for renewable energy and an early peak to emissions, the energy transition in China is undergoing a period of doubt as to the level of priority attached to promoting clean energy.

- Low oil prices have multiple effects on clean energy economics and policy. Although low oil prices may dent the economic case for EVs, charging EVs from electricity remains relatively cheap compared to China's domestic fuel prices. Lower oil prices may also hit domestic oil output in the short term as affect the economics of investing in domestic oil and gas infrastructure. Hence, if China continues to prioritize energy security and reducing import dependence, low oil prices could work against addressing energy security through the supply side, and potentially help encourage greater efforts to promote alternatives (such as EVs) on the demand side.

- In international climate negotiations, 2020 is considered a crucial year, when countries are required to increase their ambition in line with the goals of the Paris Climate Agreement—given that current nationally-determined contributions do not enable fulfilment of those goals. In 2019 China signalled willingness to increase its ambition, but the outbreak of the novel coronavirus may lead to lower motivation to take strong action on climate. The postponement of climate talks will likely exacerbate this.

GREEN STIMULUS IN CHINA 2020

What Are the Potential Ideas?

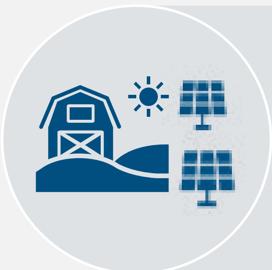
Definition of green stimulus:

Policy designed to inject large amounts of cash into real economic activity of a green or low-carbon nature, oriented towards short-term measures that can be implemented in 1-6 months, generally directed at providing cash towards individual consumers, workers, or communities directly affected by downturns.

Quotation from President Xi*:

The environment itself means the economy. If you protect the environment, you will receive rewards from the environment... Building a modern socialist country includes both the modernization of urban and rural areas.

Ideas from international experience



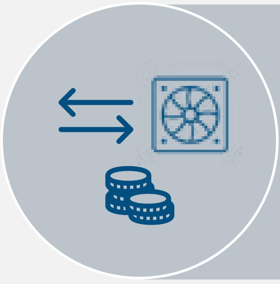
Solar for agricultural and coal communities:
Expand poverty alleviation and agricultural solar programs, aiming in particular at regions most affected by economic downturn. Such investments can also provide employment and income alternatives for villages and regions undergoing a transition from fossil fuels, facilitating a just transition for these regions. Funding for technical assistance programs through local agricultural universities could also be boosted.

Building energy retrofit:
Expand existing rural and urban building energy retrofit programs. Shortage of funding and lack of incentives are typically the main barrier to retrofit programs. Retrofit programs could target regions undergoing switch from coal heating, as well as regions undergoing industrial transition away from fossil industry employment, enabling workers to be redirected towards local retrofit activities.

Support for advanced, low-carbon agricultural practices:
Expand subsidies and payments to communities engaged in innovative agricultural techniques aimed at reducing nitrogen fertilizer usage and boosting soil carbon through techniques such as inter-cropping.

Worker training and income support for lost coal jobs:
Provide and expand programs for worker retraining in communities undergoing transition away from fossil fuels. For older workers, direct income support can take the form of early retirement, one-time bonus payments, support for child education, and health care payments. For younger workers, retraining programs and temporary income support for enrollment in training can enable a sustainable economic transition.

Vehicle buy-backs:
Rebates for scrapping old, polluting vehicles and replacement with new energy vehicles can not only promote NEV policy but also directly reduce air pollution by targeting removal of highest-emission vehicles. In China, such a policy could target replacement of old trucks, which are responsible for a large fraction of transport air emissions. Such emissions directly affect the health and immune system of workers and communities, so these investments can stimulate the economy while also helping boost resistance to disease.



Appliance buy-backs:
As with vehicle scrappage policies, rebates for scrapping old air conditioners, space heaters, and refrigerators can be directed at lower-income communities and areas with high energy consumption, not only improving energy efficiency but reducing energy costs for such communities over the long run.

Port electrification:
Subsidies for acceleration of port electrification can help modernize logistics facilities that may already be suffering from the downturn in global trade. In ordinary times, lack of funding and inadequate incentives are the major barriers to undertaking costly investments that take years to pay back, such as shore power for ships, electrification of forklifts and drayage trucks. Such a program could be combined with vehicle scrappage policies for polluting trucks.

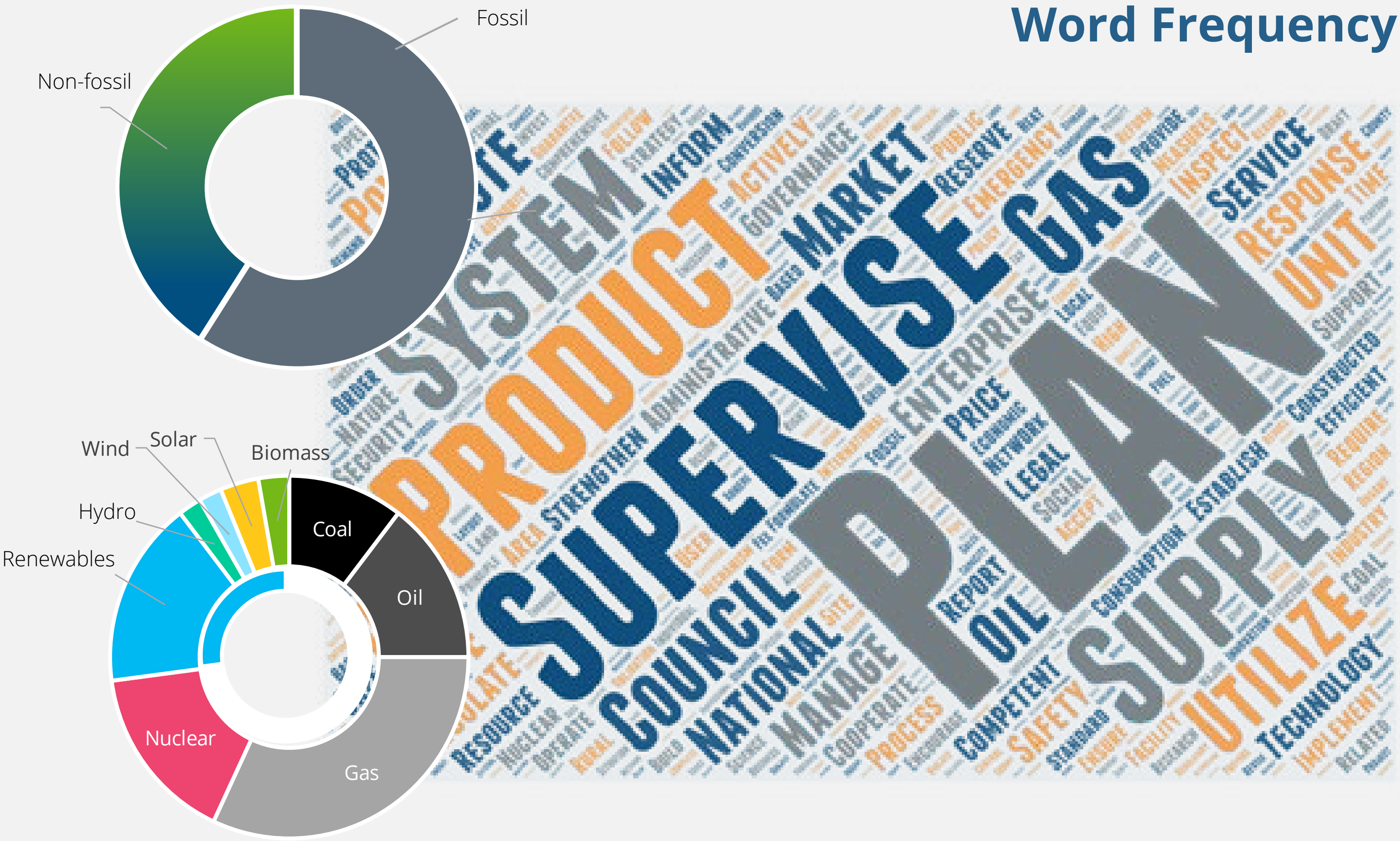
School solar and EV charging, retirement home solar and EV charging:
Schools and retirement homes often lack funds for major investment in clean energy and clean transport, and they also lack the incentive to invest in such technologies. Yet children and seniors are most vulnerable to the health effects of dirty air. Subsidies and rebates could be targeted at enabling schools and senior facilities to install building-integrated or rooftop solar and replace buses or other vehicles with new energy vehicles.

*Ma Zhenhuan and An Baijie, “Xi stresses green model of growth,” China Daily, 1 April 2020, at https://enapp.chinadaily.com.cn/a/202004/01/AP5e83ceada3103a24b110d1e7.html.

China's 2020 Energy Law 能源法

In April 2020, China issued a draft energy law that would codify many of the policies on energy transition already underway, prioritizing renewables, while also promoting gas, nuclear, and some fossil fuel technologies. In this section, we analyze the frequency of different words in the law, pointing out its focus on planning and supervision, as well as the heavy emphasis of renewables, nuclear, and gas:

Word Frequency



> Giving priority to the development of renewable energy does not mean that there will be a explosive development for renewable energy... it will replace fossil energy gradually.

Li Junfeng
Director of CREIA

Fossil Fuel

The law focuses on "clean and efficient use" of fossil fuels as well as "low-carbon development."

The law promotes the exploration of fossil energy but states the exploitation should be rational. For oil and gas, onshore and offshore oil and gas fields should have equal emphasis. Unconventional oil and gas resources such as tight gas, shale, and coal-bed methane should be developed as well.

For coal and thermal energy, the focus is on "clean, safe and efficient" thermal power generation and related technologies aimed at enhancing energy efficiency and reducing pollutant emissions. Coal-based fuels and coal chemicals should be developed "appropriately."

Renewables

The document states that the development of renewable energy should take priority, and the share of non-fossil fuel should be increased. Distributed renewables are singled out for promotion, and rural areas should increase the proportion of renewable energy in consumption.

The law codifies a recent policy to guarantee consumption of renewable energy by provinces and regions, and to set minimum targets nationally and at the provincial level. Grid companies should give priority to renewable energy for grid-connections and should follow the guaranteed purchase rule. Companies and individuals are encouraged to procure renewable energy.

Hydrogen

Hydrogen is recognised as a type of energy for the first time in official documents instead of a dangerous good.

Nuclear

There should be a safe and efficient development for nuclear power, and China will promote research and development on advanced nuclear power technology.

Market

Market should play a key role in resource allocation. An effective and competitive market structure and mechanism should be constructed. The natural monopoly segment of the market and the competitive segment should be operated separately. Pricing in the competitive segment should be formed by the market. The price of the natural monopoly segment should be set by the pricing management departments in the government.

Security

Energy security strategy involves energy layout optimization, construction of energy security reserves and peak shaving facilities, enhancement of capacity of energy supply guarantee and emergency regulation. Energy production and supply enterprises shall supply energy in accordance with laws, regulation and supply contracts on time. They shall not arbitrarily interrupt or stop energy supply, raise prices, or reduce the amount supplied.

Li Junfeng
Director of CREIA

During the 14th Five-Year Plan, there should be a shift from rapid growth to high-quality growth or green growth. Quality depends on two aspects, one is increasing renewable energy and natural gas consumption, the other is raising the share of non-fossil or renewable energy sources.

This is a large energy system change, entailing advances in renewable energy, energy storage, hydrogen and ultra-high voltage transmission lines, but also innovation of other technologies... like smart controls and blockchain.

Shi Jialin
Director of China Datang Corporation

Du Xiangwan
Academician of Chinese Academy of Engineering

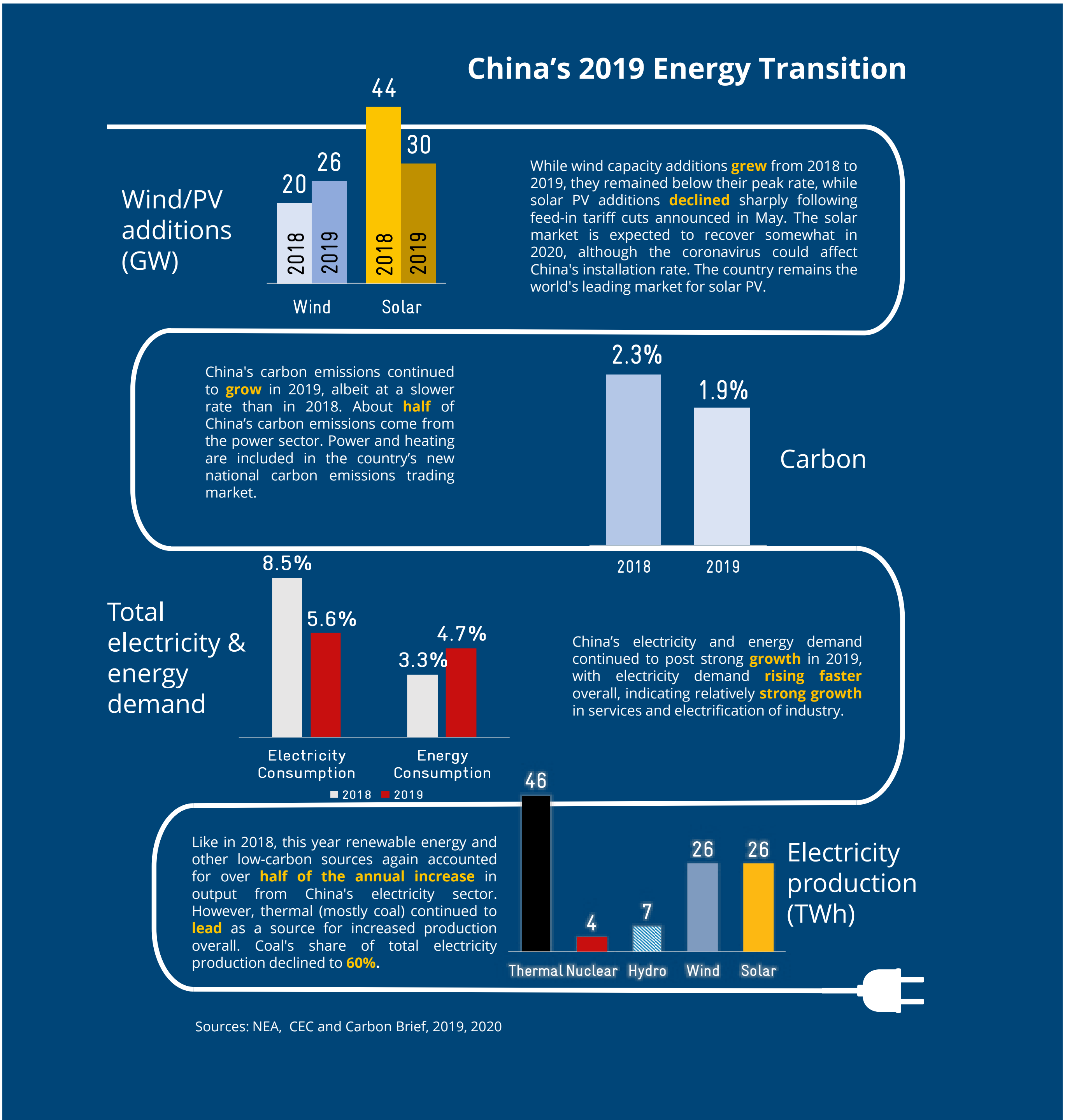
Addressing climate change and promoting low-carbon energy transition will not only boost the development of new energy, but also promote a new type of economic growth, which will be a win-win for both the economy and the environment.

2 2019 Key Energy Transition Statistics

2. 2019 Key Energy Transition Statistics

Introduction: China's energy transition slowed as renewable additions fell in 2019

China's electricity and energy demand posted strong growth in 2019, though electricity demand growth slipped from 8.5% to 5.6%. Carbon emissions continued to rise, albeit at a slightly slower rate than in 2018.[15] Although coal still accounts for over 50% of primary energy consumption and remains the mains source for electricity generation, electricity generated by renewable energy increased steadily in 2019. Solar PV additions declined sharply following a mid-year cut in quotas for new projects supported by feed-in tariff. A rush to complete and connect solar and wind projects is expected in 2020, feed-in-tariffs for conventional solar and onshore wind projects will scale off after 2020. However, the sudden COVID-19 outbreak at the beginning of the year may cause delays to the completion of renewable projects due to supply chain disruptions.



Primary energy supply

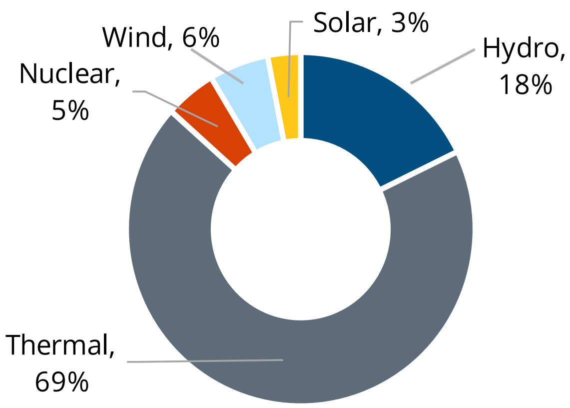
Consumption of energy reached 4.86 billion tons of standard coal equivalent, up by 3.3% compared to 2018. Among the total primary energy consumption in 2019, 57.7% was coal, 19.3% was oil, 8.1% was natural gas, and 14.9% was renewables.[16]

- Coal consumption increased by 2.6%, from 3.8 billion tons in 2018 to 3.9 billion tons in 2019, with the share of primary energy consumption decreased from 59% in 2018 to 57.7% in 2019.
- Oil consumption rose by 6.8%, from 651 million tons in 2018 to 696 million tons in 2019, with the share of primary energy consumption increased from 18.9% in 2018 to 19.3% in 2019.
- Natural gas consumption rose by 8.6%, from 280 billion m^3 in 2018 to 304 billion m^3 in 2019, with the share of primary energy consumption rising from 7.8% in 2018 to 8.1% in 2019.
- Renewable energy consumption rose in each of the major renewable categories of hydro, wind, and solar. Hydro capacity rose by 3.8 GW and output increased by 5.6%. Wind capacity rose 26 GW and output increased by 10.9%. Solar capacity rose by 30.4 GW and output increased by 26%.

Electricity

Electricity demand grew 4.5% in 2019, down from 8.5% in 2018.[17] The trend in electricity demand growth has fluctuated over the past few years, as the trend towards greater efficiency and economic rebalancing from heavy industry towards services and consumption has been counterbalanced by efforts to electrify industry.

2019 electricity production by fuel



Source: China Electricity Council, January 2020

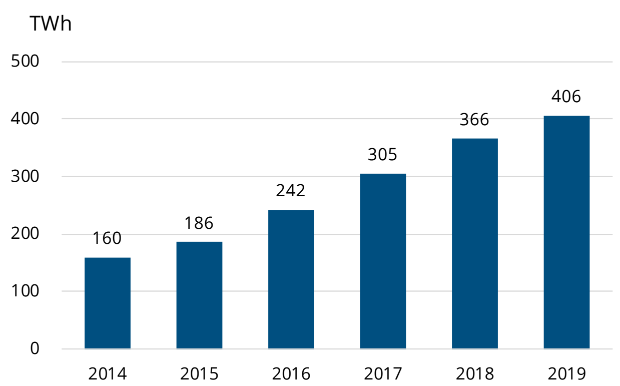
2019 electricity production and capacity by fuel

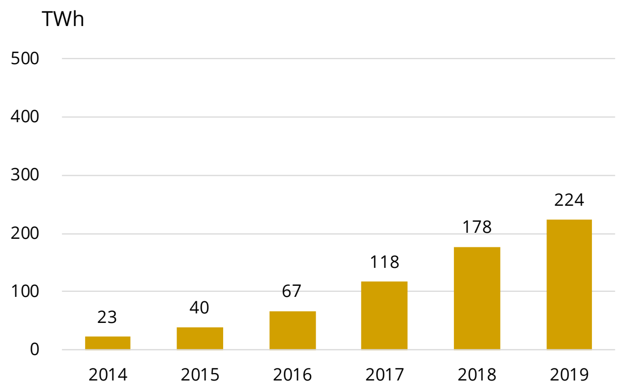
	Generation (TWh)	% of Generation	Additional capacity (GW)	Installed Capacity (GW)
Hydro	1301.9	18%	3.8	356.4
Thermal	5045.0	69%	46.5	1190.6
Nuclear	348.7	5%	4.1	48.7
Wind	405.7	6%	25.8	210.1
Solar	223.8	3%	30.4	204.7
Total	7325.3	100%	110.3	2010.4

Source: China Electricity Council, January 2020

The share of electricity generated by non-fossil fuels grew to 31%, versus 30% in 2018 and just 19% in 2010.[18] Electricity generated by renewable energy grew steadily in 2019. Compared with the prior year, power generated by hydro power rose 5.7%, wind rose by 10.9%, and solar increased by 5.7%, 10.9%, and PV by 26.5%.[19] Wind and solar each grew by 26 TWh, and non-carbon sources accounted for the majority of incremental growth in electricity production in 2019. However, thermal output (mainly coal) nevertheless grew by 40 TWh.

Electricity generation by wind (left) and solar PV (right), in TWh

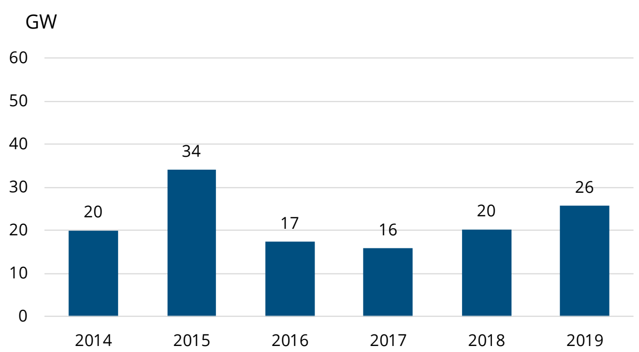


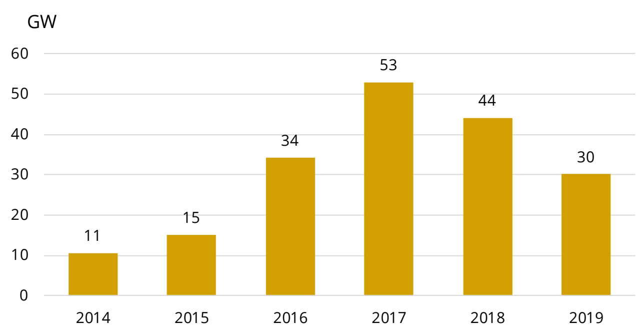


Source: for 2019 data, China Electricity Council, January 2020; historical data adapted from CNREC 2019

The total power generation capacity by the end of 2019 was 2,011 GW.[20] The installed capacity of wind reached 210 GW and solar PV reached 204.7 GW.[21] In 2019, China added 111 GW of new capacity. Thermal capacity (mainly coal) grew by 46 GW and nuclear capacity grew by 4.1 GW. Wind and solar combined grew by 56 GW. Both solar capacity additions declined from 44 GW in 2018 to 30 GW in 2019.[22] The decrease in solar installations versus the prior year relates to the mid-year cut in feed-in tariff quotas for new projects, which is aimed at reducing deficits in subsidy payment funds.

Annual additions of wind capacity (left) and solar PV (right), in GW





Source: for 2019 data, China Electricity Council, January 2020; historical data adapted from CNREC 2019

The incremental installed capacity of wind and solar concentrated in the southern, central, eastern and other provinces with high power demand. To prevent the curtailment of renewable resources, the latest policy requires that any new energy projects can only be launched when the local grid has sufficient local demand combined with transmission capacity for export.[23]

2020 forecast for renewable energy additions

Although wind and solar subsidies continue to scale off, wind and solar capacity will continue to grow in 2020, partly due to the eagerness of developers to capture remaining subsidy quotas. The incremental installation of wind and solar capacity were expected to exceed 60 GW, and the cumulative installed capacity of wind and solar are likely to reach about 480 GW in 2020.[24] However, the sudden outbreak of COVID-19 may cause delays to the completion of renewable projects due to the disruption of the supply chain. The vice chairman and secretary general of the China Photovoltaic Industry Association (CPIA), Wang Bohua, forecasted that in 2020 solar PV additions will fall from the 40-50 GW initially expected to 35-45 GW.[25] Onshore wind projects face rising costs of materials and equipment as well as construction delays. Offshore wind projects also face delays, and partly as a result, only a quarter of projects will meet a 2021 deadline.[26] Since the government will no longer grant feed-in tariffs subsidies for conventional solar and onshore wind projects after 2020, projects delays may exacerbate financial distress faced by the small and medium enterprises in the sector.

3 Coal

3. Coal

China looked more to coal in 2019 as leaders emphasized energy security

- Coal consumption grew just 1% but remained below its peak.
- Coal power output grew strongly, outpacing any other fuel source.
- NEA green-lighted more provinces for coal plant construction, citing growth in peak demand.

As part of its energy transition—which President Xi Jinping has called a revolution in energy production consumption and technology—China has set the goal of peaking CO_2 emissions by around 2030, reducing CO_2 emissions per unit of GDP by at least 60% compared to 2005 and increasing the share of non-fossil energy (including nuclear power) in primary energy consumption to 20%. The aim is to reduce coal's share in primary energy consumption to below 58% by 2020, compared to 64% in 2015 and 59% in 2018. China is likely to over-achieve this target, since coal's share of primary energy consumption has fallen from 74% in 2013 to 57.7% in 2019.[27]

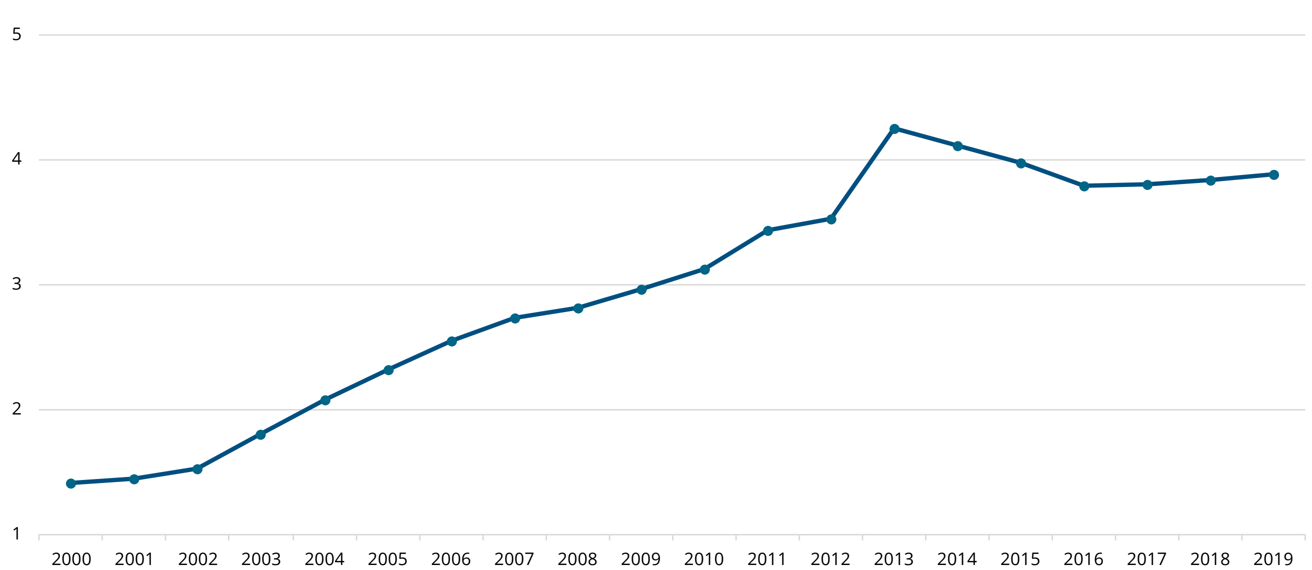
Coal policy is driven primarily by environmental and economic priorities, as opposed to climate. The target is to reduce inefficient coal consumption by closures of old power plants, as well as of small coal boilers for public heating and industrial steam. The policy also targets the reduction of coal use at the household level because small-scale coal use contributes significantly to emission of air pollutants.

Coal consumption

Despite existing overcapacity, new coal plants additions continue. The 13th Five-Year Plan (2016-2020) set a cap on the total coal-fired power plant capacity at 1,100 GW in 2020, though this cap could be set at a higher level in further years. At the end of 2018, figures from the CoalSwarm project showed that 259 GW of coal capacity was under construction or in planning.[28] As of 2019, total thermal power capacity has already reached 1,191 GW in 2019, surpassing the cap set for 2020.[29] In the medium term, coal will remain the largest source of electricity and overall energy production.

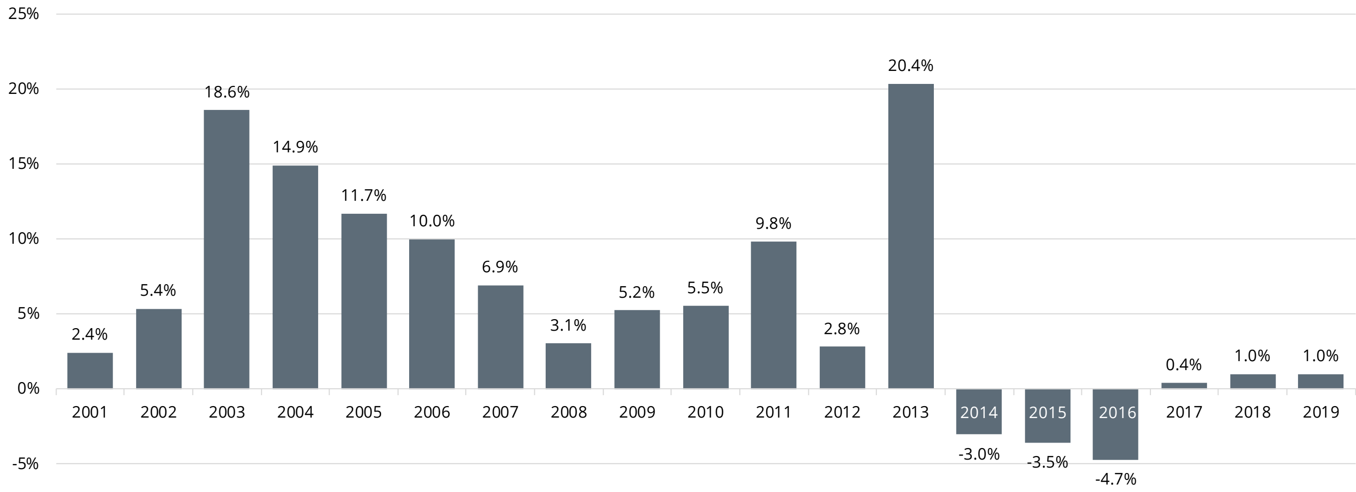
China is also increasingly exporting coal technology abroad as part of the Belt and Road Initiative. Projects of approximately 102 GW are currently under construction or proposed in 23 countries with Chinese participation.[30] These projects have the potential to lock in coal consumption in these countries for decades, and are likely to become economically stranded assets even without carbon pricing, given the rapid improvement in the economics of cleaner energy sources.

Total coal consumption from 2000 to 2019



Source: China National Bureau of Statistics, 28 February 2020

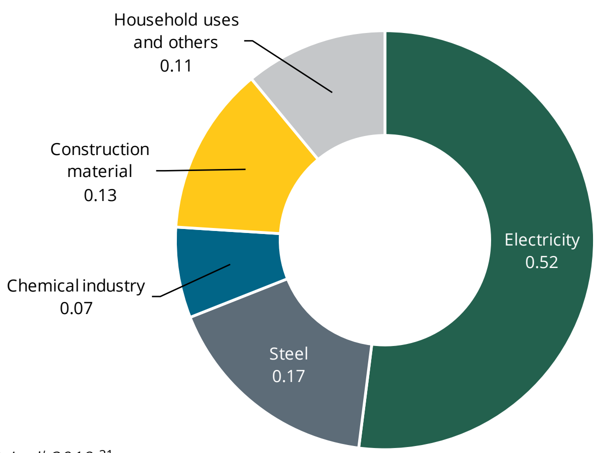
Annual growth rate of coal consumption from 2001 to 2019



Source: China National Bureau of Statistics, 28 February 2020

Around half of the coal consumption in China is used to produce electricity, according to the National Energy Agency analysis in 2017. The other uses of coal include steel production, the chemical industry, construction material, and household uses.

Breakdown of coal consumption in 2017



Source: National Energy Agency, 20 April 2019 [31]

NEA risk warning indexes on 2023 coal power planning and construction

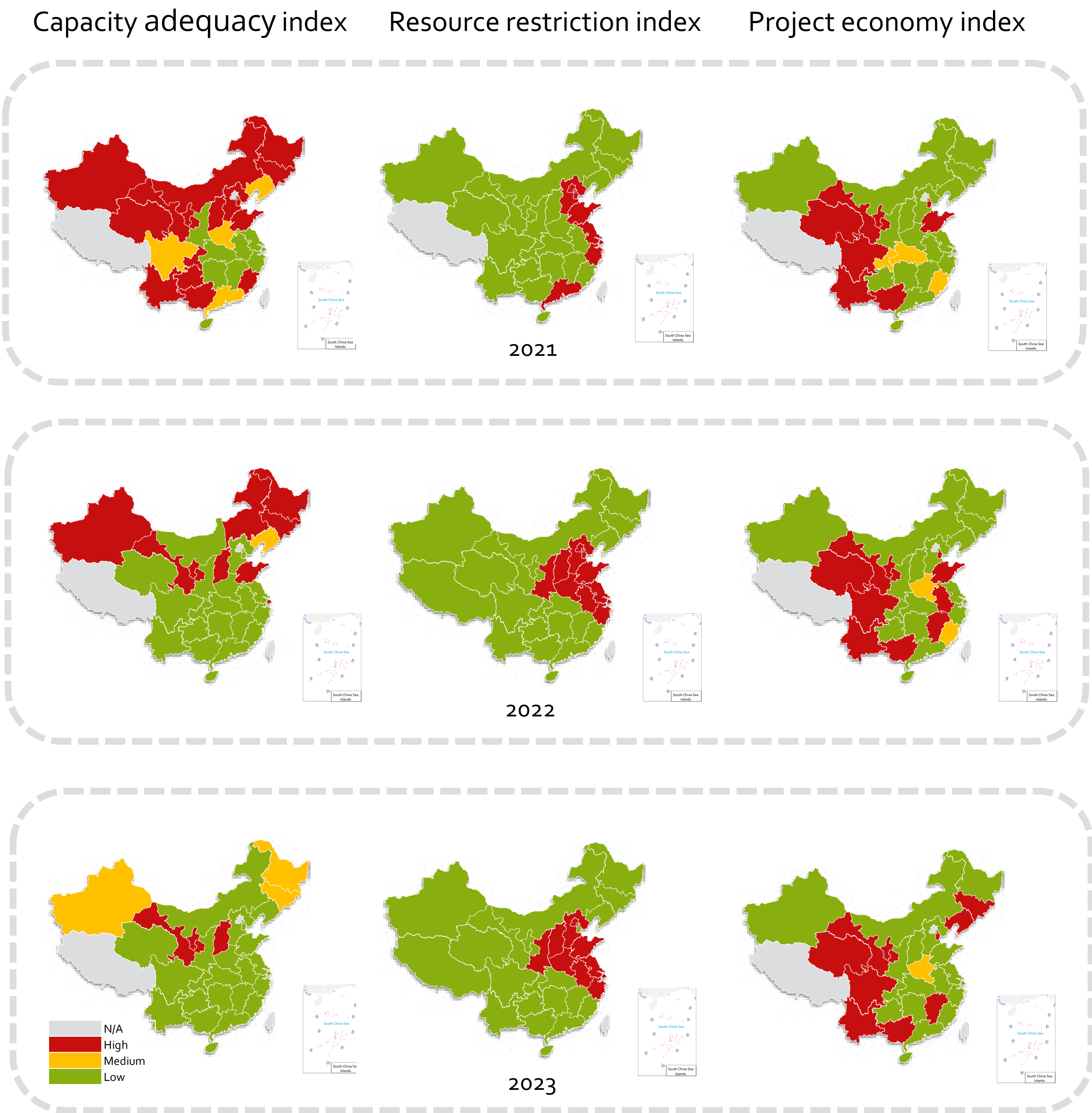
The National Energy Administration's coal capacity risk early warning index has been issued for 2021-23. Three indexes are used to grade each province in terms of risks associated with having new coal projects. The Capacity Adequacy Index takes into account the electricity supply and demand, renewable energy curtailment and coal plant utilization. The Resource Restriction Index is based on air pollutants emission, water resource, total coal consumption and other resources in the province. The Economic Risk Index evaluates the expected internal rate of return of newly built coal projects.

This year's result shifts several more provinces into the green category comparing to the previous two years' warning index, meaning coal plant construction is unrestricted. [32] This is likely to address the high peak load experienced in summer 2019, as well as to act as a source of power supply for the new Ultra High Voltage

(UHV) power transmission network. [33] A total of eight provinces are rated as green for new coal construction on all three risk maps—namely, Guangdong, Guizhou, Chongqing, Fujian, Hainan, Hunan, Hubei, and Inner Mongolia. That's up from just six provinces rated green on all three risk measures in the risk warning for 2022 and five provinces for 2021.

From the perspective of encouraging the energy transition, this is potentially worrying, since many analysts consider that additional coal investments are unnecessary given the competitiveness of clean energy, electricity market reforms that enable greater trade between provinces (making it easier to meet demand growth flexibly), and the low operating hours of existing coal plants. In 2019, reports from the International Energy Agency, the Rocky Mountain Institute, and the China National Renewable Energy Centre all indicated that China's electricity demand growth and electrification of industry, heating and transport could be met mainly through a combination of clean energy, energy efficiency measures, and improved regional power market integration.

Coal plant early warning risk indexes for 2021-2023



Source: China National Energy Administration, 2018-2020, historical data adapted from CNREC 2019

*Beijing and Tibet are not planning to develop coal at all, hence not surveyed for most indexes.

Challenges for the coal industry and structural change

Despite the continued coal expansion, many coal companies are already in economic difficulties. A study by the Think Tank Carbon Tracker estimates that 40% of Chinese coal-fired power plants experienced losses in 2018. [34] More than 75% of all existing Chinese coal-fired power plants were built after 2000. Overcapacity in China's coal industry has serious negative impacts on the rational allocation of coal resources and stable operation of the national economy. Since 2016, the Chinese government has focused on eliminating excess capacity, especially in the central and southwest regions. As a result, the number of coal mines in China has dropped from 13,000 in 2013 to 5,700 in 2019. [35]

The closure of outdated or over-capacity coal plants and mines can lead to structural unemployment. The number of employees in the coal sector was 6.1 million in 2013, 3.95 million in 2016 and is expected to decrease to 3 million by 2020. [36] Most coal mines are state-owned, hence there is a significant worker placement problem, particularly given the high average age in the sector. New economic strategies are being devised to counter the loss of coal jobs, such as coal-to-hydrogen in Shanxi province or renewable-powered data centers in Zhangjiakou. It remains to be seen whether such strategies can meet the immense challenge of transitioning coal economies.

Coal electricity de-link and coal-to-gas fuel switching

On 26 September, Premier Li Keqiang announced that the linking mechanism between electricity pricing and coal commodity prices, which has been in place since 2004, would be replaced by a market pricing policy including a benchmark price plus a floating adder. As the electricity spot market is being developed, removing the linkage between coal price and electricity prices could enable a more flexible market price, help reduce coal power sector overcapacity, and better guide investment. [37]

China has tackled air pollution in several regions, including around Beijing, through a series of multi-year action plans, with fuel switching away from coal as one of their central elements. China State Council has issued Blue Sky Defense Action Plan on 3 July 2018. The plan emphasizes coal-to-gas fuel switching, particularly focusing on the Jing-Jin-Ji region, the Yangtze River Delta region, and the north-eastern region. [38] The plan calls for the complete substitution of coal by gas for household use and winter heating before the heating season in 2020. However, the coal-to-gas fuel switching policy has faced delays and was relaxed in 2019 due to logistical bottlenecks and supply disruptions. In July 2019, the National Energy Administration streamlined the policy, allowing cities to instead choose the most accessible form of energy to guarantee winter supply. This was to avoid shortages that previously drove inland trucked LNG prices to as much as US$ 25/MMBtu in winter, twice the price of LNG at coastal terminals.

The rationalization of supply sources was reinforced by Premier Li Keqiang in a speech in October where he stressed on energy security this winter: "Based on what is practical, we should use electricity where electricity is available, gas where gas is sufficient, and coal where coal supply is ample." [39]

> From a long-term perspective, China's modern coal chemical industry has more opportunities than challenges, more potential than problems, and is still in an important period of strategic opportunities.

Ruan Lijun
Director of Coal Chemical Division, China Coal Processing and Utilization Association

Conclusion: Coal consumption returns to growth

Coal consumption continues to grow, led by demand from both the electricity and industry sectors. Data from the Centre for Research on Energy and Clean Air show that coal demand in China increased by 7% in the metals sector and by 11% in the chemicals sector in 2019 through October.[40] Its use to produce cement and glass have also increased. Even chemicals like polyester are now included as list of materials to be made from coal, since new processes that use coal to obtain ethylene glycol—a raw material for making polyester fiber and packaging resin—have gained traction in China.[41]

Shanxi province, for example, the site of some of the country's largest solar and wind-power projects, is also the heart of China's traditional coal country, dotted with large mines. In November 2019, Premier Li Keqiang gave a speech in Shanxi to policy makers emphasizing the importance of domestic coal to energy security. [42] Indeed, permits for new coal plants proliferated after regulatory authority was briefly devolved from Beijing to provincial governments, which see construction projects and coal operations as boosts to local economies and tax bases, said Ted Nace, executive director of Global Energy Monitor. [43]

The increased industrial reliance on coal has led to coal consumption returning to near peak levels after rebounding over the last three years. In addition, press reports have stated that China is building more coal-fired plant capacity than the rest of the world combined, from January 2018 to June 2019. [44] While many of these plants represent efforts to complete state-owned projects that had already been approved, a fierce debate continues about whether new coal is needed to meet electricity demand growth, considering that existing coal plants operate at low capacity factors, and that renewable energy is now economically competitive for new generation.

> Clean and efficient utilization of coal is seen as a national strategy. The utilization of renewable energy should be supported. Sustainable growth will be guaranteed by energy revolution.

Du Xiangwan
Academician of Chinese Academy of Engineering

4 Petroleum

4. Petroleum

Oil consumption grows strongly, and EV market softens

- Domestic consumption grew 7%, but production also posted slight growth, reversing a trend.
- EV sales declined following subsidy cuts, though China remains the top EV market.
- Lower oil prices in 2020 may encourage demand growth, but discourage domestic production and investment.

The production and consumption of oil remains a severe challenge for China's energy transition, as the decades-long macro trend of decreasing domestic production and rising import dependence continues. Due to efforts to boost flagging domestic production, crude oil production in 2019 only saw an increase of 0.8% compared to 2018. This is the first time that China has seen an increase in its domestic oil production since 2016. [45]

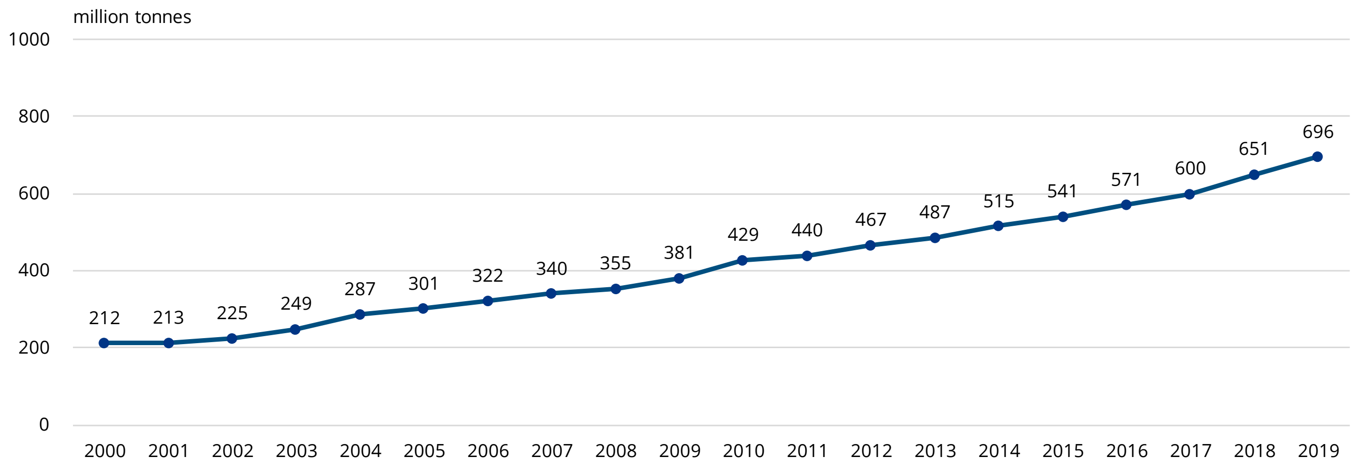
In recent years, the quality of China's exploitable oil fields has dropped significantly, which results in increased production costs and reduced incentive for companies to develop new oilfields. Under the guidance of low-carbon policy, the government will prioritise clean energy to meet incremental energy demand, potentially dampening long-term demand for high-cost domestic crude oil. [46]

Electrification in the transport sector dented oil demand to a very limited extent: China sold 1.2 million new energy vehicles nationwide in 2019, a decrease of 4% from 2018. Electric buses in China displaced 0.26 million barrels per day of oil demand—a relatively large displacement compared to cars, resulting from high daily usage. [47] As EV sales continue to rise, they should increasingly begin to displace demand growth, though the turning point will require a few more years. [48] At the same time, import dependency remains high, with China importing 70% of its oil from foreign countries.

Crude oil consumption

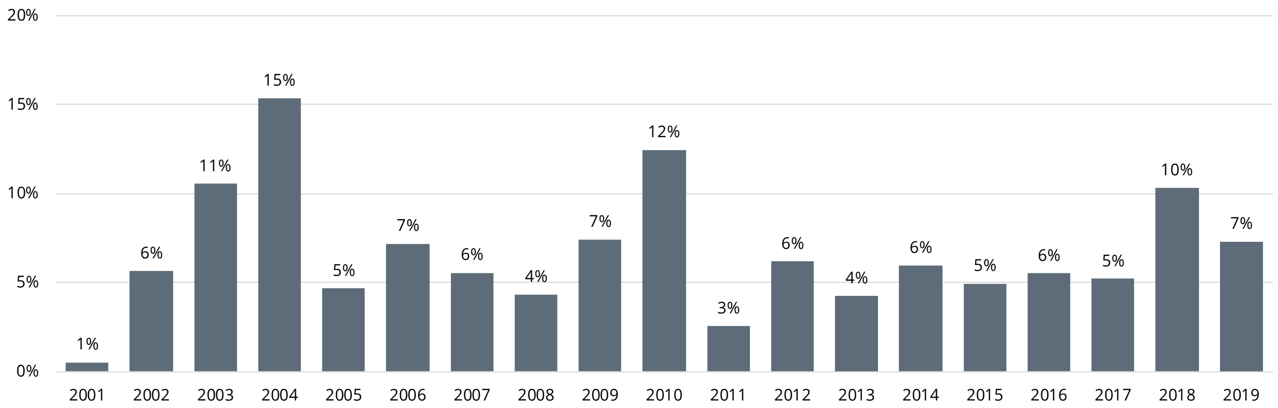
According to China's oil and gas production and import data in 2019 published by the National Bureau of Statistics on 17 January 2020, China produced 190 million tons of crude oil in 2019, an increase of 0.8% compared to 2018.

Total crude oil consumption in China from 2000 to 2019



Source: National Bureau of Statistics of China, 28 February 2020, historical data adapted from CNREC 2019

Annual growth rate of crude oil consumption from 2001 to 2019



Source: National Bureau of Statistics of China, 28 February 2020, historical data adapted from CNREC 2019

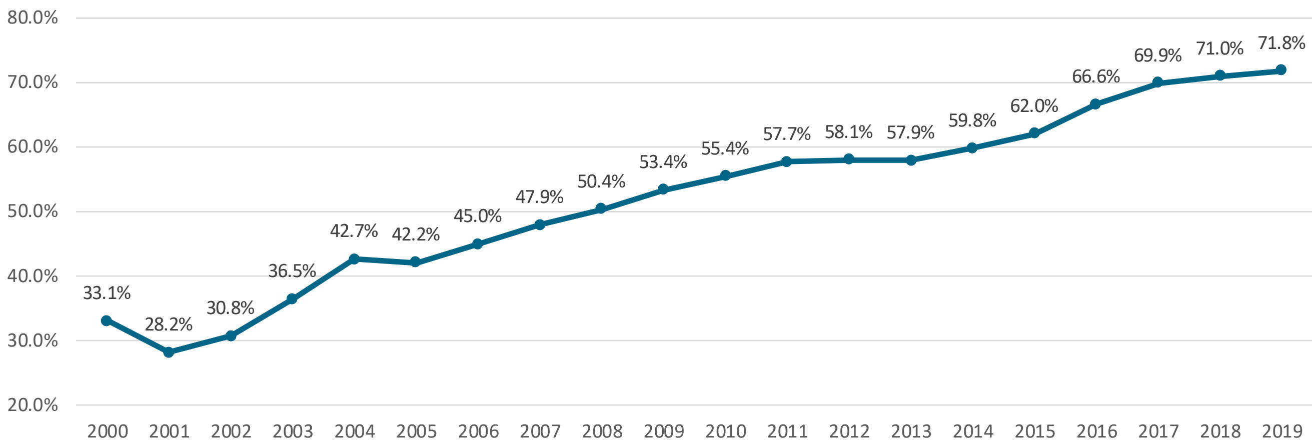
Increased import dependency

Meanwhile, China remains the largest oil importing country, with approximately 500 million tons of oil imported in 2019. This means that roughly 70% of oil consumption in China is from imports, making it very dependent on foreign producers. The largest source of imported oil in 2019 is Saudi Arabia, accounting for 18.4% of all imports. This is followed by Russia and several other OPEC countries like Angola, Iraq, and Iran.[49] China is also expected to import more oil from U.S. as a result of the Phase One trade deal signed in January this year. The deal involves China's pledge to buy US$52 billion of energy products from the U.S. over the next two years, but a large proportion of those will be LNG.[50] The impact of this deal on China's import dynamics remains to be seen.

In March 2020, international oil prices plummeted as a result of Saudi Arabia's move to boost output and reduce prices, opening a price war with Russia coinciding with the outset of the COVID-19 pandemic. The price of Brent crude fell to US$ 33 per barrel in early April, halved as compared to China's average 2019 import price of US$ 65 per barrel. [51]

While the low price would provide some relief to the Chinese economy in the midst of the coronavirus and subsequent economic recovery, researchers at the Chinese Academy of Social Sciences cautioned that the crash in international prices could lead to an increasingly monopolised supply structure as small suppliers could be priced out of the market. This goes against Beijing's long-term strategy of securing multiple sources of supply.[52] Low international oil prices could curb China's domestic production, making China even more dependent on Saudi Arabian oil this coming year.

Crude oil import dependency rate from 2000 to 2019



Source: National Bureau of Statistics of China, 28 February 2020

In 2019, China had plans to invest US$ 77 billion in expanding domestic oil production by approximately 50%, or 2 million barrels per day. China's existing fields produce oil at relatively high prices, and investments in expanded oil production were already considered uncompetitive in 2019 prior to the oil price collapse. Per barrel of incremental output, a dollar invested to boost upstream production in China was more than double that of the U.S. oil major ExxonMobil, and more in line with Canadian oil sands production, which is now experiencing a wave of project cancellations.[53] Notwithstanding the political priority attached to energy security and symbolic importance of halting domestic production declines, the poor economic efficiency of such investments versus other potential stimulus measures could ultimately result in project delays and greater efforts on reducing consumption growth and improving vehicle efficiency as a strategy for reducing import dependence.

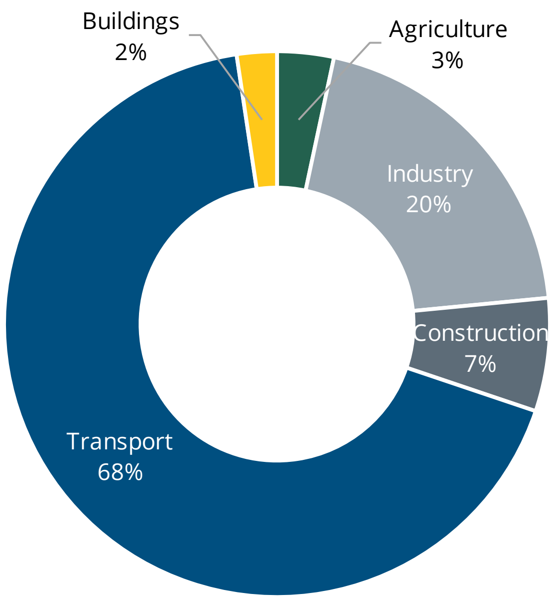
Use of oil in the transport sector and fuel efficiency

Transport remains the largest sector in total oil demand in China, accounting for around 54% of the total demand. This proportion held roughly constant from 2010 to 2018, because demand for petrochemical kept pace with rapid growth in demand for transport fuels. The boom in plastic product output has driven growth in natural gas liquids and naphtha consumption. [54]

China's consumption of transportation fuels increased on average by 2.7% per year since 2012, led by an increase of 3.0% per year for heavy-duty vehicles that amount to 34% of the country's total increase in transportation sector energy consumption. [55] Of the two main transport fuels, gasoline increased faster than diesel. China's transportation demand is now transitioning to a gasoline-driven structure as passenger vehicles outpace diesel-powered trucks and industrial machinery in incremental fuel demand. In 2010, gasoline accounted for 30.9% of total oil demand in the transport sector but this figure rose to 41.6% in 2018, while diesel fell from 62.8% in 2010 to 47.8% in 2018. [56] (Diesel is used primarily for heavy-duty transport and not a major factor in the light-duty vehicle market due to air emissions regulations.)

Researchers from China National Petroleum Corporation (CNPC) estimate that China oil demand may peak at 16.4 million barrels per day around 2030 and fall to 13.7 million barrels per day by 2050, as economic growth slows and transport demand shifts to other fuels. [57]

Breakdown of crude oil consumption in 2018



Source: China National Renewable Energy Centre, December 2018 [58]

In terms of oil usage as fuel for vehicles, in 2018, the average fuel economy of new passenger cars sold in China was roughly 5.8 L/100 km, a 4.3% improvement over the 2017 average. [59] The Ministry of Industry and Information Technology (MIIT) issues fuel efficiency standards for all new passenger vehicles sold in China and they are tightened every few years since 2005. MIIT specifically identifies CO_2 emissions reduction as among the expected social benefits of the standards and estimates that China's 2020 fuel efficiency standards will reduce CO_2 emissions by 113 million tons versus what would have been expected under the 2015 standards. [60]

The fuel efficiency standards have two main aspects. First, each vehicle must meet specific fuel efficiency standards based on its weight. Second, each vehicle manufacturer must achieve Corporate Average Fuel Consumption (CAFC) limits. These limits apply on an annual basis to each manufacturer's new fleet as a yearly whole. The official standard for 2020 is reduced to 5 L/100 km from 6.7 L/100 km in 2016. Notably, manufacturers are offered flexibility schemes where credits can be earned for vehicle electrification, as well as for including more efficiency technologies in conventional vehicles. [61] As a result, fuel consumption averages for conventional vehicles should be higher than implied by the 5 L/100 km standard.

Enforcement of fuel efficiency standards is uneven, with some experts saying manufacturers face few penalties for failing to comply. In 2018, nearly 50 out of 113 domestic auto manufacturers exceeded their CAFC limits, according to MIIT. [62]

The next phase of China's vehicle fuel efficiency program is currently under development. Some stakeholders have expressed concern that an oversupply of NEV credits could adversely affect fuel efficiency of the Chinese new vehicle fleet under the existing program and recommended changes to address this. [63]

5 Natural Gas

5. Natural Gas

Natural gas demand growth slows, and imports flat-line

- Gas demand continues to grow, but at a more moderate pace.
- Efforts moderated to switch heating from coal to gas, based partly on economics.
- Imports flattened, and rising China-U.S. tensions have left promises of big LNG imports high and dry.
- The new Power of Siberia pipeline opened up a new path for gas imports from Russia.

Natural gas, a cleaner energy source than coal, is the fastest-growing fossil energy in China, with an increased spot trading of liquefied natural gas (LNG) in particular. To achieve the national target of natural gas accounting for 10% of primary energy consumption by 2020, the NEA has promoted fuel switching from coal to gas during the 13th Five-Year Plan period. [64]

The Chinese government has emphasized exploration and development of natural gas, resulting in an increase in domestic production of 9% in 2019. [65] Through the support of central and regional policies, gas pipeline infrastructure has been improved, storage capabilities added, and supply to the northern parts of China increased to meet winter peak demand of gas. [66] Shale gas development in particular is advancing, supported by policies of tax reduction and subsidies for gas extraction companies. China became the world's 3rd largest shale gas producer in 2018, with production reaching 10.9 billion m³ and is expecting to reach 30 billion m³ by 2020.[67]

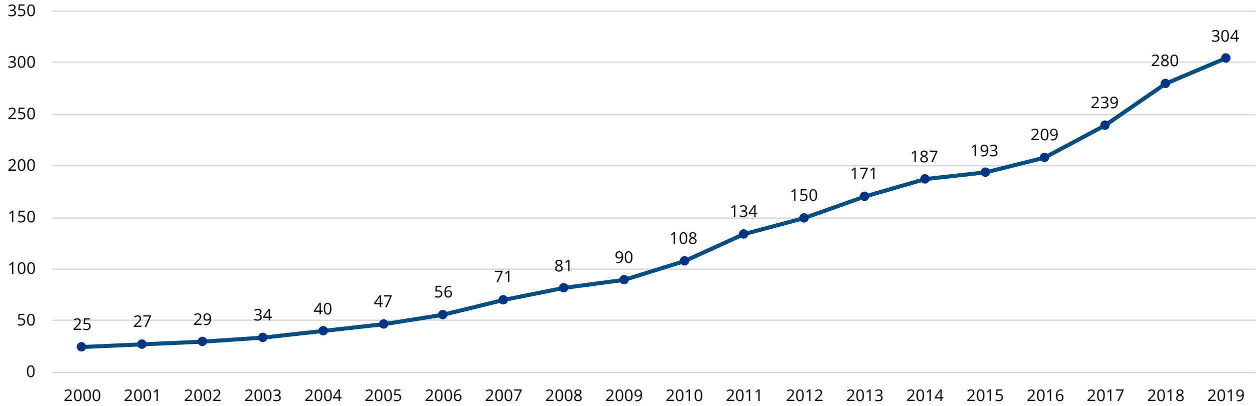
Imports of gas continue to grow, however, with imports coming 40.5% from pipeline gas and 59.5% from LNG.[68]

In December 2019, China established a new national pipeline infrastructure company, known officially as the China Oil & Gas Pipeline Network Group, as a centrally-administered state-owned enterprise (SOE). The company will be responsible for the investment, construction and interconnection of main oil and gas pipelines to form a nationwide network, overcoming bottlenecks with locally-owned oil and gas networks that have led many areas to rely on trucks for shipping gas. [69] The company assumes ownership of over 140,000 km of pipelines previously held by PetroChina, the China National Overseas Oil Corporation (CNOOC), and China National Petroleum Corporation (CNPC). The company plans to increase pipelines to 250,000 km by 2025, requiring over US$ 20 billion in annual investment. In addition, the company will own nine LNG regasification terminals. [70]

Natural gas consumption

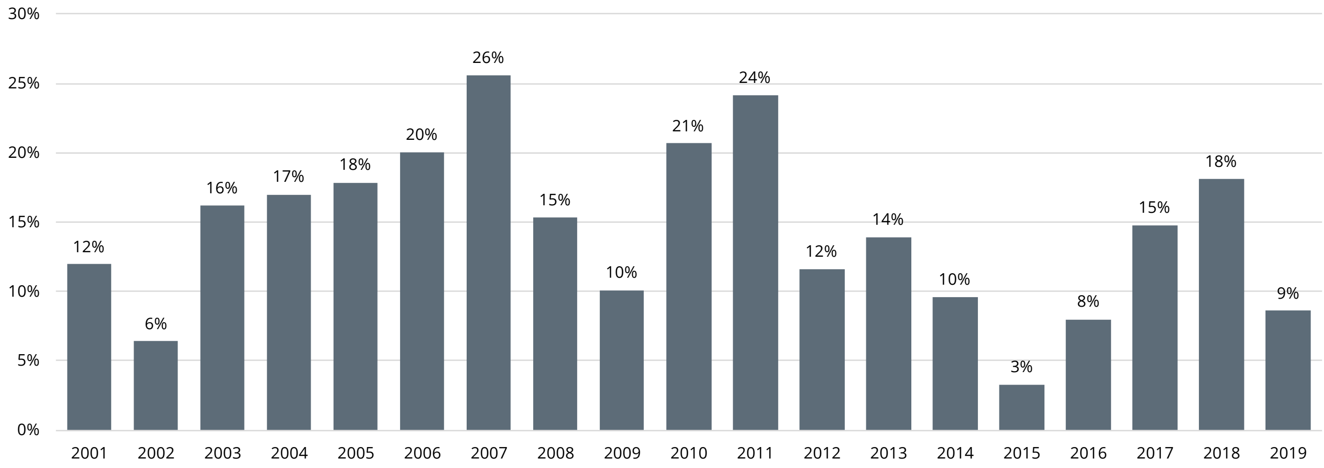
China's production of natural gas in 2019 reached 125 million tons, an increase of 9.8% compared to the previous year, while gas import reached 96.6 million tons, an increase of 6.9% compared to the previous year. The growth rate of gas imports in 2019 was significantly lower than the 32% growth experienced in 2018. [71]

Total natural gas consumption in China from 2000 to 2019



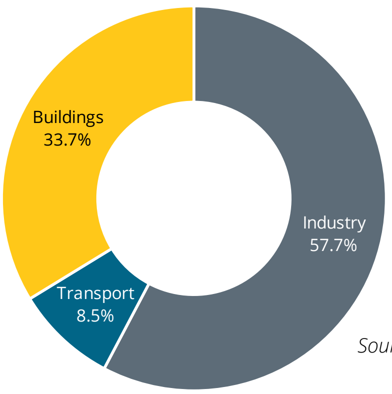
Source: National Bureau of Statistics of China, 28 February 2020

Annual growth rate of gas consumption from 2001 to 2019



Source: National Bureau of Statistics of China, 28 February 2020

Breakdown of natural gas consumption in 2018

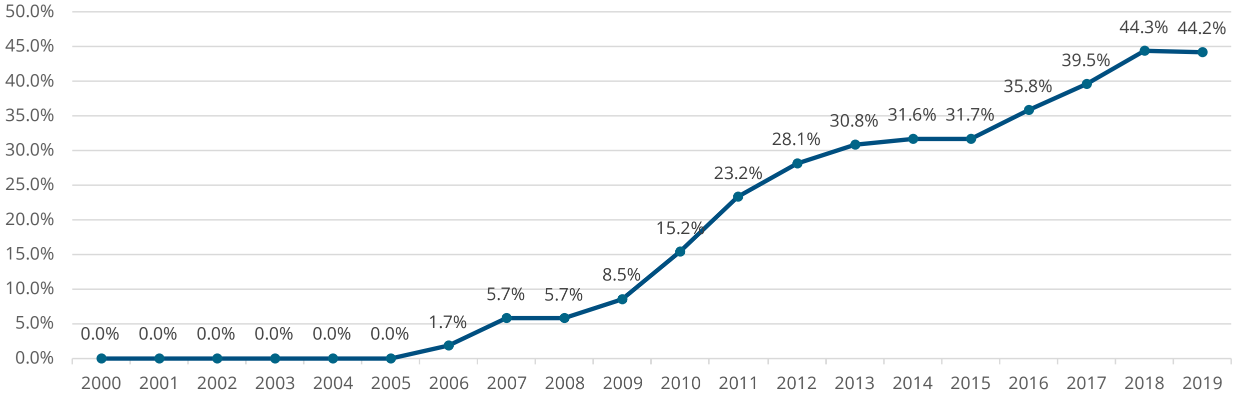


Source: China National Renewable Energy Centre, December 2018

Increased dependency on imports

Given that total natural gas consumption has grown over 10% annually over the past three years, gas production growth has been unable to keep pace. Nevertheless, import growth slowed in 2019 as domestic production rose more rapidly, and the percentage of imported gas compared to total consumption declined for the first time in 12 years. Nevertheless, the import dependency rate remains high at 44.2%, making China heavily reliant on imported gas.

Natural gas import dependency from 2000 to 2019



Source: National Bureau of Statistics of China, 28 February 2020

China imports gas mainly from neighbouring countries like Russia, Turkmenistan, Kazakhstan and Myanmar. Turkmenistan alone supplied 70% of China's piped gas imports in 2018. [72] Russia's energy giant Gazprom is contracted to supply the China National Petroleum Corporation with 38 billion cubic meters of natural gas annually for 30 years via the Power of Siberia pipeline project. [73] December 2019 marked the completion of the construction of the first section running 2,200 kilometers from the Chayandinskoye gas field to the Chinese border. [74] The first phase is expected to deliver 5 billion cubic meters for the full year of 2020. The second phase of the project will include the construction of a section stretching for about 800 kilometers from the Kovyktinskoye field to the Chayandinskoye field in late 2022. The third stage will further expand transmission capacity, and the yearly delivery capacity will slowly ramp up to the full 38 billion cubic meters once the project is completed. [75]

The inauguration of the Power of Siberia project strengthens Russia's position as the world's first gas exporter and further boosts economic ties between the two countries. [76] However, Russia's increased gas shipments to the east may not directly affect European gas markets because of the physical separation between the gas fields that supply China and those that connect to Europe. China's import volumes are presently a small fraction of the 202 billion cubic meters of gas Russia supplies to Europe. [77]

LNG imports have been a hot topic of trade talks between the U.S. and China given the priority attached to gas imports by U.S. President Donald Trump. Under the terms of a January 2020 trade agreement, China pledged to buy US$ 52 billion of energy products from the U.S. over the next two years, with LNG accounting for a large proportion. So far, the effect of the agreement remains minimal, since China has yet to lift its 25% tariff on U.S. LNG imports. Gavin Thompson of Wood Mackenzie has expressed doubt about the recovery of U.S. shipments to China if the tariff remains in place. [78] Slack LNG demand and restrictions on shipping in the aftermath of the COVID-19 pandemic may further stall LNG imports.

At the same time, China continues to sign long-term LNG contracts with Russia and Australia to secure gas supply. The abundance of supply has put LNG prices in Asia at 10-year lows, so it is reasonable to expect further demand growth from China in the near term. Analysts have expressed concerns over the low prices locking in more gas demand and thereby reducing the competitiveness of wind and solar power. [79]

Zhou Dadi
Vice president of China Energy Research Association

The focus of China's energy security is not to improve the emergency capacity of unexpected oil and gas import interruption, nor does it need to increase domestic oil and gas production regardless of cost to reduce oil and gas import dependency...
To increase energy self-sufficiency, we must find an alternative way to pursue green and low-carbon development...
There's no need to worry about the supply capacity of conventional energy not keeping up with the development of demand...

6 Renewable Energy

6. Renewable Energy

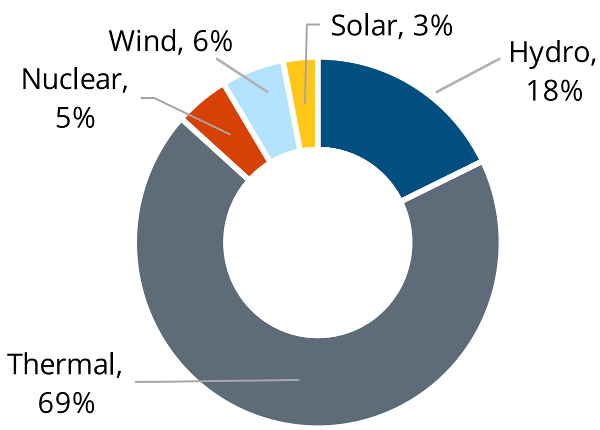
Renewable additions slowed, but output continues to grow rapidly

- Solar output grew most rapidly in percentage terms, even though solar additions fell.
- Wind and hydro output also posted strong growth, and curtailment fell.
- The policy focus is shifting from large, central plants to distributed energy, agricultural energy, building-integrated energy, offshore wind, and floating PV.

China continues to add renewable energy capacity, while also advancing reforms to its electricity and energy sectors. Both installed capacity and yearly generation for renewables grew, and the curtailment rate continued to decline. Nevertheless, renewable energy continues to face a number of policy and market barriers that slow its adoption and hinder its efficient integration.

- Hydroelectric power generation grew by 5.6%, increasing from 1233 TWh in 2018 to 1302 TWh in 2019.
- Wind power generation grew by 14.1%, increasing from 184 TWh in 2018 to 210 TWh in 2019.
- Solar power generation grew by 26%, increasing from 178 TWh in 2018 to 224 TWh in 2019.
- Renewable energy made up of 27% of electricity generation in 2019, a 0.3% increase over 2018. [80]

2019 China electricity production by fuel



Source: China Electricity Council, January 2020

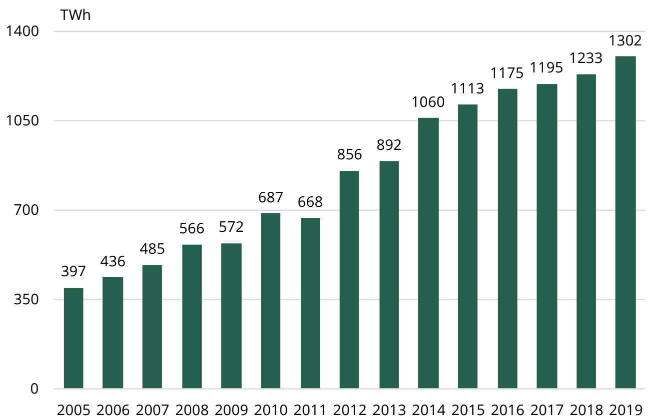
Li Junfeng
Director of CREIA

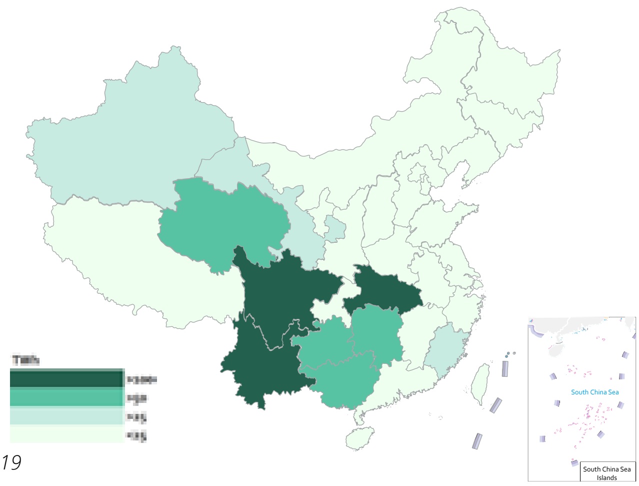
President Xi Jinping has recently issued a directive on subsidies for renewable energy development, which clarified that subsidies on renewable energy should be more flexible. The country will remain steadfast in supporting renewable energy. To increase the proportion of non-fossil energy, more renewable energy is needed, and solar PV will play a leading role.

Hydroelectric power

Hydro is the largest renewable power source in China, and output and capacity continue to grow. In 2019, China added 3.8 GW and hydro electricity output increased 69 TWh. China has large hydroelectric potentials, with total water resource standing at 2.8 trillion m^3. [81] The total installed capacity of hydro power plants in China remains the largest in the world, at 354 GW, of which 30 GW is pumped storage. In 2019, hydro generated 16% of total electricity in China, the largest proportion of all renewables. [82]

2005-2019 China hydro power generation (left); 2019 China hydro power generation by province (right)



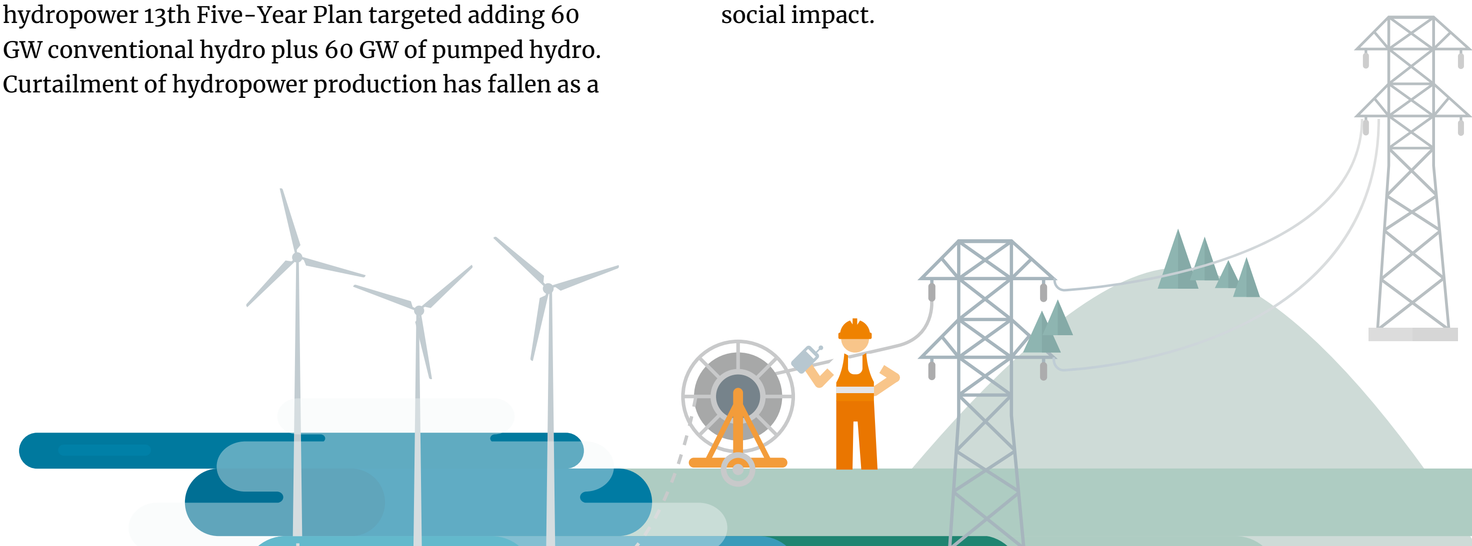


Source: China Electricity Council, 2015-2020, historical data adapted from CNREC 2019

Sichuan province has the highest hydropower generation at 308 TWh in 2019, followed by 267 TWh in Yunnan and 133 TWh in Hubei. The Three Gorges Dam, the largest hydropower station by capacity in the world, generates around 100 TWh of electricity every year, [83] constituting most of the generation in Hubei province. Xiluodu and Xiangjiaba power station rank 3rd and 7th respectively in the world in terms of capacity, located between Sichuan and Yunnan provinces, taking advantage of geographical characteristics. Rivers in these regions often have large difference in altitudes in their different sections of streams, making the area ideal for hydro power plants. [84]

The government continues to push for new development projects for hydro power in the past few years. The hydropower 13th Five-Year Plan targeted adding 60 GW conventional hydro plus 60 GW of pumped hydro. Curtailment of hydropower production has fallen as a result of new policies, and investments into hydropower construction have steadily increased since 2016. In 2018, investment reached RMB 67.8 million, a 9.7% increase compared to 2017. [85]

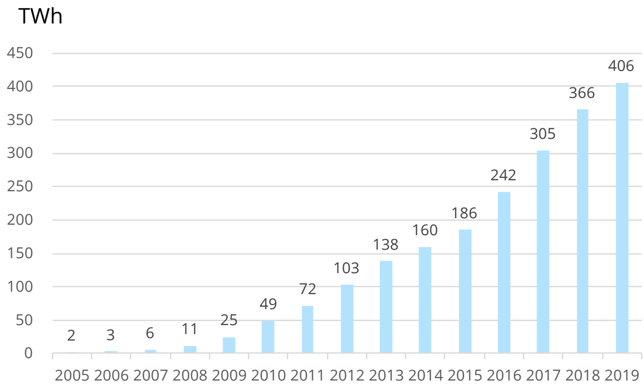
The domestic hydropower market on major waterways are close to full development. [86] Considering the resources restriction and environmental protection, many of the Chinese hydropower companies are exploring the overseas market, establishing businesses in Europe, South America and Southeast Asia in recent years to share their expertise in the area. [87] Many hydroelectric power projects are being planned for development in Belt and Road countries, and several of them are controversial in terms of environmental and social impact.

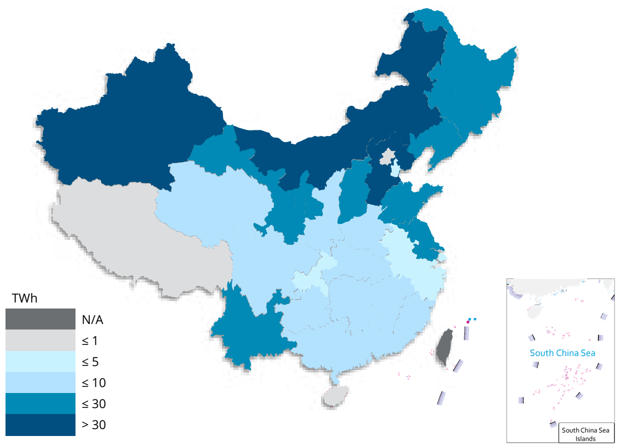


Wind

Although wind installations remained below their peak rate in 2019, wind output continued to rise, reaching 210 TWh, up from 184 TWh in 2018, representing growth of 14.1%. In the five years since 2014, China's wind output has more than doubled. Wind's share of national electricity production reached 5.5% in 2019, versus 5.2% in 2018. Wind curtailment decreased from 7% to 4% nationally from 2018 to 2019, indicating that China has successfully resolved the wind curtailment problem. [88] The largest wind electricity-producing provinces are in northern China, including Inner Mongolia, Xinjiang and Hebei provinces.

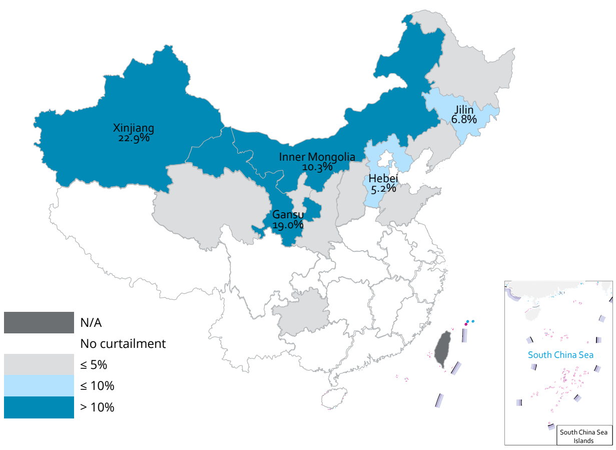
2005-2019 China wind power generation (left); 2019 China wind power generation by province (right)

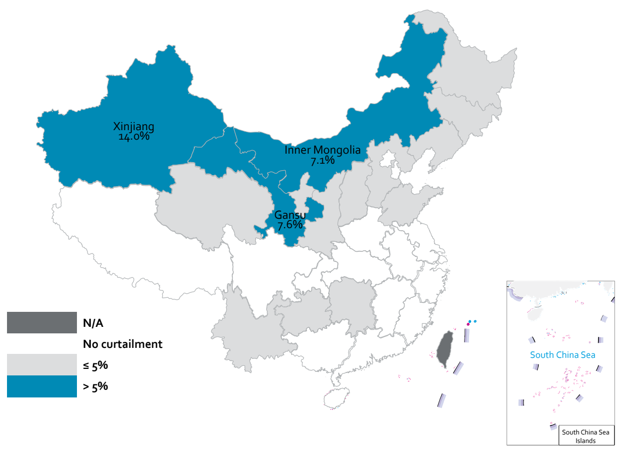




Source: NEA 2020, historical data adapted from CNREC 2019

China wind curtailment (%) by province 2018 (left) and 2019 (right)



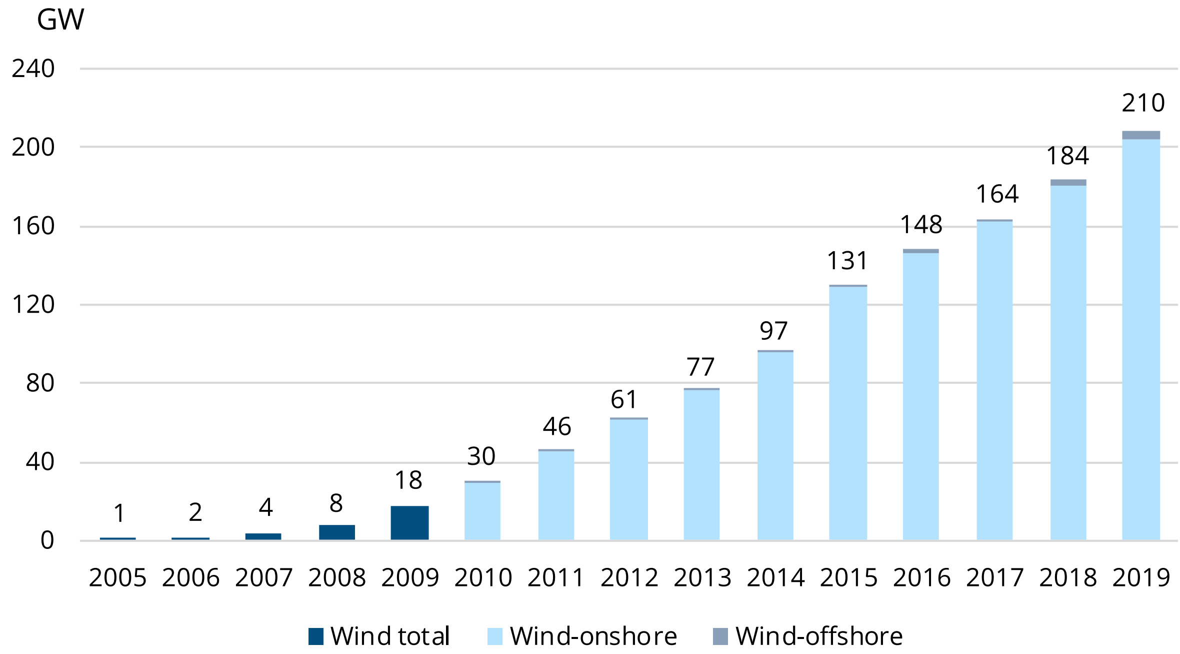


Source: China National Energy Administration, 2020

Qin Haiyan
Secretary General of Professional Committee of Chinese Wind Energy Association

The era of grid parity for onshore wind power is coming. The full guarantee of minimum purchase of renewable energy, and fixed electricity prices, will enable continued development of wind power during the 14th Five-Year Plan. The potential market for wind power plant operation and maintenance services is huge...
Although subsidies are no longer available, renewable energy still needs policy support... At the same time, green certificates, financial settlement, finance, and other measures should be used to change the payment process of subsidies.

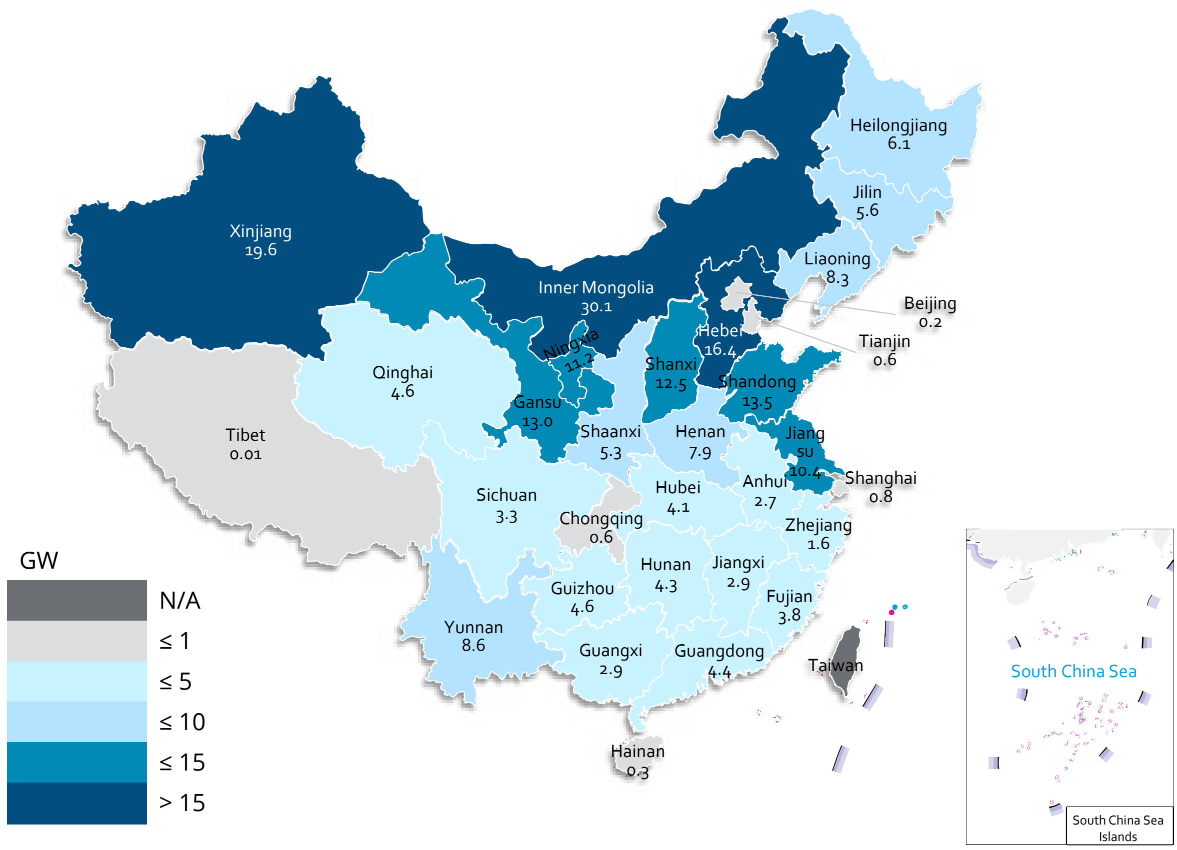
2005-2019 China wind capacity in GW



Source: China National Energy Administration, 2020

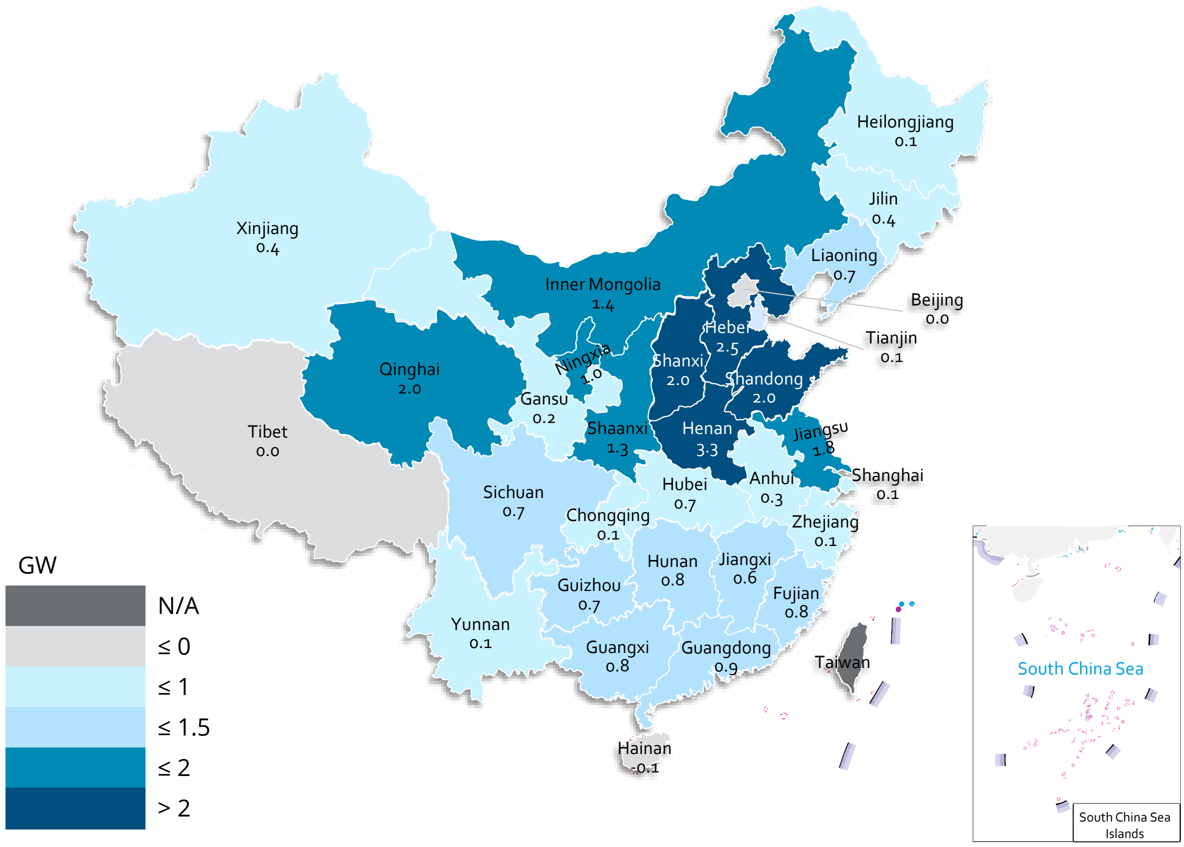
China's annual wind capacity additions rose from 20 GW in 2018 to 26 GW in 2019.

2019 cumulative grid-connected wind capacity (GW) by province



Source: China National Energy Administration, 2020

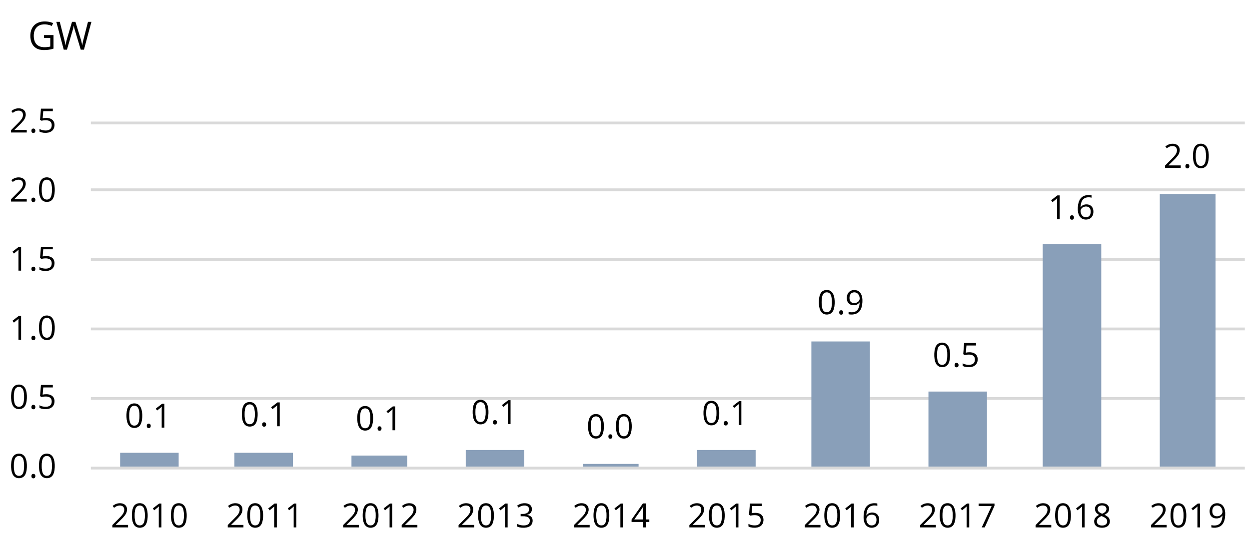
2019 additional grid-connected wind capacity (GW) by province



Source: China National Energy Administration, 2020

New wind capacity additions in 2019 mainly concentrated in central eastern provinces, such as Hebei, Henan, Shanxi and Shandong provinces—provinces with greater ability to absorb wind output locally. The leading province for new wind installations in 2019 was Henan, with 3.3 GW of new additions, followed by Hebei with 2.5 GW. Four provinces added more than 2 GW and a further 19 provinces added over 1 GW.

Offshore wind additions in GW



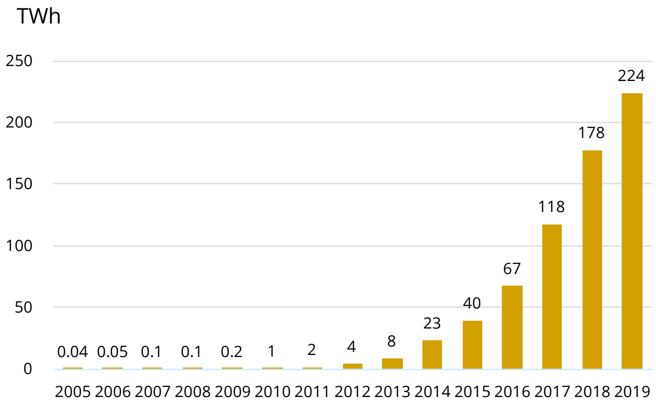
Source: China, National Energy Administration, 2020

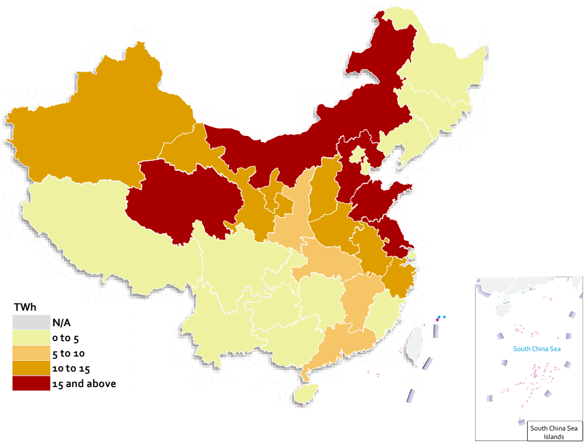
Solar PV

Although solar PV installations fell in 2019, solar PV output continued to rise strongly, reaching 224 TWh, up from 178 TWh in 2018, representing growth of 26%. In the five years since 2014, China's PV output has risen by a factor of 10. PV's share of national electricity production reached 3.1% in 2019, versus 2.6% in 2018. [89] Solar curtailment decreased from 3% to 2% nationally. [90]

According to the 2019 provincial data released by National Energy Administration, the largest PV electricity-producing provinces are in northern China, including Inner Mongolia, Xinjiang, Qinghai, Hebei, and Shandong provinces.

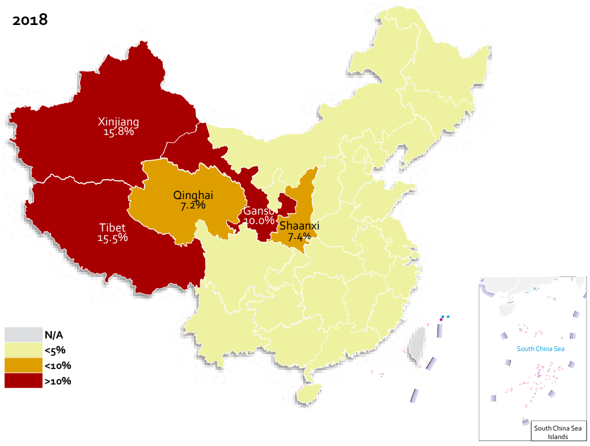
Total solar PV power generation in 2019 (left); Provincial solar PV power generation 2019 (right)

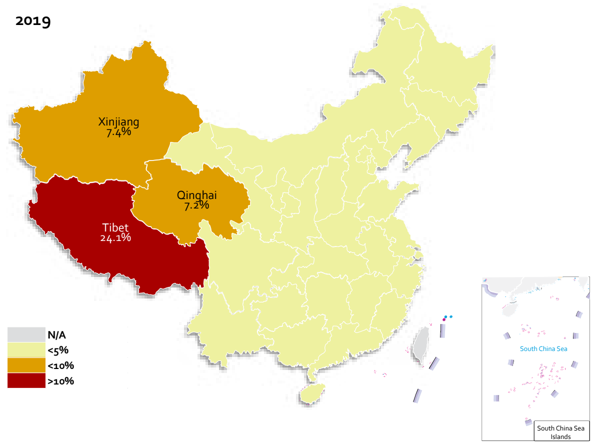




Source: NEA 2020, historical data adapted from CNREC 2019

Solar PV provincial curtailment rate 2018 (left) and 2019 (right)

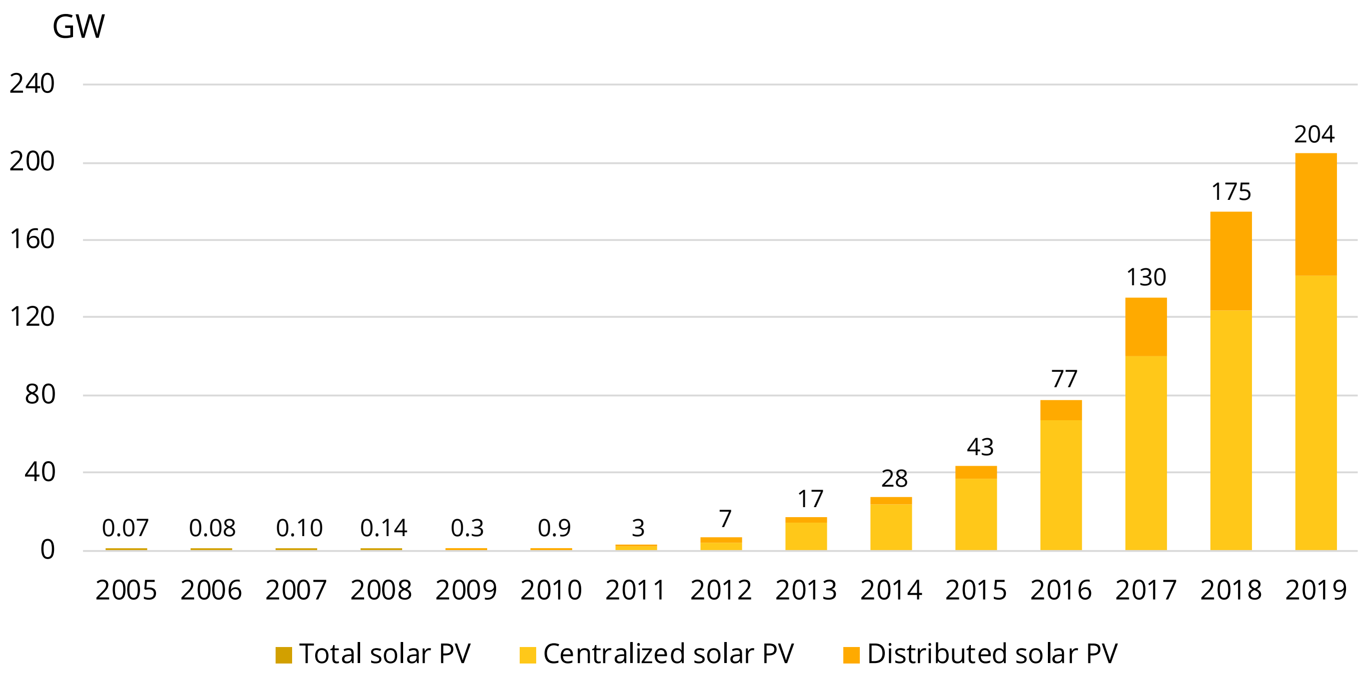




Source: National New Energy Consumption Monitoring and Early Warning Center, 3 March 2020 [91]

Solar curtailment is highest in the northwestern regions of China, namely Xinjiang, Tibet, Qinghai, Gansu, Ningxia and Shaanxi. In 2019, all of the six provinces experienced a lower curtailment compared to 2018, and only three provinces have a curtailment rate more than 5%.

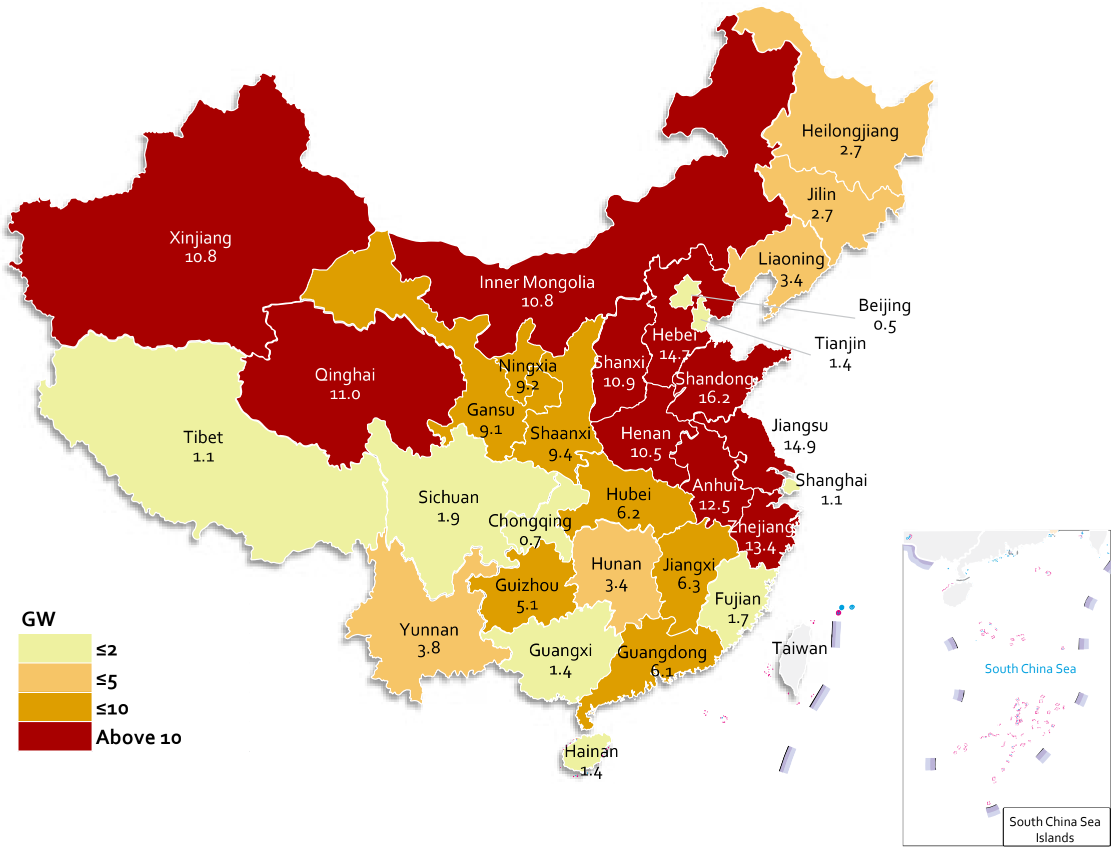
Total PV capacity, distributed and centralized from 2005 to 2019



Source: NEA 2020, historical data adapted from CNREC 2019

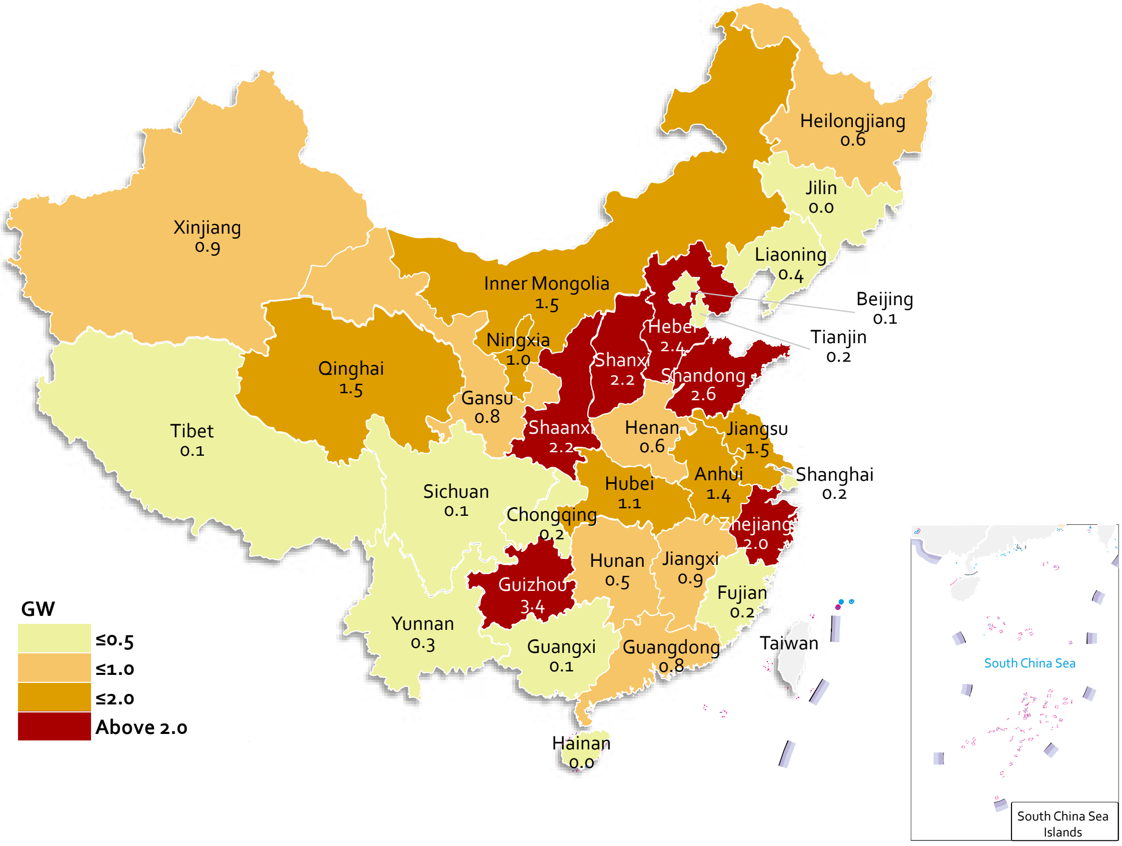
China's annual solar capacity additions fell from 45 GW in 2018 to 30

Solar PV cumulative installed capacity at year-end 2019 (GW)



Source: National Energy Administration, 2020

Solar PV newly added capacity in 2019 (GW)



Source: National Energy Administration, 28 February 2020

Annual solar PV capacity additions fell from 44.2 GW in 2018 to 30.1 GW in 2019. [92] The percentage of new distributed solar additions remained strong at 30.6%. This reflects declining quotas for central projects supported by subsidized feed-in tariffs. Whereas until recently only a tiny proportion of solar additions were rooftop solar, industry reports suggest that in 2019 approximately one-third of distributed solar projects were household rooftop projects. [93]

New solar PV capacity additions in 2019 have shifted from the sparsely populated northern and north-western regions towards eastern and southern provinces. The leading province for new solar installations in 2019 was Guizhou, with 3.4 GW of additions, followed by Shandong with 2.6 GW. Six provinces added more than 2 GW and a further five provinces added over 1 GW. Several provinces with high solar resources nevertheless added less than 100 MW of solar in 2019, including Hainan and Sichuan provinces.

> The renewable electricity consumption obligation will be a significant guarantee for solar PV development during the 14th Five-Year Plan period.

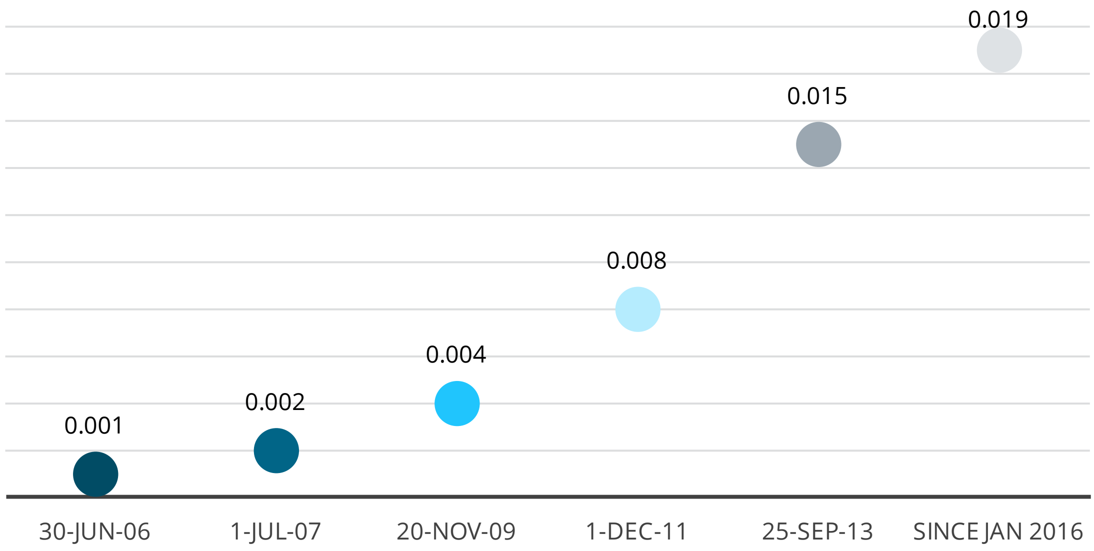
Wang Sicheng
Researcher of NDRC

Renewable energy incentives shift away from feed-in tariffs

China introduced its Renewable Energy Law in 2005, and in subsequent years held wind power capacity auctions for a limited number of projects. Wind and solar power in China only began to grow substantially after the country introduced fixed, 20-year feed-in tariffs for wind in 2009 and then solar photovoltaic in 2011. [94] Feed-in tariffs were set at different levels in various regions to account for different wind and solar resources, but were generally high enough to incentivize investment. Separate subsidies were announced for distributed solar.[95]

Funds for the feed-in tariff subsidy are paid from a surcharge on most retail electricity sales, but rapid expansion of renewable energy capacity under the feed-in tariff has caused a deficit in the surcharge fund. Though the central government raised the surcharge on several occasions, and instituted provincial quotas on new wind and solar projects that would qualify for the feed-in tariff, the deficit problem has remained. [96]

History of the renewable surcharge (RMB/kWh)



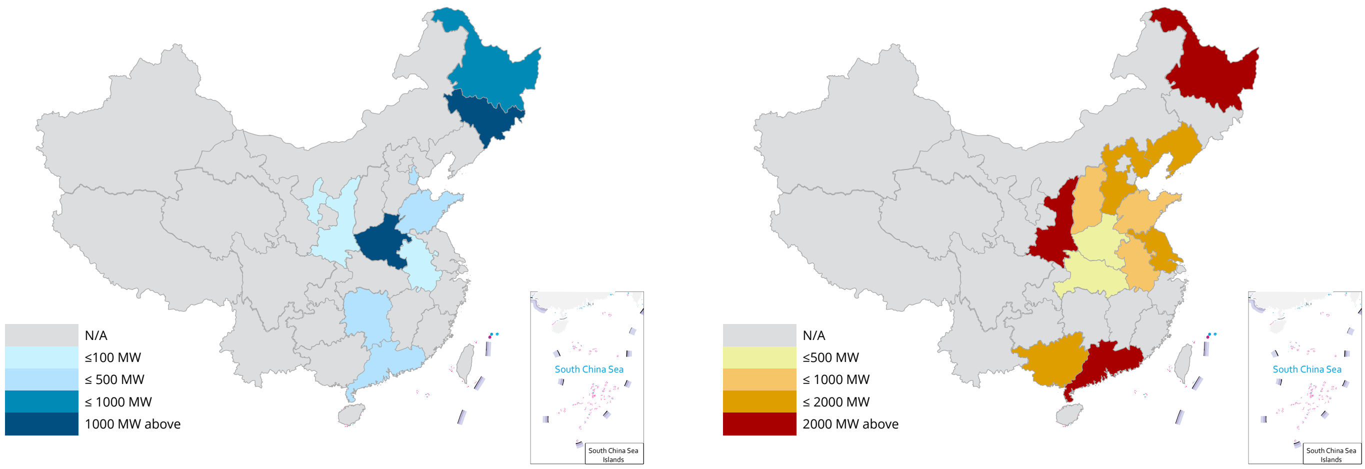
Source: NEA, accessed in April 2019

Although China's feed-in tariff was built upon the example of German renewable FITs, the Chinese surcharge amounts to 3.7% of average household retail electricity prices of RMB 0.51/kWh as of 2019. [97] That compares to current average German retail electricity prices of 30.85 ct/kWh, of which the EEG surcharge accounts for 21%. [98]

Renewable tenders/auctions: As NEA pushes to retire feed-in tariffs for new projects, it has turned to renewable tenders/auctions to set tariffs and reduce subsidy levels, starting with wind. From May 2018, new provincial centralized onshore and offshore wind power projects were required to participate in tenders to receive construction quotas and feed-in tariff subsidies. The weight of price in assessing bids was at least 40%. [99] For solar, NEA has also implemented nationwide tendering since 2019, with price as the only factor. Policymakers set a subsidy cap of RMB 3 billion for solar PV projects in 2019, of which RMB 750 million was specifically for household PV, implying 3.5 GW of construction quota for this category, according to CNREC. The allocation of the remaining RMB 2.25 billion will be determined through national tendering by utility-scale PV, industrial and commercial distributed PV. [100] Feed-in tariffs remain for poverty-alleviation solar projects in 2019. [101]

Subsidy-free renewable program: China plans to scale up wind and solar projects that receive no subsidies. In January 2019, the NEA and NDRC jointly announced a plan to launch subsidy-free wind and solar pilots in regions with superior wind or solar resources and high local electricity consumption.[102] These projects do not receive subsidized tariffs, but can receive long-term contracts at prices at or below the local benchmark feed-in tariff for coal plants. However, the policy limits the capacity for such projects, given that they receive supporting policies such as exemption from land transaction fees and 20-year feed-in tariff power purchase agreements.[103] NEA announced the first batch of subsidy-free projects in May 2019, including 4.5 GW of utility-scale onshore wind, 14.8 GW of utility-scale PV, and 1.5 GW of distributed renewables.[104] Northeast China has the largest amount of subsidy-free projects.

2019 Wind (left) and PV (right) subsidy-free pilots



Source: NEA, May 2019

Timeline for Renewable incentives

2009

Wind feed-in-tariff
NDRC announced rules for setting wind feed-in-tariff

Golden Sun Demonstration Project Announced
Funds from the central government's special fund for renewable energy will be allocated to support solar PV projects.

2011

Solar feed-in-tariff
NDRC announced rules for setting solar PV feed-in-tariff

2012

Distributed solar subsidy
MoF announced regulations regarding distributed Solar Subsidy

2014

Solar PV poverty alleviation projects
NEA and CPAD of State Council jointly announced implementation of the work plan for the Solar PV poverty alleviation project

2015

Solar PV auction pilots
A 0.2 GW project in Hothot was used as a pilot for solar PV auction.

2016

Solar PV auction pilots
The solar PV feed-in tariffs should be determined through tendering.

2018

Wind auction mandatory
The wind feed-in tariffs should be determined through tendering.

Cut in feed-in-tariff quotas announced
The number of new solar projects started to drop.

2019

First price-parity projects awarded
NEA and NDRC jointly announced the first batch price-parity wind and solar PV projects.

2020

2009-2014
RE sector were heavily subsidized

2015-2018
Subsidy slowly phased out

2019 – Present
Grid Parity

Source: various sources [105]

Distributed solar

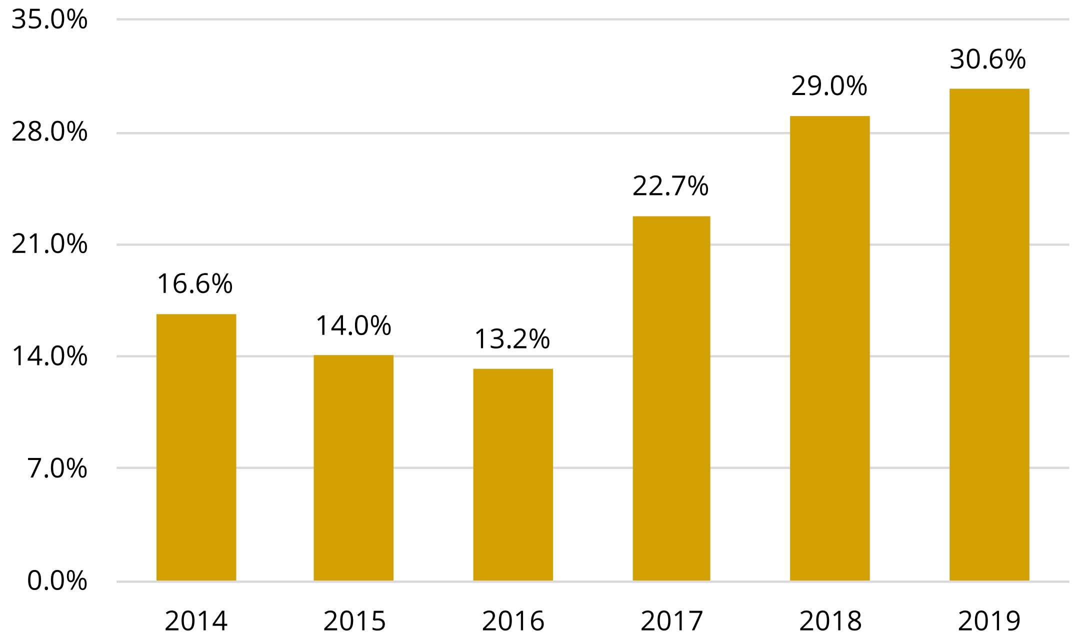
Distributed solar PV in China consists of three categories. The first is rooftop solar or, in some cases, building integrated PV (BIPV). The second is solar for self-consumption that connects to the grid at or below 35 kV, in which a single component does not exceed 20 MW of capacity. The third is rural village PV stations. [106]

The share of distributed solar in China's total solar PV began to increase strongly starting in 2016. In 2019, over 30% of total solar was classified as distributed. Residential distributed energy reached 3.55 GW in 2019 which takes up 34.5% of distributed solar PV.[107] There are several reasons for the shift to distributed solar. In May 2016, the National Reform and Development Commissions (NDRC) issued new guidelines on the size and management of distributed solar and removed provincial limits to new project approvals for distributed solar. Declining costs have also made distributed solar PV projects more attractive for developers. The average price of global PV modules decreased by 79% from 2010 to 2017. [108] An RMB 0.42/kWh subsidy from 2013-2017 on all power generated (self-consumed and sent to the grid) also improved the economics of distributed solar relative to central PV projects,[109] and in some cases project yields surpassed 20%. [110]

The announcement of pilot market trading for distributed power generation in October 2017 marked the beginning of emphasis on markets for distributed energy.[111] The feed-in-tariff for distributed solar PV fell by RMB 0.05/kWh in 2018,[112] later declined by RMB 0.15/kWh in 2019. [113] As a result, the distributed solar additions experienced a significant drop of 9 GW in 2019 from the 21 GW peak in 2018. NEA accelerated the subsidy phase out process in 2019. The plan for subsidy-free wind and solar pilots was announced in January 2019. According to this plan, distributed wind and solar projects that participate in electricity trading market will no longer receive national subsidies. NEA announced subsidy-free distributed renewable market trading pilots of 1.47 GW. [114] In April 2020, NEA will require provincial energy administrative departments to submit the first batch of subsidy-free wind and solar PV projects. Local distributed renewable market trading pilots that have been submitted to 2018 will also be included after review by NEA.

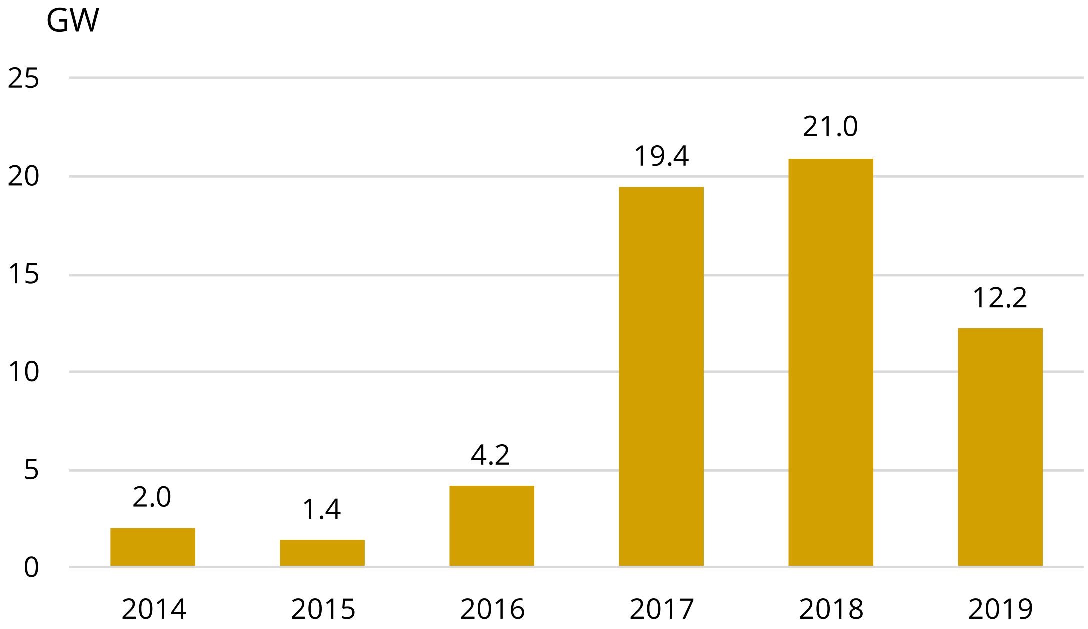
Although the subsidy for distributed PV will slowly phase out, distributed projects now receive more indirect support. Furthermore, the recently announced policy for non-hydro renewable energy states that the residential distributed solar will still receive a fixed amount of subsidy, and subsidy payment will be prioritised for poverty alleviation PV projects and residential distributed PV projects. [115]

Share of cumulative distributed solar PV capacity



Source: calculated from NEA, 2015-2020

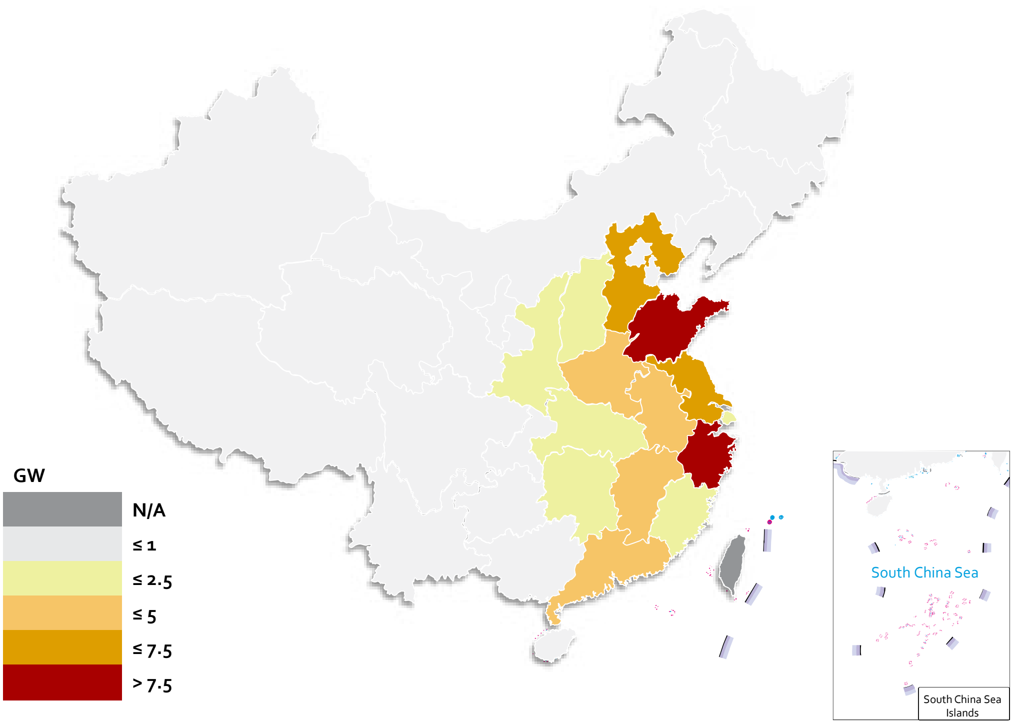
Annual distributed solar PV incremental on-grid capacity



Source: NEA, 2015-2020

Distributed solar PV has been installed mainly in eastern and southern China, in regions with reasonably high solar resources with high electricity demand. About 50% of the total distributed solar capacity is in four provinces, namely Hebei, Jiangsu, Zhejiang, and Shandong. Several of these provinces also have domestic solar manufacturing industries.

Provinces with distributed solar 2019



Source: NEA, 2020

Land use regulations are one of the restrictions for development of large-scaled wind and solar projects. China's land use laws have historically presented an obstacle has very strict law on land use. To ensure the food security, China has set a 120 million-hectare-agriculture-land red line. It is often hard for large solar PV projects to find enough land to build on. Distributed solar PV is more attractive in eastern and southern China where it's more populated. Distributed solar can also solve the chronic regional imbalance of renewable energy consumption and production experienced by China, where western provinces produce more solar and wind energy, but eastern and southern coastal provinces consume more electricity.

Floating solar PV

In the past year or so, floating solar PV (FPV) has seen rapid growth worldwide with over 1.1 GW of installed capacity in mid-2018. The main advantages for FPV are increased electricity production due to the cooling effect of water and lower water loss through evaporation. According to Chinese researchers, the efficiency of floating PV systems can increase output by about 1.6-2.0% versus traditional land-based PV systems.[116] Furthermore, installations do not require valuable land space, and can even inhibit algae growth in the water.[117] On the downside, FPV is a relatively new technology; requiring specialized racking and installation costs, potentially costing 20-25% more than conventional systems—though this premium should fall as the technology advances.[118]

China has several large floating PV systems. In 2017, a 40 MW system was installed in Huainan on the site of a former coal mine now filled with water. It extends over 93 hectares and has 132,400 solar modules. Due to the water's high mineral content, the location was unsuited to any other use. More recently, in 2019 a 70 MW system was installed in Suzhou. Three floating PV systems with an output of more than 100 MW each have been implemented, including a 150 MW plant at a mining site in Anhui.[119]

Future path for wind and solar

China is relying on large-scale energy transmission from the west to the east. Experts believe that a combination of centralised and distributed energy resources will be the solution.[120] A mix of long-distance transmission and local consumption may be the future trend for the electricity sector. It is also stated in the recent policy that the government will have a stronger policy support for distributed energy.[121] It indicates that the focus of renewable energy development in the future will be on developing distributed energy. From the market perspective, distributed energy will be more profitable and attractive for investors in the future due to declining production cost and slower decreasing rate of feed-in tariffs and subsidies (especially for residential distributed solar PV projects).

Despite the policy support and cost reduction, the development of distributed energy still faces many barriers and challenges in China. Third-party risks and low profitability exhibit to be the main challenges faced by distributed solar PV project developers. In China, the typical rooftop leasing contract is normally 5-10 years which is less than the solar PV system lifetime. This creates significant uncertainty and third-party risks for infrastructure leasing and contractual agreements. The current pricing mechanism in the power system is another barrier faced by distributed solar development. The power generated by distributed generators is normally sold to grid companies at wholesale rates, rather than at retail rates. Therefore, the generator may benefit more from self-consuming than trading with the grid which disincentivised the installation of distributed solar PV. The incentive for households to install distributed solar PV is low as well because of the rather low rate for residential power.

7 Electricity Market Reform

7. Electricity Market Reform

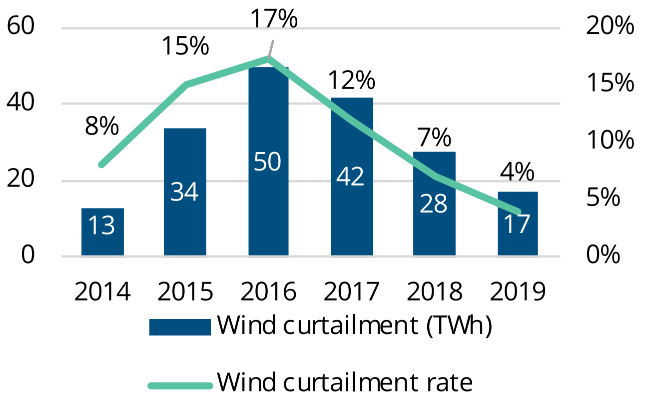
China continues to make rapid progress on market reform, benefiting renewables

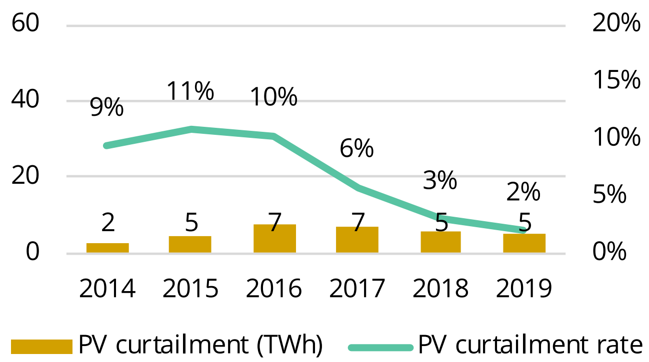
- Wind and solar curtailment fell dramatically, resulting from greater incentives to integrate renewable energy as well as increased power trading.
- Spot markets are being developed at the provincial level, using several models.
- Quotas for renewable consumption are replacing subsidies for renewables.

Market reform of the electricity sector is essential to enabling a clean energy transition and reducing the country's carbon emissions. Historically, the lack of a wholesale power market has contributed to curtailment of renewable energy, which makes renewable energy artificially less economical. China's administratively planned power system had historically encouraged the over-building of coal plants through inflexible planned operating hours contracts that enabled cost recovery for coal plant investments.[122] To ensure the solvency of state-owned power companies and maximize provincial tax revenue, provincial governments had also favoured dispatch of within-province coal plants over trading power between provinces—creating a system known as "provincial fortresses."[123] Power market reforms that were restarted in 2015 have been aimed at gradually resolving these issues through a combination of market and administrative measures, including phasing out planned operating hours and encouraging power trading among provinces.

Falling curtailment of renewable energy has been one indicator of success of power market reforms. In 2019, wind curtailment amounted to 4%, down from 7% in 2018 and a peak of 17% in 2014. [124] No provinces reported curtailment above 14%. The solar curtailment also fell in 2019 to 2% from the peak 11% in 2015. [125]

Curtailment of electricity output from wind (left) and solar PV (right), 2013-2019





Source: China National Energy Administration (NEA), 2013-2019

Power markets: China's spot markets gradually start to take shape

China's current phase of electric power market reforms kicked off in 2015, when authorities announced plans to establish market-based mid- to long-term contracts for electricity, leading eventually to establishment of market for spot-trading of electricity and ancillary services (such as load-following, voltage support, and regulation services). These reforms were motivated by the desire to rationalize power sector investment, reduce power prices, and improve integration of renewable energy.

Mid-to-long-term contracts: China began its 2015 power market drive with the transfer of monthly and annual fixed operating hours contracts with generators to so-called bilateral monthly and annual contracts, with prices set bilaterally, subject to various approvals.[126] While this in theory allows some price fluctuation, in practice the central government maintains a tight lid on prices. Most contracts are for 1-month or 1-year, and in this respect the new market resembles the prior planned operating hours system more than it does long-term power purchase contracts in other power markets, which might be on a 10-, 15-, or 20-year basis.

Spot market pilots: After the full roll-out of bilateral markets, seven spot market pilot provinces was set up, which established trading centers and began developing models for spot markets based on various practices in other countries. Guangdong has, for example, adopted a power pool arrangement with locational-marginal-pricing, whereas Zhejiang has hired the U.S. regional transmission operator PJM to consult in the design of its provincial power market.[127] While the central government subsequently expanded the spot market pilots nationally, progress is slow. While provincial pilots have all officially launched, trading is currently conducted mainly on a simulated basis. [128] The results have been published in a few cases, such as in Guangdong province. [129]

Ancillary services markets: Ancillary services markets are important to flexibility; previously, funds for ancillary services were minimal and effectively the market required coal plants to pay one another for such services. New reforms have established ancillary service market pilots, starting with Northeast China.[130] Different provinces have adapted some of the ancillary services rules from Northeast China, but most ancillary services markets are at the early stages of development and may only allow participation of some generators.[131]

T&D reform: Transmission and distribution pricing reform has been carried out nationwide, standardizing payment to grid companies for transmission and distribution services as well as cross-provincial transmission investments.[132] Presently, China is working on "incremental distribution grid pilots," which allow private players such as industrial parks to receive market-based compensation for building out new grid assets. This could benefit clean energy by enabling more innovative models for distributed energy, storage, and micro-grids.

Power trading between provinces: Northern provinces have created a kind of spot power market by proxy that enables functional trading of power between provinces; the system is known as generation rights trading, and allows generators to maintain the revenue they would receive under their existing contracts, while allowing provinces to freely buy and sell excess power without reducing the revenue of generators.[133] Under this system, provincial dispatch centers act as unitary buyer and seller of generation rights, allocating hours among generators based on a fairness principle. This differs from a normal spot market in that the generators do not bid or trade individually, but in some respects resembles the "power pool" concept used in some markets previously such as the U.K. or U.S. New England states (Nepool). Provinces in the north have seen dramatic declines in curtailment of wind power as a result.

Closure of overcapacity coal: China continues to build coal capacity, after a hiatus that began when the NEA imposed a strict coal investment Risk Alert system on provinces that effectively halted construction, including construction on plants already underway. The warning system was based on utilization, transmission capacity, environmental carrying capacity (air pollution), and curtailment of wind and solar.[134] However, NEA had recently deemed many provinces compliant with the warning system and effectively green-lighted new plants in many regions, enabling plants that were already under construction to move to completion.[135] Nevertheless, most coal plants in China continue to operate at low utilization and lose money.[136] In November 2019, NDRC and SASAC announced that five provinces in western China would have to close some overcapacity coal plants and consolidate operation to reduce losses,[137] but it is unclear if such reductions will result in net closures or simply closures of some outdated plants that can be replaced by new capacity elsewhere.

Targets and incentives for reducing curtailment: China's 2005 Renewable Energy Law, and its implementation rules set in 2007, required mandatory purchase of renewable energy including wind and solar, but implementation proved difficult.[138] Since 2016, NDRC and NEA rules have indicated that grid companies and dispatch centers were mandated to buy and absorb all renewable energy.[139] In 2019, China began to apply administrative penalties to grid companies and dispatch centers based on quotas for curtailment, implementing targets to keep curtailment below around 5% by 2020.[140] In late 2019, China issued a further clarification requiring mandatory purchase of renewables and requiring payment by grid companies for curtailed wind and solar.[141]

Provincial quotas for renewable energy and renewable certificates: After three rounds of proposals, NEA adopted provincial quotas for renewable energy consumption that apply to provincial grid companies and large industries (which often own their own power supplies).[142] While these are often compared to the Renewable Obligation (RO) of the U.K., or the U.S. Renewable Portfolio Standards, they differ in that they are only short-term administrative measures that require uptake of RE in 2019 and 2020, whereas a traditional RO or RPS is designed with 10-20-year targets to guide investment. China continues to rely on the five-year planning process to guide long-term investment decisions. Voluntary green credits or certificates are still available for purchase, but the market for these certificates has been thin, because the credits represent a transfer of subsidy payment obligation from the government to the purchaser, and therefore lack additionality.[143] Currently, the voluntary green certificates do not link to the renewable consumption obligation, but this may change in the future.

Timeline of electric power market reforms

1985
Provisional Regulations on Promoting Investment in the Power Sector and Implementing Different Power Prices
separates the responsibilities of government from business in the power sector

1997
Establishment of State Power Corporation from the former Ministry of Electric Power
NDRC announced rules for setting solar PV feed-in-tariff

1998

2002
Breakup of the State Power Corporation into five state-owned generation groups and two state grid companies
(State Grid Corporation of China and China Southern Grid)

2003
Establishment of State Electricity Regulatory Commission

2005
Renewable Energy Law mandates purchase of all renewable energy at government-established tariffs

2009
Amendment of Renewable Energy Law

2014
Shenzhen T&D pricing pilot

2015
Document 9 on Deepening Power Sector Reform
establishes long-term goals of market pricing of electricity, spot markets, and opening up market for retail electricity

2016
Rule 625
mandates purchase of all renewable energy and compensation for curtailed energy by grid companies.

Rules for market-based mid-to-long term contracts
to gradually replace administratively-planned dispatch

2017
T&D pricing reform implemented nationally
Ancillary services reforms begin
Seven spot market pilots announced

2019
New spot market pilot guidance issued by NEA
New Mandatory Purchase requirement for Renewable Energy issued

Source: various sources[144]

Challenges remain for market reforms and renewable integration

Spot market reform: Spot markets are developed at the provincial level. Provinces have previously had several motivations to protect within-province generators through market design and dispatch practices.[145] Ensuring market supervision and fair competition are key to effective spot market design.

Distributed energy: China recognizes the need for more distributed energy, given constrained transmission and the trends in other countries towards distributed solar and storage. China has thus maintained feed-in tariffs for distributed PV, but other obstacles to rooftop PV remain, such as regulatory complexity, slow approvals, objections from grid companies, and limited financing tools. These obstacles also apply to distributed energy storage and micro-grids.

Lack of transparency: Despite a great deal of discussion of smart grid and Energy plus Internet, China's grid, dispatch, and power pricing are operated without public information platforms that could enable market players or the public to analyze their operations or potentially participate via new business models. Transparency can not only enable the effective operation of spot markets, but also is likely necessary for market monitoring as well as business models such as aggregation of EV charging or certain forms of energy demand-side management.

Zeng Ming
Director of Energy Internet Research Center, North China Electric Power University

During the 14th Five-Year Plan, the supply of electricity will still rely on thermal power, but thermal power should increasingly be used for peak shaving and flexibility for renewables. It is necessary to consider various ancillary service markets and electricity energy markets together create a comprehensive power market.

8 Energy Efficiency

8. Energy Efficiency

Energy efficiency improves, but policies face obstacles

- China has focused on industrial energy efficiency using mandates on large energy consuming industries.
- Various obstacles face efforts to promote the energy service company (ESCO) model, but opening of retail electricity markets could help.

China has set ambitious targets over the years on energy efficiency, covering every aspect of the economy, from housing to industry. According to the 13th Five-Year Plan, China aims to reduce energy intensity by 15% by 2020 compared to 2015. The 13th Five-Year Plan set an upper limit for 2020 primary energy consumption of 5 billion tons of standard coal.[146] Such national requirements are broken down directly to local officials and the most energy-intensive companies.

Instruments for increasing energy efficiency in industry

The overall framework for improving energy efficiency comes from the 2007 amendments to the Energy Conservation Law, which sets forth the obligations of both government and companies to save energy and to establish monitoring systems. To achieve the energy saving goals, the central government supports measures to increase energy efficiency with subsidies. Participating large companies primarily support investments in selected energy efficiency technologies. One of the most important measures for this is the 100-, 1,000-, and 10,000-company program, which includes more than 16,000 companies, including large energy consumers in the transport and building sectors, together accounting for 60% of primary energy consumption.

In addition, China has various measures for energy savings and efficiency. These include the promotion of energy management systems, measuring devices and online monitoring systems, energy audits and energy flow analyses. Policies also promote district heating, demand-side management (DSM), green building standards, industrial waste heat recovery, and the promotion of efficient coal plants.

Overview important policies and measure for energy efficiency in China

The Chinese government sees energy efficiency as an important corner stone for the energy revolution along with RE-expansion, similar to German Efficiency First

Overarching objectives

- Reduction of energy intensity per unit of GDP by 60% compared to 2005
- PEC limitied to max. 146.5 bn GJ by 2020 (2018: 136.9 bn GJ)

Top Runner pilot projects

- Promotion of energy-efficient products
- Energy efficiency in companies
- Energy efficiency in public buildings

Energy intensive industries

- 100, 1000, 10000 company program
- Voluntary energy efficiency measures in companies

Financing

- Tax incentive and subsidies
- Funding for green and clean projects

Market instruments

- ETS and electricity market reform
- Quota for energy consumption
- Energy efficiency labels

Digitalization and technology

- Priority on research and funding of energy efficient and low-carbon technologies

Sector Coupling

- Interaction between consumption and generation
- Energy efficiency and renewable energy
- Integrated energy management

Campaigns

- Energy Saving Week
- Green consumption and green lifestyle

Source: GIZ, 2020

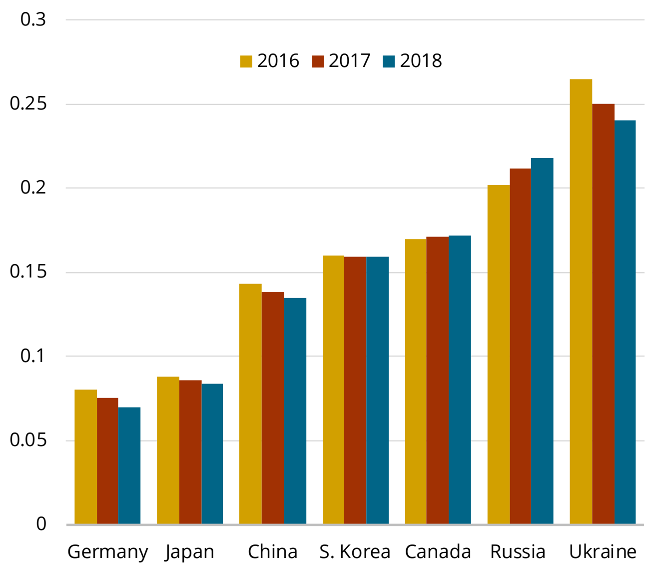
Building energy efficiency

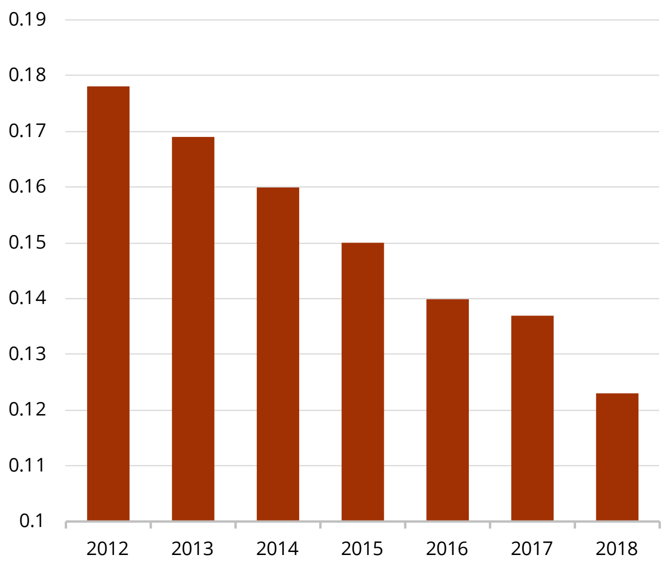
To reduce building energy consumption, China mainly relies on the tightening of regulatory requirements and standards. Incentive mechanisms are rarely employed. To increase the energy efficiency in the building stock, the Ministry of Housing and Urban-Rural Development (MOHURD) has concentrated on energy efficiency retrofit of buildings in northern Chinese and expanding consumption-based billing of heating—which is usually billed on the basis of floor area. In the case of new buildings, requirements for energy efficiency have gradually tightened, and the government has promoted green buildings through the national Three Star standard. The National Government Offices Administration (NGOA), in charge of the public building stock, is responsible for setting a positive example by adhering to high energy efficiency standards in public buildings.

Energy intensity

China has made progress in energy efficiency over the past decade and the energy intensity of the Chinese economy has continued to decline, both as a result of efficiency measures, as well as through productivity gains and structural shifts towards less energy-intensive services and consumption. China's energy intensity remains high compared to most OECD countries.

Energy intensity of selected countries (left) and China (right) in kg of oil equivalent and 2015 US$





Source: Enerdata, February 2020

China's energy intensity per unit of GDP fell by approximately 30% between 2010 and 2018. The decoupling of economic growth and energy consumption is visible in overall energy trends. At the March 2019 session of the National People's Congress, Premier Li Keqiang announced that China's GDP had grown 6.6% the previous year and energy intensity had dropped 3.1%. In 2019 the economy grew by 6.1% with an expected reduction in energy intensity of about 3%.[147]

Analysis of the 12th Five-Year Plan (2011-2015) show that efficiency measures in large, energy-intensive industries (steel, cement, and aluminum) made only a small contribution to reducing the energy intensity. Rather, the reduction of energy consumption in heavy industries is mainly due to a change in the economic structure and reduction of overcapacity.

Problems and challenges of energy efficiency policy

In common with most countries, China faces a number of challenges in designing and implementing more comprehensive energy efficiency policies. Political objectives and instruments often lack coordination. For example, when carrying out energy audits, there is inadequate implementation, application and updating of existing energy efficiency standards. Other challenges include the lack of trust between large industrial energy consumers and energy service providers, especially regarding independent advice on energy-saving measures, as well as the lack of long-term planning and consideration of life cycle costs when making investment decisions. Furthermore, expertise and knowledge, particularly in the integrated consideration of energy systems and efficiency measures in each district as well as in the industrial area, should be improved. Finally, China's industrial power rate is around US$ 0.084/kWh, relatively low compared to other countries around the world.[148] This low energy price could discourage efficient usage and investment in energy efficiency measures.

9 New Energy Vehicles

9. New Energy Vehicles

EV sales fall, but new 25% target will support market

- NEV sales fell by 4% in 2019, with most of the drop occurring after the mid-year subsidy cut.
- A 25% NEV sales target for 2025 could indicate sustained support for NEVs.
- A GIZ-Tsinghua-ERI analysis shows EVs will help improve Beijing air quality despite most electricity coming from coal.

China strives to become a world leader in the global automobile market, and the central element of this effort is the country's policy on new energy vehicles (NEVs), which includes electric vehicles (EVs) and fuel cell vehicles (FCVs). Large subsidies have been directed to companies in this field, including via subsidies paid to manufacturers for every qualifying NEV sold, and supported the industry with regulatory measures such as preferential policies for NEV license plate issuance, and an annual quota for NEV sales.

In December 2019, the Ministry of Industry and Information Technology (MIIT) issued a request for comment on a new draft NEV Industry Development Plan (2021-2035).[149] The plan's purpose is to promote the market for battery electric vehicles and make progress toward commercialization of fuel cell vehicles. The plan attempts to shift from industry support via subsidies and administrative targets towards a more market-oriented approach that could promote innovation. A 2025 requirement of 25% market share for new energy vehicles in annual vehicle sales implies an annual sale of around 5-6 million, assuming a steady vehicle market. Assuming EV market share rises in compound-growth fashion to reach this percentage figure, this implies around 20 million EVs on the road by 2025.

Continual NEV sales growth but slower

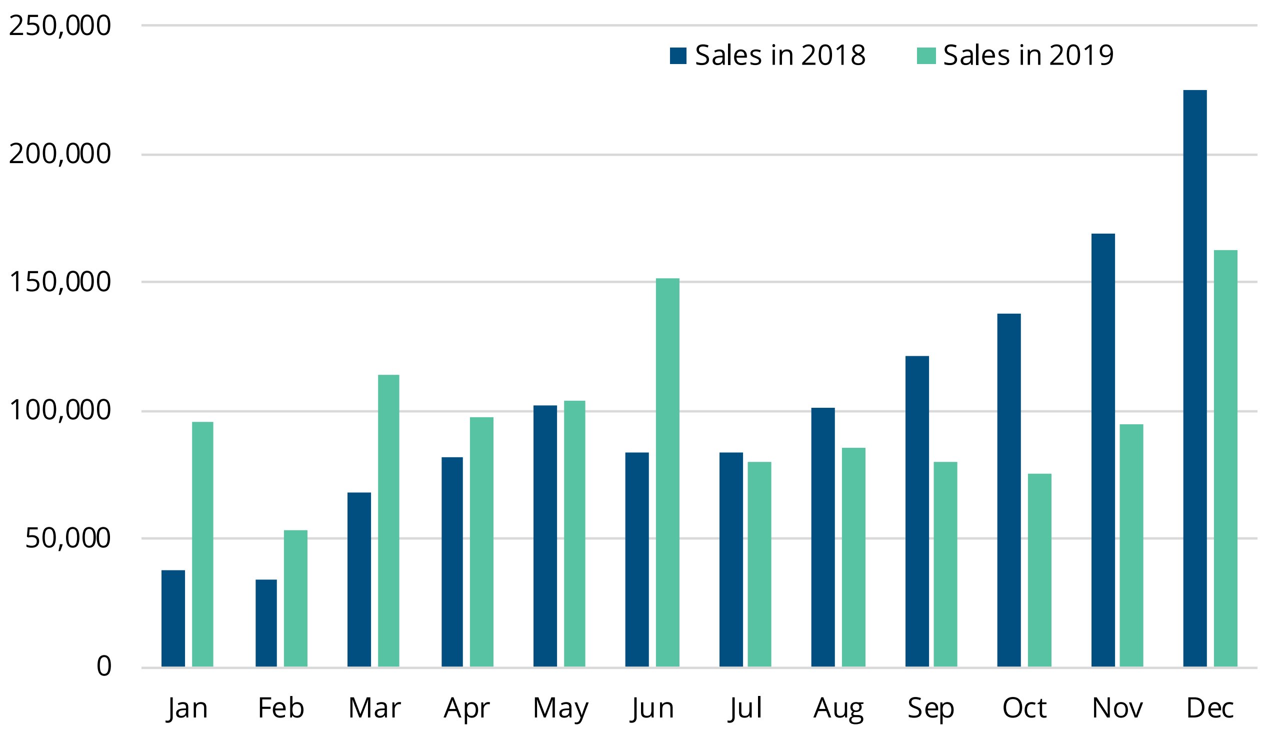
Between 2012 and 2018, China achieved an unprecedented ramp in electric vehicle sales: NEV sales rose from approximately 13,000 units in 2012 to 1.25 million units in 2018, corresponding to 5% of annual vehicle sales. [150] So far, sales have been concentrated in some comparatively developed cities, especially Beijing, Shanghai, Shenzhen, and Guangzhou. However, second and third tier cities are increasingly important NEV markets.

A July 2019 cut in NEV purchase subsidies led to a sharp decline in sales. Annual sales fell 4% in 2019 from the prior year to 1.2 million. Sales surged right before the expected cut in subsidies in June, but sales in the second half of 2019 following the subsidy cut fell 57.3% versus the prior year.[151] Nevertheless, China's electric vehicle market share in 2019 increased to 4.7% from 4.5% in 2018, due to the overall decline in all types of vehicle sales. [152] January 2020 sales showed continued declines, and the EV market began to feel the effects of the coronavirus.

Shi Jialin
Director of China Datang Corporation

"New business models are needed, as are EV smart charging, increased charging station coverage, and hydrogen stations..."

Monthly NEV sales in 2018 and 2019



Source: China Association of Automobile Manufacturers, January 2020 [153]

While government officials expect fossil vehicles sales to fall again in 2020, EV sales could remain relatively healthy, helped by a stable incentive environment and substantial numbers of Tesla's locally made vehicles.[154]

Modification to the subsidy

Given the sharp rise in NEV sales and consequent increase in subsidy outlays, the government seeks to shift from a subsidy-driven market to one driven by a combination of consumer demand as well as administratively set targets and other non-monetary incentives. The quota set by the central government's directive in 2017 required manufacturers to meet NEV sales of 10% in 2019 and 12% in 2020, referring to credit points that each manufacturer must acquire through the production of battery-electric vehicles and plug-in hybrids. This corresponds to approximately 4-5% of vehicle sales. The quota is set to increase by 2% every year from 2021 to 2024.[155]

Some industry officials doubt that the NEV quota and mandates for fleet purchases of NEVs will suffice to achieve the Chinese government's NEV production targets. To boost overall auto sales, the central government has suggested local governments relax caps on annual license plate registrations for conventional cars, which could diminish the attraction of NEVs versus regular vehicles. At the same time, policy makers have tightened standards for receiving NEV incentives, such as by raising thresholds for receiving subsidies in terms of vehicle range minimums and battery energy density. On 26 March 2019, the Ministry of Finance announced a modification of the NEV purchase subsidy scheme, tightening the requirements in terms of range, battery energy density, and energy efficiency. The subsidy ends for NEVs with an NEDC range under 250 km, and the maximum subsidy—available only to vehicles with an NEDC range above 400 km—was cut in half. In terms of battery energy density, no subsidy is available for vehicles with batteries under 125 Wh/kg, and the maximum subsidy requires at least 160 Wh/kg.[156]

Change in subsidy from 2017-2019 in terms of range

Type of Vehicle	Range (NEDC)	Subsidy in 2017 (Thousand RMB)	Subsidy in 2018 (Thousand RMB)	Subsidy in 2019 (Thousand RMB)
Pure Electric Vehicles	100≤R<150	2	/	/
	150≤R<200	3.6	1.5	/
	200≤R<250		2.4	/
	250≤R<300	4.4	3.4	1.8
	300≤R<400		4.5	1.8
	R≥400		5	2.5
Plug-in Hybrid Electric Vehicles	R≥50	2.4	2.2	1

Source: Ministry of Finance, March 2019[157]

Although the shift from subsidies to other incentives is likely to continue, the sharp drop in NEV sales in 2019-2020 may have caught policy makers by surprise, and undercut the national target of 25% NEV sales by 2025. Given the further sales impact of the coronavirus, the Chinese government has decided to further extend the EV subsidies for 2 more years, as revealed on the State Council's executive meeting on 31 March 2020. The extension comes in as policy makers realised that the market drivers for EV are not yet enough to push for the development of EV without government support. This new policy signifies China's determination to support NEV development, and the continued support will gradually shift emphasis from subsidies to vehicle usage and charging infrastructure. [158]

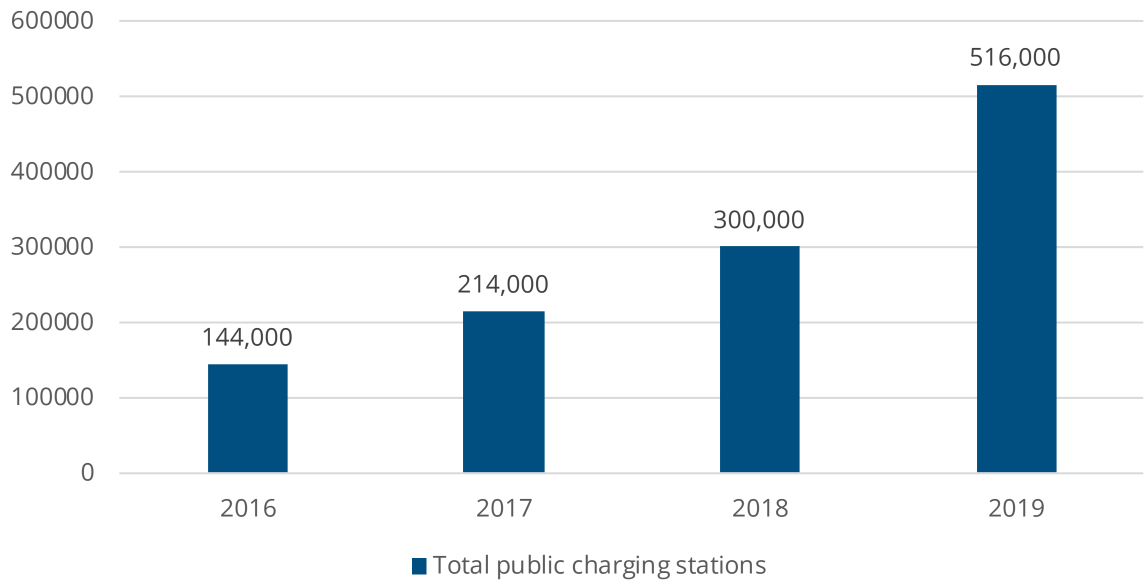
Battery manufacturing continues to scale up, and energy density has increased

China is also striving to become the world market leader in battery cell production. The Chinese battery producer CATL dominates the Chinese market, with a current market share over 50%. Together with Korean companies LG Chem and Panasonic, the three companies hold an EV battery market share of 62.5% globally, with CATL having the largest global market share among the three, at 27.9%.[159] The rapid rise of CATL was made possible in particular by the fact that until mid-2019 all manufacturers on the Chinese market could only receive NEV purchase subsidies if they installed Chinese-made batteries in their vehicles. [160] According to analysts' forecasts, CATL will already become the world's largest producer in 2020 due to the rapid expansion of its production capacity. [161] The second largest Chinese producer is BYD, which primarily builds batteries for its own vehicles. All three German manufacturers have concluded supply contracts with CATL for the local production of NEVs, and CATL has also started to build a production facility in Thuringia.[162]

Charging infrastructure expansion continues

The government has set ambitious expansion targets for charging infrastructure, calling for construction of 4.8 million charging posts by the end of 2020, including 500,000 public charging stations and 4.3 million private charging points, as well as 800 intercity rapid charging stations.[163] As of December 2019, there were a total of 1.03 million charging points in China, including approximately 516,000 public or semi-public charging points. [164] China has the largest public charging infrastructure network of any country, which reflects ambitious government targets as well as the need for public charging infrastructure in cities where many lack access to dedicated parking spots with electricity access.

Total public charging stations in China 2016-2019



Source: EVCIPA, January 2020 [165]

In terms of regional availability of charging infrastructure, public charging stations are distributed unevenly across provinces, reflecting greater availability of charging where EV adoption is already highest—such as in Beijing, Shanghai, and Guangdong. Provinces with few electric vehicles, on the other hand, have less charging infrastructure, although almost all provinces have at least 500 public charging points. [166]

In terms of ownership and operation of charging infrastructure just three companies own 70% of public charging stations in China: two private companies—TGood and Star Charge—and one state-owned company State Grid Corporation of China, which operates the majority of the country's power grid.[167] The expansion of charging infrastructure is subsidized by the state; unlike the sales subsidies for electric vehicles, this funding is likely to continue—although charging infrastructure policy is likely to also focus on industry upgrading and improving reliability.

A user-friendly and needs-based charging infrastructure is important for the further growth of electric mobility in China, especially since EV sales will increasingly be market-driven after the EV subsidies expire. However, several problems still exist in this regard: The expansion of the charging infrastructure has so far been largely driven by policy and not based on actual demand. For this reason, many charging station operators lack a sustainable business model and face difficulties generating profits. In addition, charging stations are poorly distributed and are often not where they are needed. Due to low utilization, operators lack incentive to provide adequate maintenance. This lack of incentive results not only in broken or balky chargers, but also reduces the incentive for operators to improve interoperability and the online information environment (such as charging apps) to ensure EV drivers can easily locate and access functional charging equipment.

Unlike the expansion of the public charging infrastructure, the expansion of charging points in private buildings has so far been slow because of high cost as well as administrative red tape. China also has too few public chargers offering charging rates over 100 kW, which many experts estimate is necessary to enable convenient long-distance trips.[168] The Electric Vehicle Charging Infrastructure Promotion Alliance (EVCIPA) anticipates that the average new public charger in 2020 will have a speed of 100 kW, up from 80 kW average for those added in 2019.[169]

Charging standards

China has nationwide standards for fast charging and normal charging of electric vehicles. These are binding for all vehicles sold in China. Most public charging stations can thus be used by all electric vehicles, regardless of vehicle manufacturer.

A harmonization of Chinese and European standards was achieved with normal charging with alternating current. Germany had also campaigned for China to adopt the European-American quick charging standard CCS (Combined Charging System), but this failed to reach fruition. China ultimately developed its own quick charging standard, and currently China is also developing a new ultra-fast charging standard called ChaoJi ("super"). ChaoJi should enable bidirectional charging and vehicle-to-grid (V2G) capability. German experts are involved in the development of ChaoJi through the sub-working group on electromobility of the German-Chinese standards commission.

There are currently differences of opinion within the Chinese government as to whether ChaoJi should be compatible with the Japanese fast charging standard ChaDeMo or whether it should be developed as a purely Chinese standard.[170]

EV charging from clean energy

Although China is driving the expansion of renewable energies, it still generates 69% of electricity from coal. For this reason, an electric vehicle in China causes significantly more emissions than the same vehicle in Germany, which has a significantly higher share of renewables in the power grid (around 38% renewable share of electricity consumption in 2018, should increase to 65% by 2030).[171] Due to their higher efficiency, electric cars produce fewer emissions in China than traditional combustion engines.

Assuming NEVs reach a 25% market share by 2025, or approximately 5-6 million units per year,[172] and using estimates of EV taxi, bus, and truck fleets from the EVCIPA,[173] we calculate 2025 EV electricity consumption of around 200 TWh. This additional electricity

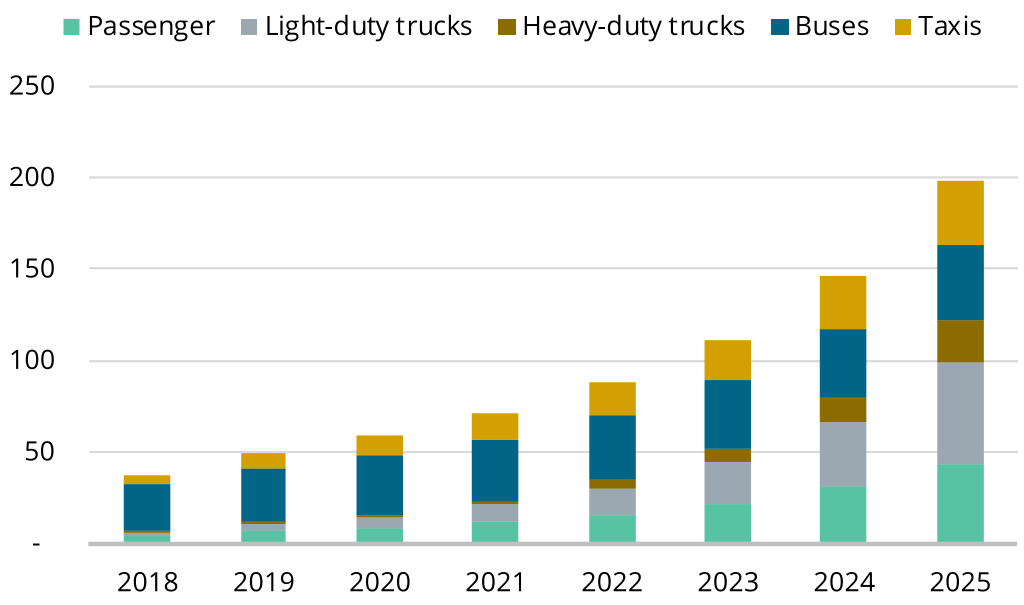
requirement can probably be more than covered by the expansion of renewable energies without new coal-fired power plants. Between 2017 and 2018 alone, electricity generation from renewables rose by 169.2 TWh.

The Chinese government wants to use electric vehicles to stabilize the power grid and increase the share of renewables in electricity consumption. However, these efforts are not yet well advanced. There are currently no direct incentives in China to charge an electric car when renewable electricity is produced. Electric vehicles are mostly charged at home in China, but the price of household electricity is fixed by the state and does not vary according to the time of day or night. China also does not yet have a real wholesale spot electricity market.

There are currently no business models in which the storage capacity of electric vehicles would be bundled and sold on the market. According to a recent study by the International Energy Agency (IEA), electric vehicles could play an important role in China by 2035 in order to offset fluctuating renewables and thus increase the share of renewables in electricity consumption. According to experts, China could generate up to 35% of its electricity from wind and solar power in 2035 (currently around 7.5%).[174]

With the vehicle-to-grid technology of the new V2G quick charging standard, electricity could then be stored both in times of high wind and sun, and fed back into the grid in times of little wind and sun.

Estimated electricity consumption by EVs through 2025 under 25% NEV target



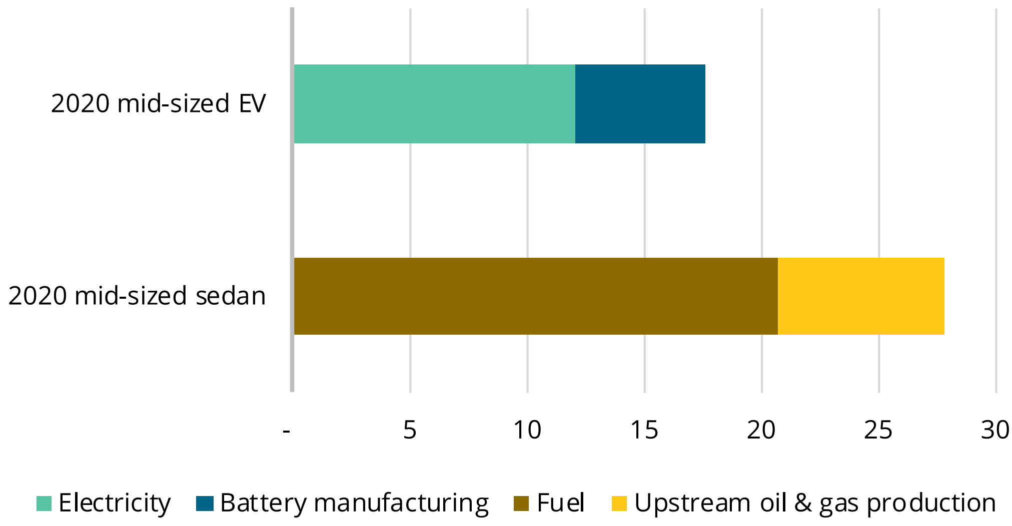
Source: GIZ calculations based on EVCIPA data, January 2020

EVs and air quality

Electric vehicle policy has several motivations, including industrial policy, reducing oil imports, and addressing air quality. Due to the preponderance of coal-fired power in the electricity sector, the impact of electric vehicles on emissions has been a hot topic. Overall, EV adoption reduces carbon emissions and has benefits to urban air quality, even considering China's coal-heavy power sector and the emissions from manufacturing batteries.

For carbon emissions, the greater efficiency of electric vehicles compared to fossil energy generally reduces the emissions of EVs when compared to gasoline or diesel vehicles. The greater efficiency of electric vehicles is sufficient to accommodate the higher weight of batteries as well as the embodied emissions of manufacturing vehicle batteries.[175] Vehicle emissions labels for EVs in China are expected to account for upstream battery manufacturing emissions. An additional factor to consider is the upstream emissions from oil and gas production, [176] which add up to 20-30% on top of the direct emissions from fuel consumption for propulsion. EV carbon emissions in China are therefore significantly lower than those of conventional vehicles.

Comparison of life-cycle emissions for EVs and fossil-fuel vehicles in China, kg CO_2 per 100 km

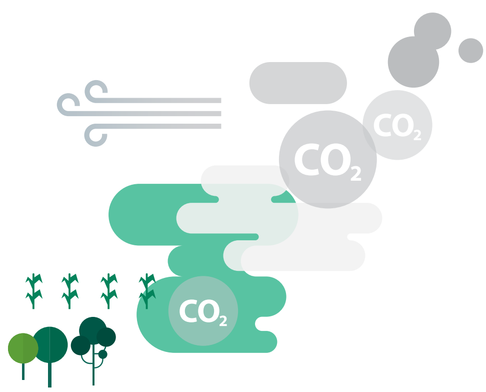


Source: author calculations, GIZ, 2020

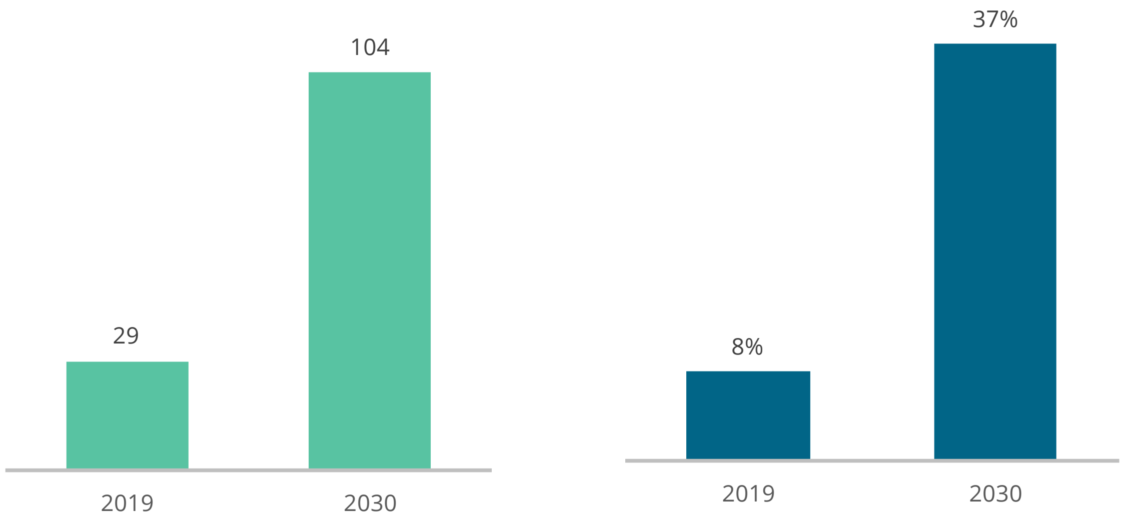
Although calculations of EV emissions typically assume they are charged from the average electricity sector fuel mix for the present, in reality EVs are especially concentrated in a few cities with dramatically different electricity mixes—for example, Beijing, Shenzhen, and Shanghai. Furthermore, EVs have the potential to charge preferentially from low-carbon energy, which could not only reduce emissions from charging, but could enable EVs to serve as a flexible resource for the power system, either via charging timed to coincide with renewable output, or by using vehicle batteries as storage for the grid with vehicle-to-grid (V2G) technology. These efforts are at an early stage.

EVs also have a positive influence on urban air quality. This issue is particularly complex, because air quality cannot be fully understood by looking at pollutant emissions alone—such as comparing smokestack and tailpipe emissions of each pollutant. Urban air quality changes rapidly from day to day due to atmospheric conditions, wind directions, and the degree of chemical mixing and formation of secondary pollutants, such as ozone or PM2.5.[177] Hence, to understand the impact of EV adoption on air quality, it is essential to utilize air quality models that incorporate emissions from all sectors, as well as multiple meteorological patterns.

Over the past year, GIZ has worked together with researchers at the China National Renewable Energy Centre (CNREC), the NDRC Energy Research Institute, and Tsinghua University to model the impact of EV adoption in the Jing-Jin-Ji (Beijing-Tianjin-Hebei) region. This region is a target of national policies to reduce urban air pollution in regions that have historically experienced severe air quality problems. Jing-Jin-Ji also has a high proportion of coal-fired power in its electricity mix, and coal is expected to continue to dominate through 2030 even though wind and solar capacity in the region are rising quickly. To model the impact of EV adoption on air quality in 2030, Tsinghua adapted its existing emissions inventory and emissions projections to incorporate forecasts of EV adoption and power sector renewable capacity additions provided by CNREC and the NDRC ERI. Under this forecast, wind and solar capacity in Jing-Jin-Ji rise from 29 GW in 2019 to 104 GW in 2030. The combined wind and solar share of Jing-Jin-Ji electricity production would rise from under 8% in 2019 to 37% of production in 2030. By 2030, the forecast assumes that there will be 2.14 million private passenger EVs on the road in this region (roughly 25% of the fleet), plus 165,000 EV taxis, 82,800 EV buses, and 28,000 EV delivery vans consuming 13.7 TWh of electricity annually. This represents a change in electricity consumption of just 2.6% versus the baseline with no EVs.

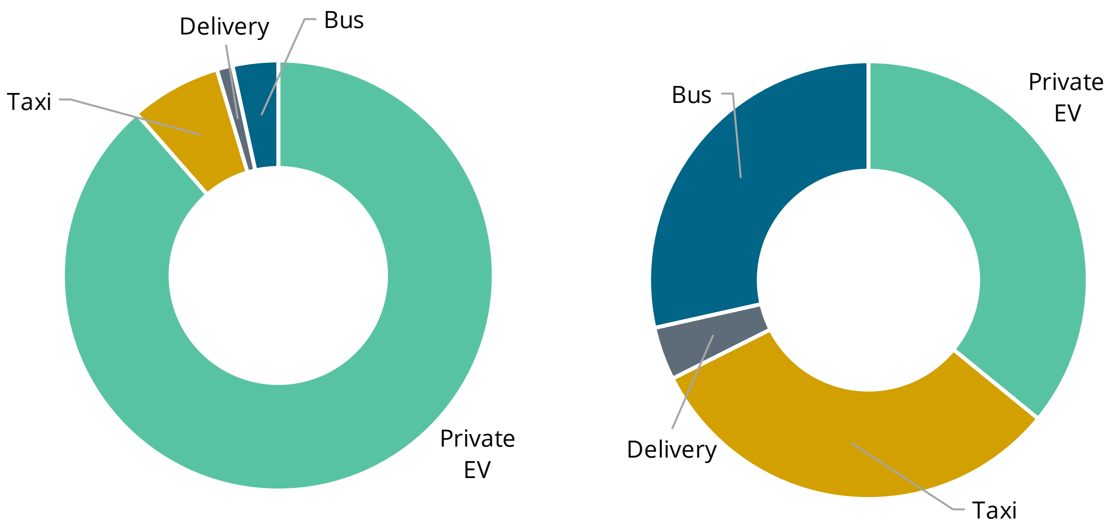


Jing-Jin-Ji 2019 and projected 2030 wind and solar capacity in GW (left) and proportion (right)



Source: CNREC, NDRC ERI, 2019

Jing-Jin-Ji 2030 EV fleet by number of vehicles (left) and by electricity consumption (right)

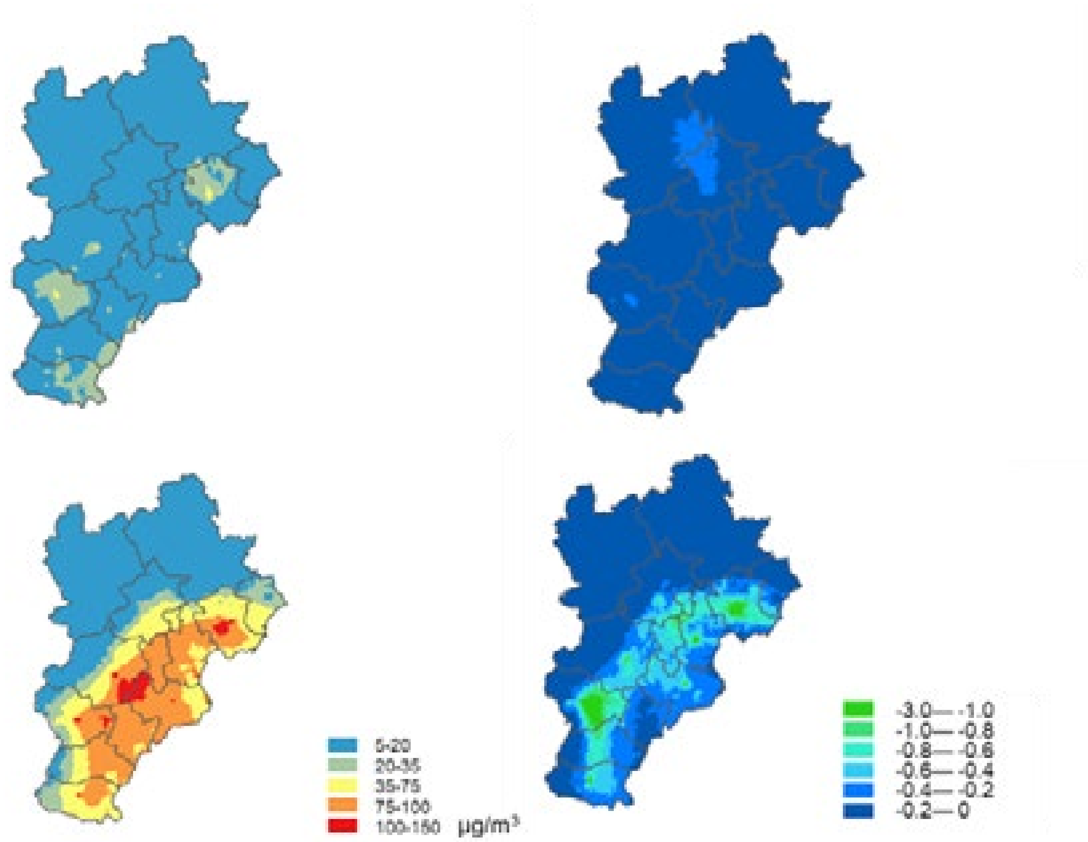


Source: NDRC ERI, 2019

Based on these assumptions, analysts at the Tsinghua School of the Environment and the Tsinghua School of Electrical Engineering worked to incorporate realistic EV charging times into existing regional air quality models, based on the Community Multi-Scale Air Quality (CMAQ) model. CMAQ is a three-dimensional, gridded atmospheric chemistry and transport modelling system that simulates ozone, particulate matter, toxic airborne pollutants, visibility, acidity, and nutrient pollution throughout the atmosphere. It is a regional model designed for regulatory and policy analysis as well as scientific analysis of the interactions of atmospheric chemistry and physics.[178]

The results show that EV adoption in this region would have the greatest impact on air quality during the winter. This is due to the frequent occurrence in winter of unfavorable weather patterns that lead to periods of stagnant air and/or air inversions, which can cause local traffic emissions to accumulate and mix with other pollutants.[179] For example, PM2.5 levels from 2015-2019 averaged 50% higher in December versus July.

Impact of EV adoption on regional air quality in Jing-Jin-Ji in July versus December



Source: Forthcoming, Tsinghua School of Environment, 2020

The final aspect of the analysis considered changing the charging times of EVs to correspond to periods of high renewable energy output. The analysis considered the typical vehicle driving patterns of various vehicle use cases to ensure vehicles were fully charged each day and able to complete trips on demand, altering only the daily charging times to match renewable output. Because the CNREC model's forecast for the region's electricity sector output is still rather fossil-heavy in 2030, and because the power sector's contribution to air pollution in urban areas is negligible compared to the effect of reducing emissions of conventional vehicles, the model found no significant change to urban air quality resulting from orderly charging. However, orderly charging of EVs from renewables did have a positive impact on air quality in the region north of Beijing near Zhangjiakou, where many coal plants are located. In addition, orderly charging improved uptake of renewable energy locally by a small but meaningful amount.

Coordinated charging of EVs is likely to have a larger effect in regions with higher renewable penetration, and in the long term V2G could have an even larger benefit to both renewable integration and air quality.

10 Smart Grids

10. Smart Grids

China is focusing on smart grid infrastructure including storage and micro grids

- Past smart grid efforts have included meters, transformers, and a variety of pilot projects.
- Increasingly, attention is turning to integrating energy storage, EV charging, and micro grids.
- State Grid has proposed a Ubiquitous Power Internet of Things for 2024.

China views smart grid infrastructure as a critical next step in the technical evolution of the power sector. A number of pilot projects have been undertaken over the years, employing such technologies as smart grid control, smart transformers, smart meters, and control systems for demand side management. Increasingly, pilots are turning towards integrating renewable energy and energy storage on the demand side or on the grid side, in many cases linked to electric vehicle charging. Smart grid is expected to be an integral aspect of the 14th Five-Year Plan for energy.

Definitions

A smart grid is a communication network on top of the electricity grid to gather and analyse data from different components of a power grid to predict power supply and demand which can be used for power management. A smart grid is a potential way to improve reliability and security, increase the flexibility of the grid, enable two-way transmission of power and greater control of power grid operations, and improve the economic and physical management of the grid.[180] Examples for smart grid technologies include digital substations, battery energy storage stations, electric vehicle charging equipment, as well as Internet of Things (IoT) technologies such as intelligent appliances and smart meters.

IoT is a worldwide network of interconnected and uniquely addressable objects, based on Transmission Control Protocol (TCP) and Internet Protocol (IP). A broader definition is a connection of people and things at any time, in any place, using any path, network, or service. IoT is commonly associated with connection of devices that had previously not needed network connection—the first such device to be referred to as part of IoT was a refrigerator—as well as a wider deployment of connected sensors, tags (such as radio-frequency identification), and smart devices.[181]

Smart grid development plans

The term smart grid has been in use in China for several years. At the political level, smart grids were first mentioned in the 12th Five-Year Plan (2011-2015).[182] In 2011, China's State Grid Corporation (SGCC) announced its Strong and Smart Grid initiative, focused on investments in several different fields, including conventional transmission and distribution investments as well as ultra-high voltage power lines. The Strong and Smart Grid plan included deployment of smart meter infrastructure, as well as several pilot projects such as advanced transformers and grid management technology upgrades. One example is the system for automatic fault detection and correction in Foshan which can identify the fault location, isolate it and restore the power supply within 1.5 seconds—thus reducing the average power failure time in the test area to 5.2 minutes and increasing the network reliability to 99.99%.

In 2019, State Grid announced a continuation and expansion of the Strong and Smart Grid plan. The new strategy includes the Ubiquitous Power Internet-of-Things (UPIoT) concept which refers to the interconnection and interaction of information at any time, any place, anyone, and anything in the power sector.[183] The plan aims to create an interconnected digital ecosystem linking the internet with the electricity supply which could, for instance, enable smart cities.[184] So far in 2019, State Grid has identified 57 construction tasks, 25 demonstration projects and 160 expansion projects including 49 science and technology projects related to the IoT construction.[185] The first phase includes the building of a preliminary basis of the UPIoT and is planned to be finished by 2021, followed by a second phase that should finish by 2024. No details on the second phase are available.

China's Smart-Grid Plan

	Strong and Smart Power Grid			Ubiquitous Power Internet-of-Things		
Period	2009-2010	2011-2015	2016-2020	2019-2021	2022-2024
Phase	1st phase Initial planning and pilot phase	2nd phsae Comrehensive construction phase	3rd phase Ubgrading and enhancing phase	1st phase	2nd phase
Main objectives and activities	• Developemnt of a master plan for smart grid construction; • Development of standard and technologies; • Development and Selection of the first pilot projects	• Setting up a smart grid infrastructure: UHV lines, smart meters, demand management systems, charging stations for electric vehicles	• Build an all-round strong and smart power grid • Grid integration of renewable energies • Development of UHV capacities	Status in end 2019: • Identified 57 construction tasks, 25 demonstration projects and 160 expansion projects including 49 science and technology projects related to IoT construction	No details available yet

Source: Based on Zhao, 2014

Zeng Ming
Director of Energy Internet Research Center, North China Electric Power University

During the 14th Five-Year Plan, China should link centralized and distributed energy resources, and consider both long-distance transmission and local consumption as elements of energy security...
The energy supply side should focus more on multi-energy complementarity, and energy planning must take this into consideration...
A variety of energy storage technologies should be considered. These technologies include storing energy on the generation side, grid side, and demand side...

Smart meter infrastructure

A smart meter is usually an electrical meter that records consumption in intervals of an hour or less and communicates that information at least daily via some communications network back to the utility for monitoring and billing purposes.[186]

Accounting for 52% of global shipments in 2018, and 70% in 2017, China is the world's largest market for smart meters. Chinese smart meters have the lowest costs worldwide because of the highly competitive nature of the market, relatively low-level technical specifications compared to the U.S. or EU, and the economies of scale achieved through high order volumes. [187]

In China's first round of smart meter deployment in the early 2010s, the AMR (Automatic Meter Reading) Meters enabled automatic meter reading, collection of data for billing and one-way data transmission. It's upgrade, the AMI (Advanced Meter Infrastructure) Meter, is the basic infrastructure needed to allow consumer participation in the power system by enabling two-way communication capabilities and transmission of real-time data between the meter and the central system. Although the AMI roll-out was already completed in mid-2018,[188] the short replacement cycle of 5 to 8 years [189] for Chinese meters, combined with the huge market (470 million installed base) means domestic demand will still be 55-60 million per year for the foreseeable future. According to various market research companies, the market should grow by an average of 3-6% by 2020. While the technological upgrade of old meters continues to drive the market, falling real estate growth is reducing the demand for new smart meters.[190] Nevertheless, China is likely to remain the largest growth market for smart meters in the future.

In the area of demand side management (DMS), several cities such as Foshan in Guangdong, Shanghai, and Beijing have served as pilot cities. However, the implementation of DMS has been challenged by difficulties faced by third party energy management companies in obtaining energy data. Real-time data is often unavailable to support DMS private customers. Enhancing smart meters and opening up the retail electricity market may help address this barrier in the coming few years.

Micro grid infrastructure

A micro grid is a small, intelligent power grid and represents the smallest unit of a smart grid, typically connecting consumers and power generation at a local level, such as within an office campus or industrial park. An important motivation for micro grids is the intelligent distribution of energy from renewable plants. Micro grids can be classified as self-contained or fully grid connected. Self-sufficient micro grids are not connected to a centralized network, and instead meet customer electricity demand from generation within the grid, as might be the case in rural areas or small islands. Connected micro grids are hooked to the conventional power grid and can use grid power to supplement local generation output, such as during peak demand periods or periods of low renewable output.

The first initiatives for research and development of microgrids in China date back to the 12th Five-Year Plan, when universities and research institutes developed early pilot projects. One micro grid from this period was Guangdong's Dangao Island, which replaced diesel generators with a hybrid system that replaced 70% of the electricity from diesel with renewables. This reduced costly fuel imports and addressed noise complaints from the island's growing tourist industry.[191]

The 13th Five-Year Plan further promoted microgrids, announcing an additional 28 national demonstration projects by 2020, which were approved by the NDRC and NEA in May 2017.[192] A report of the Ministry of Industry and Information Technology listed 22 smart PV pilot demonstration projects, including a few micro grid PV pilot projects, such as 13 MWh PV and energy storage microgrid demonstration at Suixi, the TBEA Xian industrial park PV storage, EV charging microgrid demonstration projects, and the Qingdao Neusoft Carrier Park microgrid project.[193]

One example of a DC micro grid is the TBEA Xian Industrial Park 2 MW source network load storage coordination microgrid demonstration project which aims to build a commercial solar PV storage and charging station. The photovoltaic component has a capacity of 2.14 MW and is equipped with 1 MW/1 MWh lithium iron

TBEA Xian Industrial Park microgrid demonstration project overview

Element	Detail
Solar PV system	2.1 MW solar PV located on several campus rooftops, with four 500 kW inverters.
Energy storage system	1 MW/1 MWh lithium iron phosphate (LFP) battery for bidirectional power flow and uninterrupted power supply for data center.
EV charging system	16 DC charging posts of 60 kW each, for use of Xian public transport and commuter buses in the park.
Energy manage-ment	Intelligent micro network system to optimize generation, network, load, and storage scheduling through artificial intelligence and big data analysis.
Control system	Real-time data monitoring of PV inverters, energy storage converters, parallel network and relay protection, the system enables precise control the real-time power flows for voltage and frequency control, as well as rapid fault clearance.

Source: TBEA, September 2019

phosphate battery, and 16 60-kW charging posts. For the first time, a demonstration project introduces a demand response technology and an economic optimization scheduling algorithm based on a two-part electricity price in the micro network of an industrial park, which can reduce both the per-kW demand charges and per-kWh energy charge. Through the construction of a solar PV storage and charging micro network system, combined with an energy management system, the system coordinates and controls the source network load storage, and optimizes and dispatches the energy consumption of the industrial park, aiming to provide energy for the industrial park with high reliability and low-cost.[194]

The Qingdao Neusoft Carrier Park microgrid project is China's first microgrid project to integrate wind, solar, energy storage, and EV charging. The system includes both AC and DC loads, a complete energy control platform, and full potential for operation in grid-connected, off-grid operation, and off-grid switching modes. System integration focuses on enabling businesses in the park to maximize their utilization of clean energy. The system includes 20 kW of wind, 1.4 MW of PV, 4 DC charging posts, and 4 AC charging posts.[195]

Over the coming decade, the microgrid market has the potential to grow rapidly due to the opening up of the retail electricity market, increased attention to local, distributed energy, increased EV adoption for business, logistics, and public service fleets, and lower cost of energy storage.

11 Hydrogen

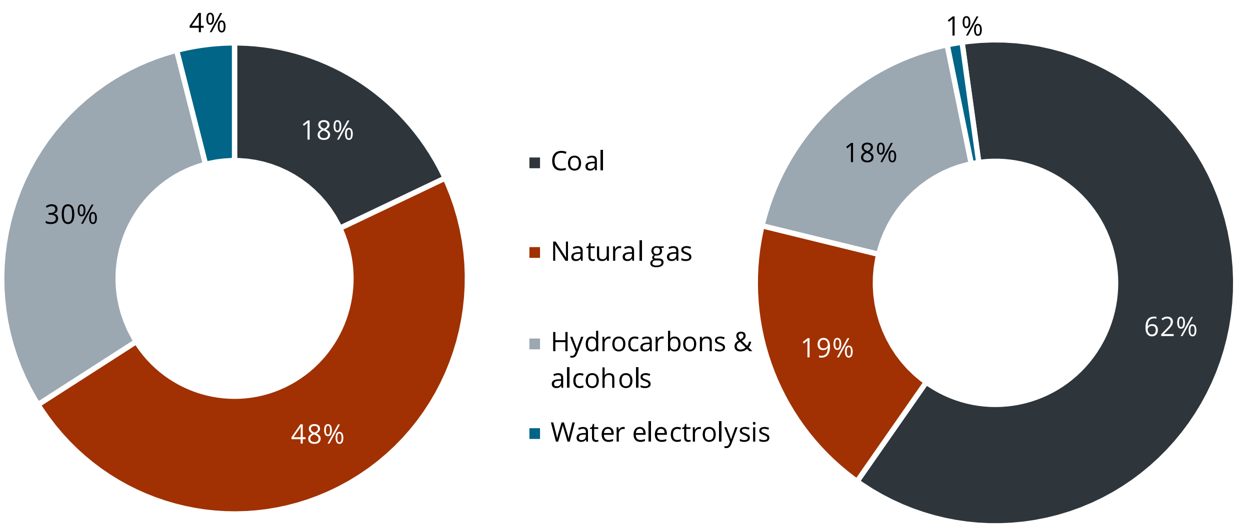
11. Hydrogen

Introduction

China is the world's largest producer and consumer of hydrogen; however, it is still at an early market development stage. In 2018, China had about 21 million tons of hydrogen production, and consumption of about 22 million tons. This is expected to increase to 35 million tons in 2030 and 60 million in 2050.[196]

Most hydrogen in China is consumed as a feedstock by the petrochemical industry, especially in the fields of synthetic ammonia, oil hydrogenation, and electronics processing.[197] However, the China Hydrogen Alliance projects led to strong growth for hydrogen in transportation, particularly in heavy-duty vehicles. The alliance forecasts transport consumption could reach 24.6 million tons by 2050, or 19% of total transport energy consumption, of which freight would account for 70% of hydrogen output, followed by industrial consumption. The steel industry will see the biggest increase in hydrogen consumption, followed by the chemical industry which will see an increase of hydrogen consumption until 2030 and a decline after 2030.[198]

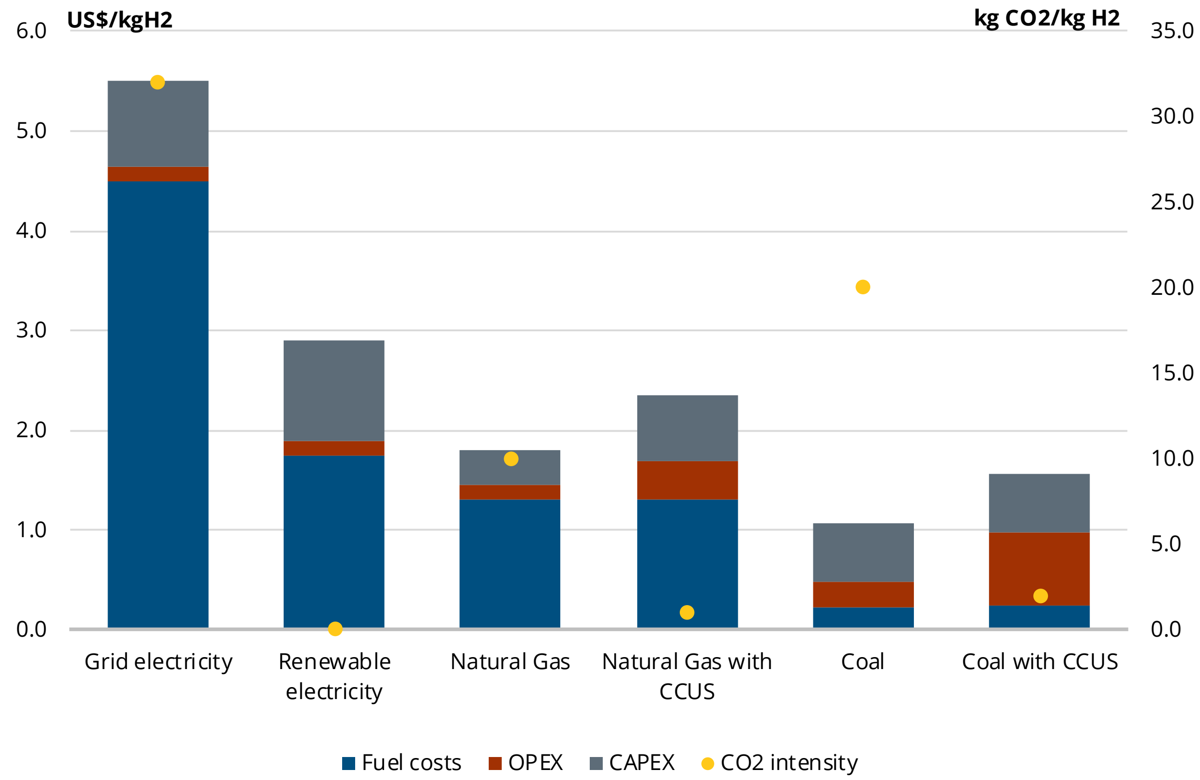
Energy sources for hydrogen production worldwide (left) and China (right)



Source: International Conference on Advances in Energy and Environment Research, 2019

The high share of coal-based hydrogen in total production is due to cost advantages: China has an established coal industry and, due to a lack of domestic deposits, no access to cheap natural gas as an alternative for hydrogen production. According to the IEA, coal-based hydrogen combined with CCUS which has a CO_2 intensity of 2 kg CO_2/kg H_2 is the lowest-cost and clean ratio hydrogen production route in China with about US$ 0.2/kg H_2.[199]

Hydrogen production costs in China today



Source: IEA, 2019

Policy interest in hydrogen is influenced by the country's industrial policy and is reflected in strategies for the development and production of fuel cell vehicles and FCV infrastructure. Although there is high interest in hydrogen, China's central government currently lacks a comprehensive hydrogen strategy.

Hydrogen is sometimes mentioned in China as a potential solution for improving integration of renewable energy, particularly wind and solar, which have and still face problems with curtailment. However, there are several reasons why this does not appear to present a major opportunity for hydrogen in the near term. China presently derives only a small percentage of electricity from wind and solar—under 10%—and the largest barrier to wind and solar integration has been a lack of spot markets and obstacles to trading electricity between provinces. Those provinces with high proportions of wind and solar, such as Gansu and Qinghai, have been able to resolve curtailment through improved dispatch and strengthened mandates for renewable energy consumption. Provinces with high demand for industrial hydrogen presently have low levels of curtailed renewable energy, and still derive only a small fraction of electricity from wind and solar.

In order to push green hydrogen production in China forward, Beijing-based Jingneng has announced plans in March 2020 to build a 5 GW green hydrogen production and storage plant in Inner Mongolia that will combine wind, solar, energy storage, and hydrogen.[200]

Political framework

There are more than 20 national guidelines and documents that explicitly deal with the topic of hydrogen. The National Innovation-Driven Development Strategy and the Action Plan for Innovation in the Energy Technology Revolution (2016-2030) list hydrogen and fuel cell technology as central components of the future China energy system. The 13th Five-Year Plan for Strategic Development in Emerging Industry suggests systematically promoting research and industrial development in the FCV area. The aim was to achieve mass production of FCEVs by 2020—a target that has yet to be realized.[201]

Both the central government and local governments are increasingly focused on the development of the hydrogen industry. The topic was discussed several times in 2018 at the National People's Congress, where proposals put forward regulatory reforms, the expansion of hydrogen infrastructure and development, and the creation of clear responsibilities for hydrogen in ministries and authorities.[202]

Local authorities see hydrogen as a path for industrial development and investment. For example, the city of Datong, in Shanxi Province, a major coal mining centre, is using hydrogen to promote local economic growth. Datong plans to focus on making hydrogen from local coal, for use in municipal buses and other vehicles.[203]

Similarly, in January 2018 Wuhan published a plan for hydrogen industry development calling for the city to become the capital of hydrogen energy vehicles in three years. Wuhan is focused on R&D in hydrogen storage and proton exchange membrane (PEM) electrodes. The plan stated that by 2025, the annual output from the city's hydrogen fuel cell industry chain should reach RMB 100 billion, making Wuhan a "world-class hydrogen energy city."[204]

Industrial strategies for hydrogen at a city level generally include the generation of grey hydrogen from coal. Many Chinese officials and experts see fossil hydrogen as a clean energy source because policymakers prioritize local air pollution and place less emphasis on carbon emissions. Therefore, a broad political debate about whether policy should support all forms of hydrogen or only low-carbon forms has yet to begin.

Hydrogen in the transport sector

The main challenges in the market ramp-up of fuel cell vehicles are insufficient supply of domestic vehicle models and lack of fueling infrastructure. China's target for FCV development is to deploy 1 million FCVs by 2030, and China aims for zero emission in the transport sector through joint development of FCVs and electric vehicles by 2050.[205] Regarding hydrogen demand and supply, China's strategy is to match domestic supply with domestic demand. A recent IEA forecast suggests China's annual hydrogen consumption would reach 35 million tons by 2030, and the cost of production from renewable electricity cold fall by 30% due to declining cost of renewables and scaling up of hydrogen production.[206] China has several pilot projects with hydrogen for buses, trains, and boats. Of these, buses are at the demonstration stage, whereas hydrogen trains and boats are at the stage of one-off, small-scale and experimental pilots.

Goals and status of hydrogen fuel cell mobility in China

		Year			
		2018	2020	2025	2030
FCEV	Number	1,527 (1,418 buses, 109 trucks)	5,000 (60% buses, 40% trucks)	50,000 (20% buses, 80% trucks)	> 1 million (commercial use)
Hydrogen stations	Number	17	> 100	> 300	> 1,000
Hydrogen production	Amount H2 per year	70 billion = 5.8 million tons	72 billion = 6 million tons	-	100 billion = 8.3 million tons (>50% green hydrogen)

Source: Based on Strategy Advisory Committee of the Technology Roadmap for Energy Saving and New Energy Vehicles SAE China, 2016 [207]

Hydrogen refuelling infrastructure

Regarding fuel cell vehicles, China mainly uses heavy-duty vehicles such as buses and trucks that are operated by commercial fleets and are refuelled at a pressure of 350 bar, lower than the 700-bar stations deployed in the U.S., Japan, Europe. As of 2019, 24 hydrogen filling stations were in operation in China. Large state-owned companies such as Sinopec are among the manufacturers and operators of Hydrogen Refueling Stations (HRS).

Sinopec recently built the first hydrogen filling station in China integrated into a conventional filling station.[208] Demonstration projects are underway in Zhangjiakou to provide hydrogen fuel cell bus transportation for the 2022 Winter Olympics. Project activities include the construction of HRS, deployment of hydrogen vehicles, and development of a continuous hydrogenation industry supply chain demonstration project. [209]

Buses

Currently several companies manufacture and sell small numbers of fuel cell buses. In 2018, 1,527 fuel cell vehicles—1,418 buses and 109 trucks—were manufactured and sold in China. The target for 2020 is 3,000 and for 2025 even 10,000 fuel cell buses. By 2022, there may be as many as 30 different bus models offered by Chinese manufacturers.[210]

Trucks

China is also leading in the deployment of fuel cell trucks and has a number of fuel cell truck demonstration projects. In April 2018, the cities of Rugao, Nantong, Suzhou, Yancheng and Shanghai launched the Hydrogen Corridor Development Plan in the Yangtze River Delta. The project focuses on hydrogen fuel stations along highways to establish a hydrogen highway corridor. The project consists of four phases starting in 2019 and ending in 2030 with a hydrogen corridor connecting all cities in the region by at least 20 highways. [211] Air Liquide and the Chinese start-up Shanghai Sinotran New Energy Automobile Operation Co. (STNE) signed a partnership in 2018 to develop hydrogen freight transport; STNE owns HRS in Shanghai and a fleet of around 500 fuel cell delivery trucks. Air Liquide will provide supply chain expertise including hydrogen production, storage and distribution. [212]

Beyond the freight truck category, in October 2018, Weichai power, the National Energy Group and Beijing National Institute of Low Carbon Clean Energy signed an agreement to research and manufacture heavy-duty mining trucks running on hydrogen with a carrying capacity of more than 200 tonnes.[213]

Trains

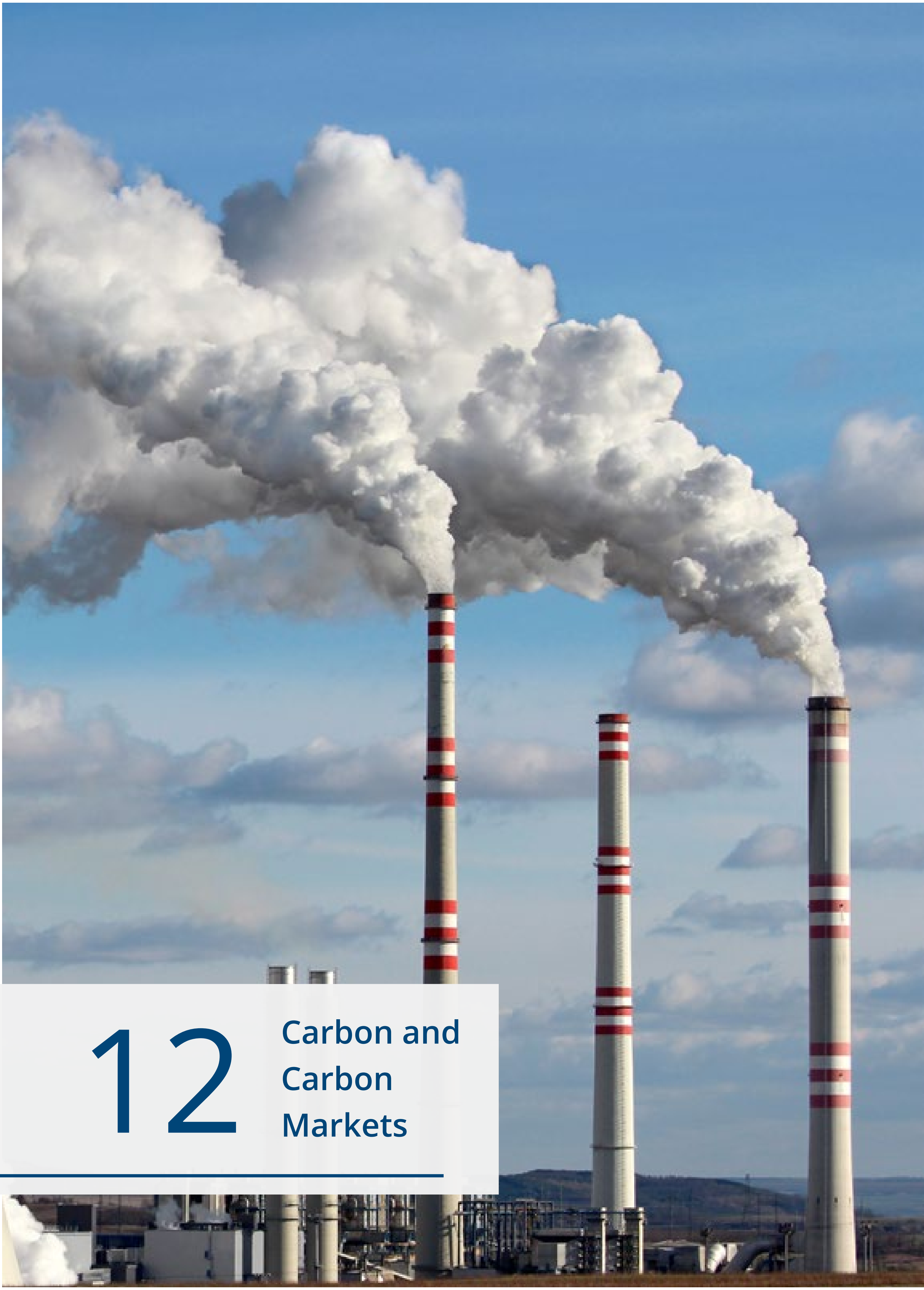
In 2015, Ballard Power Systems Inc., a Canadian manufacturer of fuel cells, signed a joint development and supply agreement with CRRC Qingdao Sifang Co., Ltd. to develop fuel cell engines for low floor trams which were ultimately used for the worldwide first commercial hydrogen-fueled hybrid low-floor tram launched in October 2017 in Tangshan, Hebei province.[214] 2017 saw another Ballard-CRCC contract for eight fuel cell trams for a demonstration line in Gaoming district, Foshan, with a total length of 17.4 km and 20 stations. The first phase - consisting of the commercial operation of the trams on a 6.57 km long route, and covering 10 stations, was completed in December 2019. The trams use a 200-kW engine, have a maximum operating speed of 70 km/h, and a maximum capacity for 285 passengers. Equipped with 6 gas cylinders and a hydrogen storage capacity of 20 kg, each tram and can run for 100 km before refuelling. [215]

Shipping

Whereas Europe, Japan and the U.S. already have several ongoing projects, China is lagging behind in the fuel cell-powered shipping industry. The Wuhan Institute of Marine Electric Propulsion and the Guangzhou subsidiary of China State Shipbuilding Corporation (CSSC) are researching fuel cells application in the shipping industry. However, these developments are still in an early phase.[216]

International Cooperation

Chinese companies and organisations are actively seeking domestic and international collaboration on hydrogen and fuel cell technology. For example, Weichai Power, China's largest engine manufacturer, will invest over €5 billion in fuel cell development by 2030 and is cooperating with Ballard and Bosch to achieve this. At the political level, the National Alliance of Hydrogen and Fuel Cells (NAHFC) was founded in February 2018, an association of companies from the energy and mobility industry supported by the Chinese government. The NAHFC serves as a platform for companies and as a think tank for further developing China's hydrogen strategy.[217]



12 Carbon and Carbon Markets

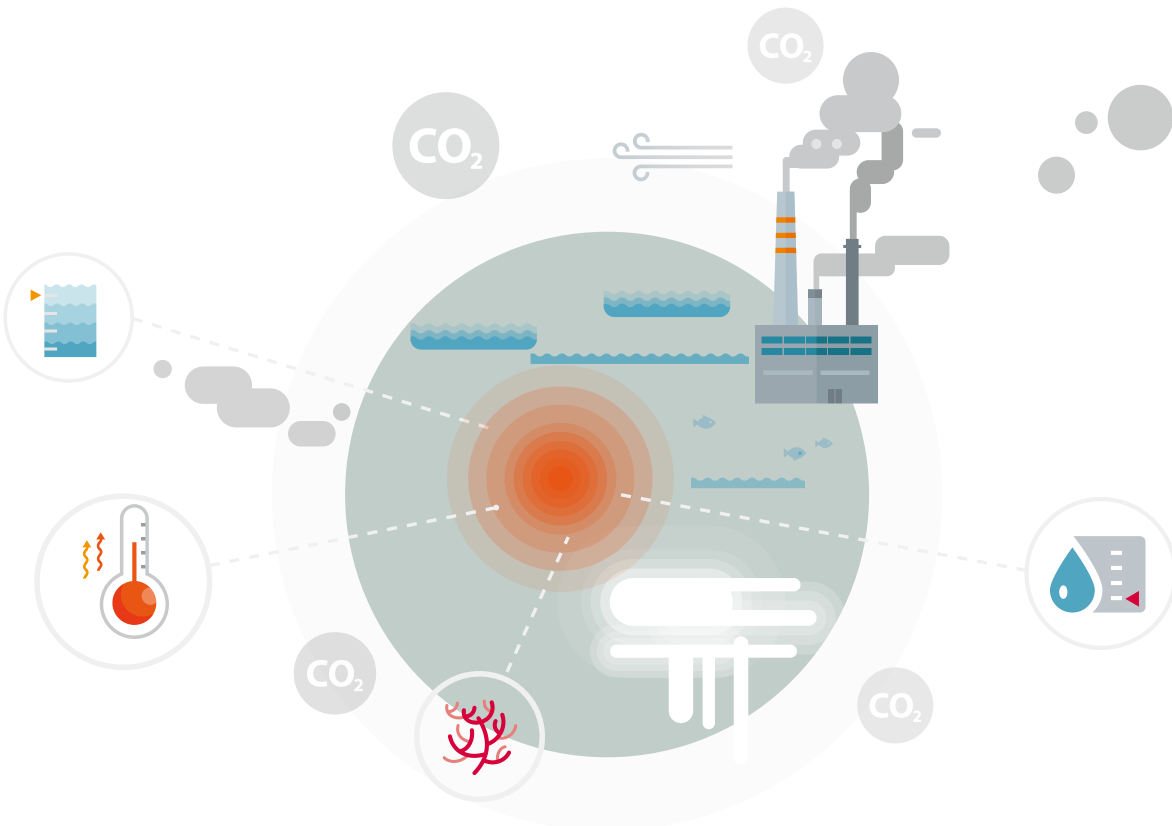
12. Carbon and Carbon Markets

China's carbon emissions continue to grow, carbon market roll-out ongoing

- Carbon emissions returned to growth in 2018 and 2019, though economic contraction could cause a dip in 2020.
- New carbon market rules were issued, focusing on carbon intensity targets within the coal power sector.

China accounted for 27% of the world's carbon emissions in 2017, and according to the UN Environment Programme 2019 Emissions Gap Report, the world has just a few years left to bring carbon emissions down sufficiently to reach the 1.5 degree goal set by the Paris Climate Agreement.[218] As of 2019, China's carbon emissions rose 1.9%, accounting for almost all of the world's increase in carbon emissions from fossil fuels for 2019, according to estimates from the Global Carbon Project.[219] In recent months—and prior to the COVID-19 pandemic—carbon policy has started to receive less emphasis in major speeches and policies compared to topics such as energy security and economic growth. Meanwhile, China is continuing to evolve its plans for the world's largest carbon market, moving from the period of provincial pilots towards the next step of a national scheme covering the electricity and heating sectors.

In 2013, China launched seven regional pilot carbon trading market in five cities, namely Beijing, Shanghai, Tianjin, Chongqing and Shenzhen, and the two provinces of Guangdong and Hubei. Each pilot has its own mechanism designed by the local authorises taking into account local circumstances. In 2019, China's eight pilot regional carbon markets saw trading volume of 696 million tons CO_2-equivalent and a cumulative transaction volume of RMB 1.56 billion.[220] China's carbon emissions continued to grow in 2019, albeit at a -slower rate than in 2018. [221]



Rules for 8 regional pilot carbon trading markets

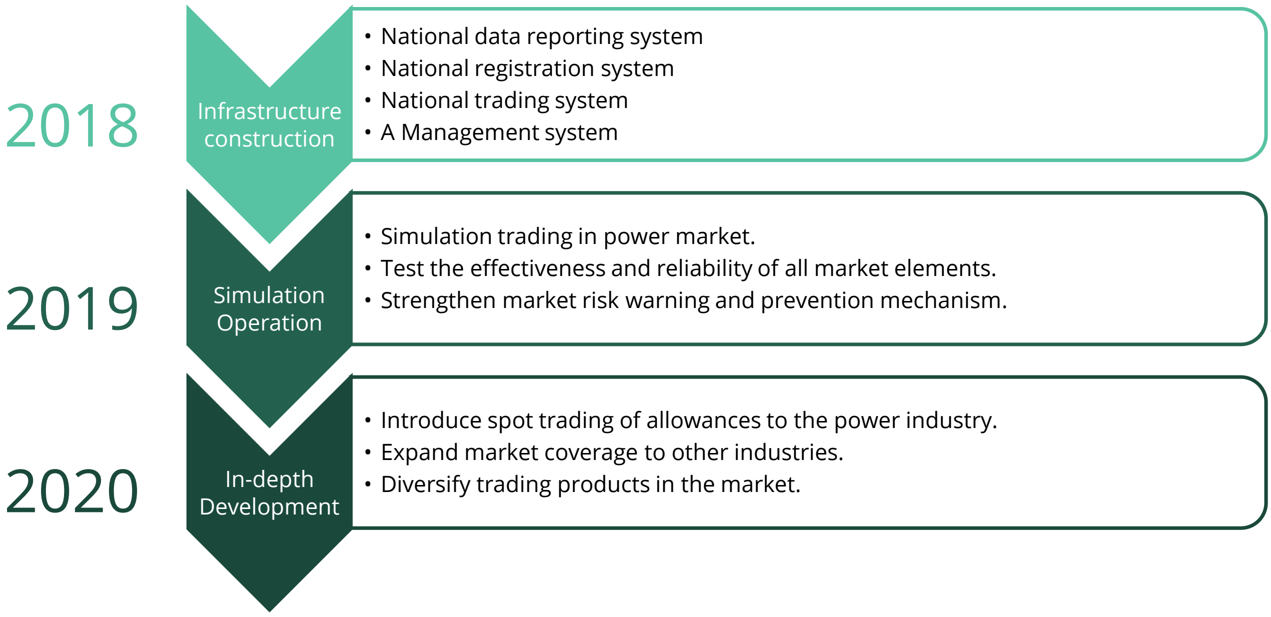
Pilot Region	Allocation	Quota allocation Method	Sectors
Shenzhen	Free	Benchmark based on sectoral historical carbon	Power, water, gas, manufacturing, buildings, and transportation (port, subway, buses)
Shanghai	Free	Sector-specific benchmarks; historic emissions intensity	Airports, aviation, chemical fibre, chemicals, power and heat, water suppliers, hotels, iron and steel, petrochemicals, ports, shipping, non-ferrous metals, building materials, paper, railways, rubber, textiles and some service sectors
Beijing	Mostly free	Historical emissions of carbon intensity for existing firms; benchmarks for electricity generators and new entrants.	Electricity, Heating, cement, petrochemicals, other industrial enterprises, manufacturers, service sector and public transport
Guangdong	A combination of free allocation and auctioning	Benchmark and grandfathering with a possibility to include an additional reduction factor	Power, iron and steel, cement, papermaking, aviation and petrochemicals
Tianjin	Mostly free	Grandfathering based on 2009-2012 emissions or emissions intensity; benchmarks for new entrants and expanded capacity	Heat and electricity production, iron and steel, petrochemicals, chemicals, oil and gas exploration
Hubei	Free	Benchmark and grandfathering based on the emissions from the previous three years	Power and heat supply, iron and steel, nonferrous metals, petrochemicals, chemicals, chemical fibre, cement, glass and other building materials, pulp and paper, ceramics, automobile and general equipment manufacturing, food, beverage and medicine producers
Chongqing	Free	Historical emissions.	Power, electrolytic aluminium, ferroalloys, calcium carbide, cement, caustic soda, iron and steel
Fujian	Free allocation on an annual basis		Electricity, petrochemical, chemical, building materials, iron and steel, nonferrous metals, paper, aviation, and ceramics

Source: GIZ, 2018

National Carbon Market

In 2017, NDRC issued the Construction Plan for National Carbon Emission Trading Market for the power generation industry, which marked the establishment of a national carbon trading market. The national carbon market will be introduced gradually in three phases. The first phase will focus on the construction of infrastructure. This will be followed by simulation trading for the power sector in the second phase. After achieving a stable carbon market in the power generation industry, the market's coverage will gradually expand to other industries.

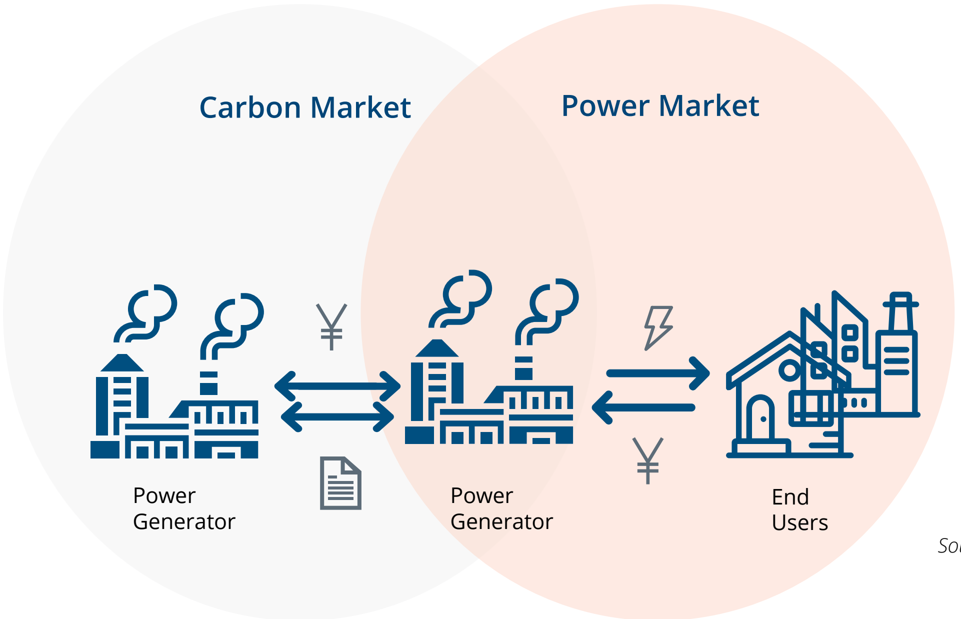
Construction Plan for National Carbon Emission Trading Market



Source: NDRC, 2017

Accounted for about half of China's total CO_2 emissions, the power industry is the core industry of China's national carbon market. According to the construction plan, the national carbon market will first be established in the power industry before expanding to other industries. The participants of this national carbon market are enterprises or other economic organizations (including self-owned power plants of other industries) that have an annual emission of 26,000 tons of CO_2 or above in the power generation industry. [222] More than 1,700 companies were included in the first batch of carbon trading accounting for an estimated 3 billion tons CO_2-equivalent.[223] The national carbon trading market will consist of three main mechanisms and four supporting systems. The three main mechanisms include carbon emission monitoring, reporting and verification; quota management for major emitters and market trading. The four supporting systems are the carbon emission data reporting system, the carbon emission registration system, the carbon emission trading system and the carbon emission trading and settlement system.

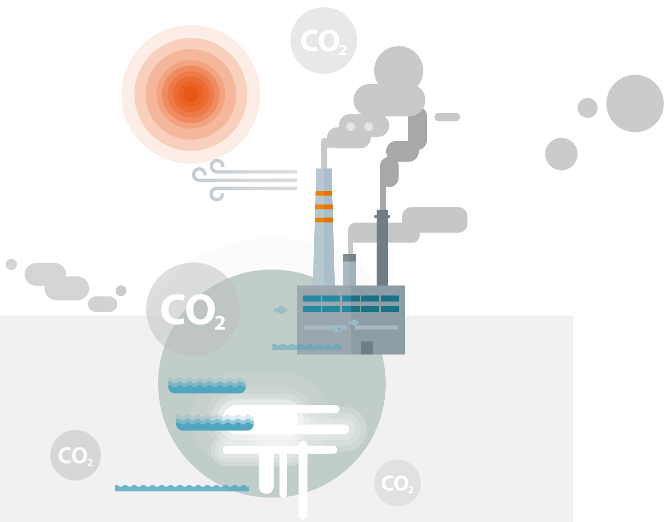
Interactions Between Carbon Market and Power Market



Source: GIZ, 2020

One of the problems faced by the carbon market in China is the lack of price transmission mechanism between the carbon market and the power market. Under the current power market mechanism, the power generators need to bear all the emission reduction costs, as the price of electricity is regulated by the government and the cost of emission reduction can't be passed to the end users. If the cost of emission reduction is too high, generators lack incentive to reduce emissions, since they can buy surplus allowances from the market. According to vice-chairman of China Electricity Council Wang Zhixuan, the burden for the thermal power companies will increase, as the amount of free allowances gradually declines each year.[224] The increasing cost should eventually pass to the end users.

While China officially launched national carbon markets at the end of 2017,[225] and issued a number of market rules, the actual practice of carbon trading has lagged. In mid-2019 China announced that power markets would trade carbon credits on an emissions intensity basis,[226] meaning that there would be no emissions cap within a single year. The national market trading for 2,000 coal and heating plants, covering 40% of China's greenhouse gas emissions, will begin trading in the third quarter of 2020.[227] Only coal plants and heating plants are allocated credits, meaning that there is no economy-wide price on carbon that would encourage investment in low-carbon energy sources, nor is the market linked to other sectors. Intensity targets and emissions goals are often set a year or two in advance, and could be subject to adjustment, limiting the ability of the market to incentivize long-term investment in low-carbon industries or technology. Carbon prices are expected to remain low to avoid affecting industries.



Timeline of China carbon markets

2011

Carbon market pilots announced
General Office of NDRC announced Carbon Market pilots in 5 cities and 2 provinces.

2013

Carbon pilots launched
In Beijing, Tianjin, Shanghai, Shenzhen, Hubei province and Guangdong province.

2015

China submitted NDC to UNFCC
Developing carbon market is included in the NDC as a policy action.

2017

National carbon market
NDRC issued National Carbon Emission Trading Market Construction Plan for power generation industry.

2019

Carbon market rules issued for comment
MEE required for comment on provisional regulations for carbon emission trading.

2011-2017
Preparation

2017-2020
Construction of Carbon Market in China

Source: various sources[228]

13 Air Quality

13. Air Quality

China continues to post major improvements to air quality, resulting from multi-pronged approach

- Air quality improvements were strongest in PM2.5 and SO_2.
- Ozone remains a growing challenge.
- Recent comments suggest that air quality may take a lower priority for policy and enforcement following the economic disruptions caused by COVID-19.
- Weather has a major impact on day-to-day and even annual air quality changes, leading to occasional haze events even though air quality has continued to improve steadily since 2013.

Air quality remains one of the leading motivations for the energy transition in China. Overall, since China declared the start of its long War on Air Pollution in 2013, the country has made immense progress. This includes enhancing enforcement of air emissions regulations, instituting new rules on environmental impact assessments for new industry, restricting high emissions activities ranging from large industry to street-side BBQ grills, and accelerating the transition to clean energy and electrified transport.

The results of this effort are clear. From 2013 to 2019, PM2.5 concentrations in China fell dramatically. Whereas in 2012 and 2013, concentrations in the worst months of winter regularly surpassed 500 micrograms/m^3, in the last three years the worst days have rarely exceeded 200 micrograms/m^3. In 2013, the worst month recorded by the monitor at the U.S. embassy averaged 199 micrograms/m^3, in 2019 the worst month was 58 micrograms/m^3—lower than the best month recorded for all of 2012-2013. The average concentration in August 2019 was 21 micrograms/m^3, just one third of the concentration in the best month of 2013.

The positive trend has also continued in the p ast year. In Beijing, annual average PM2.5 levels fell to 42 micrograms/m^3, down 12.5% from the prior year, while PM2.5 levels declined by 2.4% in the Yangtze River Delta region. Across all national air quality monitoring stations, 2019 PM2.5 concentrations averaged 36 micrograms/m^3, basically flat from 2018, while SO_2 levels fell 15.4%, NO_X levels remained roughly constant, and ozone levels increased 6.5%.[229] Whereas air pollution measures in the past few years have focused on PM2.5, which is associated with China's episodic periods of intense regional haze, ozone is expected to become a more important policy priority over the next few years.

Beijing ambient PM2.5 concentration monthly averages, micrograms/m^3, 2008-2019

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Jan			90	45	119	199	118	108	72	124	34	54
Feb		65	98	150	84	124	175	97	45	76	58	58
Mar		81	95	58	97	127	110	89	93	64	87	54
Apr	104	87	80	91	87	67	96	79	66	56	66	53
May	98	84	87	65	91	85	72	60	55	61	62	43
Jun	100	97	109	108	97	112	59	55	59	40	49	37
July	90	106	124	108	80	69	89	55	60	51	35	32
Aug	65	108	98	104	81	62	63	45	39	33	30	21
Sept	59	108	123	96	60	91	71	47	51	56	27	36
Oct	84	93	119	145	95	107	141	72	83	53	42	44
Nov	73	155	138	110	87	91	104	124	105	48	74	48
Dec		109	97	109	113	98	78	162	144	46	43	50
Yearly Avg	**85**	**102**	**104**	**99**	**91**	**102**	**98**	**83**	**73**	**59**	**50**	**43**

Note: colors are based on default Excel conditional formatting, and do not represent the air quality index of any country.

Source: U.S. Embassy, 2020

The future of air quality policy

The policies China has adopted have already had a substantial effect, but China's air quality has yet to reach national targets or recommended ambient air quality levels published by the World Health Organization. To date, many policies have focused on the largest emitting sources, such as heavy industry and the coal power sector, as well as coal heating. Focusing on the largest emitting sectors has enabled China to rapidly improve air quality, but as a result the proportionate contributions of these sectors has fallen more rapidly than other, more dispersed pollution sources. In the Beijing area, for example, the contribution of local coal power and industry to PM2.5 has fallen dramatically, and the share of transport emissions has increased from under 30% to over 40%. [230] Similarly, policies targeting coal and industry have dramatically reduced sulphur and primary PM2.5 emissions, but emissions of NO_x and volatile organic compounds (VOCs) have seen smaller declines.[231] Ammonia has also drawn increasing scrutiny for its role in formation of secondary PM2.5.

Beijing and other major Chinese cities are likely to continue to experience severe haze episodes due to the relatively unfavourable geographic and meteorological situations. Often, unfavourable wind, humidity, and air inversion conditions can lead to rapid deterioration in urban air quality, and researchers believe even steady efforts to reduce emissions from all sources will not entirely prevent such haze events.[232] Haze events also favour the formation of secondary PM2.5, which therefore does not correlate directly to local changes in primary emissions. [233] While media and the public often look to short-term economic or topical explanation for daily, weekly, or even annual variation in air quality, these factors cannot be ignored.

One event that has undoubtedly affected air quality across China in 2020 is the 2019 novel coronavirus, or COVID-19, which led to major disruptions in industrial output and urban traffic across China in the first part of 2020. Sharp reductions in NO_x, SO_2, and PM2.5 were observed via satellite during this period. Coal consumption was 36% lower than in the same period in 2019. [234]

In 2020, the effect of the coronavirus increases the uncertainty around the priority of air quality policy. The government has announced further economic stimulus policies, which have traditionally favoured heavy industry and infrastructure—but the 2020 stimulus will focus more on the service sector and clean energy, according to plans announced so far. At the same time, the urgency attached to resuming economic activity may lead to enforcement taking a lower priority. At a press conference in March 2020, Cao Liping, the director of the enforcement bureau of the Ministry of Ecology and Environment, reportedly stated that "environmental supervision should be adjusted in accordance with practical needs and social economic situations." [235]

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