China Renewable Energy Outlook

2020

Energy Research Institute of Academy of Macroeconomic Research/NDRC

Summary

Implementing Unit

Financial Support

Technical Support

Preface

China Renewable Energy Outlook 2020 is the fifth annual outlook from Energy Research Institute.

Since 2016 we have analysed the long-term visions and possibilities for a Chinese energy system with renewable energy as the backbone. We have developed appropriate modelling tools and methodology to make detailed scenario analyses to 2050 for the transformation of the Chinese energy sector. A particular focus has been on the power sector, with detailed analyses of how to integrate large amounts of fluctuating power production from wind and solar PV into the power system and how it can be dispatch in a least-cost way.

The aim has been to analyse and showcase how the Chinese energy system can develop into a clean, low-carbon, safe, and efficient energy system with three main drivers: green power system, energy efficiency in end-use sectors, and electrification of industry, transport, and building sectors. Also, we wanted to analyse how China can contribute to the fulfilment of the Paris agreement targets for a future with a below 2 °C rise in temperature due to human-made climate changes.

This year, the focus on a long-term low-carbon vision has become even more topical. 22 September 2020 President Xi Jinping announced at the General Debate of the 75th Session of The United Nations General Assembly that "China will scale up its Intended Nationally Determined Contributions by adopting more vigorous policies and measures. We aim to have CO2 emissions peak before 2030 and achieve carbon neutrality before 2060". Even though these targets are challenging, our analyses show that it is possible to reach the targets and that a low-carbon strategy is the only feasible way to ensure sustainable economic growth for China in the future.

China Renewable Energy Outlook 2020 is the last outlook that focuses on renewable energy. From 2021 Energy Research Institute will prepare comprehensive China Energy Transformation Outlooks.

I want to thank the ERI team for their strong efforts, the Danish Energy Agency, Energinet, and NREL for their strong support and input to the analyses, and, not least, our long-term cooperation partner, Children's Investment Fund Foundation (CIFF), for funding and support to ERI. I am looking forward to continuing the cooperation with the international partners and CIFF in the future.

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2020 was a game-changing year

The frontrunner countries are heading towards carbon neutrality

An increasing number of governments are translating the Paris Agreement into national strategies setting out visions of a carbon-free future. By the end of 2020, 26 countries were on Climate Home's list of countries with a net-zero goal. Most Western European countries, the Nordics, and countries such as Canada, Chile, Japan, New Zealand, Singapore, and South Korea have committed to a carbon-free future. China is committed gradually to replace the current fossil energy consumption with clean energy. In the absence of federal targets, many US states and cities are pursuing net-zero goals, including California, New York City, and Hawaii. For example, California passed a law to make electricity entirely renewable from 2045. At COP25, 177 companies, combined with annual direct emissions equivalent to France's annual total CO_2 emissions, pledged to reach net-zero emissions by 2050.

The European Commission's Green Deal vows European countries to achieve climate neutrality by 2050. The European Commission has set out a vision of achieving climate neutrality by 2050 and proposed the first European' Climate Law' in March 2020 for public consultation. The European Green Deal contains plans for, amongst other things, a new circular economy, building renovation, zero-pollution, external relations, ecosystems & biodiversity, and a "Just Transition Mechanism" to help regions most heavily dependent on fossil fuels.

Denmark leads the way for climate policies and commits to a 70% reduction in CO_2 emissions by 2030. A broad majority of the Danish Parliament successfully negotiated a climate act that sets out to reduce Denmark's greenhouse gas emissions by 70% in 2030 compared to the 1990-level. The Danish Government has adopted a whole-of-the-government approach and established the ministerial Committee for the Green Transformation - to ensure a comprehensive, targeted and coordinated effort across government departments to tackle the climate crisis. The Danish Parliament has approved several action plans to fulfil the climate act target by 2030.

China is committed to implementing a profound energy transformation. China is the largest developing country globally, with a large population and the world's largest energy consumption. China has a coal consumption of half of the total global consumption and is a high-carbon energy consumer. President Xi Jinping emphasises that "low-carbon energy system directs human future." It is paramount for China to achieve the emission reduction targets in cooperation with the world by exploring and implementing energy pathways to a low carbon future. Success in China would support leadership towards other countries and regions' efforts to address global climate crises.

China aims to fully implement the new energy security strategy of "Four Revolutions and One Cooperation" and firmly follow the road of green, low-carbon and sustainable energy development. Firstly, China will continue to adhere to the priority policy of energy conservation and promote a green production lifestyle that saves energy and gives priority to the use of clean and low-carbon energy. Secondly, China will accelerate the use of low-carbon energy to replace high-carbon energy and non-fossil energy to replace fossil energy, rely on non-fossil energy and other clean energy to meet incremental energy demand, and gradually make clean energy the main body of energy supply. Thirdly, China will continue to strengthen energy science and technology innovation, break down energy resource constraints through technological progress, and add new momentum to economic and social development. Fourthly, China will continue to deepen the reform of energy markets and improve the energy governance mechanism[1].

In the near to mid-term, the low carbon and green pathway will reduce the use of coal, stabilise oil consumption, increase gas consumption, and vigorously develop renewable energy. In the medium and long-term, it will reduce oil consumption, stabilise gas consumption, massive deploy renewable energy, and finally reduce gas consumption and have a stable development of renewable energy.

"Humankind can no longer afford to ignore the repeated warnings of Nature and go down the beaten path of extracting resources without investing in conservation, pursuing development at the expense of protection, and exploiting resources without restoration.

The Paris Agreement on climate change charts the course for the world to transition to green and low-carbon development. It outlines the minimum steps to be taken to protect the Earth, our shared homeland, and all countries must take decisive steps to honour this Agreement.

China will scale up its Intended Nationally Determined Contributions by adopting more vigorous policies and measures. We aim to have CO2 emissions peak before 2030 and achieve carbon neutrality before 2060.

We call on all countries to pursue innovative, coordinated, green and open development for all, seize the historic opportunities presented by the new round of scientific and technological revolution and industrial transformation, achieve a green recovery of the world economy in the post-COVID era and thus create a powerful force driving sustainable development."

Statement by H.E. Xi Jinping President of the People's Republic of China at the General Debate of the 75th Session of The United Nations General Assembly 22 September 2020

Building a clean, low-carbon, safe and efficient energy system is to achieve three goals: first, to achieve energy supply security, which can meet the needs of China's economic development (GDP per capita to reach 30,000 US dollars in 2050 - in 2005 US dollars). Secondly, it aims to achieve energy and environmental security, with a fundamental solution to environmental pollution issues and the construction of ecological civilisation, addressing China's PM2.5 issues and reaching the World Health Organization standard by 2050.

[1] "新时代中国能源在高质量发展道路上奋勇前进," China Daily, 31 December 2020, accessed at http://www.nea.gov.cn/2020-12/31/c_139631430.htm.

Thirdly, to achieve energy and climate security, fulfil the Chinese Government's commitment to the Paris Agreement, take a low-carbon energy transition pathway, limit global warming to below 2°C by the end of this century and try to keep it within 1.5°C.

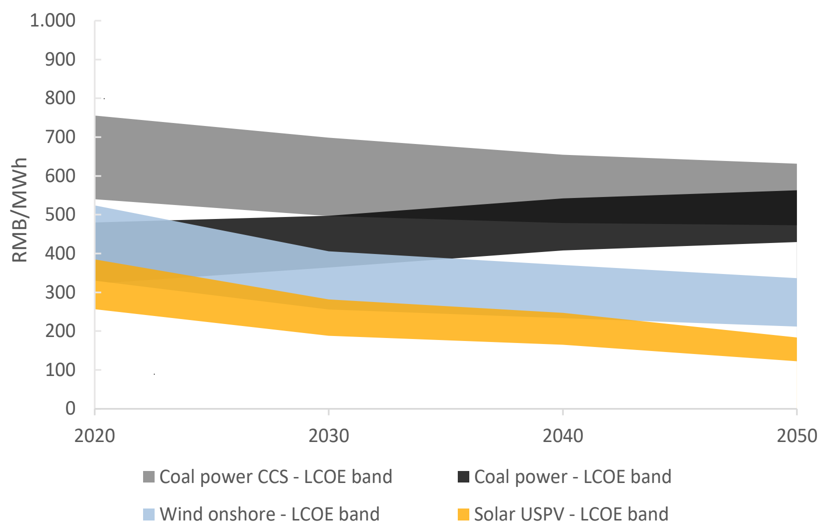
Solar and wind became mainstream and cost-competitive technologies

Electricity costs from renewables have fallen sharply over the past decade, driven by improving technologies, economies of scale, increasingly competitive supply chains and growing developer experience. As a result, renewable power generation technologies have become the least-cost option for new capacity in almost all parts of the world. The global weighted-average levelised cost of electricity (LCOE) of utility-scale solar photovoltaics (PV) fell 82% between 2010 and 2019, and the levelised cost of concentrating solar power (CSP) fell 47%, onshore wind by 39% and offshore wind at 29%, According to the latest cost data from the International Renewable Energy Agency (IRENA).

In sharp contrast to all other fuels, renewables used for generating electricity should have grown by almost 7% in 2020, according to IEA's Renewables 2020 report. Global energy demand is set to decline 5% – but long-term contracts, priority access to the grid, and continuous installation of new plants are all underpinning strong growth in renewable electricity. This more than compensates for declines in the use of bioenergy for industry and biofuels for transport due to lower economic activity. The net result is an overall increase of 1% in renewable energy demand in 2020.

Wind and solar in China is cost-competitive with fossil generating sources already, and soon wind and solar power in China will be cheaper than coal power (with and without CCS), even with the most conservative assumptions regarding their annual full load hours. Figure 1 illustrates how the evolution of LCOE of four key technologies with CREO technology and market assumptions within ranges of annual full load hours.

Figure 1: LCOE by fuel in China from 2015 towards 2050



For coal power CCS, the full load hours band is between 4500 and 7500, while for coal power without CCS the range indicated is between 2000 and 6000 FLH for all years, thus the upper part of the band corresponds to a coal power plant having 2000 full load hours, while the lower part of the band corresponds to 6000 full load hours. Onshore wind starts in the range of 1700 to 2700 full load hours in 2020 which are increased 7.5% by 2050 due to projected technological development. Likewise, solar USPV is between 1000 and 1550 full load hours in 2020, both increasing by 3 % by 2050.

Despite looming economic uncertainties, investor appetite for renewables remains strong. From January to October 2020, auctioned renewable capacity was 15% higher than for the same period last year, a new record. Simultaneously, the shares of publicly listed renewable equipment manufacturers and project developers have been outperforming most major stock market indices and the overall energy sector, thanks to expectations of healthy business growth and finances over the medium term. In October 2020, shares of solar companies worldwide had more than doubled in value from December 2019.

In China, wind power and solar PV installations' deployment showed a record year in 2020 with a total of 120 GW new grid-connected capacity, while the curtailment rates maintained low. For wind power, 72 GW new capacity was installed in 2020, which gives a total of 282 GW wind power in the Chinese energy system, of which 271 GW was onshore projects, and 9 GW was offshore projects. For solar PV, 48 GW new capacity in 2020 bring the total capacity of solar PV to 253 GW. Utility-scale PV accounted for 174 GW, and distributed PV accounted for 78 GW. The blowout growth of wind power and solar PV is mainly because the Government no longer provides subsidies for new wind power projects from 2021 and because the NDRC issued a policy clarifying that the delayed grid connection of solar PV projects will be reduced or eliminated in subsidies. Notable, within the 14th and the 15th Five-Year Plan periods, the target of 1,200 GW of wind power and solar PV would be realised with stable capacity additions at the 2020 level, all existing capacity notwithstanding.

Figure 2: Total installed capacity of wind (left) and solar (right) power in China from 2005 to 2020

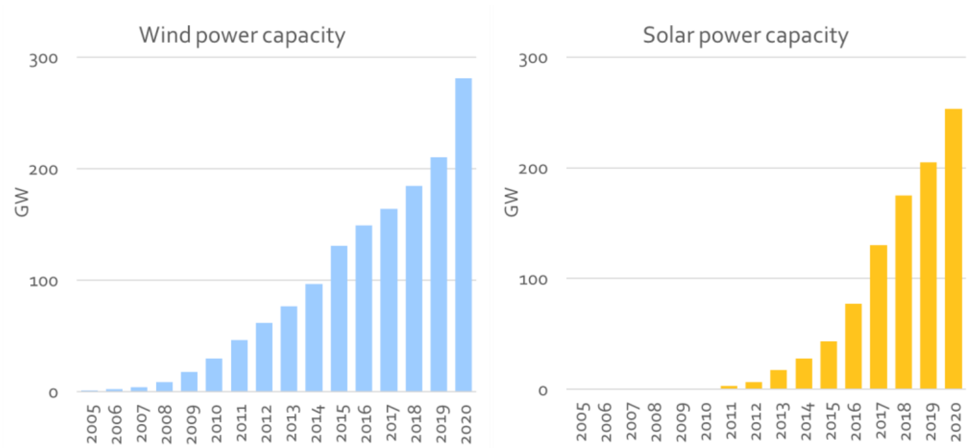
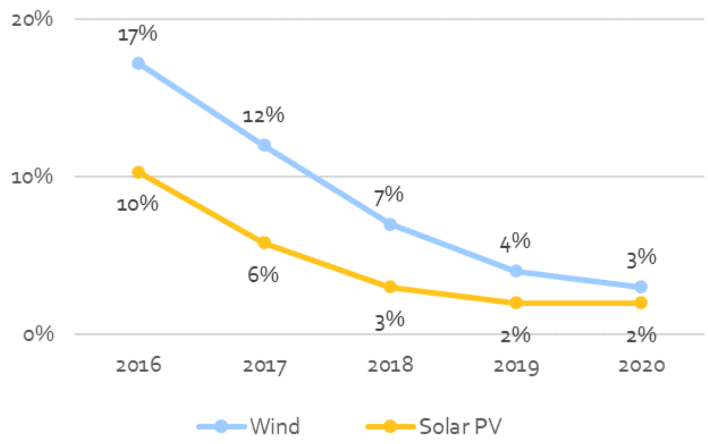


Figure 3: The average wind power and solar PV curtailment rates in China from 2016 to 2020



The pathway to carbon neutrality in 2060

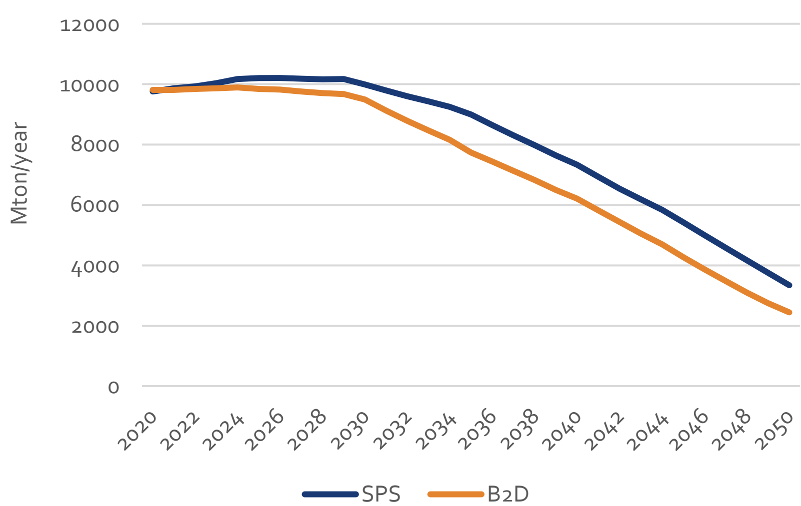
The scenarios in CREO comprises two development pathways for the Chinese energy system. The *Stated Policies scenario* (SPS) expresses firm implementation of the announced energy sector and related policies. The Below 2 °C scenario (B2D) shows how China can build an energy system for the ecological civilisation. The main driver for the B2D scenario is a hard target for energy-related CO_2 emissions through a strategy with renewable electricity, electrification and sectoral transformation at the core. The CREO scenarios illuminate the first 30 years of China's journey towards carbon neutrality.

CO_2 emission peak before 2030

"We aim to have CO_2 emissions peak before 2030 and achieve carbon neutrality before 2060." – President Xi Jinping, 22 September 2020

The CREO scenarios show that it is possible to have a CO_2 peak before 2030 for the Chinese energy sector, as shown in Figure 4. In the SPS, energy-related CO_2 emissions peak in 2029 and thus, the scenario achieves the stated objective. The B2D scenario has a lower CO_2 emission throughout the period to 2050 compared with the SPS. The CO_2 emission peak happens just before 2025, highlighting the importance of significant transformation during the 14^{th} five-year plan period for China to make a solid contribution to achieving the Below 2 °C target. In 2050 the CO_2 emission in the B2D will be lower than 2500 Mton, and it will be easier to reach the 2060 carbon neutrality than in the SPS, which has a CO_2 emission of 3342 Mton in 2050.

Figure 4: Energy sector CO_2 emissions in the CREO scenarios from 2020-2050



China's energy-related emission envelope

The envelope of China's energy-related CO2 emissions towards carbon neutrality will consume around 21.8 per cent of the remaining global carbon budget for keeping temperature increase below 2 °C[2].

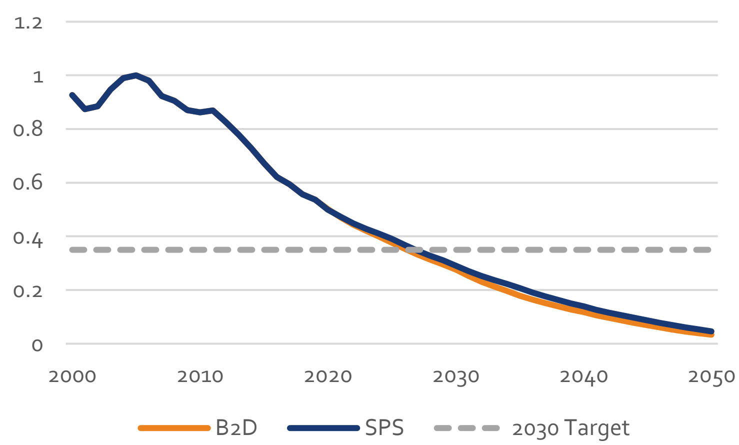
With China accounting for 18.5 per cent of the global population, 19 per cent of global GDP and starting from 29 per cent of the global emissions in 2019, this is a vital contribution in combating global climate change. The scenario does not consider the potential contribution from negative emissions (CO_2 sinks) after 2060. The results demonstrate the opportunity and necessity to explore further opportunities to increase the pace and depth of decarbonisation, particularly in pursuit of the goal of 1.5 °C.

China's carbon emission intensity reduced in 2030

"China will lower its CO2 emission per unit of GDP by over 65% in 2030 from the 2005 level" – President Xi Jinping, 12 December 2020

China's economy has grown tremendously over the past decades, and most of this economic growth has been driven by fuel and CO_2 intensive industries. Since 2005, China's carbon intensity has been declining. The goal of a 40-45% reduction by 2020, first announced in connection with the Copenhagen Accord in 2015 and as part of the thirteenth five-year plan, was overachieved. The 60-65% reduction target for 2030 set at that time is now strengthened to exceeding 65% by 2030 in 2020. In the scenarios, this target is achieved, with the intensity being reduced by 71% by 2030 in the SPS and by 72% in the B2D scenario.

Figure 5. CO_2 intensity per unit of GDP in the CREO scenarios with 2005 as index=1



[2] theThe IPCC finds that the global budget CO_2 emissions budget for maintaining temperature increase below 2°C with high confidence is approximately 1170 Gt from beginning of 2018 (Rogelj et al., 2018)

ERIs energy system modelling tool

The scenario's development in CREO is supported by the ERIs energy system modelling tool, consisting of interlinked models covering the energy sector of Mainland China.

Final energy demands are directed in the END-USE model

Based on the Long-range Energy Alternatives Planning system, LEAP (https://energycommunity.org/), the END-USE model represents bottom-up models of end-use demand and how this demand is satisfied. Assumed developments in key activity levels specified for each subsector and the economic value added for where no other driver is available drives the consumption in the end-use sectors. These drivers translate to energy consumption when combined with assumptions, as well as end-use behavioural features adjustment. Transformation and resource activities aside from district heating and power are also covered by LEAP, including upstream refinery activity.

EDO models the Power and district heating sectors

The EDO (Electricity and District heating Optimisation) model is a fundamental model of power and district heating systems built on the Balmorel model (www.balmorel.com). The power system is represented at the provincial level, considering the interprovincial grid constraints and expansion options. The model includes thermal power (including CHP), wind, solar (including CSP), hydro, power storage, heat boilers, heat storages, heat pumps, etc. It also considers demand-side flexibility from industries, options for charging electric vehicles and the option of a fully integrated coupling with the district heating sector.

The model can represent the current dispatch in the Chinese power system on an hourly basis, including technical limitations on the thermal power plants and interprovincial exchange of power, as well as the dispatch in a power market, provincial, regional or national, based on the least-cost marginal price optimisation. Key characteristics relate to the detailed representation of the variability of load and supply (e.g. from VRE sources) as well as flexibility and flexibility potentials, which can operate optimally and be deployed efficiently in capacity expansion mode.

Combined summary tool

Results from the two models are combined in an integrated Excel-based tool, which provides an overall view of the energy system, combining fuel consumption from the power and heating systems from EDO with direct consumption in end-use sectors and other transformation sectors from LEAP.

The transformation pillars

The strategy for the energy transition explored in CREO 2020 relies on three pillars:

- Energy efficiency is a critical demand-side pillar to ensure the pace and scale of supply-side deployments are adequate to support the required economic growth.
- Electrification and market reforms will change the rules of the game and create the opportunity to replace fossil fuels with electricity in the end-use consumption, in conjunction with decarbonised electricity supply.
- Green energy supply – technological progress and cost reduction allow renewable energy to provide clean energy in bulk, mainly through renewable electricity.

The energy consumption control decouples energy demand from economic growth

The total final energy consumption in the B2D scenario will peak at 3971 Mtce around 2030, with a very flat peak, as shown in Figure 6. The increase in final energy consumption is the biggest in the SPS, which peak around 2034, reaching 4068 Mtce.

Figure 6: Total Final Energy Consumption (Mtce) in the SPS and B2D scenario

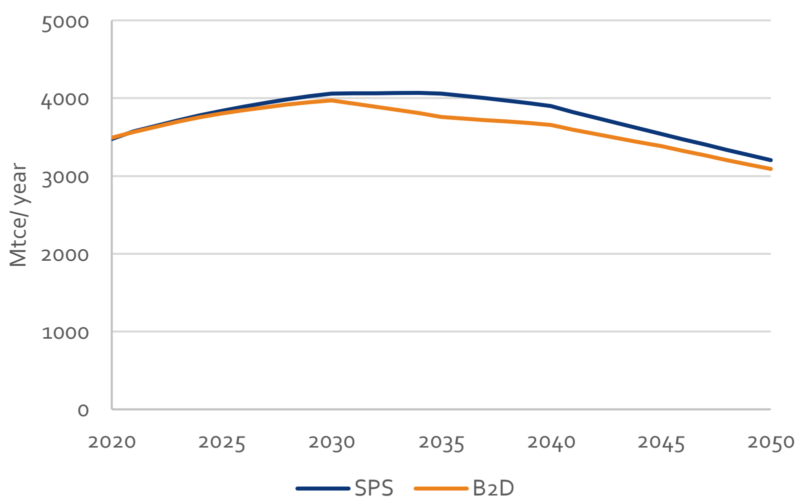
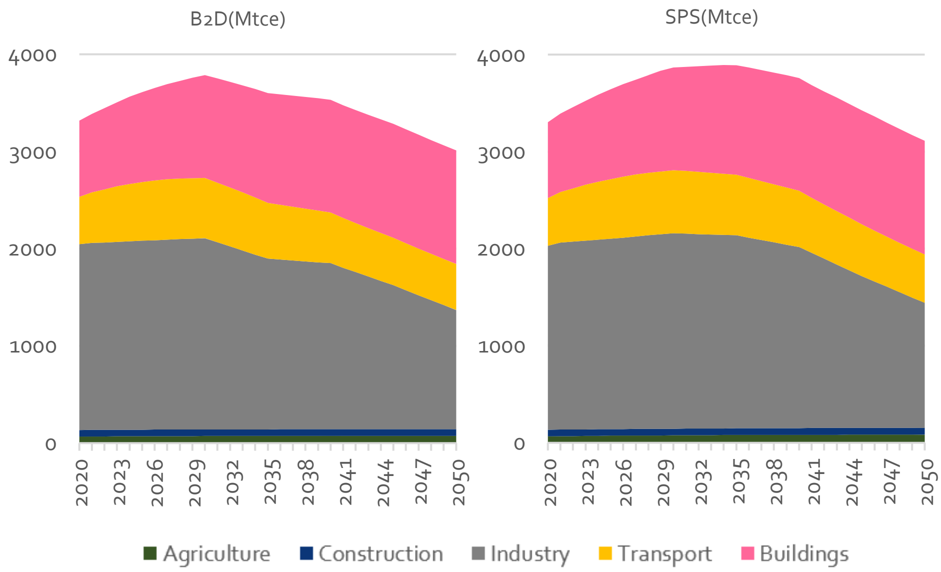


Figure 7: Energy consumption (Mtce) in the end-use sectors



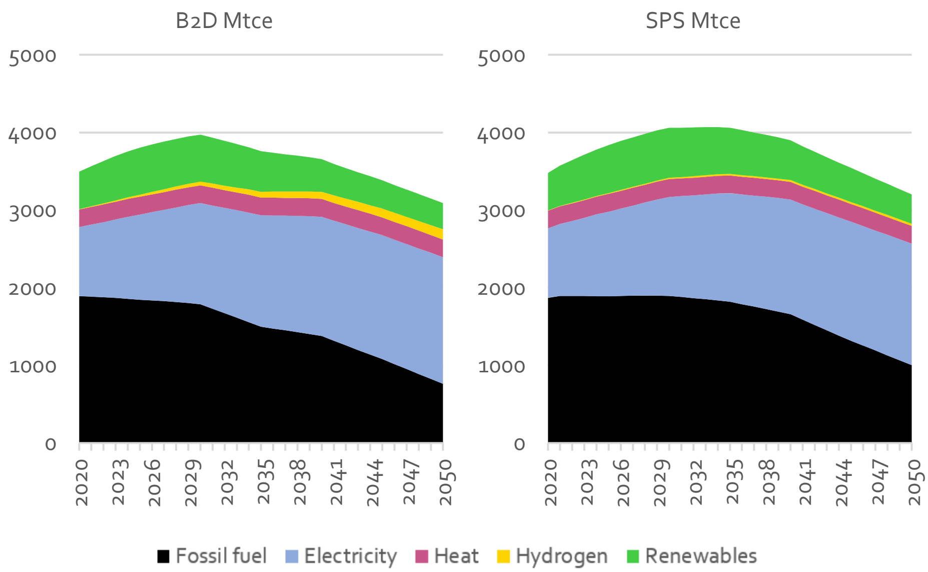
Final energy consumption decreases at a rate of 0.4% per year in B2D from 2020 to 2050, while gross domestic product grows by 4.5% annually over the same period. Meanwhile, the structure of the final energy consumption is also changed due to the economic reform process in China. The share of industrial energy consumption drops from 58% in 2020 to 41% in 2050. Several drivers cause the decoupling of the final energy consumption from the economic growth:

- Firstly, the economic reform in China will move economic activity from heavy industry with high energy consumption towards high tech industry and services with much lower energy consumption per value-added.
- Secondly, the shift from direct fuel combusting to the use of electricity in the industry and transport sectors will increase the energy efficiency in the end-use sectors significantly (see below for more details about electrification).
- Thirdly, focus on energy efficiency and efficiency gains from replacing old equipment with new will lower the energy consumption in the different sectors, especially in the industry sector.

Electrification strategy decreases coal and oil in the end-use sectors

An essential part of the energy transformation is to substitute fossil fuels in the end-use sectors with electricity from a green power system. Furthermore, the introduction of green hydrogen produced by wind and solar power is an indirect way to electrify the end-use sectors.

Figure 8: Energy consumption in the end-use sectors on energy carriers in SPS and B2D scenario



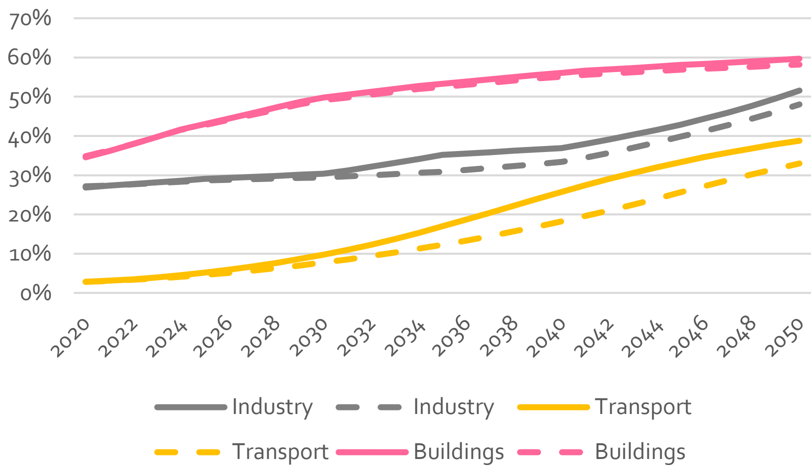
With the deepening of industrial electrification (especially the iron industry) and the promotion of electric vehicles, electricity consumption will increase substantially. In 2050, the general electrification rate in the end-use sectors reaches 56% in SPS and 68% in B2D.

In industry, the most rapid electrification will happen in the subsectors: ferrous metals, non - ferrous metals, chemicals, machinery manufacturing, food and paper. The electrification rate (share of electricity of the total final energy consumption) in the industry sector will increase from around 27% in 2020 to 52% in 2050 in the B2D scenario and 49% in the SPS.

In the transport sector, electric vehicles and plug-in hybrid vehicles will be the main route for long-term development. According to the analysis, 450 – 490 million electric vehicles (including passenger and freight) are expected on the road by 2050. As a result, the electrification rate in the transport sector will grow from 3% in 2020 to 39% in 2050 in the B2D scenario and 33% in the SPS.

In the building sector, the electrification rate will grow from 35% in 2020 to 60% in 2050.

Figure 9: Electrification rate development for key end-use sectors in B2D and SPS (solid line = B2D, dottted line = SPS)



Solar and wind power makes the power sector green and clean

In both scenarios, the total electricity generation grows in the period towards 2050, doubling from around 8000 TWh in 2020 to almost 16000 TWh in 2050 in the B2D scenario and an increase to slightly below 14000 TWh in the SPS.

The electricity consumption is generally higher in the B2D scenario than in the SPS due to the more ambitious electrification of the end-use sectors.

Coal-based power production is gradually phased out and replaced by electricity from renewable energy, mainly solar PV and wind turbines. The share of renewables in power production increases from nearly 30% in 2020 to 88% in 2050 in the B2D scenario and 85% in the SPS.

The Stated Policies scenario has 707 GW of wind and 880 GW of solar to a combined 1587 GW by 2030, and the total installed capacity of wind power and solar PV is thereby higher than the target of 1200 GW. This is mainly due to the economic competitiveness of wind and solar compared with other technologies combined with the target to have a CO_2 peak before 2030. The B2D scenario has 850 GW wind and 1010 GW solar installed in 2030.

Figure 10: Power generation in the two scenarios (TWh)

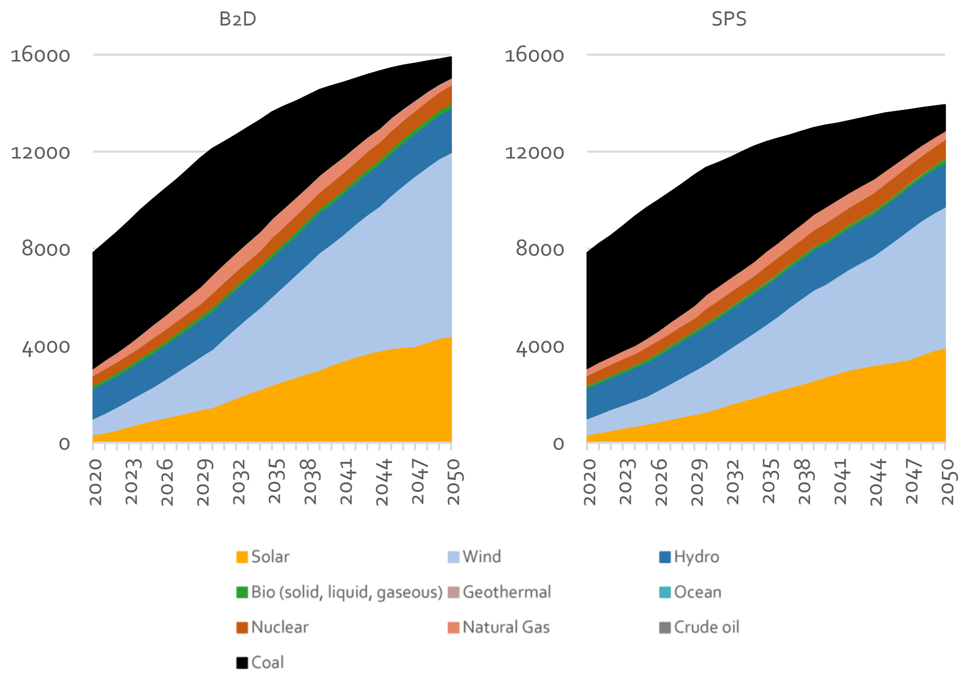
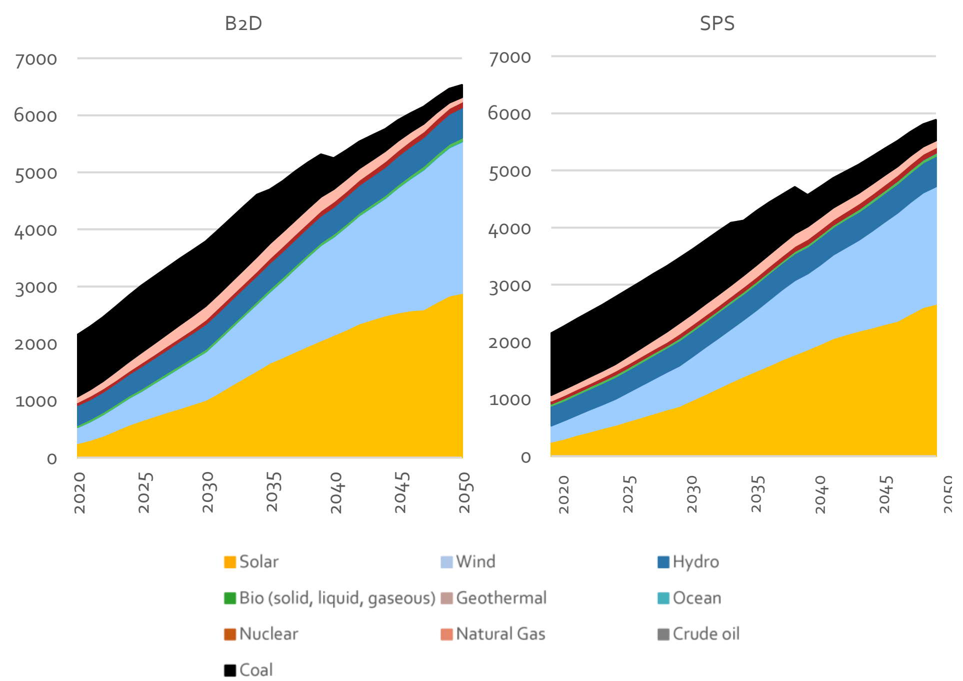
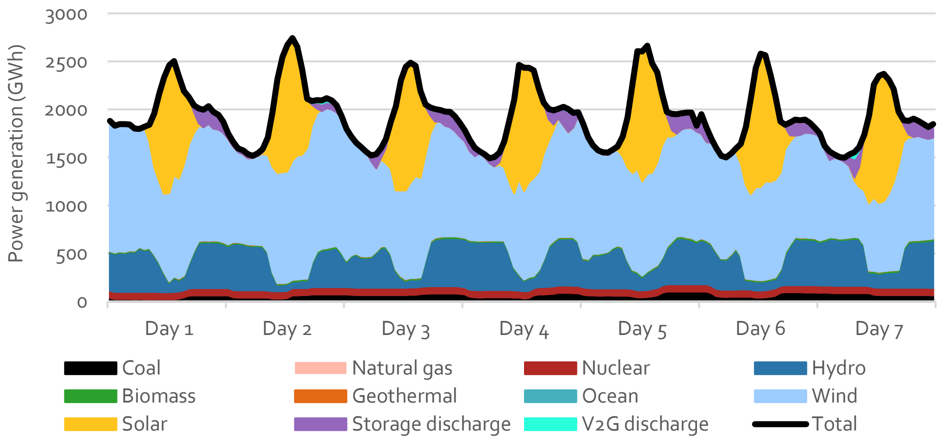


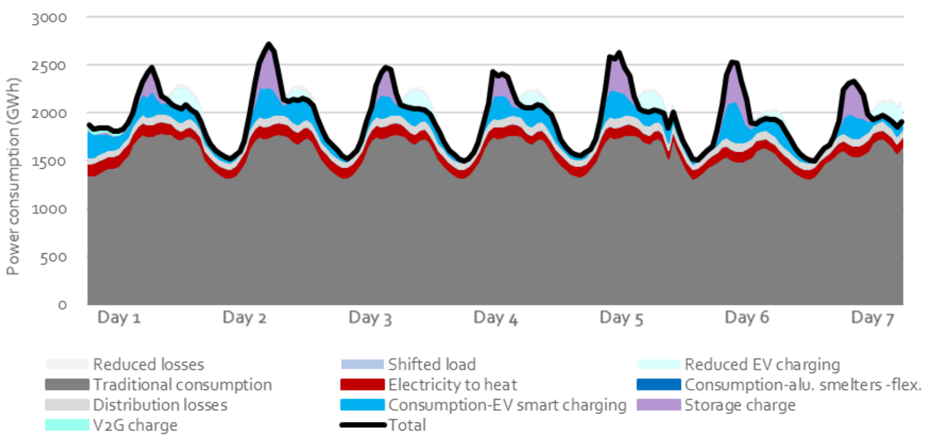
Figure 11: Installed power capacity in the two scenarios (GW)



Reliability will depend on a more extensive sharing of resources between regions, a more robust grid, and advanced coordination between grids. Reliability will also depend on introducing a variety of power sources that can reduce the risk of failure due to weather-related technical failures and a shortage of resources and fuels.

Figure 12: Hourly balance of supply and demand in China's power system for a week in 2050



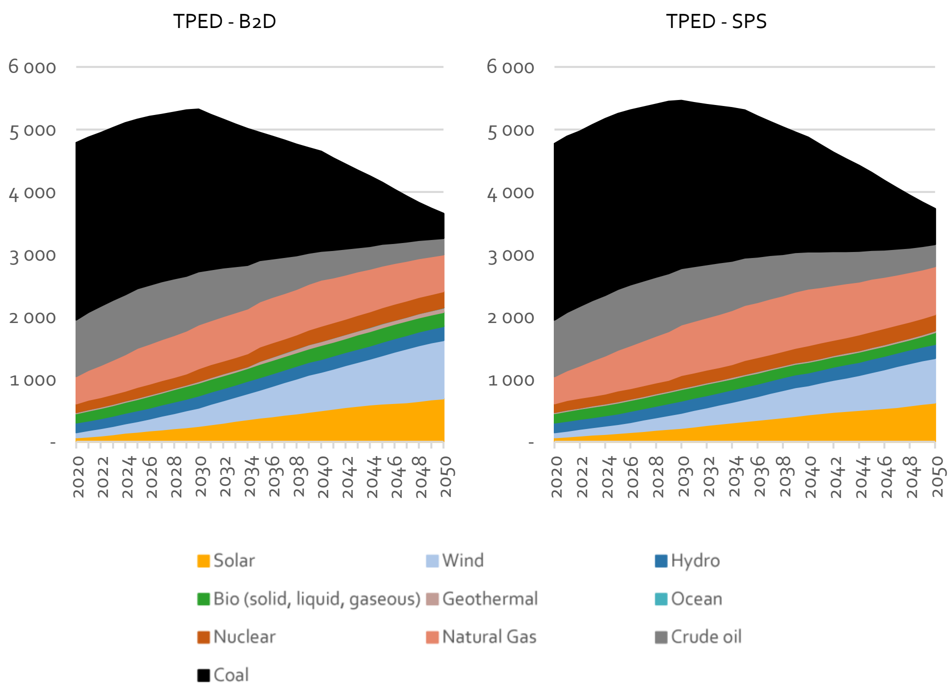


The energy roadmaps towards 2050

Primary energy demand peak in 2030

As a result of the different drivers for the energy transformation, the total primary energy demand (TPED) will peak in 2030 in both scenarios, with a lower peak and a steeper decrease in the B2D scenario compared with the SPS, as shown in Figure 13.

Figure 13: Total Primary Energy Demand (Mtce) in the two scenarios 2020 - 2050

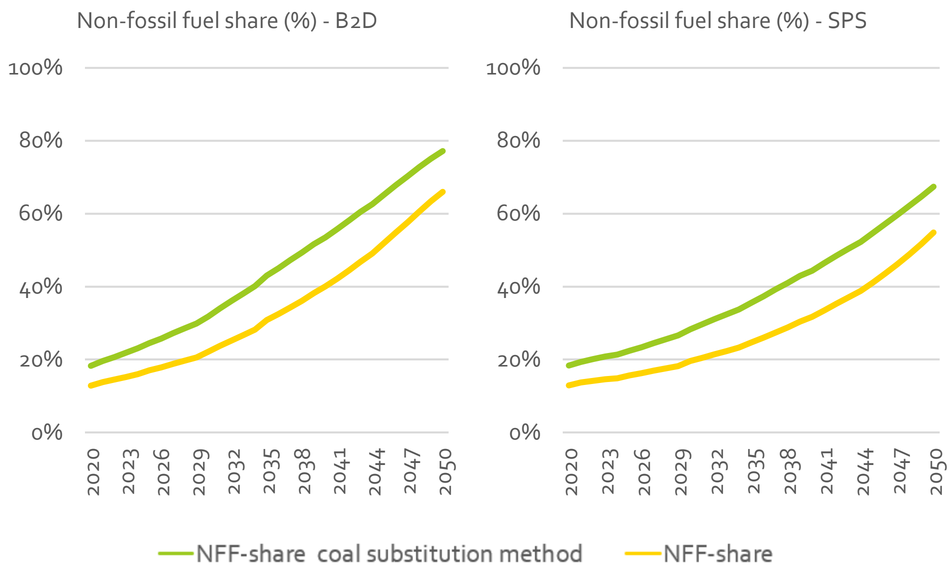


In both scenarios, non-fossil fuels and natural gas gradually substitute coal from 2020. After 2025, oil consumption starts declining. Natural gas peaks in 2040, with a slight decrease towards 2050. Wind and solar energy play a more prominent role in the B2D scenario than in the SPS, while the natural gas consumption is larger in SPS.

A steady increase in non-fossil fuel share

The non-fossil fuel shares (NFF share) are calculated in two ways. The official targets are based on the coal substitution methodology, where non-fossil fuels are included by the substitution of coal in the energy system. The other method is to include non-fossil fuels with the equivalent calorific value. Figure 14 shows both calculations for the two scenarios. In the B2D scenario, the non-fossil fuel share reaches 66% (77% using the coal substitution method) in 2050, while the share is 55% (67% using the coal substitution method) in SPS 2050.

Figure 14: Non-fossil fuel share (%) - direct equivalent and coal substitution method



A peak in CO_2 emission before 2030 and a rapid decrease afterwards

The CO_2 emission is stable in the B2D scenario until 2030, with a small peak in 2024.

After 2030 the scenario has a steep decrease, and in 2050 the emission is reduced to 2442 Mton, less than 25% of the 2020 level. The SPS has a plateau of around 10,800 Mton in 2025-2029 and a decrease after 2030. In 2050 the emission is calculated to 3342 Mton in the SPS.

Coal is the dominant source for CO_2 emission, but natural gas emissions become more critical by the end of the period. In both scenarios, the CO_2 emission from the non-power sector is more significant than the emission from the power system.

Figure 15: CO_2 emission (Mton) in the two scenarios

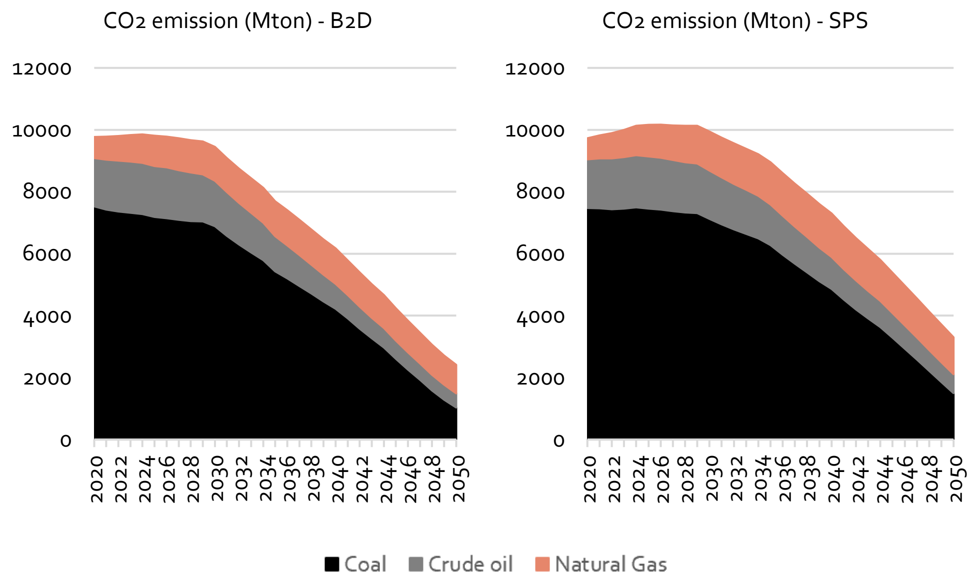
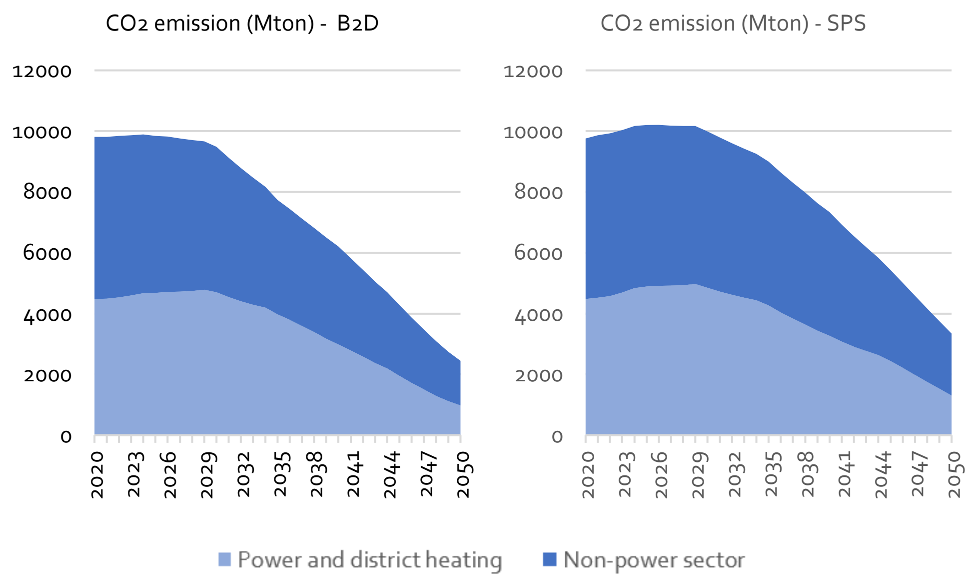


Figure 16: CO_2 emission (Mton) on power and non-power sector



Key results for the two scenarios

Figure 17: Key results for the B2D scenario

B2D		2020	2025	2030	2035	2050
Energy basis						
Total Primary Energy Demand (TPED)	*Mtce*	4,784	5,158	5,318	4,946	3,650
Total Final energy consumption (TFEC)	*Mtce*	3,491	3,803	3,971	3,758	3,091
CO2 emission	*Mton*	9,807	9,847	9,488	7,736	2,442
Non-fossil fuel share of TPED (NFF)	*%*	13%	17%	22%	31%	66%
RE share of TPED	*%*	10%	14%	18%	26%	59%
Coal share of TPED	*%*	59%	52%	49%	41%	11%
Coal share of TFEC	*%*	34%	28%	24%	18%	4%
Gas share of TPED	*%*	9%	12%	13%	15%	16%
Oil share of TPED	*%*	19%	19%	16%	13%	7%
Electrification rate	*%*	28%	33%	38%	46%	68%
Coal substitution method						
Total Primary Energy Demand (TPED)	*Mtce*	5,103	5,667	6,072	6,005	5,440
Non-fossil fuel share of TPED (NFF)	*%*	18%	24%	32%	43%	77%
RE share of TPED	*%*	16%	21%	28%	39%	72%
Total installed power capacity	*GW*	2,150	3,016	3,791	4,699	6,532
Renewable	*GW*	919	1,598	2,343	3,413	6,142
Hydro	*GW*	350	388	439	456	533
Wind	*GW*	282	515	850	1,250	2,656
Bio (solid, liquid, gaseous)	*GW*	34	40	44	45	60
Solar	*GW*	253	651	1,002	1,650	2,870
Solar CSP	*GW*	1	4	9	10	16
Geothermal	*GW*	0	0	0	1	5
Ocean	*GW*	0	0	1	1	2
Nuclear	*GW*	53	66	79	87	100
Fossil fuels	*GW*	1,178	1,351	1,369	1,200	290

Figure 18: Key results for the SPS

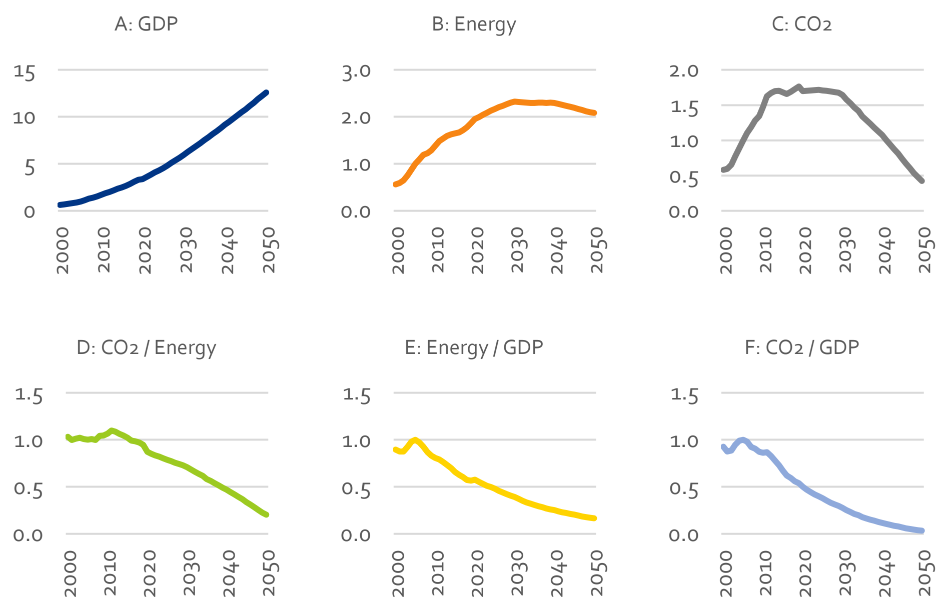
SPS		2020	2025	2030	2035	2050
Energy basis						
Total Primary Energy Demand (TPED)	*Mtce*	4,766	5,251	5,458	5,307	3,726
Total Final energy consumption (TFEC)	*Mtce*	3,476	3,837	4,058	4,060	3,203
CO2 emission	*Mton*	9,759	10,198	9,988	8,995	3,342
Non-fossil fuel share of TPED (NFF)	*%*	13%	16%	20%	25%	55%
RE share of TPED	*%*	10%	12%	16%	20%	48%
Coal share of TPED	*%*	59%	53%	49%	44%	15%
Coal share of TFEC	*%*	34%	28%	25%	23%	6%
Gas share of TPED	*%*	9%	12%	15%	17%	21%
Oil share of TPED	*%*	19%	19%	17%	14%	10%
Electrification rate	*%*	28%	31%	35%	38%	56%
Coal substitution method						
Total Primary Energy Demand (TPED)	*Mtce*	5,084	5,706	6,122	6,204	5,164
Non-fossil fuel share of TPED (NFF)	*%*	18%	22%	28%	36%	67%
RE share of TPED	*%*	16%	19%	25%	32%	62%
Total installed power capacity	*GW*	2,150	2,784	3,465	4,121	5,885
Renewable	*GW*	919	1,426	2,064	2,884	5,307
Hydro	*GW*	350	388	439	456	533
Wind	*GW*	282	450	707	990	2,052
Bio (solid, liquid, gaseous)	*GW*	34	38	37	37	50
Solar	*GW*	253	546	872	1,390	2,652
Solar CSP	*GW*	1	4	9	11	16
Geothermal	*GW*	0	0	0	0	2
Ocean	*GW*	0	0	1	1	2
Nuclear	*GW*	53	66	79	87	100
Fossil fuels	*GW*	1,178	1,291	1,322	1,150	478

Development indices 2000 - 2050

A helpful way to understand the long-term development trends is to show the index of key results relative to 2005, as shown in Figure 19 for the B2D scenario. We assume that the total GDP in real terms will grow 12,58 times from 2005 to 2050 (A). At the same time, the scenario analysis shows that the primary energy demand will peak in 2030 and decline afterwards (B). The CO2 emission has a steep increase from 2000 to 2010, a plateau from 2010 to 2030 and a steep decrease from 2030 to 2050 (C).

As explained in the previous chapters, the development is driven by a cleaner energy system with a lower CO2 emission per energy unit of consumption (D) and a decoupling between economic growth and energy consumption (E). Hence, the CO2 intensity per GDP will continue to fall steadily towards 2050 (F).

Figure 19: Indices for GDP, Energy and CO2 in the B2D scenario. Index 2005 = 1)



Regulation and reforms can support the energy transformation

The scenario analyses show that it is technically feasible and beneficial to have a genuine transformation of the Chinese energy sector towards 2050 to reach the goals for an ecological civilisation with a clean, low-carbon, safe and efficient energy system. This will also be a precondition for the 2060 carbon neutrality target for China.

However, the energy transformation does not happen by itself. A dedicated policy effort is necessary to encourage change and remove barriers to implementation. The effort includes regulations and reforms like

- Power sector reforms, including wholesale and retail electricity markets, unbundling of monopolies, third party access to grids and markets and transparency regarding market information
- Coordinated use of economic measures like emission trading systems, taxation, and marginal pricing in power markets (wholesale and retail)
- Promotion of green investments, which can reduce risks for green technologies and remove protection for black, fossil fuel-based technologies
- Existing control measures like caps for coal consumption, quotas for RE consumption, pollution control, etc.
- Focus on a transformation that preserves jobs and a healthy local economy, using green growth as a driver.

Power markets as the key driver for power system transformation and RE integration

Experiences from Europe[3], the US, and other regions demonstrate that establishing efficient, transparent and liquid short-term power markets with clear price signals is fundamental for enhancing the flexibility in the power system, easing the integration of variable power production from wind and solar power.

China relaunched its power market reform in 2014 and has established several pilot project for wholesale markets. However, it is crucial that the practical power market design and implementation consider the need to stimulate the integration of fluctuating power production.

Besides the fundamentals in power market design[4] – spot markets based on marginal pricing, transparency for all market participants, access to grids and markets for all producers etc. - the market design should also include trading close to the operating hour, allowing adjustments to changes in production patterns, especially for VRE. Also, a well-defined

[3] "European Experiences on Power Markets Facilitating Efficient Integration of Renewable Energy," Danish Energy Agency, March 2018.
[4] "Electricity Market Design, Integrating renewables at low cost," Danish Energy Agency, August 2020.

market for ancillary services is in the spotlight when defining market products that reflect the specific flexibility need of the power system in question. Correctly designed products meeting particular needs can substantially reduce the power system costs by reducing the need for large reserves. Furthermore, integrating markets into larger market areas has significant economic benefits for integrating renewable energy, which can be achieved even without complete harmonisation[5].

Retail markets, exposing the price signals for the end-use consumers, can play an essential role in shifting load away from peak hours and reducing the need for expensive peak capacity.

Transparency of market data, system data and infrastructure data are preconditions for a well-functioning power market. The EU transparency efforts[6] could be an inspiration for China to develop its transparency policy.

From a policy point of view, power markets are tools for the energy transition. It is essential to conduct comprehensive energy system analyses based on rigorous modelling, which will reproduce the market function in combination with policy measures to evaluate the interplay between regulation and market forces.

Lower risk for green investments will boost the deployment of renewables

In addition to introducing power markets for all production technologies, including renewable energy, policy measures to reduce the risk for investments are essential to the rapid deployment of renewable energy[7]. Support schemes like feed-in-premium or contracts for differences (CfD) might be necessary for a period for technologies like offshore wind and concentrated solar power (CSP), while power purchase agreements (PPA) would be a risk minimising tool for more mature technologies. These instruments must be developed in line with the power market set up to support the market function and integration of renewable while reducing investor risks.

Power market reform is necessary to improve VRE integration, but market and regulatory risk may adversely affect the appetite for RE investments. Striking the right balance is critical.

The introduction of market discipline is essential for the green transition, but how can this be introduced, while it is assumed that nobody (no SOEs) should lose out, and without

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[5] "Power markets and power sector planning in Europe - Lessons learnt for China," Danish Energy Agency, October 2015.

[6] "Electricity Market Transparency," ENTSO-E, accessed in February 2021 at https://www.entsoe.eu/data/transparency-platform/.

[7] "Spot market models for renewable energy integration - international experience," China National Renewable Energy Centre and Danish Energy Agency, May 2020.

bringing down the house of cards. Wind and solar are the cheapest sources of new electricity generation in China - cheaper than coal, yet coal investments continue and bring moral hazard to the system.

Control measures to guide the transformation in the right direction

At the level of policy design, the Chinese Government has continuously formulated plans and regulations focusing on structural energy reform, carbon emission reduction and air pollution control. China's renewable energy support policy has begun to transform in 2019 and has gradually shifted from a purely supply-side incentive to a consumer-side responsibility. NEA has implemented the mandatory renewable power consumption mechanism since 2019. It is a binding policy, requiring that a certain percentage of electricity consumption of each province be from renewable energy and non-hydro renewable energy, respectively. The general idea is to raise the provincial consumption targets year by year and gradually reduce the difference in the proportion of consumption among provinces in the 14th and 15th Five-Year Plan periods. The purpose is to realise that all provinces will bear the responsibility for the development and consumption of renewable power equally by 2030.

To curb CO_2 emissions and transition to clean energy, China is working to decrease the share of coal in its overall energy mix and decrease the dominant role of coal in electricity generation, aiming to control the total annual coal consumption within 4.1 billion tons by 2020. In the 13th Five-Year Plan period, the Government has further promoted supply-side structural reform by phasing outdated coal production capacity and stabilising coal prices. While shutting down the outdated small coal mines, coal mining has become further concentrated in areas with high-quality coal resources. To reduce fluctuations in coal prices, the coal market has increased the proportion of medium- and long-term trading contracts. The Government has further reformed coal prices to stabilise supply and demand. Specifically, in the power sector, NEA and NDRC set a clear target of keeping the total coal power capacity under 1,100 GW by 2020. More than 20 GW of outdated thermal power capacity was targeted for closure. Any remaining coal-fired units under 300 MW should meet ultra-low emission standards.

Besides CO_2 emission reduction, China also stipulates in explicit policies the *Air Pollution Prevention and Control Action Plan (2013-2017)* and *Three-Year Blue Sky Action Plan (2018-2020)* to control major air pollutant emissions such as SO_2 and NO_x, as well as reduce the concentration of PM 2.5 and number of heavily polluted days. The Ministry of Finance issued dedicated funds annually to carry out relevant activities across the country, especially in key control areas, including the Beijing-Tianjin-Hebei region, the Yangtze River Delta region and the Fenwei Plain (Shaanxi and Shanxi) region.

Policy recommendations

Wind and solar development towards 2035

Our analyses show that wind and solar power can become the backbone of the Chinese energy system in the future and that such a transformation will be essential to reach the climate goals for China.

For the period towards 2035, we recommend a gradual increase in wind and solar capacity deployment. In the period 2020 to 2025, an annual deployment of 120-130 GW is recommended. From 2025 to 2030, the yearly deployment should increase to 135-140 GW, and from 2030 to 2035, the annual deployment should be around 205-215 GW.

Figure 20: Average deployment of wind and solar power (GW/year) in the five-year periods to 2035

	2020 – 2025	**2025 – 2030**	**2030 – 2035**
Average deployment of wind and solar (GW/year)	120-130	135-140	205-215

Coordinated drivers for a green energy transition

China has already several policy instruments available for boosting the green energy transition. If they are coordinated in the right way, they will be able to significantly push the deployment of renewable energy, especially wind and solar PV.

Combination of consumption targets, green certificates, power markets and ETS

The mandatory consumption targets for non-hydro renewable energy can be crucial for wind and solar PV deployment. According to the NEA proposal, the individual provinces will be responsible for ensuring that renewable energy will cover a particular share of the total electricity consumption in the province. The targets for the provinces will gradually be harmonised, and by 2030 the provinces should have the same percentage. Renewable energy production could either be local within the province or come from other provinces through cross-provincial transmission.

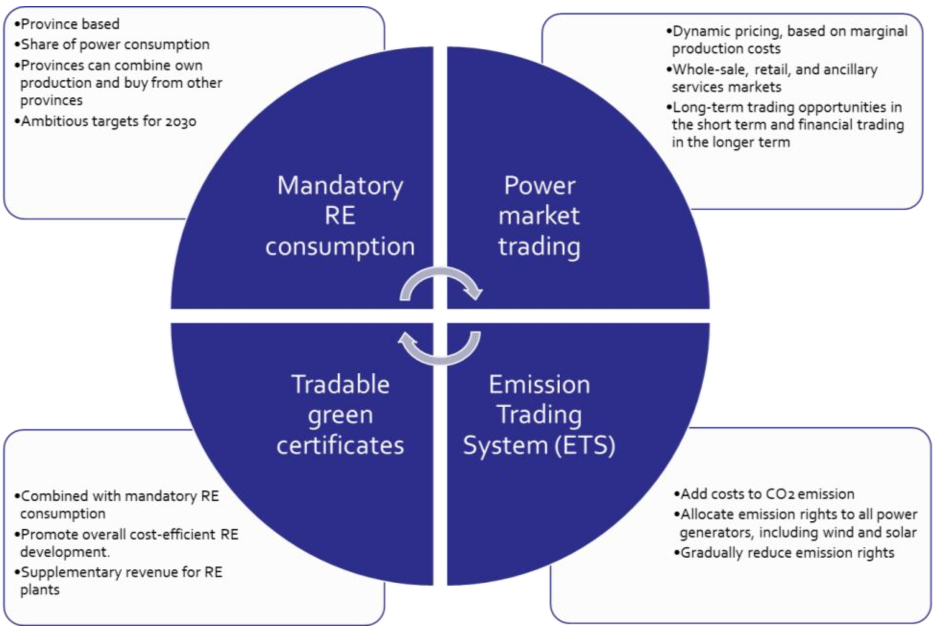
To ensure an efficient allocation of RE power plants, the consumption targets could be linked with *tradable green certificates*. These certificates should document the purchase of RE production to reach the mandatory consumption targets. They would ensure a flexible way for provinces to decide on local production or buy from other provinces. Provinces with good conditions for wind and solar power would be able to export to provinces with less favourable conditions to benefit overall economic efficiency. The purchase of green certificates would give a supplementary income to the owner of the renewable energy plant.

The primary income for the RE producer will be electricity sales. Here, the development of well-functioning *power markets* is essential for integrating renewable energy into the power system. Power markets must deliver opportunities for medium and long-term price risk management and an efficient system dispatch. The medium and long-term power trading must be accessible for RE producers to ensure that other generators physical positions establishing within this trading window do not crowd RE producers out of the market. PPAs can also be used for guaranteeing long-term price security for RE producers, and market exposed consumers. Once well-functioning spot markets provide a liquid and credible price reference, e.g., system marginal prices (SMPs), price risk management should be augmented by financial power trading. The medium and long-term physical trades should be transitioned to financial contracts such as futures and contracts for difference (CfDs), with reference to the system marginal price.

A spot market based on marginal and dynamic pricing would ensure that wind and solar power would be dispatched before thermal power plants. The pricing would reflect the scarcity of production compared with the demand and ensure that the system as a whole is operated efficiently.

Finally, the CO2 emission trading system (ETS) would support the energy transformation by raising the cost of power production from power plants using fossil fuels. If emissions allowances are allocated, they should be granted to all power plants, including wind and solar power plants, which would give additional income for the RE power producers, who would sell the emission rights to power producers with fossil-fuelled power plants. If ETS allowances are instead auctioned, which would be more efficient, the revenues from this should promote the energy transition.

Figure 21: Coordinated policy measures to boost the deployment of renewable energy



In such a coordinated policy system, the RE power producers will generate income from three different sources:

1. Power market trading
2. Green certificate trading
3. Emission rights trading

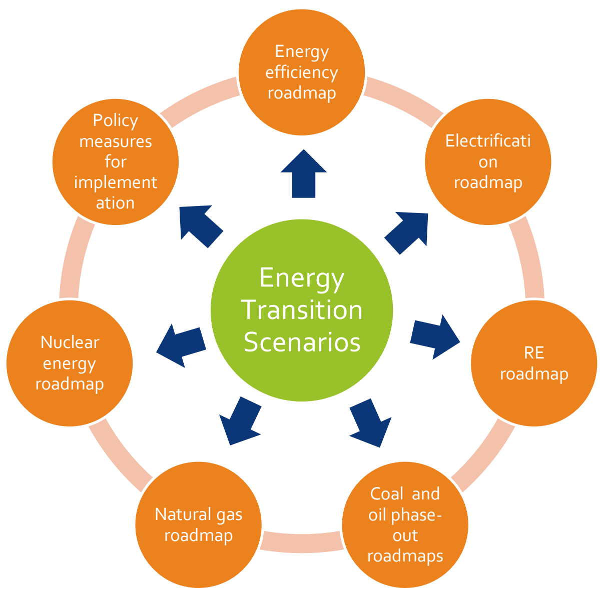
To get these measures to work efficiently, it is essential that the consumption targets and emission trading rights are based on the ambitious long-term targets needed to reach carbon neutrality in 2060 and avoid stop-go situations where the targets are temporary fulfilled.

Use energy transition scenarios as a platform for energy roadmaps

Based on our experiences from preparing annual outlooks for renewable energy in China, it is highly recommended to continue using comprehensive energy system scenarios as a platform for targeted roadmaps for phase-out of coal and oil, development of renewable energy as the backbone for the future energy system, nuclear and natural gas development, for electrification and energy efficiency roadmaps, and in-depth assessment of the comprehensive policy measures needed to make the energy transformation happen.

The energy transition scenarios are instrumental for both medium-term and long-term energy strategy development, including emission peak planning and carbon neutrality planning. In an international context, the energy transformation scenarios will give a clear input to the global efforts for climate change mitigation.

Figure 22: Comprehensive energy system transition scenarios as a platform for targeted energy roadmaps



Additional key findings from the Outlook research

This chapter summarises other key findings from the CREO 2020 report.

Power sector

Electrification in the end-use sectors boosts electricity consumption. The energy transition requires a high penetration of renewable energy in the power sector.

Electrification is one of the key elements in energy transition. It provides space for efficiency improvements on the end use of energy and considerable potential for electricity supplied by renewable energy that can significantly accelerate the energy transition. According to Below 2 °C Scenario, the electrification rate grows from 30% in 2019 to 46% in 2035 and 68% in 2050. The electricity consumption in 2050 is nearly doubled compared with the 2019 level. It is mainly driven by the transport and agriculture sectors and increasing applications of hydrogen produced from electricity.

Renewable power technologies are the most promising and mature technologies that can efficiently and cost-effectively reduce CO_2 emissions in the energy sector. Along with growing electricity consumption, the power sector needs to provide clean energy by integrating a high penetration of renewable energy. Our results show that in the Below 2 °C Scenario, the share of renewable energy generation in the power sector increases from 25% in 2019 to 57% in 2035 and 88% in 2050. Renewable energy in the power sector contributes to 72% of overall renewable energy consumption in 2019, 78% in 2035 and 83% in 2050, respectively.

An energy transition driven by renewables requires a reimagining of China's power system.

To adopt renewable power generation in the power system, the integration becomes critical, as renewable generation is fluctuant, distributed and uncertain. The scenarios demonstrate that while the post-transition power system outperforms the present system according to all relevant criteria, it is radically different. Characteristics in asset mix, dispatchability, operational paradigm, cost structure, operational timescales, and topology will transform. The system cannot be planned or operated according to today's principles, using today's sources of flexibility under today's regulatory paradigms. Every aspect of the power industry needs to be changed, including market designs, regulatory setups, product and service definitions, and stakeholder roles. Power system planning, innovation, and reform must be forward-looking. Managing uncertainty, variability, and complexity will be essential.

To accommodate the high penetration of renewable sources, China's electricity market should mobilise existing flexibility through efficient price signals and market services and guide investments in unavailable flexibility sources through long-term market design. The power system should be structured to efficiently dispatch available flexibility such that fluctuations and uncertainties can be handled without interfering with system security.

Renewable energy is competitive on a cost basis, on value adjusted basis, and in the long run, it can reach high penetration levels if cost-effective flexibility is deployed.

Based on recent years' experiences, it is projected that renewable energy costs will continue to decline, making wind and solar competitive with investing in new coal power plants during the 14th Five-Year Plan period. When the external costs of coal power plants are accounted for, investments in new renewable energy sources will be cheaper than continuing to operate existing coal plants. The focus on cost reduction of onshore wind and solar PV will be shifted from reducing equipment and construction cost to improving the capacity factor.

The power reforms and meaningful carbon price levels will take some time to implement. The scenario results suggest that the carbon market is a very efficient tool to make non-fossil fuel competitive with fossil fuel, which indicates that the additional system integration cost by renewable energy still needs stimulations through policies. The price of CO_2 should translate to a higher market value for renewables and a disincentive for fossil-fired generation as a (partial) proxy for the external costs of fossil fuel combustion. Auctioning CO_2 allowances could finance accelerated investments in the energy transition.

The role of coal and natural gas in future power system.

To facilitate the structural reform and proceed energy transition, coal capacity does not significantly increase during the 14^{th} Five-Year Plan period. From 2025 to 2050, coal capacity gradually declines since the role of coal plants is turned to providing flexibility and spinning reserve from simply serving the baseload. The role of natural gas plants in the future power system is the same as coal plants, except that natural gas plants bring less CO_2 emission. The development space for natural gas power is determined both by the CO_2 cap and the flexibility demand of the power system.

Grid planning

The substantial expansion of variable renewable energy generation challenges the paradigm of grid planning in China. The importance of coordinating wind and solar deployments with the planning of grid connectors to bring renewable electricity to consumption areas has been long recognised in China. Several large and long-distance transmission projects find justification in facilitating remote RE developments in areas with abundant endowments of RE resources. However, historically large-scale wind and solar deployments in China have been developed in conjunction with traditional coal power generation as backup and support. As the overall VRE penetration levels increase, this bundling of coal with wind and solar gradually becomes infeasible, notably as such thermal capacity is reduced.

In CREO's power system simulations, there is a clear indication that new transmission capacity between provinces provides value to:

- Connect structural surplus generation areas with deficit areas,
- smoothen out VRE variability over broader geographical footprints,
- efficiently and dynamically connect flexible resources to areas they are needed.

These results are derived from the holistic optimisation applied to capacity expansion and dispatch. On a per timestep basis, down to hour-by-hour simulations, the marginal cost of supplying electricity to each region is a result. This can be interpreted as spot market prices within each timestep. Regional price differences reflect the value of having the capability to transmit electricity in each hour between locations. Over the year, the value of this capability is the sum of distinct values, given 8760 (hourly) different supply and demand situations.

Presently, the business cases in transmission planning in China are based on the difference in the average cost of supply between regions – essentially as reflected in the first bullet above. When VRE penetration increases and flexibility gains importance in power dispatch, it becomes increasingly important to value both dispatch and investment planning purposes. The business cases for new transmission lines in the future must be adapted to reflect this reality.

- Grid expansions are an essential component in the realisation of either CREO 2020 scenario. The simulations indicate that not expanding interprovincial grid capacity increases the overall economic cost by 900 billion per year in 2030, and at the same time produces inferior environmental outcomes.
- In further developing grid planning methodology in China, there are significant and relevant lessons to be learned from Europe and the process applied by the European Network of Transmission System Operators for Electricity (ENTSO-E) to develop Ten-Year Network Development Plans (TYNDP). Globally, this remains the single comprehensive grid planning coordination methodology applied at a scale proportional to that of China.
- The development of well-functioning spot market(s) in China will provide essential information to grid planners and refine the possibilities for creating sound cost-benefit analyses of power transmission projects to accurately reflect the expected societal benefits of transmission projects to weigh against the costs.
- Compared with Europe, the needs for grid development in China, as identified in the CREO scenarios, are substantial. This implies that the Chinese equivalent of a TYNDP would be complex and comprehensive, including many opportunities for cost-effective grid reinforcements and complex interactions in the value determinations of many potential projects under consideration.

Grid planning analyses presented in the CREO report have been prepared for work under the **EU-China Energy Cooperation Platform, ECECP**[8]. This work builds on the CREO 2020 Scenarios. It uses supplementary simulations to look at grid planning in China in a market-based context, following ENTSO-E's TYNDP process methodology.

[8] Specifically, the activity *A4.1.1: ENTSO-E Grid Planning Modelling Showcase for China*. For more information in the EU China Energy Collaboration Platform visit the ECECP website at http://www.ececp.eu/.

Electric vehicles and renewable energy

Electric vehicles (EVs) can act as energy storage in the power system and thereby increase the flexibility of the system. This flexibility includes peak shaving, frequency control, reactive compensation, modern information and communication technology, power electronic technology and optimal control technique. The widespread use of EVs also provides considerable potential for renewable energy grid integration when renewable energy is generated but not needed immediately. This has historically been one of the main limitations of renewable energy, namely, the problems of short-term storage so that the cycles of demand and supply can be more readily reconciled. The transport sector may have a pivotal role to play here. The combination of different EV storage options and the expansion of EVs provide the necessary capacity for short-term energy storage.

The flexibility potential of EVs can be realised through four pathways: Smart Charging (SC), Battery Swap (BS), Vehicle to Grid (V2G) and Repurposing Retired Batteries (RB).

Pathway 1: Smart Charging (SC)

EVs can shift their charging time according to the power system demand through smart charging. The concept is similar to the conventional power demand response but potentially with improved flexibility and reduced cost. The storage capacity of smart charging is determined mainly by driving behaviour, but the theoretical maximum storage capacity equals the electricity consumption for transport use.

Pathway 2: Vehicle to Grid (V2G)

Vehicle to Grid (V2G) exploits the storage potential from onboard batteries via bidirectional power flows between the vehicle and the grid. The theoretical storage capacity of a V2G EV is decided by onboard battery storage capacity.

Pathway 3: Battery Swap (BS)

A battery swap (BS) offers a quick refuelling solution and could also release the maximum storage potential of EV batteries. A swapped battery can be charged and discharged according to the power system demand as a stationary storage unit. The lifetime of batteries could also be extended through the relaxation of the fast charging requirement. The volume of off-board batteries determines the storage capacity of the battery swap.

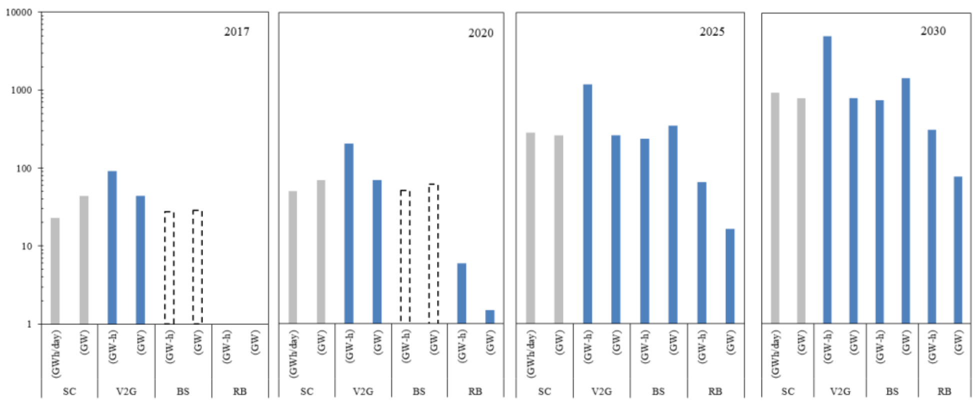
Pathway 4: Repurposing Retired Batteries (RB)

Because retired EV batteries usually hold about 70-80% of the charge of new batteries, the use of these repurposed batteries for storage (RB) could add to their residual value. It should be noted that the storage value of retired batteries can only be delivered after batteries' onboard duty has been completed, and this is typically 6-10 years after the beginning of the battery lifecycle.

The theoretical capacity of the four EV storage pathways is illustrated in Figure 23. We refer to the pumped hydro storage capacity for comparison. Pumped hydro storage currently dominates over 90% of the energy storage market and serves various applications in the power system in China. However, given the geological and water resource conditions, the proven reserves of pumped hydro storage capacity in China are 150GW, or 1.2TWh, assuming an average of 8 hours discharge. Therefore, the theoretical capacity of V2G storage by 2030 is about 6 (power) or 4 (energy) times that of pumped hydro.

To realise a future with high VRE penetration, policymakers and planners need to know the potential role of EV in the energy system and how EV-RE coordination can be implemented in a cost-efficient way. We find that the development of EVs is the fundamental driver for making substantial cost reductions in energy storage. Large scale investment in EVs and the purchase of these vehicles can also offer a flexible solution in a cost-efficient way, as the potential capacity for storage increases with the number of EVs. Of the four different but complementary pathways by which EV flexibility can be delivered, V2G provides the largest capacity, whilst RB shows diminishing market competitiveness in the longer term than the other EV-RE coordination pathways.

Figure 23: Theoretical Energy Storage Capacity of Electric Vehicles



We have examined four pathways in combination to determine the range of options available, together with some of the costs, risks and uncertainties involved with each. The four EV-RE coordination pathways all rely on different business models and policy instruments. SC is technically mature with the least cost and should be promoted firstly by, for instance, the implementation of the time of use (TOU) charging tariff. The discharging tariff, referring to the TOU charging tariff, should also be developed in parallel to encourage the application of V2G. The potential of BS can be realised in a relatively efficient way for EV fleets, such as buses and freight vehicles.

Policymakers should formulate standards/protocols on battery designs, cascade use and material recycling as early as possible. All these factors will have a decisive impact on the EV potential and the cost of RB. Given the concern on the limited battery life, the current R&D on battery technology should focus on the performance parameters such as specific energy and fast-charging capacity and the number of cycles, as this is the critical factor in realising EV storage potential for the power system.

EV flexibility needs to address complex issues related to intra-day storage demand resulting from the high penetration of variable renewable energy and tends to facilitate a distributed energy system where end-users can support each other instead of purely relying on the main grid. Innovations in the transport sector, such as car-sharing and vehicle automation technology may influence EV-RE coordination. Still, EVs can always extract a considerable amount of flexibility from the variation of daily transport demand (the gap between peak and off-peak). BS and RB can offer the highest flexibility where vehicle use is highest, such as in applying autonomous driving technologies.

Hainan Green Island

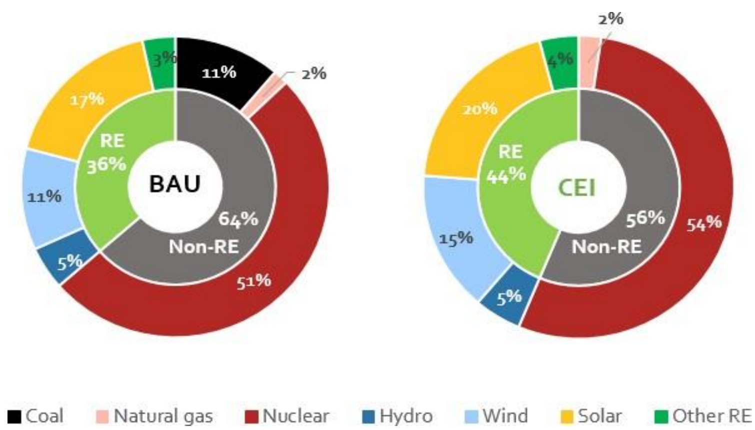
Provincial low-carbon development planning is also necessary and valuable to facilitate the national energy transition. As the national Free Trade Zone, Hainan province has announced clean energy targets, aiming to develop low-carbon technologies and reduce dependence on fossil fuel. Hence, under the CREO 2020's modelling set up, a long-term energy scenario analysis was carried out to investigate technical feasible and cost-efficient roadmaps to achieve Hainan's 2030 Clean Energy Island (CEI) targets.

"By 2025, about 50% of primary energy consumption should be supplied by clean energy; by 2030, petrol-driven vehicle sales shall be completely banned; and by 2035, the transition process shall be completed."

The study shows that wind and solar power deployment is the lowest cost path for achieving Hainan's ambitious clean energy targets. Under the CEI scenario, reducing energy exports and increasing generation from renewable sources are the two central pillars, resulting in the complete removal of coal from the electricity generation mix by 2030. Replacing coal with wind and solar would only have a 2 per cent higher annual cost than the business-as-usual (BAU) scenario. Such a shift would reduce the annual CO_2 emissions from the power sector from 7.0 million tons to 1.3 million tons.

Based on the CEI scenario, the study also carried out a sensitivity analysis, showing to which degree alternative pathways for coal displacement are less cost-efficient and bring other benefits, such as further emissions reduction. An extra 650 MW of gas, nuclear and transmission capacity is added to the CEI-Gas, CEI-Nuclear and CEI-Trans scenario. However, none of these displacements impacts CO_2 emissions.

Figure 24: Electricity generation mix in 2030 for Hainan, comparison between the BAU and CEI scenario



China Renewable Energy Outlook

2020