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CNREC 国家可再生能源中心 CHINA NATIONAL RENEWABLE ENERGY CENTRE

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China Renewable Energy Outlook 2018

Energy Research Institute of Academy of Macroeconomic Research/NDRC

China National Renewable Energy Centre

Executive Summary

“We will promote a revolution in energy production and consumption, and build an energy sector that is clean, low-carbon, safe, and efficient.”

“What we are doing today to build an ecological civilization will benefit generations to come. We should have a strong commitment to socialist ecological civilization and work to develop a new model of modernization with humans developing in harmony with nature. We must do our generation’s share to protect the environment.”

President Xi Jinping

at the 19th National Congress of the Communist Party of China
October 18, 2017

Implementing Unit

Financial Support

Technical Support

Domestic Supporting Institutes

College of Environmental Sciences and Engineering, Peking University
State Grid Hebei Economic Research Institute
North China Electric Power University

Foreword

China is in the beginning of an energy transition with the aim to build an energy system for the future. The 19th Party Congress in October 2017 confirmed and reinforced the direction and ambitions to complete the development of a moderately prosperous society by 2020; to achieve basic modernisation by 2035 and build a great and modern country which is prosperous, strong, democratic advanced, harmonious and beautiful by 2050. Strong emphasis is placed on the transition of the development of the economy from High Speed to High Quality, a paradigm shift which shall also be adhered to in the energy sector. With the important milestones for 2020, 2035 and 2050, it is the policy of China to develop a "clean, low carbon, safe and efficient energy system".

This year's China Renewable Energy Outlook (CREO 2018) uses these ambitions as a starting point for defining a clear vision for the energy system in 2050. A vision which can not only support a continuation of economic development but also complies with the ambitious energy and environmental objectives for a sustainable ecological civilisation. A roadmap for implementing this vision is analysed and compared with the development pathway from the current policies influencing the energy system development. Finally, the report analyses the short-term policy measures to promote renewable energy as part the energy transition.

It is my firm belief that working with visions for the future is a necessary step in the energy transition process. Without strong visions for the energy system, the transition process will be too incremental and inevitable fail to achieve the long-term goal. On the other hand, the vision must be rooted in comprehensive quantitative analyses of the whole energy system to demonstrate how the visions can be realised and to link the energy system development with the enabling policy measures.

The energy transition is a complex process with many stakeholders and with many, often conflicting interests. It is my hope that CREO 2018 can contribute to a build a strong analytical platform and a foundation for the policy making and eventually for the successful energy transition in line with the overall goals from the 19th party congress.

Like the previous years, the CREO 2018 has been developed by ERI and CNREC in a strong cooperation with national and international partners. The research has been made possible by funding from the Children's Investment Fund Foundation and from the Danish and German governments. This strong and on-going support is invaluable for the quality and depth of the research and I am grateful that we can continue this unique cooperation between energy experts and donors.

Wang Zhongying

Acting Director General, Energy Research Institute of China Academy of Macroeconomic Research / China National Development and Reform Commission.

Director, China National Renewable Energy Centre

Summary and Key Recommendations

Introduction

Favourable Conditions for Coal Built the Current Energy System

In three Five-Year plans - from 2000 to 2015 the 10th, 11th and the 12th - coal and oil have been strongly promoted as the main fuels for China's economic development. The coal power plants have been pampered with favourable dispatch rules, access to cheap capital, promoted by strong state-owned companies, and strongly supported by local governments. The industry has been allowed to surge coal consumption without the necessary consideration for the environment, and the transport sector has made the oil consumption rise to a level, where two-third of the consumption is imported.

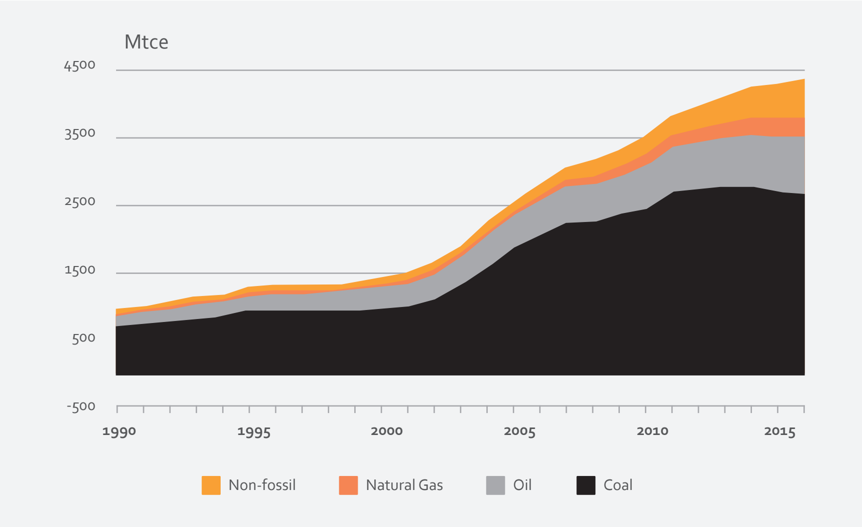


Figure 1
China's total primary energy demand (Mtce) 1990-2016

This build-up of the energy system has enabled rapid economic growth, but is also responsible for severe pollution of air, water and soil. The energy system is characterised by low energy efficiency, cost-efficiency has not been in focus in the energy sector, and China has become increasingly reliant on imported fuels.

Renewable energy has been promoted, but only as an add-on to the existing system. The result has been high curtailment of wind and solar power due to lack of integration into the power system and relative high subsidy levels to compensate for the additional risk factors for RE projects.

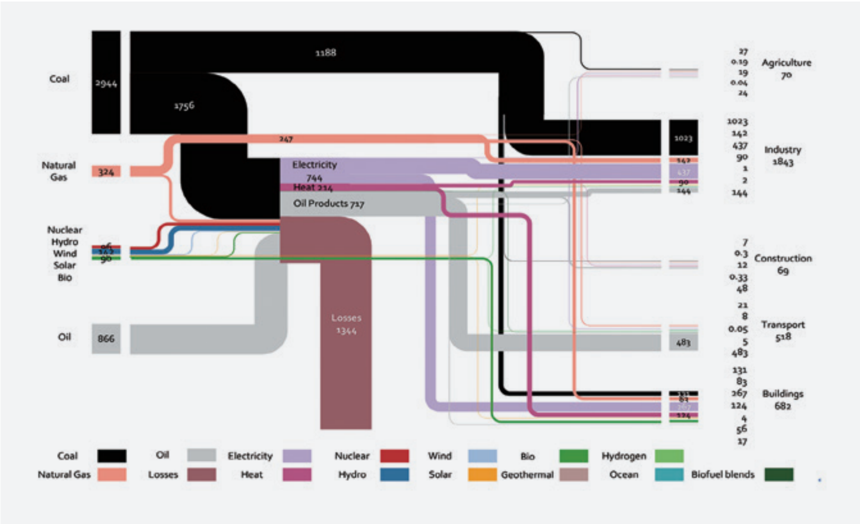


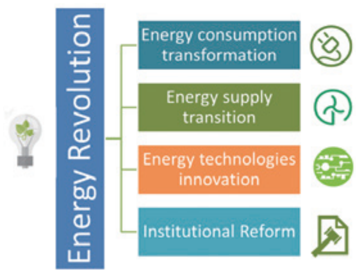
Figure 2
China's energy balance (Mtce) for 2017

Shift in Focus from Coal to Ecological Civilisation

The 13th Five-Year plan changed this development trajectory. The plan introduces ambitious targets for the future energy system development, "to build a clean, low-carbon, safe and efficient energy system and safeguard the energy security". The favourable conditions for coal power plants have been lessened for new plants, planned and approved coal power projects were stopped or delayed, an effort to better integrate renewable energy was launched, and more focus has been put on development of electric cars as a long-term solution for the ever-increasing oil-dependency in the transport sector. A power sector reform was re-initiated, and an ETS system for CO_2 was launched as regional and national pilots. China launched an innovation plan, China 2025, with focus on quality instead of quantity and with new technologies, including renewable energy technologies and electric vehicles as strategic emerging industries, which should form the backbone of the Chinese economy in the future.

In 2017, The Chinese Government released its Energy Revolution Strategy, which includes four parts: energy consumption transformation to check unreasonable energy consumption and cap primary energy (coal in particular) growth; transition in energy supply with a focus on clean coal and renewable energies; energy technology revolution to stimulate innovation; energy system revolution with institutional arrangement.

Figure 3
The four pillars in the Energy Revolution Strategy



The 19th Party Congress Marks the Beginning of a New Era

The 19th party congress marks a new era for China's development strategy. The long-term (2050) and medium-term (2035) visions have become clearer and the concept of the "ecological civilisation" has been confirmed as a main driver for the economic development, with focus on clean air, clean water and clean soil, with equal attention to social and environmental sustainability, and with the clear understanding that economic development without ecological development is not any longer possible.

Hence the task for us in the research for the outlook for renewable energy in China is to make the ambitions from the 19th Party Congress concrete, quantitative and measurable, to set-up a feasible pathway towards the 2050 energy system, and to explore how such a vision can be implemented through short- and medium-term policy measures.

The Global Context

"We call on the people of all countries to work together to build a community with a shared future for mankind, to build an open, inclusive, clean, and beautiful world that enjoys lasting peace, universal security, and common prosperity." - Xi Jinping's report at 19th CPC National Congress

The Chinese energy transition should not be seen in isolation but rather in a global context because development trends in individual countries and regions impact possibilities and actions in other countries and regions.

Globally, climate concerns have become a main driver for energy transition. The Paris agreement set a new agenda for the global efforts to mitigate human made climate change, but it is also clear, that the world is not on track for meeting the Paris agreement goals.

The EU and Its Member States Move to Exceed NDC Commitments

The EU has set a long-term goal of reducing GHG emissions by 80-95% by 2050 compared to 1990 and set concrete targets for 2030 regarding emissions and share of renewables. EU has launched the "Clean Energy for all Europeans" package as part of the energy transition efforts. The package includes elements regarding energy targets, strengthening the harmonised energy markets and market regulation and measures on improving energy efficiency. Germany and Denmark are frontrunners in the energy transitions in Europe, and both countries have long term plans for the energy transition. In Germany, a special coal commission on growth, structural economic change and employment is working on a consensus among stakeholders on a deadline for the exit of coal and on a detailed plan for how to deal with the structural changes this will bring. In Denmark, a new energy agreement will eliminate coal consumption in the Danish power sector by 2030, replacing coal with wind and solar power along with biomass and biogas power generation.

The U.S. Sustains Progress on Energy Transition Despite Setbacks at Federal Level

The U.S. has seen several developments over the past two years that affect its energy transition. These include policy changes at the federal level eliminating policies related to climate change, state policies enhancing commitments to renewable energy, market reforms related to flexibility and distributed resources, and policy changes that could support energy storage paired with renewable energy. Independent of the federal government, several states and cities have formed the U.S. Climate Alliance to implement the U.S. NDC of economy-wide GHG reductions between 26-28% below 2005 levels by 2025 at the state level. A key policy instrument to achieve this goal has been the Renewable Portfolio Standard (RPS), versions of which have been enacted by 29 states. To date, RPS policies have contributed to 56% of the cumulative deployment of renewables in the U.S. since 2000. Since 2015, 10 states have raised or extended their RPS since 2015, and more states are likely to do so in coming years.

Mexico's Rapid Reorientation Exemplifies Feasibility of Complex Energy Reform

Mexico is an example of how a developing country with a high dependence on fossil fuels can launch a rapid and comprehensive turn-around of the energy sector, both in terms of institutions and mechanisms. A power market reform is expected to be fully implemented during 2018. Three years since the initiation of reforms, technology-neutral auctions have been successful in driving down costs of new clean generation capacity and attracting qualified investors, and there is potential for Mexico to become even more ambitious regarding clean energy. Hence the country is likely to meet its clean energy goals more rapidly than announced.

China's Development Strategy is a Platform for Renewable Energy Leadership

Take-aways from the Global context examples for China should be clear. China's leadership in key aspects of renewable technology development, and forward thinking in terms of linking long-term development with visions for an ecological society, and ability to direct implementation of central policy towards massive implementation is an enviable platform for decarbonisation and a position of strength. Strengthening targets as in EU countries in effort to exceed that of NDC commitments, is critical and feasible and comes tremendous benefits as demonstrated in this report. Opposing forces may stall but not halt the energy transition as exemplified in the U.S. But it also highlights the need to seriously address the vested interest and ensuring support in areas negatively affected by energy transition, with different approaches and outcomes in Germany and the U.S. as an example. A cost-efficient transition can be achieved by joint efforts to push down the costs of new renewables and integration technologies, and by rapidly modernising energy and market regulatory frameworks and mechanisms taking inspiration from best practices in both developed and developing countries as exemplified by Mexico.

The 2050 Energy System Vision for China

The Chinese 2050 Energy System is Clean, Low-carbon, Safe and Efficient

The Chinese energy system should in 2050 comply with all overall quality criteria, reflected in the 13th Five-Year plan and in the visions for an ecological civilisation as expressed in the 19th Party Congress:

- A clean energy system does not pollute the air, water or soil due to activities in the whole energy supply chain from mining to disposal of waste. This implies a drastic reduction of coal outside of the power sector, less coal-mining and efficient use of flue gas cleaning for the remaining coal-use in the power sector.

- A low-carbon energy system requires a general transition away from fossil fuels towards non-fossil fuels. Even though coal has the highest CO_2 content per unit of energy, oil and natural gas should also be restricted in a low-carbon energy system.

- A safe energy system is a reliable system, and a system with limited sensitivity to fuel import dependence. It follows that the use of oil and natural gas should be reduced since the inland resources are limited.

- An efficient energy system is efficient in the use of energy, meaning that useful energy is not wasted, the transformation losses are low and the energy efficiency in the end-use sectors is high. It also is a cost-efficient energy system, where the dispatch of the power system is based on least-cost optimisation, minimising the total cost for the whole system. Furthermore, planning and investment in new generation, and other energy infrastructure creates a cost-effective portfolio of assets working together to reduce overall costs. China has chosen to use the market forces as a decisive part of the economic transition and increasing the role of markets in the energy system specifically.

Combining these objectives, we get clear guidelines for the 2050 energy system of China:

- The dependency of fossil fuels, in particular coal, is reduced as much as possible, and substituted by non-fossil fuels in all sectors

- Energy efficiency is obtained by rigorous measures in the end-use sectors, by replacing thermal power plants with large conversion losses with renewable energy, particularly solar and wind which have low losses, and by electrifying the end-use consumption, primarily the industry and transport sector. Efficient deployment of distributed energy sources further reduces overall system losses.

- The economic efficiency of the energy system is ensured through efficient power markets, and an incentive and taxation system, reflecting the direct and indirect costs of energy supply. This includes efficient costing of CO_2 emission and other pollutants.

CREO Models and Scenarios

CNRECs Modelling Platform

The analyses in CREO is based on a comprehensive modelling platform for the Chinese energy system. The platform consists of an end-use model using the LEAP software, a power and district heating model (EDO) based on the Balmorel model, and an economic model based on national input-output tables.

The end-use model represents the main economic sectors on a national level and uses relationships between drivers, energy intensities and fuel mix to estimate the future energy demand. The EDO model is a mixed integer/linear programming model, optimising the combined power and district heating system. The model represents the energy system on a provincial level, reflecting the constraints in the transmission system, and optimising the dispatch of the power generations and investments in the future power system.

CREO Scenarios

CREO 2018 has two main scenarios: The Stated Policies scenario assumes full and vigorous implementation of the current and stated policies for the energy sector as expressed in the 13th Five-Year Plan and the 19th Party Congress. The Below 2 °C scenario goes further in the reduction of CO_2 emissions to support achievement of the Paris agreement goals. By comparing the two scenarios, it is possible to identify gaps between today’s policies and the 2050 visions, and how they can be bridged by enhanced policies, targets, and measures.

Key assumptions

Below, the main scenario boundaries and scenario assumptions are introduced.

Scenario Boundaries

The boundaries for the long-term energy and economic development are constraints to the deployment of various energy technologies:

- Renewable energy resources are constrained at provincial level, and wind and solar are divided into categories of costs, type and quality.
- Hydro power plants are limited to deployment of 532 GW, based on existing capacity and environmentally sustainable build out opportunities.
- Nuclear capacity is limited to 120 GW along coastal regions.
- CCS is not taken into account as a technology option, since no clear data on technology costs and performance is available.

Scenario Assumptions

The scenarios are based on the following main assumptions:

- The Stated Policies scenario assumes full and vigorous implementation of the current and stated policies for the energy sector as expressed in the 13th Five-Year Plan and the 19th Party Congress. This includes a power market reform and an national CO_2 emission trading scheme.
- Economic development objectives must increase GDP by a factor of 4 in real terms, from RMB 82 trillion in 2017 to RMB 324 trillion by 2050.
- Both scenarios actively supports the new economic development by creating markets for strategic emerging industries like electric vehicles, data centres and IT services with high consumption of electricity and clean energy technologies.
- Population is expected to be on today's level at 1.38 billion in 2050.
- The short-term goals in the 13th Five-Year Plan on energy will be fulfilled in 2020, as well as the targets in the Three-Year Action Blue Sky Protection

Plan, the 13th FYP for Environment Protection and the North China Clean heating plan.

- Energy efficiency vigorously reduces final energy consumption, e.g. in the Below 2 °C scenario is thereby 56% of a no improvement situation by 2050 and slightly higher in the Stated Policies scenario.

- Strong electrification of the final energy consumption, aiming at around 60% electricity in the end-use sectors.

- Focus on security of supply including strong efforts in reducing dependency of imported oil and natural gas.

- China achieves the goal of 10% of natural gas in total primary energy consumption by 2020 and in the Stated Policies scenario, natural gas consumption will increase to 15%. The Below 2 °C scenario does not require the share to increase after 2020.

- The 50% non-fossil electricity generation target of the Energy Consumption Revolution strategy is attained, and in practice exceeded in the scenarios.

- The Stated Policies scenario has the carbon intensity reduction target of 40-45% by 2020 and 60-65% by 2030, though this is not binding. CO_2 prices in the in the power sector rise linearly from RMB 50/tonne in 2020 to RMB 100/tonne in 2040.

- The Below 2°C scenario, the accumulated energy sector emissions from 2017-2050 is kept below 230 billion tons. This is based on several different simulations from the IPCC AR5 database with a greater than 66% chance of staying Below 2°C.

- Technology costs are assumed to have declining installation and operational costs per MW as well as quality improvements of RE technologies. Grid parity is achieved for most wind and solar installations in the 2020s on LCOE basis, and most mainstream RE is significantly less costly than fossil generation by 2050.

- Coal and natural gas prices follow the indexed development of the IEA

World Energy Outlook 2017 New Policies scenario in the Stated Policies scenario, and the IEA's Sustainable Development scenario in the Below 2 °C.

- Coal is constrained to 1 billion tons by 2050.

A Quick Overview of the 2050 Energy System

Based on the above-mentioned criteria the 2050 energy system can be described broadly as follows based on our Below 2 °C scenario. Greater detail is provided later in this summary and in the outlook chapters.

Lower Final Energy Consumption and Much More Electricity in Industry and Transport Sector

Due to the transformation of the Chinese economy, massive focus on energy efficiency and electrification of industry and transport sector the final energy consumption in 2050 is lower than in 2017 and the distribution on energy sources is much different.

Energy efficiency measures bring final energy consumption to 56% of consumption without increased end use efficiency by 2050 (down from 5045 Mtce). Ensuring efficient system integration of variable renewable energy is the primary power system development challenge.

Renewable Energy Replaces Fossil Fuels in the Energy Supply

The energy supply in 2050 is dominated by renewable energy, mainly wind and solar in the power sector. Coal consumption is reduced to a minimum, allowing for flexible use of the coal power plants. Oil is confined mainly to the transport sector and reduced through electrification despite significant higher transport activity in 2050. Natural gas does not play a big role in the energy supply in 2050 since it is too expensive compared with renewable energy sources. Hydro and nuclear power deliver a steady power production although both energy sources are limited in potential and siting possibilities.

Figure 4
Final energy consumption on different sector in 2017 and 2050

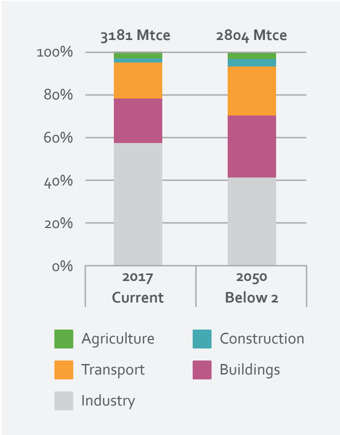
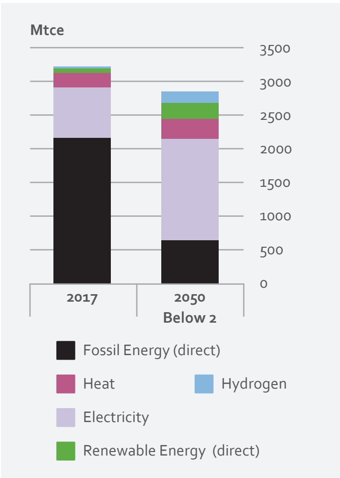


Figure 5
The shares of different energy sources in the final energy demand



The transformation of the end-use sectors and the supply system in combination with energy efficiency measures give a completely different energy balance in 2050 compared with the 2017 situation as illustrated in Figure 2 and Figure 7. Transformation losses have been reduced significantly, and renewables and electricity dominate the supply.

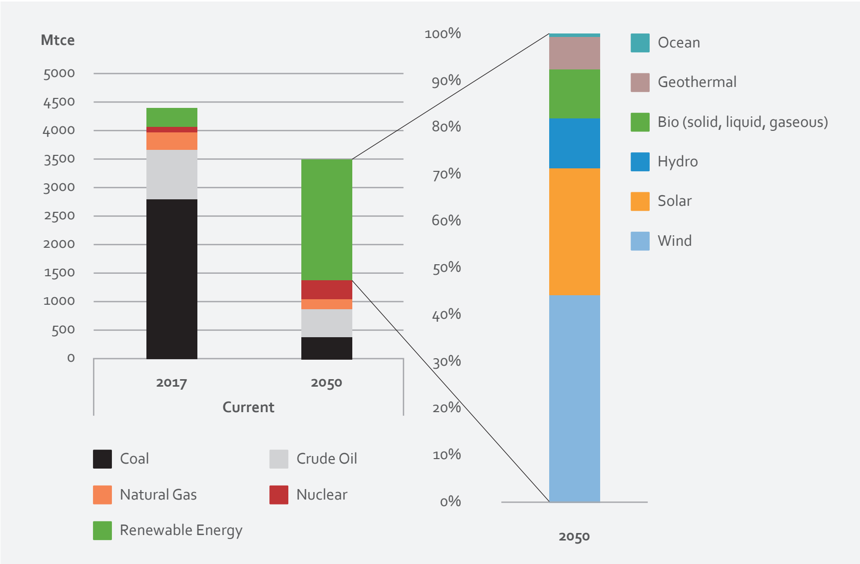


Figure 6
The primary energy consumption in 2050 in the Below 2 °C scenario compared to the 2017 (left) and the composition of renewable energy sources in 2050 in the Below 2 °C scenario (right)

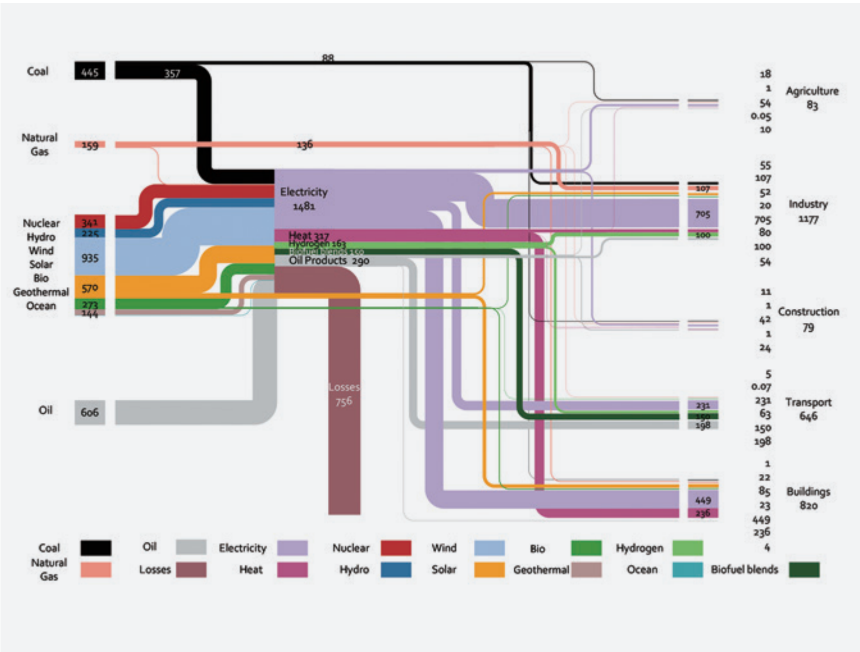


Figure 7
China's energy balance (Mtce) in 2050 in the Below 2 °C scenario

Power Economic Generation in 2050 Points to Renewable Electricity

In 2050 wind and solar will be the cheapest and most abundant sources of electricity – indeed, they likely already are, considering external costs – and the infrastructure and policies will be in place to ensure they can form the core of the power system.

Ensuring efficient system integration of variable renewable energy is the primary power system development challenge.

Wind and Solar Dominate Future Generation Investments by Default

Coal must peak in the short- or mid-term to meet air quality and climate goals. The price of gas, and dependence on imported gas, limits its development, and in the long-run so does its associated carbon emissions. Hydropower development is slowing due to environmental impacts and increasing investment cost. Biomass resources are scarce, and several other applications have higher value than power generation. Geothermal resources and development costs are uncertain, and ocean energy is in its infancy. Nuclear is restricted to coastal areas for safety reasons.

The Power System in 2050 is Dynamic and Radically Different from Today's

Characteristics in terms of mix of assets, dispatchability, operational paradigm, cost structure, operational timescales, and topology, will transform. The system cannot be operated according to today's principles, using today's sources of flexibility nor today's regulatory paradigms. Every aspect of the power industry will reinvent itself, from market designs and regulatory setups, to product and service definitions, to stakeholder roles. Converging on the 2050 power system will require substantial investments in new software alongside the hardware. Power system planning, innovation and reform must be forward-looking, and be able to manage uncertainty, variability and increasing complexity.

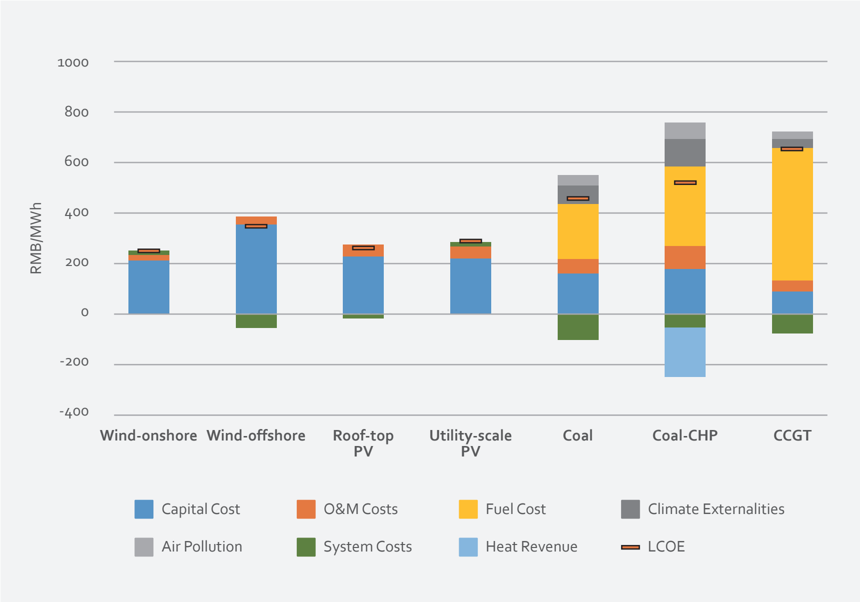


Figure 8
Levelised costs of electricity generation (LCOE, in RMB/MWh) in 2050

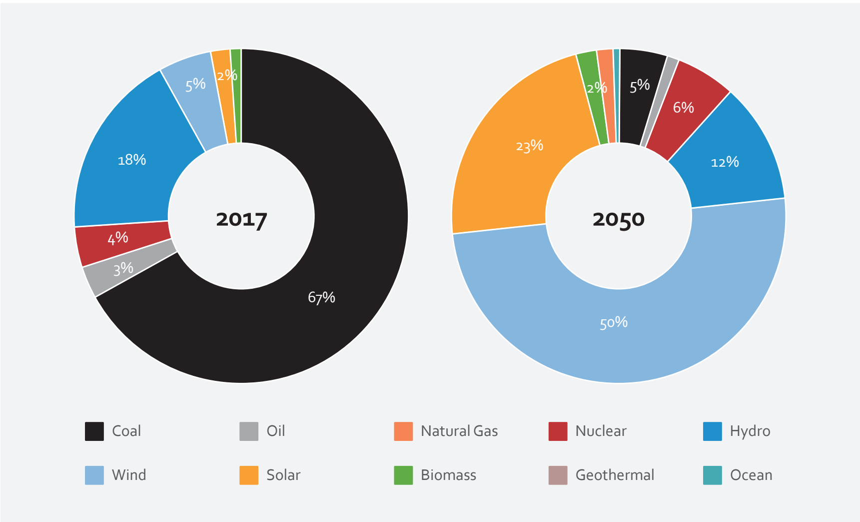


Figure 9
China's power generation mix in 2017 and 2050

Balancing the System in 2050 Requires Optimal Use of Flexible Resources

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

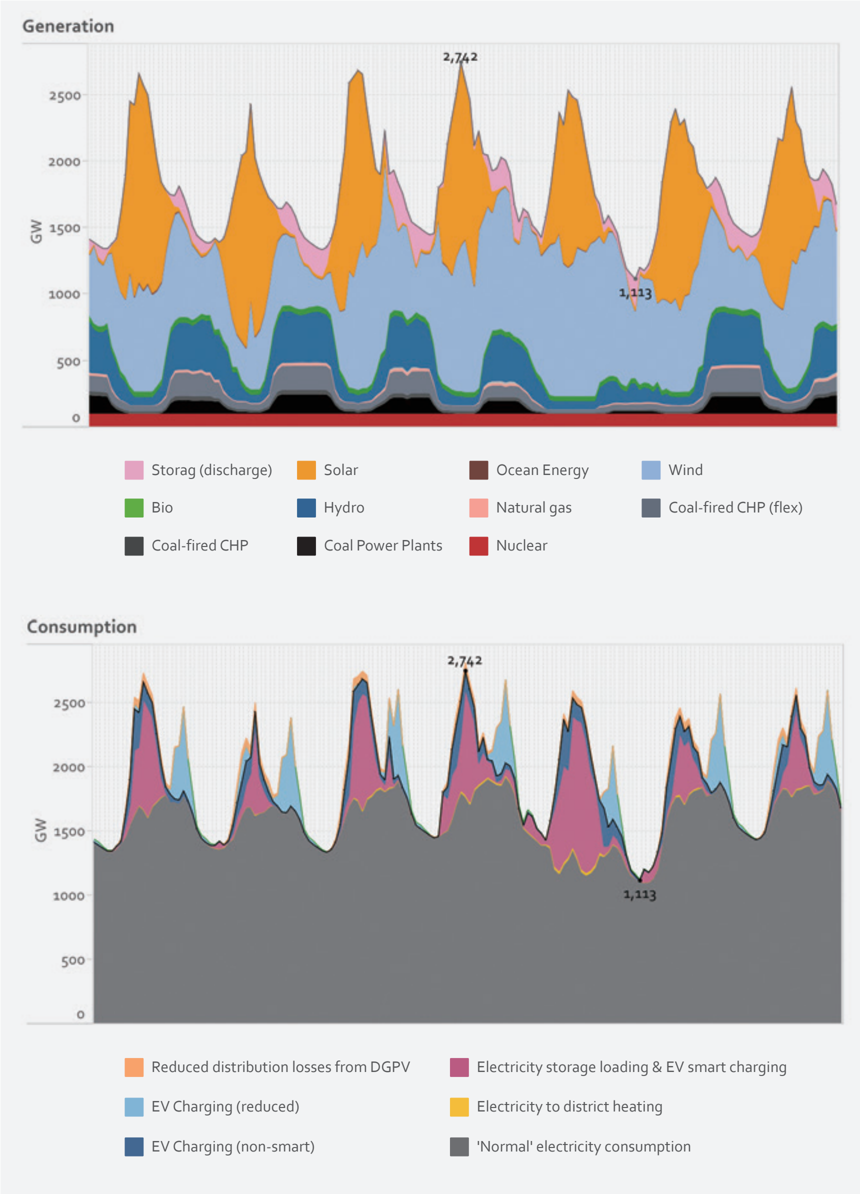


Figure 10
Hourly balance of supply and in China's power system in for a week in 2050.

The Development Pathway

To achieve the visions for 2050, the energy system must change rapidly in the coming years. In the Below 2 °C scenario coal is phased out of the end-use sectors onwards from now, electricity consumption increases rapidly from the mid-2020s, the use of oil (including oil products blended with biofuel) decreases throughout the period, and hydrogen (produced using electricity) is introduced as a new secondary fuel in the industry and transport sectors.

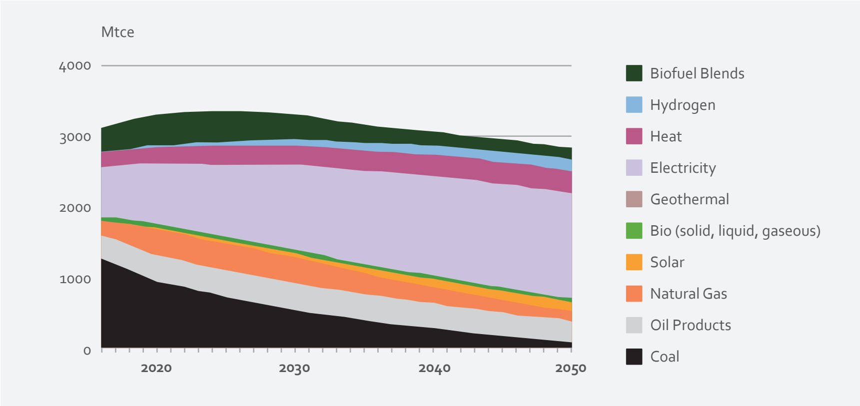


Figure 11
Total Final Energy Demand (Mtce) from 2016 to 2050 in the Below 2 °C scenario

Primary energy demand peaks before 2025 and wind and solar gradually become the dominant energy sources in the energy system (see Figure 12). Coal consumption is reduced throughout the period with an accelerated phase-out from the late 2020s. While Natural gas increases in the short term, it does not play a major role as a bridging fuel between coal and renewable energy, since renewable energy quickly becomes economically more attractive than natural gas in the power sector.

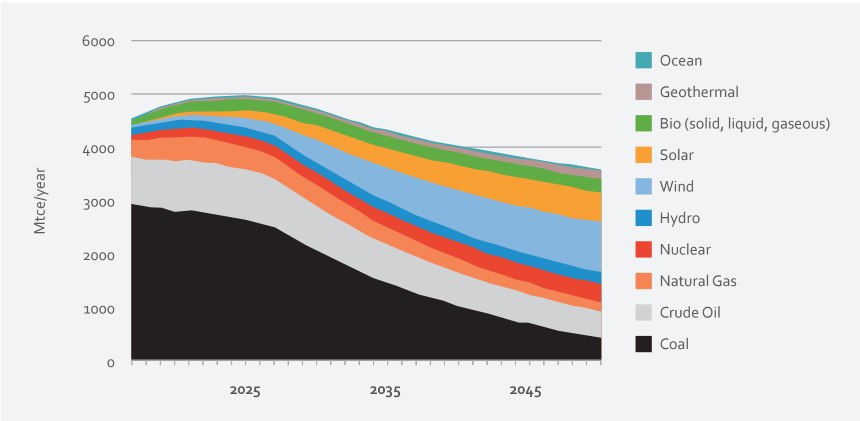


Figure 12
Total Primary Energy Demand (Mtce) from 2017 to 2050 in the Below 2 °C scenario

Renewable energy, especially wind and solar, is deployed throughout the period, most rapidly in the late 2020s, as shown in Figure 13.

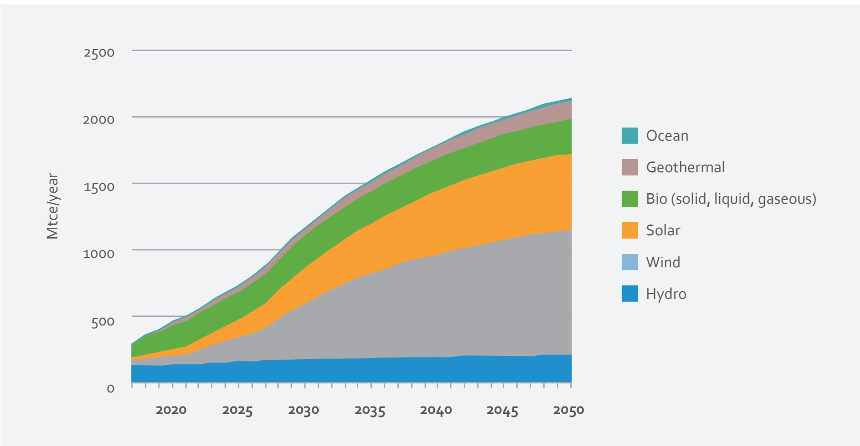


Figure 13
Renewable energy production (Mtce) from 2017 to 2050 in the Below 2 °C scenario

Key figures for the milestone years is shown in Table 1 and Table 2.

		Current	Below 2		
	Unit	2017	2020	2035	2050
Total Primary Energy Supply	**Mtce**	**4 360**	**4 640**	**4 167**	**3 483**
Coal	Mtce	2 806	2 648	1 351	387
Crude Oil	Mtce	864	939	716	487
Natural Gas	Mtce	306	441	334	164
Nuclear	Mtce	96	165	274	341
Renewable Energy	Mtce	288	448	1 492	2 105
Hydro	Mtce	142	153	199	225
Wind	Mtce	40	61	634	935
Solar	Mtce	22	47	378	570
Bio (solid, liquid, gaseous)	Mtce	83	165	206	218
Geothermal	Mtce	0	22	72	144
Ocean	Mtce	-	0	3	12
Total Final Energy Demand	**Mtce**	**3 178**	**3 283**	**3 134**	**2 805**
Coal	Mtce	1 192	945	391	88
Oil Products	Mtce	340	356	367	290
Natural Gas	Mtce	242	385	299	136
Solar	Mtce	4	11	73	137
Bio (solid, liquid, gaseous)	Mtce	58	65	63	44
Geothermal	Mtce	-	-	-	-
Electricity	Mtce	748	852	1 315	1 496
Heat	Mtce	213	238	288	317
Hydrogen	Mtce	3	10	107	164
Biofuel Blends	Mtce	381	434	262	160

Table 1
Key figures on Total Primary Energy Demand and Total Final Energy Demand for the Below 2 °C scenario in 2017, 2020, 2035 and 2050

	Unit		Below 2		
		2017	2020	2035	2050
Total Power Generation Capacity	**GW**	**1 746**	**2 108**	**5 366**	**6 814**
Renewable	GW	621	842	4 362	6 159
Hydro	GW	313	343	454	532
Wind	GW	163	221	1 826	2 664
Bio (solid, liquid, gaseous)	GW	15	48	64	57
Solar	GW	130	224	1 962	2 803
Solar CSP	GW	0	5	38	33
Geothermal	GW	0	1	5	20
Ocean	GW	-	0	13	50
Nuclear	GW	36	58	96	120
Fossil Fuels	GW	1 088	1 208	907	536
Total Electricity Generation	**TWh**	**6 313**	**7 859**	**13 324**	**15 324**
Renewable	TWh	1 676	2 186	9 545	13 488
Hydro	TWh	1 153	1 249	1 622	1 831
Wind	TWh	328	496	5 159	7 612
Bio (solid, liquid, gaseous)	TWh	44	146	221	268
Solar	TWh	151	277	2 380	3 439
Solar CSP	TWh	0	14	100	86
Geothermal	TWh	0	4	38	153
Ocean	TWh	-	0	26	100
Nuclear	TWh	257	442	735	915
Fossil Fuels	TWh	4 381	5 231	3 044	920

Table 2
Installed power generation capacity and total electricity generation for the Below 2 °C scenario in 2017, 2020, 2035 and 2050

The Stated Policy Scenario

The Stated Policy scenario is based on the current and stated policies regarding the energy transition, climate policy and environmental policy. Compared to the Below 2 °C scenario, the main differences in the assumptions and target setting are:

- More ambitious targets for CO_2 reduction in the Below 2 °C scenario to ensure compliance with a below 2 °C increase in global temperature

- Targets for use of natural gas until 2030 in the Stated Policy scenario, while the Below 2 °C scenario has no targets after 2020.

- Increased emphasis on electrification of end use consumption.

As a result, the Stated Policy scenario has a lower deployment of renewable energy after 2020, and a higher consumption of coal, oil and natural gas than the Below 2 °C scenario as shown in Figure 14, and the electrification of end-use consumption is also less than the Below 2 °C scenario.

As a result, the Stated Policy scenario has a lower deployment of renewable energy after 2020, and a higher consumption of coal, oil and natural gas than the Below 2 °C scenario as shown in Figure 14, and the electrification of end-use consumption is also less than the Below 2 °C scenario.

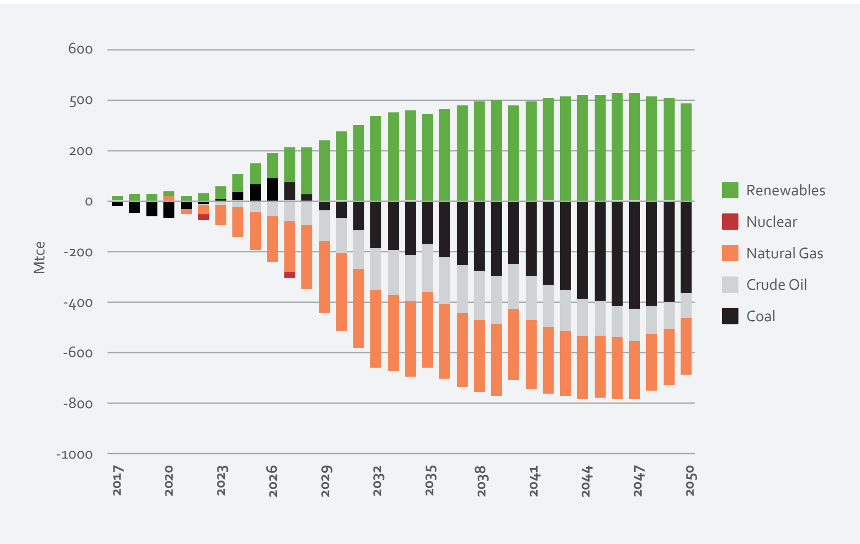


Figure 14
Differences in Primary Energy Demand (Mtce) between the Below 2 °C scenario and the Stated Policy scenario towards 2050

Compliance with the Beautiful China Energy System Visions

The quality of the two scenarios is measured by their ability to fulfil the policy visions for the energy system in 2050 – building a clean, low-carbon, safe and efficient energy system.

Clean 2050 System in Both Scenarios, but Cleaner Pathway in Below 2 °C Scenario

Air pollution from the energy system falls substantially by 2050 in both the Below 2 °C and the Stated Policies scenarios on all air pollution parameters except for ammonia (NH_3), which originates mainly from the agricultural sector. However, the Below 2 °C scenario projects a faster reduction of air pollutants than the Stated Policies scenarios. Black carbon (BC), organic carbon (OC), nitrogen oxides (NO_X), sulphur dioxide (SO_2), carbon monoxide (CO), and non-methane volatile organic compound (NMVOC) emissions are all lower in the Below 2 °C scenario in the 2030s due to the earlier reductions of coal and oil use in this scenario. This leads to relative reduction in pollution related cases of serious illness and premature mortality, resulting in significant socio-economic benefits.

In both CREO scenarios, total water consumption for energy falls despite a doubling of power production due to improvements in technology. Energy sector water consumption in the Below 2 °C scenario is much lower than in the Stated Policy scenario. In the Below 2 °C scenario, water consumption is reduced from 2020, while the Stated Policies scenario sees increased water consumption until 2030 after which it declines.

Significant CO_2 Reduction in Both Scenarios

IIn its design, the Below 2 °C scenario sets a limit on total CO_2 emission from 2017 to 2050 of 230 billion tons, aiming for China to provide a significant contribution to meeting the Paris agreement goals. Based on the allowable accumulated emissions, an annual CO_2 budget is established to ensure a smooth reduction from today's level to the 2050 level. The largest reduction in CO_2 emission is in the industrial sector, which is due to its extensive electrification. The power and district heating sectors also realise significant carbon emissions reductions despite doubling in electricity consumption.

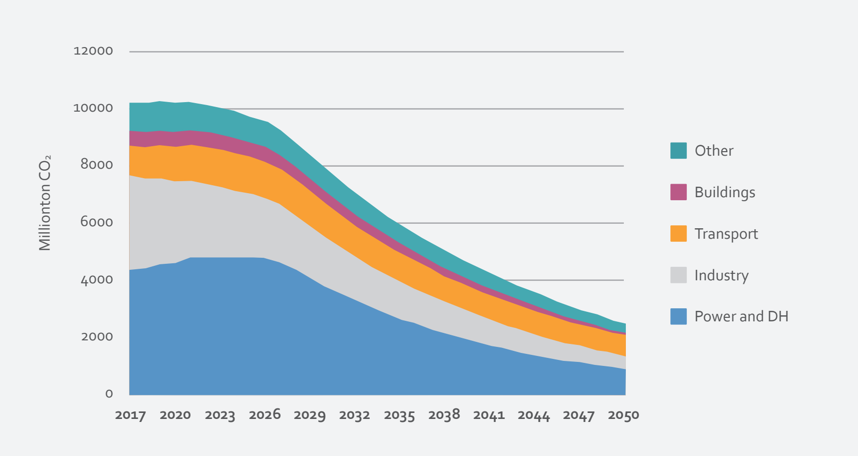


Figure 15
Energy related CO_2 emissions in the Below 2 °C scenario 2017 – 2050 on sectors

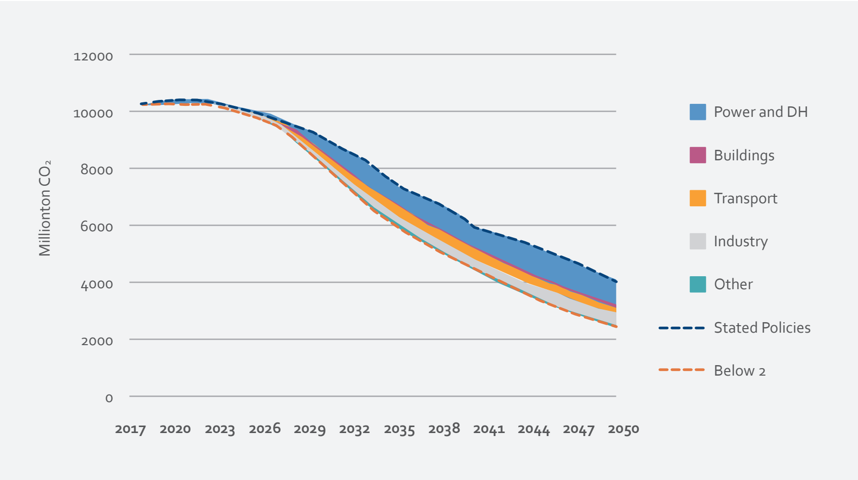


Figure 16
CO_2 emission and differences between Below 2 °C scenario and Stated Policy scenario 2017 – 2050

The Stated Policies scenario is less ambitious in terms of CO_2 emission reductions and does not comply with the CO_2 cap. Compared to the Below 2 °C scenario, the power sector has higher emissions.

Dependence on imported fuels significantly reduced

The energy system in 2050 is much more diverse in terms of the mix of different energy sources compared to the situation today, where coal and other fossil fuels dominate the energy supply. Dependence on fossil fuels declines to 40% in the Below 2 °C scenario and to 50% in the Stated Policy scenario.

Dependence on fuel imports is reduced in both scenarios as well. The Below 2 °C scenario has a quicker and deeper import reduction than the Stated Policies scenarios for both oil and natural gas, which constitute the main import challenge.

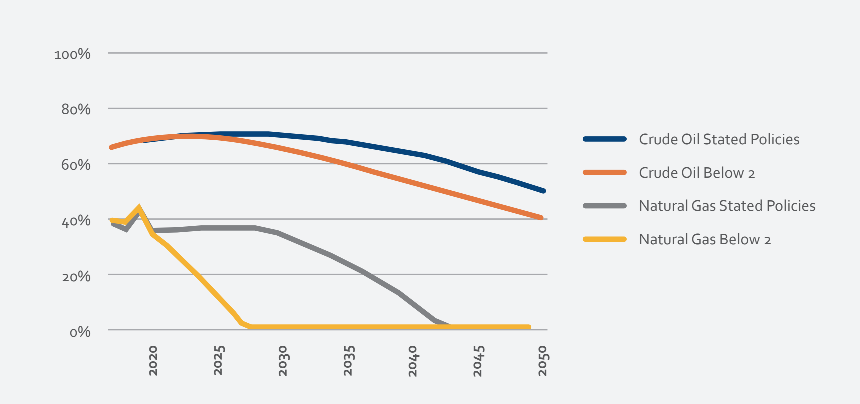


Figure 17
Import share of oil and natural gas in Below 2 °C scenario and Stated Policy scenario

More Efficient use of Energy

By 2050, China's primary energy consumption is only 80% of the 2017 consumption in the Below 2 °C scenario. Meanwhile, the gross domestic product (GDP) quadruples and energy intensity improves greatly.

In the two scenarios, energy efficiency offsets increasing demand for many end-uses. It compensates for the inertia in the industrial supply chain and enables the system to radically shift the energy mix. Increased efficiency also mitigates energy consumption growth in the buildings and transport sectors and flattens the upwards trends in final energy consumption between 2017 and 2050. On the supply side, the shift from coal-based thermal power plants with high losses to renewable energy without major transformation losses add to the energy efficiency of the entire energy system.

Cheaper Electricity in the Future

Due to continued cost reductions in renewable energy technologies and the gradual retirement of uneconomical assets, it is possible to supply electricity at lower cost than today. In both scenarios the cost of electricity supply is lower in 2050. The more stringent focus on CO_2 emissions reductions in the Below 2 °C scenario promotes a more rapid transition to an energy system based on renewable energy. As a result, society spends less on fuel and relatively more on infrastructure and system-related costs.

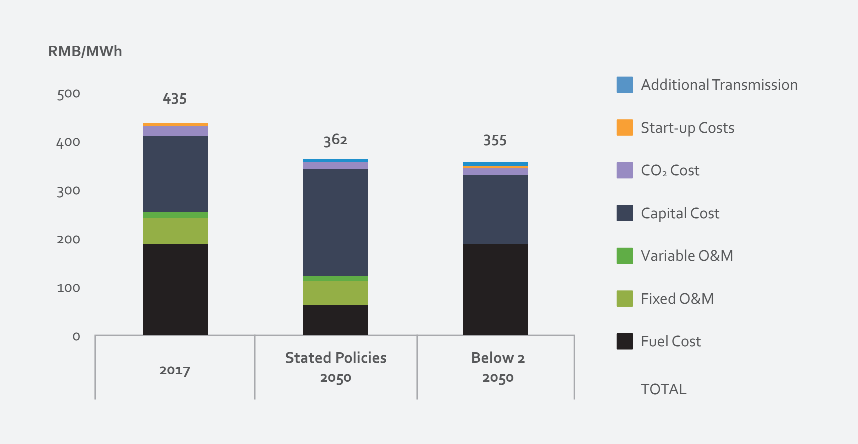


Figure 18
Power system costs (RMB/MWh) for 2017 and 2050 in the Below 2 °C scenario and Stated Policy scenario

Job Creation and GDP Impact

The rapid development of the renewable energy industry will play a positive role in promoting macroeconomic development. From 2025 to 2035, the swift growth of manufacturing scale will boost the demand for employment in sectors directly or indirectly related to renewable energy. This positive effect is greater than the negative effects related to a decrease in employment in fossil energy such as coal and thermal power generation.

The development of the renewable energy industry promotes the overall adjustment of the country's macroeconomic structure. The renewable energy supply chain covers electronic components, information and communication, computers, professional technical services and other industries. These sectors feature high added value and the modernisation of the economy.

Falling costs for renewable energy technologies will increase the operating efficiency of the energy industry. This creates development space for the provision of value-added services such as energy information and data analysis based on basic energy services, distributed energy, energy production and consumption (prosumer) services, energy storage, and EV charging.

Significant Progress in Stated Policy Scenario, Additional Benefits in Below 2 °C Scenario

In summary, all the criteria for the future energy system is greatly improved both in the Stated Policy scenario and the Below 2 °C scenario. However, from a comprehensive viewpoint, considering energy security, environmental impact and energy system costs, it is worthwhile taking the energy transition one step further than the pathway given by the current and stated policy framework. Hence, the Below 2 °C scenario could be the feasible vision and basis for the coming year's policy making.

Policy Measures to Promote the Energy Transition

In Part 3 of the CREO 2018 report several policy measures and crosscutting topics are discussed. Here is a short summary of the key findings in the different chapters in Part 3:

RE Incentives

China aims to change the policies for supporting wind and solar, shifting from fixed-support mechanisms based on feed-in tariffs to more flexible, market-oriented approaches, including auctions and renewable obligations. The changes include:

- Policies that will set renewable obligations for each province based on current renewable development, the renewable potential, and local electricity demand.

- A reform of subsidies for renewable energy, which will include auctions for onshore wind and solar PV, and relatively fixed tariffs for energy sources like biomass and ocean energy that have yet to reach scale. Price competition will be a central element of ensuring subsidies can be phased out, while continuing to promote growth in wind and solar.

- Other market reform measures essential to enabling renewable energy to compete without subsidies. These include reforming transmission pricing to prevent cross-provincial transmission fees and cross-subsidies from impeding export of renewables, adopting distribution grid reforms favourable for developing distributed renewable energy, reforming tax structures (including carbon and land taxes) to reflect external costs of various energy sources, enabling renewable energy (including distributed energy) to participate in spot markets as well as medium- and long-term power markets, and promoting green finance to support development of clean energy.

In this context it is highly relevant to look at international experiences on renewable energy auctions. Germany's auctions have featured strong participation, good project realization rates, and steadily falling prices for winning bids. Key factors in Germany's success include transparent procedural steps, a regular schedule for conducting auctions, regulatory stability to ensure bidders and project financiers have confidence relevant rules will remain in place and emphasizing technology-specific tenders to ensure steady development of the renewable industry. The chapter concludes by describing the characteristics of present auction policies in China and their future development.

Renewable Energy in Power Markets

Progress is being made in China's ongoing power market reform, and 2018 has seen a justified increased emphasis on the development of spot markets. This is a healthy development from the perspective of the integration of renewables. With the penetration of renewable energy increasing the question of how renewable generation should participate in and contribute to the price formation in the electricity market.

We describe how mandatory grid uptake of renewables and feed-in tariff (FIT) projects are the beginning rather than the endpoint of RE development. Renewable energy generation can participate in market trading in financial, day-ahead, intraday, and real-time balancing markets, as well as provide other ancillary services. The way renewables are considered in the market design, can significantly affect their profitability and exposure to market and regulatory risks. A balance should be struck to ensure that the market incentives are there to motivate efficient deployment and operation from a system perspective, while not impeding the energy transition by overburdening RE projects with risks, which translate into higher financing costs and prolong renewable energy technologies reliance on subsidies.

The power system reform has shifted from top-level design to implementation. The electricity market development has been tasked to provincial governments for design and implementation within their administrative jurisdiction. However, the electricity market requires further consensus regarding top-level design elements and a clear implementation path from provincial piloting to a well-functioning and integrated power market in China.

Carbon Pricing

Since last year's CREO, the Chinese national pilot for an emission trading system has been set-up for the power sector as a starting point.

This chapter begins with an overview of the current status of China's ETS, summarizes the experiences from Europe on the relationship between ETS and RE support policies, and gives an overview of the most recent changes in the policy setting for the European ETS.

In general, the European case does not involve direct coordination of renewable supports and targets with carbon markets. Instead, the European experience shows that a stability reserve mechanism, combined with retirement of excess allowances, has the potential to avoid excess allowance situations from developing.

The chapter concludes with recommendations for the next step in the further development of the Chinese ETS from a RE promotion policy perspective.

Interconnectors: Transmission

The chapter begins with an overview of China's power grid development:

China's grid has expanded rapidly in recent decades to meet demand growth and enable renewable integration. However, China's power grid development has been focused on large-capacity and long-distance UHV transmission, and many existing 500-kV and 750-kV inter-provincial and inter-regional transmission lines have seen low utilization.

China's system also focuses on single-direction transfers of electricity from sending regions to high demand regions, making the system less flexible that it could be. Meanwhile, barriers to trading power between provinces remain high.

Drawing on international experience, the chapter describes how European countries are working to optimize cross-zonal connections under the principle that bottlenecks and constraints should be resolved through investment wherever net positive socio-economic benefits can be achieved. Europe will likely evolve into a highly meshed AC grid with point-to-point connections to a few countries in the North and South, plus highly-flexible DC interconnectors between regions.

With the European case in mind, the chapter analyses the flexible use of interconnectors in China, showing that increases in grid flexible operation in China leads to substantially lower-cost electricity, reductions in CO_2 emissions, higher renewable energy penetration, and lower curtailment.

The Role of Distribution Grids

In centralized power systems with large thermal power plants, distribution grids are used to distribute electricity from the transmission grid to end consumers like households. In energy systems with increasing shares of RE, the role of distribution grids changes since they also become the connection point for the electricity feed-in of distributed generators. Power flows will become increasingly bi-directional, creating the need for new concepts to address the technical and procedural challenges that result from this change. The chapter describes briefly the situation in distribution grids in China, noting the following key points:

- China has increased the automation of its distribution grid somewhat, but the potential for improvement is still very large.

- The distribution grid still suffers from relatively low reliability.

- The distribution grid is unable to cope with high levels of small-scale distributed energy, storage, and electric vehicles.

As a result, China needs to rapidly upgrade and modernise distribution grids with smart grid technology, create policies to incentivise distribution grid operators to accept more distributed energy, and improve distribution grid pricing and business models to this end.

Demand Side Response

Due to the volatility of power generation from RE, more flexibility is needed in the power system in order to better integrate renewable energies and to ensure the stability of the power system. With flexible processes, energy consumers can contribute to the system integration of renewable energy. This chapter introduces the international cases of Germany and France regarding the use of DR in a market context, describes the current framework for the use of demand side flexibility in China, and offers suggestions for further action.

Successful implementation of demand response depends on full implementation of ongoing power market reform in China, including establishing markets for spot markets in wholesale power markets, as well as retail markets.

Demand response also depends on long-term and short-term price signals, and on whether all relevant parties can benefit from compensation for adjusting demand to reflect these price signals. Unbundling grid operation and retail sales could help resolve conflicts of interest that currently prevent efficient transmission of wholesale price signals to retail users.

Given the complexity of DR, stakeholder involvement is also critical. Stakeholders such as large industrial customers, aggregators, grid companies, and generators all need to understand the framework for DR and who can benefit and participate. This may require marketing campaigns, educational efforts, and pilots for industrial customers to gain and share experiences.

Heating

Given its situation with many large, dense cities, and high variety in potential waste heat providers and customers, China may opt for a regulated heat planning approach including environmental and climate benefits of heat planning. For rural areas, where unabated coal heating is still common, heat pumps and solar heating may offer the best solution. For cities, including small- and medium-sized cities, district heating may be the best option. Currently, waste heat from many power and industrial processes is wasted in cooling towers. While China has plans to expand combined heat-and-power, China could go beyond CHP and create integrated markets for heating and power. In particular, we suggest:

- Variable wholesale and retail prices for both heating and power are necessary to prevent market failures, such as curtailment of renewable energy in winter. With market incentives, district heating can become an efficient heat "battery" to store heat for when it is needed.

- In cold and severe cold areas and even in temperate areas district heating supply should be measured and delivered for both heating and domestic hot water supply all year.

- In areas with hot summers and cold winters and even in areas with hot summers large buildings should be equipped with ventilation systems, which can be heated in winter via district heating and cooled in summer with absorption heat pumps supplied with heat from district heating.

- Ensure energy and environmental taxes are applied efficiently at the level of units of emissions and fuel, to prevent double-counting of environmental attributes and effective price signals of external costs to users of heat and power.

Offshore Wind

China has ample offshore wind potential, but offshore wind development has lagged onshore wind and solar growth for several years. China's offshore wind projects have shown lower output than projected given available wind resources, and China's process for selecting offshore wind sites and project developers appears cumbersome and lacking in transparency. These failings have helped drive up the price of electricity from offshore wind, further slowing the development of this resource.

This chapter draws on international experience, particularly in Denmark, to present various suggestions on how to improve on the present pattern of offshore wind development in China, including the following:

- Carry out a thorough screening and planning before designating areas for offshore wind turbines, accounting for wind conditions, sea depths, grid connection options, seabed conditions, and marine life. Regulators should then rank the potential projects based on expected economic performance given these conditions and limitations.

- Developers should have greater flexibility to design the wind farm and choose foundations, turbines and other components, without local content requirements that can prevent innovation or restrict price competition for components and services.

- Involve all affected parties with interests at sea at government level already at the beginning of planning to avoid future conflicting interests. Consider clarifying competing interests such as shipping routes, environmentally sensitive sites, fishing areas, resources and extraction up front in planning.

- Employ existing studies on environmental impacts in the public domain before requiring expensive and time-consuming analysis as part of the EIA requirements. If no such resources are available, set up a general framework for environmental impact assessments (EIAs) and ensure their results are public for the benefit of future offshore wind planning.

Key Recommendations

Based on the analyses in CREO 2018, the following actions are recommended.

Coal and Oil Reduction Measures

The single most important step now is to reduce coal consumption in China. The following measures are proposed:

Keep Coal Reduction as a Key Priority Via Strict Controls

The decisions and targets for coal reduction must be enforced strictly to avoid stranded investments and reduce vested interests in a continuation of high coal consumption.

Stop New Coal-fired Power Plants Now

Investments in new coal power plants are unnecessary for a long period and such investments have a high risk of turning unprofitable. New coal plants also lower the profitability of previous investments by reducing the utilisation of existing power plants and maintaining the curtailment of wind and solar power. A moratorium on new coal power plant construction should be introduced immediately.

Reduction of Coal Use in Industry by Sectoral Rebalancing and Electrification

In the next years, cutting excess capacity in heavy industry and destocking property inventory should be promoted to ensure a decrease in demand for coal in industry. In addition, electrified steel-making and green cement production technologies should be promoted to further phase out the majority of the remaining coal demand.

Stop Growth in Oil Consumption by Encouraging Ambitious Deployment of EVs in the Transport Sector

The increasing import dependence for oil should be stopped via a continued effort to deploy electric cars in the transport sector.

Ensure a Sufficiently High Cost on CO_2 Emissions, Also in the Short Run

To build a low-carbon energy system a strict CO_2 cap on the energy sector is needed. Efficient carbon-pricing could be one way to include the costs of CO_2 emissions in the power price and thereby create a more level playing field between fossil fuel based power and renewable energy. The announced national pilot for CO_2 emissions from the power sector currently seems insufficient to ensure a high enough carbon price. Further measures should be considered as short-term solutions, including a carbon tax and/or a floor-price within the carbon market. In addition, carbon-pricing and carbon markets must include other sectors beyond the power sector, particularly as coal consumption is also large in the industrial sector.

Raise Deployment of Renewable Energy to A New Level in the Next Decade

According to the undertaken analyses, the 14th and 15th Five-Year plan periods should have significantly higher deployment levels of solar and wind power than the 13th Five-Year Plan period. This will further accelerate the economic viability of renewable energy compared to fossil fuel technologies. However, renewable energy remains vulnerable to policy choices, and it is important to focus on removing barriers for RE deployment and set incentives to encourage investors and developers to accelerate this massive effort. The following short-term measures would help move in this direction:

Clear Guidance for Power System Development

The moratorium on new coal power plant development should be followed by clear signals for promoting renewable energy. Absence of firm power sector reform implementation would impede necessary RE scale-up. Implementation of power market reform, including spot markets with expanded access for renewables, full technical flexibility of the existing coal fleet, shifting renewable installation to low curtailment areas, and completion of planned transmission corridors should enable resolution of curtailment by 2020, in line with government targets. This is imperative for renewable development in the 14th Five-Year Plan period, and any worsening of curtailment would risk stalling renewable energy cost reductions and jeopardise China's long-term clean energy targets. To reach a pathway to achieving the Paris agreement, the Below 2 °C scenario projects non-fossil electricity should reach 44% by 2025. In the 14th FYP period, annual solar PV installation should achieve 70-85 GW per year and wind 40-70 GW per year on average.

China should target non-fossil power generation to account for about 77% by 2035, and for renewable generation to supply at least 67%. Consequently also, the 50% non-fossil power generation target for 2030 should be increased.

Flexibility services should be valued, priced, and commercialised. Supply and demand sides provide different kinds of flexibility services, with efficient signals from power market. Grids and power markets should be increasingly interconnected, dynamically operated, according to the imminent needs of the system. Diverse flexibility resources will allow more efficient integration of renewables and faster reduction of CO_2 emissions. With the reductions in storage costs, 400-600 GW of accumulated storage capacity could be in the system by 2035. With increasing electrification, the demand side can increasingly provide flexibility, and smart charging of electric vehicles can play a central role in ensuring the system balance.

The key players in the power sector transformation must be the driving forces for the deployment of renewables. The large power producers should adapt their strategies for the future, the grid companies should adapt their planning of transmission for the new era, and local governments should play an active role in the transition from coal to renewables. The implementation of power sector reform will have a decisive role for creating the proper incentives for all stakeholders.

Remove Barriers for Distributed Generation and Offshore Wind

Deployment of renewable energy near energy load centres should be promoted via development of a smoother approval process. This requires stronger coordination between ministries and between central and local governments to remove institutional barriers for renewable energy. The off-shore wind planning and approval process should also be streamlined through better coordination between authorities.

Gradually Shift the Subsidy System to Avoid Stop-go Situations

A firm and clear pathway for transformation of the subsidy system for renewables will assist developers in project planning and implementation and reduce the potential risks for investors. Utilisation of auctions for large renewable energy projects could further reduce costs, while a stringent implementation of the renewable energy quota system would provide key players with a more central role in deployment and reduce the need for a continuation of feed-in tariffs.

China Renewable Energy Outlook

2018