

China Renewable Energy Outlook 2019

Energy Research Institute of Academy of Macroeconomic Research/NDRC
China National Renewable Energy Centre

Executive Summary

“Low-carbon energy development concerns the future of humanity.”

“China attaches great importance to low-carbon energy development and actively promotes energy consumption, supply, technology and institutional transformation.

The country is ready to work with the international community to strengthen energy cooperation in all aspects, safeguard energy security, address climate change, protect the ecology and environment, promote sustainable development and bring more benefits to people around the world.”

President Xi Jinping

congratulatory letter to Taiyuan Energy Low Carbon Development Forum

October 18, 2019

Implementing Unit



Financial Support



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Foreword	1
Key Recommendations	2
The energy transition has started, but an energy revolution is needed	2
Comprehensive energy transition to build the Ecological Civilisation	2
The 14 th Five-Year Plan should accelerate the energy transition	2
Continue the energy revolution in the next five-year plans	3
China's emerging energy transition	4
Energy consumption development	4
Energy sector investment	5
Carbon and other air pollutant emissions	5
Eight spot power market pilots have launched	5
Renewable energy in China	6
Major challenges for RE in China	9
Energy scenarios for China's energy transition	10
Ecological civilisation fuelled by clean, low-carbon, safe and efficient energy	10
Overview of the 2050 Energy System – The Below 2 °C scenario	13
Roadmap for Energy Transition	17
Sustainable economic growth while building the ecological civilisation	17
Clear capacity targets for renewable power development	18
Developing a coupled energy system with electrification as the crux	20
Strengthened energy efficiency targets needed for the next era	21
Strict coal controls to halve consumption by 2035	22
Breaking the curve of energy related CO ₂ -emissions	23
Policy emphasis in the 14th Five-Year Plan	24
Ambitious, but realistic end-targets for the period should be set	24
Clear guidance for power sector needed in 14 th Five-Year Plan period	24
The 14 th Five-Year Plan is key to reform of renewable energy policy	25
Renewable energy participation in the power market	26
Clean heating with a central role for district heating	28
Renewable energy gas	29
Biofuels	30

Foreword

In the 13th five-year plan, China launched the idea of an energy revolution with the aim to develop a clean, low-carbon, safe and efficient energy system towards 2050. Since then, there have been progress in a number of areas. The air in the big cities is cleaner today than five years ago, the share of coal in the energy consumption is lower, there has been a massive deployment of renewable energy, and new policy instruments like power market reforms, emission trading schemes and mandatory consumption target for renewable energy have been introduced.

However, this is only the beginning of the revolution. To reach the long-term vision of an ecological civilisation with an economic development within ecological boundaries, the efforts and pace of the energy transition must reach a new level. The benefits of a green energy transition are enormous and will enable China to continue the economic development into a moderately prosperous society with a reasonable economic growth, but it is important to realise that the transition will create both winners and losers in the short term when the energy system changes from black to green. Hence the transition process must address these challenges without losing sight of the long-term goal.

The next five years will be crucial for the energy transition. The 14th five-year plan will set the direction and pace for the transition, and China's commitment to the Paris Agreement in the coming years will be decisive for the possibilities to solve the global climate crisis. Therefore, this year's China Renewable Energy Outlook, CREO 2019, has a clear focus on the short-term actions in the context of the long-term visions for the Chinese energy system. The rapid cost reduction for solar and wind power gives basis for stepping up the deployment rate of these technologies, but a number of barriers must be removed to ensure a smooth and cost-efficient integration into the whole system.

The outlook has been prepared by ERI and CNREC, in close cooperation with national and international partners. It builds on the previous year's research and outlooks, but it is updated with the latest development and new analyses. The present summary report highlights the key findings and the key recommendations of the research. The detailed research is documented in the full CREO 2019 report, available from the program website www.boostre.cnrec.org.cn.

The research has been made possible by funding from the Children's Investment Fund Foundation and from the Danish and German governments. I would like to express my sincere gratitude to the sponsors and our partners for their support and hard work.

Wang Zhongying,

Acting Director General, Energy Research Institute of China Academy of Macroeconomic
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Key Recommendations

In *China Renewable Energy Outlook 2019* (CREO 2019) the possible role for renewable energy in the Chinese energy system is analysed and the scenarios provide a consistent vision as a foundation for policy development.

- The *Stated Policies scenario* expresses the impact of a firm implementation of announced policies.
- The *Below 2 °C scenario* shows a pathway for China for building an ecological civilisation and the role China could take in the fulfilment of the Paris agreement.

This summary report provides a concise walkthrough of the main insights of CREO 2019.

The energy transition has started, but an energy revolution is needed

China has developed leading capabilities and practical experience with core scientific, technological, and industrial fields necessary for building the new system to sustain the Ecological Civilisation; and it has the necessary policy blueprint for this next era.

The fossil economy, whose rapid expansion fuelled the revival of China's economy, must now be replaced by an efficient low-carbon system, tailor-made to the future's requirements. As stated in the 13th five-year plan an energy revolution is needed, or more precisely an *Energy Consumption Revolution* and an *Energy Supply Revolution*.

Comprehensive energy transition to build the Ecological Civilisation

The *Energy Consumption Revolution* is an Energy Efficiency Revolution with the key feature of deep electrification. Energy efficiency is a key demand-side pillar to ensure the pace and scale of supply-side deployments are adequate to support the required economic growth. Electrification is a means to drive fossil fuels from end-use consumption, in conjunction decarbonised electricity supply.

The *Energy Supply Revolution* is a Renewable Energy Revolution, with strong emphasis on renewable electricity. Technological progress and cost reduction make renewable energy able to provide the clean energy in bulk, particularly through renewable electricity.

The 14th Five-Year Plan should accelerate the energy transition

The 14th five-year plan period 2021-2025 will be a watershed in China's energy transition history. A confluence of developments provides risks and opportunities. Many renewable energy technologies are cost-competitive and removing the subsidy element from these technologies is a necessary step in the energy transition process to stop uncertainty in the short term. Fossil fuels' external costs remain largely untaxed, and the emissions trading scheme (ETS) needs refinement to promote renewable energy over coal. The delicate process of macroeconomic adjustment could invoke traditional policy responses, reversing the energy transition.

Mismanagement of the situation risks a reversal of RE development trends and a resurgence of fossil generation and investments, exacerbating technology lock-ins, more stranded assets and overshooting of China's GHG emissions vis-à-vis the Paris targets. Hence, strong and coordinated

policy measures are necessary to ensure the process moves in the right direction in a cost-efficient manner.

Key recommendations for the 14th Five-Year Plan

- Set ambitious, but realistic end-targets for the period: Achieve 19% non-fossil energy by physical energy content, target a reduction of energy intensity of the real GDP by 21%, and reduce CO₂ emissions targeting a reduction of real GDP CO₂ intensity by 27%.
- Leverage the cost reductions in wind and solar and scale-up the pace of RE installations, including averaging annual additions of wind 53 GW and solar 58 GW.
- Ensure supporting RE policies, such as strong RE purchasing requirements, after the transition from subsidy to market prices.
- Internalise fossil fuels' damage and/or abatement costs through the refined ETS mechanism.
- Pursue electrification with focus on industry to reduce coal consumption and transport to stymie the growing consumption of oil products.
- Avoid new coal power plants and conduct orderly prioritised closures of inefficient plants and coal mines.

Continue the energy revolution in the next five-year plans

To reach the 2050 visions, the energy revolution must continue and further accelerate in the 15th and 16th five-year plans. CREO 2019 shows a clear roadmap for the energy system development. It is, however, too early to come up with detailed policy recommendations for these plan periods. The planning process should be carried out as an iterative process, where research and analyses give basis for policy actions, while on the other hand the development process and new opportunities in technologies and institutional settings pave way for new scenarios and research. The main imperative in the process is to stick to the long-term visions and requirements given by the Chinese leadership for the Ecological Civilisation with a clean, low-carbon, safe and efficient energy system.

China's emerging energy transition

China is in the beginning of an energy transition with the aim of building an energy system for the future. The 13th five-year plan made it clear that China should start an energy revolution and, with the important milestones for 2020, 2035 and 2050, build a "clean, low carbon, safe and efficient energy system."¹ At the 19th National Congress of the Communist Party of China, President Xi Jinping confirmed that China will promote a revolution in energy production and consumption. The country's plans emphasise shifting economic development from high growth to high-quality growth, a paradigm shift that also applies to the energy sector.

Energy consumption development

China's energy trend shows slowing growth and improving efficiency

In 2018, China's GDP grew by 6.6%, the lowest level since 1990, and primary energy consumption reached 4,640 Mtce (136 billion GJ), an increase of 3% year-on-year. Gradual improvement in energy intensity of the economy continued: energy consumption per unit of GDP decreased 3.1% in 2018, indicating an increase in energy efficiency.²

Coal showed second consecutive year of absolute consumption growth in 2018

Residential consumption of coal has decreased due to policies aimed at controlling emissions. Nevertheless, due to industrial consumption growth, China's coal consumption reached 3.84 billion tonnes, an increase of 1% year-on-year.³ The proportion of coal used for power generation increased by 8% compared with 2017.⁴

China's crude oil consumption increased by 6.5% in 2018

Oil consumption reached 639 million tonnes, 3.4 times more than domestic output. Oil import dependence reached 72%, an increase of 2.4 percentage points from the prior year.

Natural gas consumption is the fastest-growing fossil energy source in China in 2018

Natural gas consumption increased by 18% in 2018, with a total volume of 282 billion cubic metres (bcm), 10 percentage points higher than natural gas production growth rate.⁵ China's natural gas production reached 160 bcm. Import dependence rose to 45.3%.⁶

China's 2020 target for non-fossil energy will be achieved

Non-fossil energy consumption accounted for 14.3% in 2018, implying China's 2020 target of 15% non-fossil energy will likely be achieved ahead of schedule.⁷

Electricity consumption continued to increase.

China's total electricity consumption in 2018 reached 6,846 TWh, an 8.5% annual increase, the highest annual growth since 2012. While accounted for 57% of the total consumption growth, the growth rate was higher in services (12.7% year-on-year) and households (10.4% year-on-year) than in industry which showed 7.1% growth year-on-year.

Energy sector investment

In 2018, China's energy structure has become more diversified, and the efficiency of the whole system improved. Although coal still dominates energy consumption, this is gradually changing, and natural gas has become a new growth point for fossil fuels.

Overall investment dropped while renewable energy is still attractive

In 2018, China remained the world's largest energy investment market, although its overall sector investment dropped by 1.5% compared to 2017.⁸ The investment of newly added coal-fired power plants decreased by more than 60% and energy efficiency improved by 6% in the past three years, which led to the investment decrease. In contrast, about 70% out of US\$ 120 billion invested in the power sector was spent on renewable energy.⁹

Natural gas infrastructure build-out continues

Due to shortages of residential gas supplies in winter 2017, China promoted the expansion of gas pipelines and LNG import terminals in order to increase gas supply capacity.¹⁰

China's EV and grid-side energy storage market has continued to expand rapidly

In 2018, the sales of all passenger vehicles in China declined for the first time since 1990, while new EVs continued rapid sales growth.¹¹ China has ranked as the largest EV market in the world for four years running, and 2018 saw 62% of global EVs sold in China.¹²

The grid-connected energy storage sector also showed strong growth in 2018. Newly built battery energy storage facilities exceeded 600 MW, of which 36% was on the grid side.¹³ Cumulative installed capacity reached 1,020 MW.¹⁴

Carbon and other air pollutant emissions

Carbon and major pollutant emissions intensity of production continued to decline

We estimate that CO₂ emissions intensity dropped by ~2% per unit of real GDP in 2018. In China's 338 cities at or above prefecture level, ambient PM₁₀ concentrations dropped by 5.3% and ambient PM_{2.5} dropped by 9.3% in 2018 versus the prior year, and the nationwide average number of haze days declined from 27.6 days in 2017 to 20.5 days in 2018. Acid rain measurements showed improvement in most Chinese regions with the lowest average frequency since 1992 when records began.¹⁵

New Blue-Sky Action Plan released.

The State Council issued a new three-year air pollution control plan in 2018.¹⁶ The plan focuses on reducing the total emissions of major air pollutants, and reducing greenhouse gas emissions, particularly in the Beijing-Tianjin-Hebei region, the Yangtze River Delta region, and the Fenwei Plain (Shaanxi and Shanxi) region, reducing the concentration of PM_{2.5} and the number of days of heavy pollution, and improving the quality of ambient air. This is the first time to include Shaanxi and Shanxi as targeted regions.

China's national ETS marks first anniversary

China's national ETS was officially launched at the end of 2017. At the time, the schedule for establishing the ETS called for a preparation phase, followed by trial operation, and then official operation. The ETS currently remains in the preparation period.

Eight spot power market pilots have launched

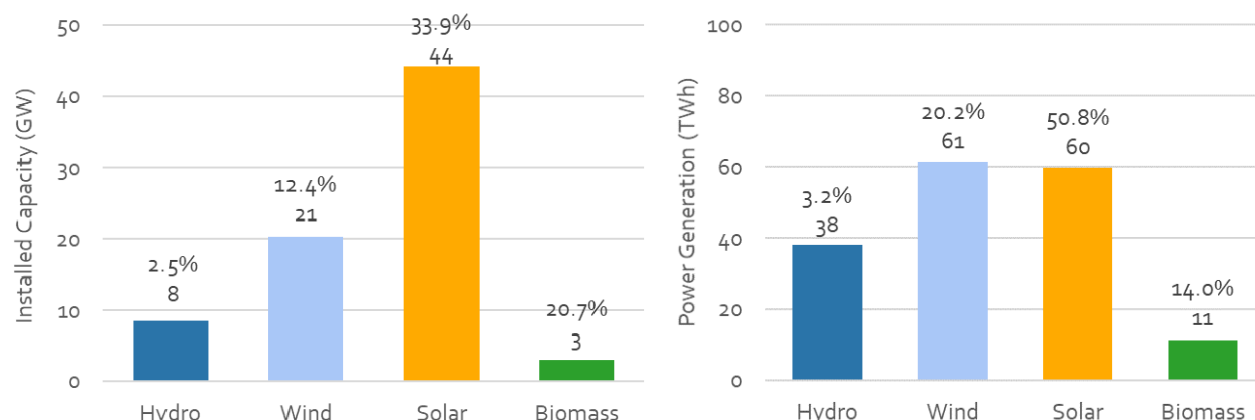
NDRC and NEA jointly announced the first batch of spot power market pilots in August 2017. These pilots covered eight regions and aimed to complete market designs by the end of 2018.¹⁷ Almost all pilots have faced delays.

Renewable energy in China

Current progress

China has made substantial progress on scaling up renewable power as well as reducing the cost of renewable energy in the past 20 years, and as a result China has fulfilled the 13th Five-Year Plan targets ahead of time. Wind and solar PV have gradually entered the post-subsidy era, and nationwide subsidy-free and FiT tendering projects will be the new trend.

Figure 1: 2018 Incremental installed renewable capacity (left); 2018 Incremental renewable power generation (right)



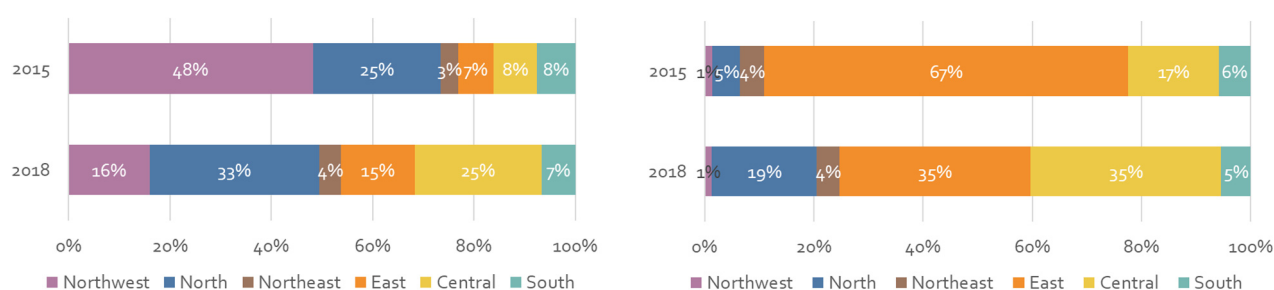
Source: Hydro data from China Electricity Council (CEC), January 2019; other data from China National Renewable Energy Centre (CNREC), March 2019

In 2018, the government promoted consumption of renewable energy via setting mandatory caps on curtailment and minimum consumption targets. Nevertheless, obstacles such as subsidy payment delays and unclear land use policies still remain. More long-term targets and measures are needed to meet the challenges and maintain healthy industrial development.

Major RE development regions shift from west to east

There has been a substantial switch in the distribution of renewable energy deployment. Historically, the resource quality was the main driver of project localisation. Increasingly, it is evident that proximity to demand, absence of curtailment reinforced by policy guidance, is determining for the geographical distribution.

Figure 2: Regional proportion of new grid-connected wind capacity (top left) and distributed solar PV capacity (top right) in 2015 and 2018; categorization of regional power grids (bottom)

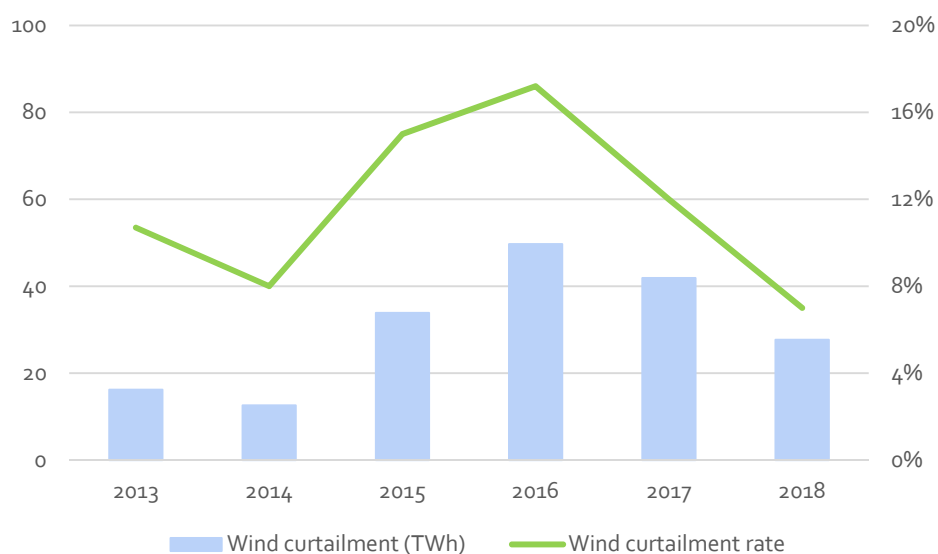


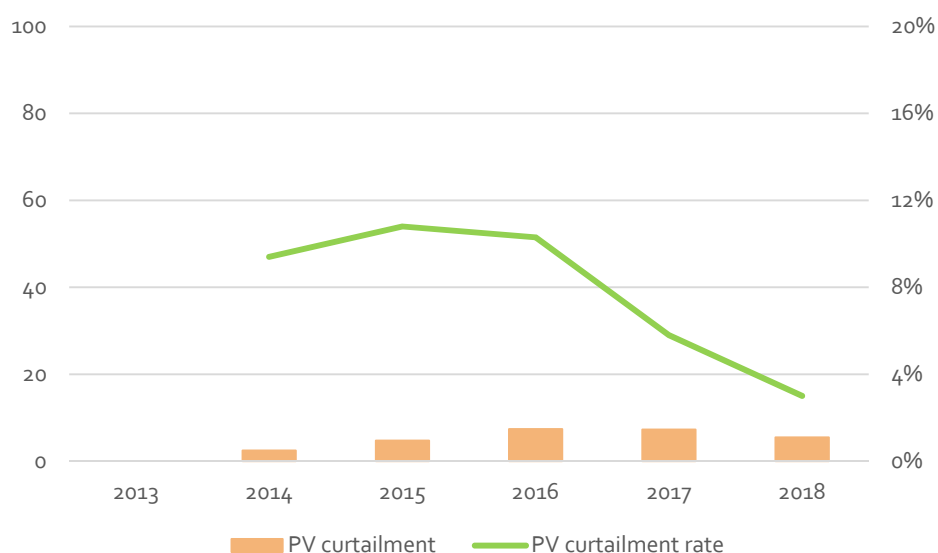


Renewable energy curtailment decreasing

In 2018, China experienced wind power curtailment of 7%, a five-percentage point improvement versus 2017. The majority of severe curtailment regions have improved: wind curtailment rates in Jilin and Gansu decreased more than 14 percentage points, while Inner Mongolia, Liaoning, Heilongjiang and Xinjiang experienced a reduction of more than five percentage points. China saw solar power curtailment of 3%, 2.8 percentage points less than in 2017. Xinjiang and Gansu saw the most improvement: solar curtailment rate decreased by 6 percentage points and 10 percentage points. Officials cited high renewable energy capacity, large scale thermal power plants and lack of transmission capacity as the main causes of high curtailment.

Figure 3: China 2018 curtailment of wind (top) and solar PV (bottom)



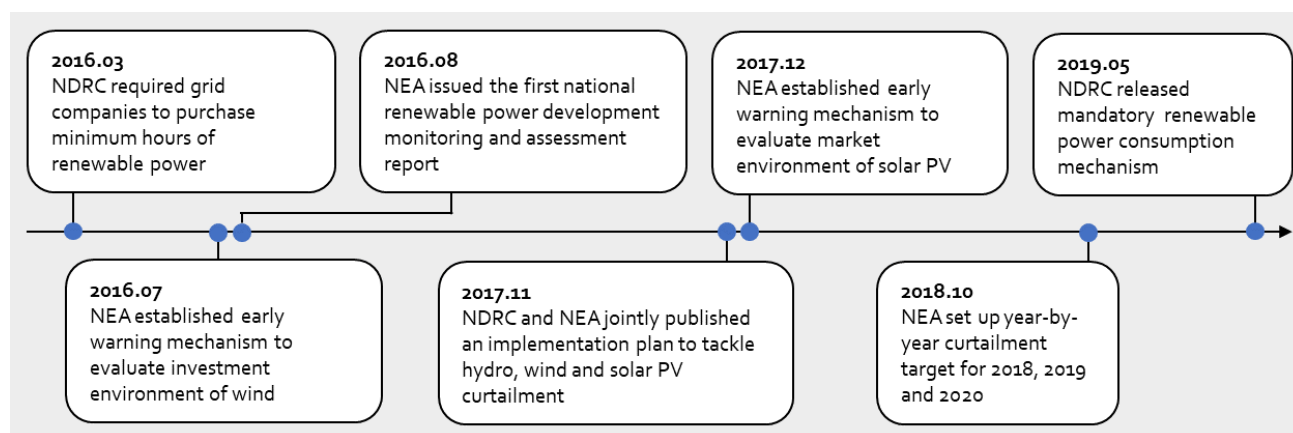


Source: China National Energy Administration, February 2019

In 2018 and 2019 a number of policy measures have been launched to promote the deployment of renewable energy. As part of a three-year clean energy consumption action plan, aims to substantially reduce the curtailment of wind and solar with a more focused deployment plan and by promoting on interprovincial exchange of renewable energy.

Also, a mandatory renewable energy consumption mechanism has been launched, with quotas for each province, requiring power retailers and end-users to increase renewable power consumption.

Figure 4: Development of policies for renewable energy consumption



Source: NEA and National Development and Reform Commission (NDRC), accessed in July 2019

Wind and solar are almost competitive with coal

The rapid scale-up of wind and solar in China and worldwide has reduced costs for these technologies. The cost of wind power is around RMB 0.5/kWh in regions with typical wind conditions, down to RMB 0.35/kWh in the windiest regions. Solar PV has achieved the 2020 target of price competitiveness with the retail electricity price in 2018 and LCOE has declined to approximately RMB 0.37-0.51/kWh.

China has begun to shift from fixed feed-in tariffs to tendering and subsidy-free renewables

For new wind and solar power projects, tenders will gradually replace feed-in tariffs. The feed-in tariffs have been capped for solar power with a limit for the total subsidy amount. Besides the

subsidised deployment, NEA and NDRC encourage the deployment of subsidy free wind and solar projects. These projects receive special attention regarding removal of barriers and there are no capacity limits for these projects.

Besides these direct supporting mechanisms, distributed renewable energy project are also encouraged to participate in the various power markets.

Major challenges for RE in China

Despite these new policies, renewable energy development has encountered setbacks at the national, regional, and individual levels. On the national level, the implementation of the mandatory consumption mechanism remains unclear. The lack of flexible resources, up-to-date energy and power systems planning, renewable electricity consumption has become a long-standing challenge. Subsidy payment delays, interference in market trading and pricing by local governments, and increasing soft costs all bring risks for renewable projects. More long-term targets and measures are needed to meet the challenges and maintain healthy industrial development.

Energy scenarios for China's energy transition

CREO 2019 continues the tradition from previous outlooks by defining two core scenarios for the energy systems development. The scenarios provide a clear and consistent vision for the long-term development as basis for short-term decisions

Ecological civilisation fuelled by clean, low-carbon, safe and efficient energy

The *Stated Policies scenario* expresses the impact of a firm implementation of announced policies, while the *Below 2 °C scenario* shows a pathway for China to achieve the ambitious vision for an ecological civilisation and the role China could take in the fulfilment of the Paris agreement.

Scenarios' strategy

Economic growth is a bottom-line precondition of China's socioeconomic objectives for 2050. It is required that GDP grows 4.2 times from 2018 level in real terms by 2050. However, the growth shall be sustainable and supported by the transition of the Chinese energy system – an essential component in the efforts to build China's Ecological Civilisation.

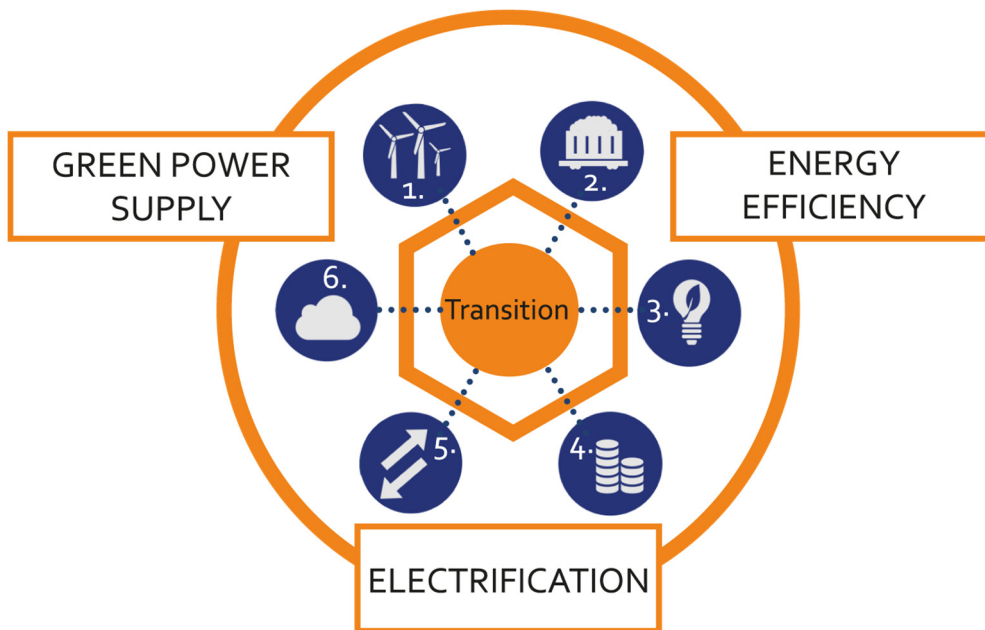
The strategy for the energy transition explored in CREO 2019 relies on three pillars:

- **Energy efficiency** is a key 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 drive fossil fuels from end-use consumption, in conjunction decarbonised electricity supply.
- **Green energy supply** – technological progress and cost reduction makes RE able to provide the clean energy in bulk, particularly through renewable electricity.

The strategy is supported by key drivers:

1. **RE promotion:** Supporting frameworks must ensure continued development, as subsidies are phased out.
2. **Coal control:** Coal is the main culprit of China's environmental challenges and greenhouse gas emissions, requiring firm control of both production and consumption.
3. **Energy efficiency measures:** Energy efficiency potentials in China's energy system are profound but must be supported by strong policy. This goes hand in hand with the restructuring of the economy towards less energy intensive sectors.
4. **Power markets:** Power market reforms shall deliver significant efficiency gains, enabling electricity to be a cost-competitive energy carrier for more consumption applications. Increased variable generation makes dynamic short-term power markets important for motivating comprehensive balancing participation.
5. **Flexible power system:** Variable generation will become the crux of the power system, and flexibility services a prerequisite. Cost-efficient transition requires using all cost-effective sources including generation, demand, grid and storage.
6. **Efficient carbon control policy:** Pricing and control of carbon emissions is promised to be guided by market forces under the national emissions trading system being piloted in the power sector, to be further expanded to all main emitting sectors.

Figure 5: Drivers of the energy transition in the scenarios



Stated Policies scenario expresses firm implementation of announced policies

The scenario assumes full and firm implementation of energy sector and related policies expressed in the *13th Five-Year Plan* and in the *19th Party Congress announcements*. Central priorities are the efforts to build a clean, low-carbon, safe and efficient energy supply. The scenario also includes the *NDC* climate target to peak in emissions before 2030, the effects of the *Blue-Sky Protection Plan*, aspects of the *Energy Production and Consumption Revolution Strategy*, and the *National Emissions Trading scheme*.

Policy trends are extrapolated to set the longer-term policy drivers.

CNREC's energy system modelling tool

The scenario's development in CREO is supported by CNREC's 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

The END-USE model, based on Long-range Energy Alternatives Planning system, LEAP (<https://energycommunity.org/>) represents bottom-up models of end-use demand and how this demand is satisfied. End-uses are driven by assumed developments in key activity levels specified for each subsector and the economic value added for where no other driver is available. 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.

Power and district heating sectors are modelled in EDO

The EDO (Electricity and District heating Optimisation) model is a fundamental model of power and district heating systems, built on the Balmore model (www.balmore.com). The power system is represented at 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 of electric vehicles and the option of a full 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 optimization. Key characteristics relate to the detailed representation of 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.

Below 2 °C scenario shows how China can build an energy system for the ecological civilisation

The main driver is a hard target for energy related CO₂ emissions through a strategy with renewable electricity, electrification and sectoral transformation at the core. The cap is set at 200 million tons of energy related CO₂ emissions in total between 2018-2050.

Main assumptions in the Below 2 °C scenario

- Population of 1.38 bn in 2050.
- GDP increased 4.2 times in real terms to RMB 380 trillion by 2050.
- Urbanisation rate of 78% by 2050
- Primary energy consumption stable after 2030 below 6 bn tce.

- Coal consumption restricted to 1 billion tons of coal (714 billion tce) by 2050.
- Natural gas to peak in 2040 in the range 580-600 bcm
- Diversified supply with significantly reduced dependence on imported fuels.
- Energy intensity shall be reduced by 85% relative to 2018.
- Non-fossil energy to cover 2/3 of primary energy.
- CO₂ emission 2018-2050 below 200 billion tons cumulative, and 2050 emissions less than 2500 million tons.
- Electrification rate above 60%

The Stated Policies scenario adopts a similar pathway, but with a less ambition electrification target (50%) and without a strict CO₂ boundary.

Overview of the 2050 Energy System – The Below 2 °C scenario

In CREO, the main scenario is the Below 2 °C scenario, since the scenario comply with all long-term goal to build a clean, low-carbon, safe and efficient energy system. Furthermore, China's contribution is essential for global efforts to comply with the temperature objectives of the Paris agreement. Hence, emphasis for the Chinese energy transition should be on the Below 2 °C scenario for a Low Carbon Energy system compliant with Paris objective.

In the following the main results from the Below 2 °C scenario in the medium- and long-term are presented and explained.

Table 1: Key result for the energy sector development in the Below 2 °C scenario

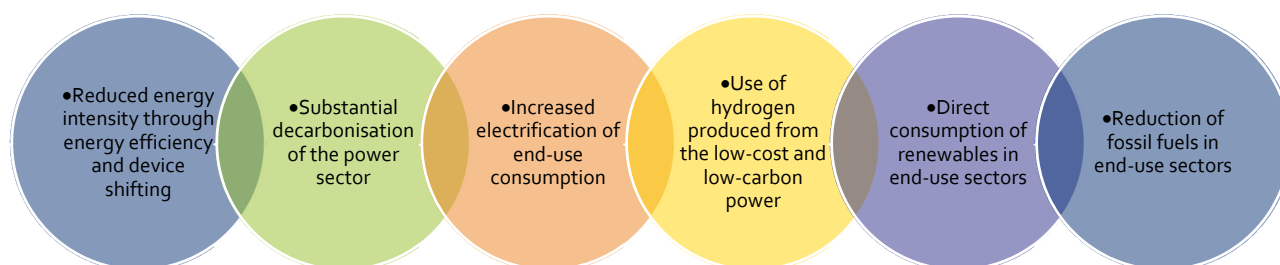
		2018	2020	2025	2030	2035	2050
Energy basis							
Total Primary Energy Supply (TPES)	Mtce	4 346	4 476	4 610	4 432	4 025	3 536
Total Final energy consumption (TFEC)	Mtce	3 165	3 252	3 396	3 438	3 349	3 046
CO ₂ emission	Mton	9 525	9 337	8 804	7 184	5 079	2 532
Non-fossil fuel share of TPES (NFF)	%	10%	14%	19%	29%	42%	65%
RE share of TPES	%	8%	11%	16%	25%	37%	58%
Coal share of TPES	%	61%	56%	47%	36%	23%	11%
Coal share of TFEC	%	33%	29%	20%	14%	10%	4%
Gas share of TPES	%	8%	10%	13%	15%	18%	16%
Oil share of TPES	%	20%	20%	21%	19%	16%	7%
Electrification rate	%	26%	29%	35%	41%	48%	66%
Coal substitution method							
Total Primary Energy Supply (TPES)	Mtce	4 684	4 891	5 253	5 549	5 603	5 766
Non-fossil fuel share of TPES (NFF)	%	17%	21%	29%	44%	59%	79%
RE share of TPES	%	15%	18%	26%	40%	55%	74%

Energy CO₂ emissions reduced 45% by 2035 and 75% by 2050 from 2018

The 2018 level of 9,550 million tons of annually energy related CO₂ emissions is reduced to 5,150 million tons by 2035 and 2,600 million tons by 2050. The scenario has approximately 195 billion tons of accumulated CO₂-emissions in the period 2018 – 2050, a pathway for China, which significantly and responsibly contributes to the global emission reduction effort.

The CO₂ emission reductions are realised through multiple measures as shown in Figure 6.

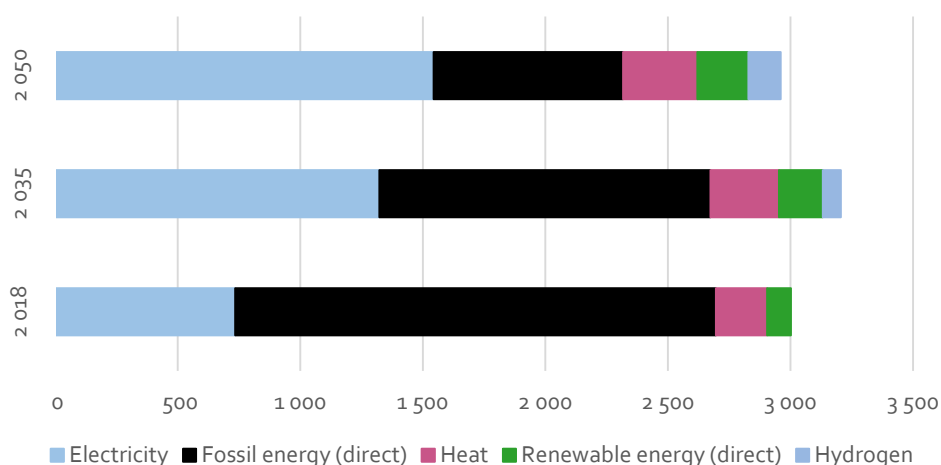
Figure 6: Measures to reduce CO₂ emissions for the Chinese energy system



Final energy consumption stabilises at current levels

Energy savings, device shifting, and economic restructuring, enables the 2050 total final energy consumption to be slightly below its 2018 level, at 3,050 Mtce/year. Until 2035, the final energy consumption increases to around 3,350 Mtce/year.

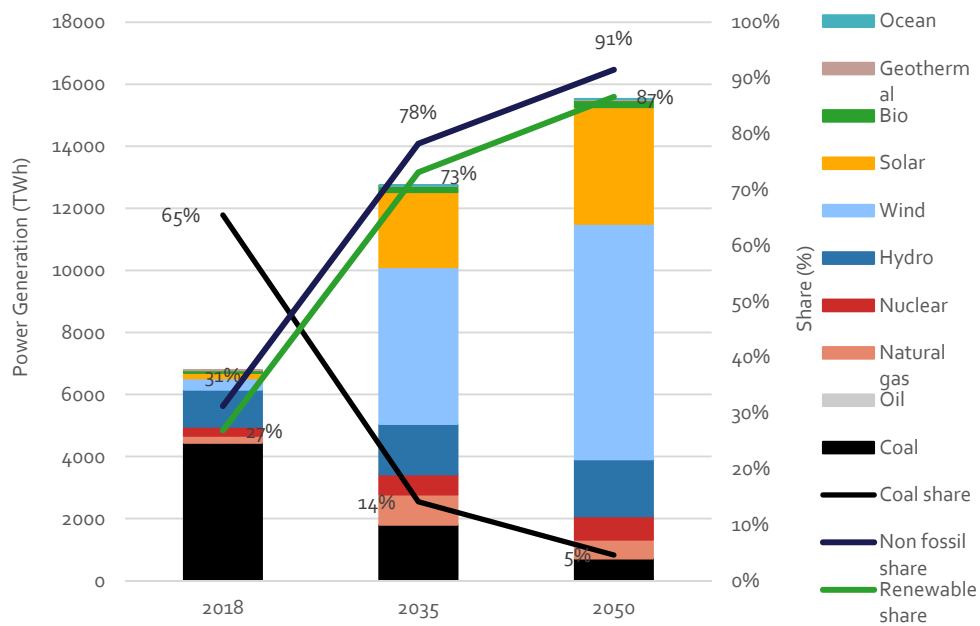
Figure 7: Final energy consumption by energy carrier in the Below 2 °C scenario (Mtce)



The energy transition is thereby able to support the targeted economic expansion without a long-term increase in final energy consumption, partly as consequence of the changes in economic structure, partly by improvements in energy efficiency of devices and production measures, as well as shifting away from direct use and combustion of fossil-fuels towards consumption of electricity.

Electricity is decarbonised with 78% non-fossil electricity by 2035 and 91% in 2050

This presupposes firm implementation of key policies including the ongoing power market reform and an efficient CO₂ ETS mechanism, ensuring a competitive level playing field for renewable electricity. Wind and solar account for the lion's share of this transition, with 58% of the total electricity generation by 2035 and 73% by 2050.

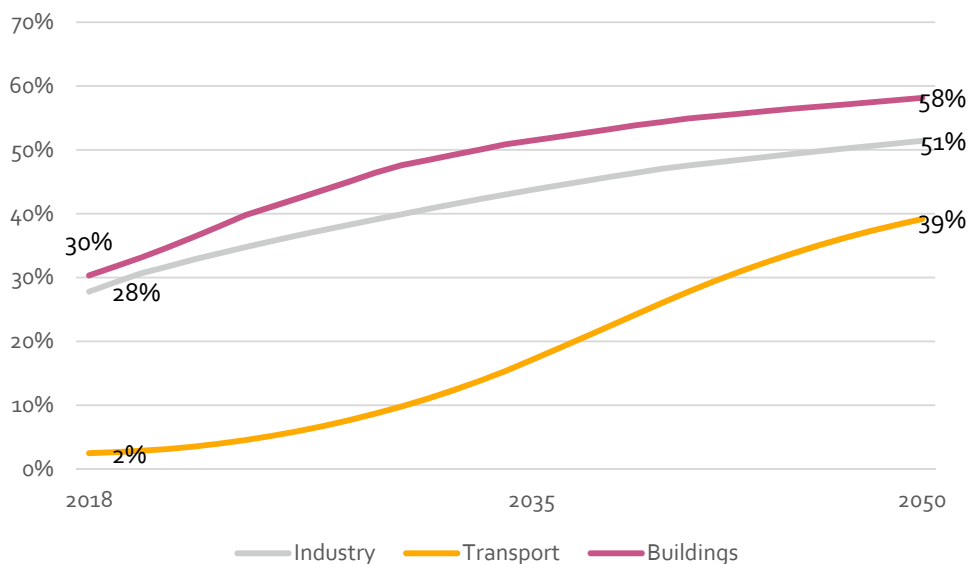


Electrification enhances the reach of decarbonised electricity supply

The IEA (2018) states in that “A doubling of electricity demand in developing economies, puts cleaner, universally available and affordable electricity at the centre of strategies for economic development and emissions reductions.”¹ Due to the cost-reductions in renewable electricity supply sources, electricity becomes an increasingly cost-competitive energy carrier and thereby a means to replace direct consumption of fossil fuels.

The electrification rate increases from approximately 26% in 2018 to 48% by 2035² to 66% by 2050. By 2050, transport sector has reached 39% electrification in the Below 2 °C scenario, from 2% in 2018. Industry has increased from 28% to 51% and buildings from 30% to 58%.

Figure 8: Development of electrification rate in transport, industry and buildings



¹ International Energy Agency. "World Energy Outlook." Paris (2018). <https://webstore.iea.org/world-energy-outlook-2018>

² The electrification rate is defined as the electricity generation / final energy consumption (including power plants own consumption).

Hydrogen offers feasible ways to expand the use of renewable electricity

The use of hydrogen produced by electricity is expanded in long-haul transport (as fuel), chemicals (as feedstock), and iron and steel (replacing coke). The share of hydrogen in the final energy consumption reaches 2.3% in 2035 and 4.5% in 2050, adding respectively 1,047 TWh and 1,536 TWh of electricity consumption.

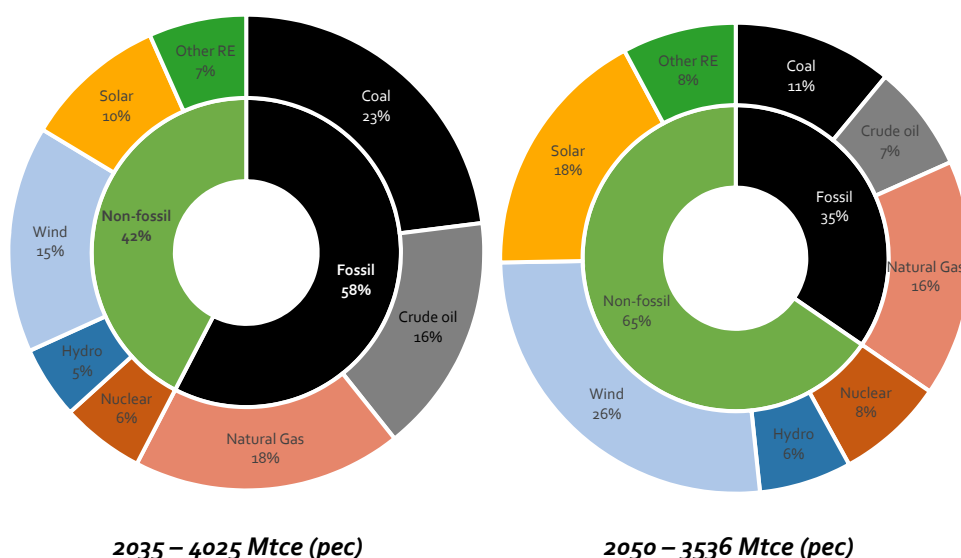
The heating system and the central role of district heating

Heat consumption in buildings grows from around 4,500 TWh/year in 2020 to around 5,900 TWh in 2050, with the consumption stabilising around 2035. Until 2050 district heating satisfies a stable ~50% of heating demand. Electric boilers, heat pumps and heat storages are deployed to scale, and deliver much needed flexibility to the power system. District heating and better-insulated buildings are main sources of building energy conservation.

Primary energy consumption mix is diversified as low-carbon sources replace coal

By 2035, coal's contribution towards primary energy consumption has been reduced by 62% and further by 82% in by 2050. Coal's share is reduced from approximately 61% 2018 to 11% 2050³. Natural gas' contribution to primary energy expands considerably from around 8% in 2018 to 18% in 2035 and 16% in 2050. Oil's contribution is reduced from 20% in 2018 to 16% and 7% in 2035 and 2050.

Figure 9: Primary energy mix after two coming eras of transformation (Below 2°C)



Non-fossil energy accounts for 42% by 2035 and 65% by 2050

By the coal substitution method of primary energy accounting, the non-fossil energy proportion becomes 47% and 59% in the two scenarios respectively. Thus by 2035, the non-fossil energy proportion would far exceed the official policy target of 20% by 2030, just five years later. ***It is apparent, that the official 2030 target should be increased as part of the Government of China's goal setting in the 14th five-year plan.***

³ These shares are calculated based on the physical energy content method (pec).

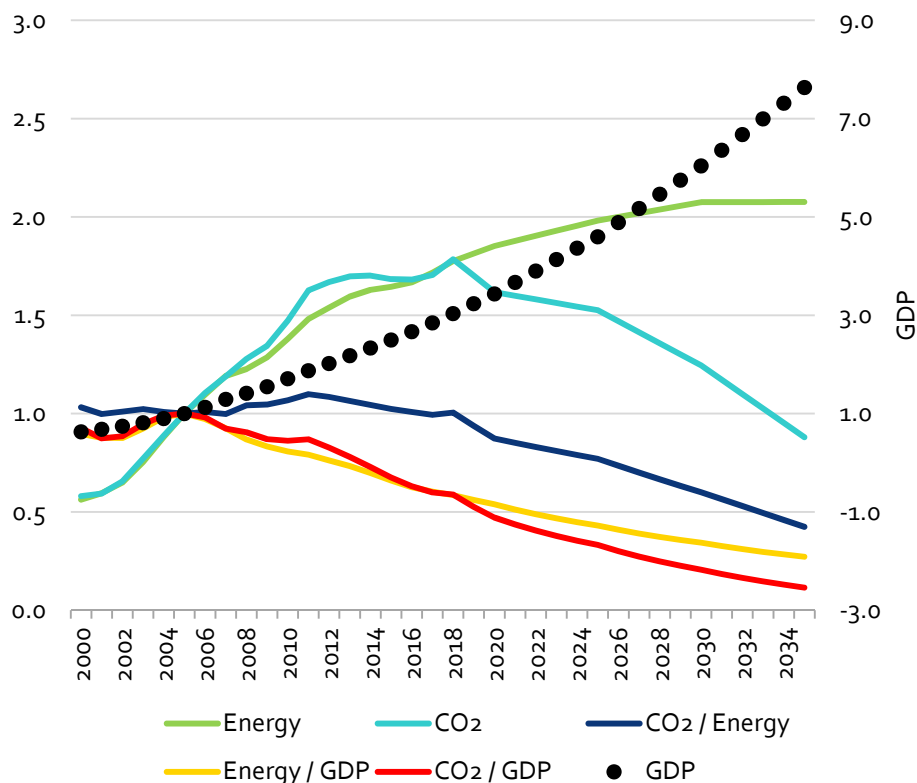
Roadmap for Energy Transition

The *Energy Consumption Revolution* is an Energy Efficiency Revolution with the key feature of deep electrification. The *Energy Supply Revolution* is a Renewable Energy Revolution, with strong emphasis on renewable electricity. Renewable electricity is the most cost-effective large-scale decarbonisation approach. To ensure that renewable electricity by 2035 is at the core of the energy system steps the 14th, 15th and 16th five-year plans are crucial.

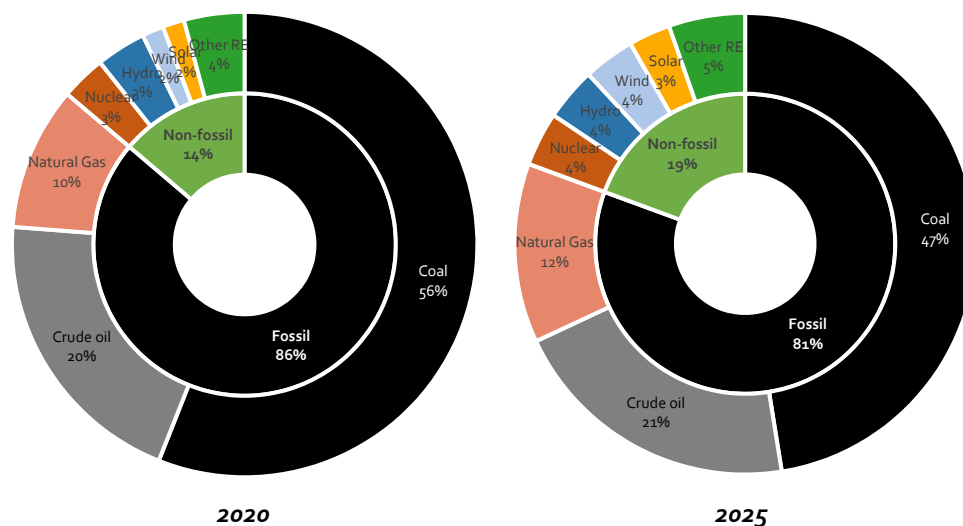
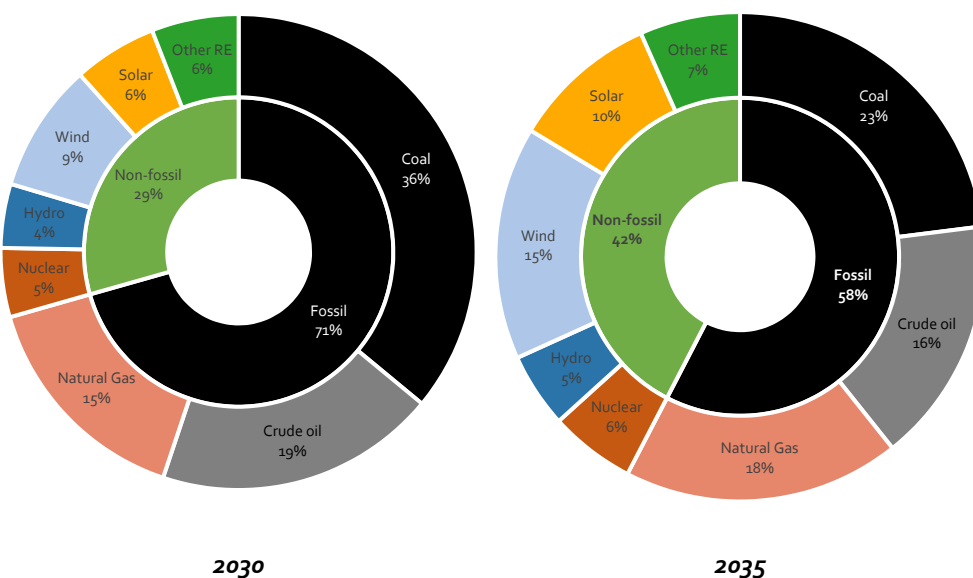
Sustainable economic growth while building the ecological civilisation

During the 14th FYP is expected to grow the economy by 34% in real terms from 2020-2025. Meanwhile, coal consumption declines by 11%, the War on pollution must be won, primary energy consumption growth should be limited to 6% (8% by coal substitution). Energy consumption intensity of the economy should be reduced by 19% and energy CO₂ intensity should be reduced by 27% - a total reduction of CO₂ intensity of 66% relative to 2005.

Figure 10: Kaya identity in the Below 2 °C scenario relative to 2005



The subsequent 15th and 16th FYP should grow the economy by 31% and further 26%, respectively. Energy consumption intensity should be further reduced by 20% and 21% in the 15th and 16th FYP respectively. Meanwhile, CO₂ intensity of real economic growth should be reduced by 31% and 36% in the 15th and 16th FYP.

Figure 11: Shift in primary energy consumption mix during 14th FYP (Below 2°C)Figure 12: Further switch in primary energy mix during 15th and 16th FYP (Below 2°C)

Note: Figure shows primary energy mix in terms of statistical energy content method

Clear capacity targets for renewable power development

While the cost of wind power and photovoltaic keeps decreasing in 14-FYP period, some projects still depend on subsidies from the government. It is important to maintain annual additional capacity targets for the projects, so that a level of industrial scale of equipment suppliers and construction ability can be maintained while the total amount of subsidy can be limited to an affordable level.

Renewable electricity deployment the next 3 five-year plans must a pattern of three steps:

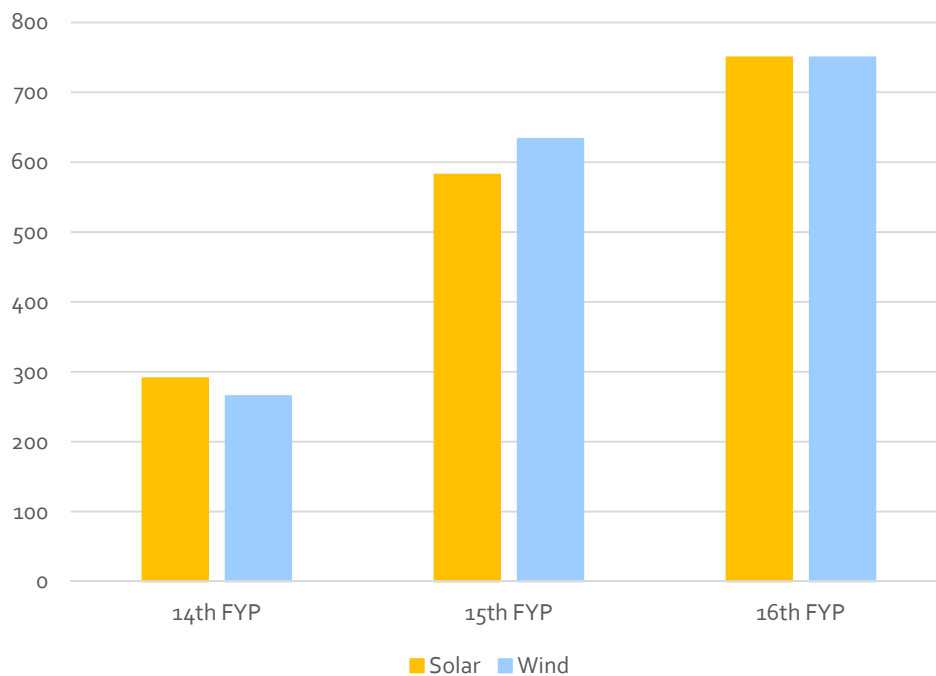
14th FYP – Industry scale-up: average annual additions of wind 53 GW and solar 58 GW

15th FYP – Establish: Wind averages 127 GW and solar 116 GW annually.

16th FYP – Revolutionise: ~150 GW per year of wind and solar

For the power sector decarbonisation, the critical targets to be achieved by 2025, is that wind power cumulative installed capacity exceeds 500 GW, contributing with potential annual generation of approximately 1350 TWh of electricity. Moreover, solar power cumulated installed capacity should reach 530 GW, and contributed with electricity generation of around 690 TWh.

Figure 13: Wind and solar installations under by five-year-plans



The 14th FYP period will be a critical phase for renewable energy installations, where in tandem with scaling-up the industry and annual deployment levels, investors and asset owners must learn to navigate the uncertainties of simultaneous reforms.

- RE investments must wean off the comfortable business model of fixed price subsidies and navigate the emergence of spot-markets as well as medium- to long-term contracting markets as these are developed.
- Investors and asset owners shall have confidence that they are able to capture adequate prices for their electricity generation, and that they will not be curtailed, while being exposed to the market. There must be evidence that system flexibility develops as needed; alternatively, they must develop more complex business models bundling VRE sources with own investments in flexibility and storage.
- The market must respond timely to the development of the demand for green, clean or non-fossil electricity – the pull from demand and the requirements from regulation. Finally, there must be confidence that, despite a slowing energy consumption growth resulting from energy efficiency and economic restructuring, there will be increased electrification, and that the authorities will abstain distorting the markets by supporting competing power offerings from coal and gas and depress the prices.

The 14th FYP should give priority to developing capacity and balancing capability near consumption centres, including giving focus on wind offshore developing, opening for more distributed siting of wind, and improving conditions for DGPV.

Table o-1: Suggested targets for 14th, 15th and 16th FYP period based on the Below 2 °C scenario

Category	Indicator	14 th	15 th	16 th
1. Renewable power generation capacity target (GW)	Total	1481	2.718	4.108
	1. Hydropower	386	438	455
	2. Wind power	507	1.109	1.763
	3. Solar photovoltaic	532	1.109	1.825
	4. Solar thermal power generation	4	9	11
	5. Biomass power generation	51	54	54
2. Renewable electricity generation target (TWh)	Total	3662	6.416	9.308
	1. Hydropower	1397	1.576	1.625
	2. Wind power	1347	3.160	5.053
	3. Solar photovoltaic	694	1.448	2.393
	4. Solar thermal power generation	11	22	28
	5. Biomass power generation	214	210	210

In the 15th FYP, the pace of RE capacity additions moves towards the peak, while growth rates in power consumption, drops to 3.5% p.a. on average. The 15th FYP must thread the needle of building the capacity for a long-term sustainable renewable energy industry.

The 16th FYP will be the period of disruptive transformation. We are past the economic tipping points with significant impact to asset utilisations. Wind and solar annual installations should reach their peak at around ~150 GW/year and new electricity storage should be coming online at the pace of 30 GW per year. Utilisation rates of fossil-thermal plants shall decline significantly, and strategic plant closures should be considered.

Developing a coupled energy system with electrification as the crux

Electrification plus renewables can economically displace fossil fuel consumption in other sectors. Meanwhile, the consuming sectors shall be developed to further support the electricity sector in maintaining the system balance cost effectively through provision of flexibility.

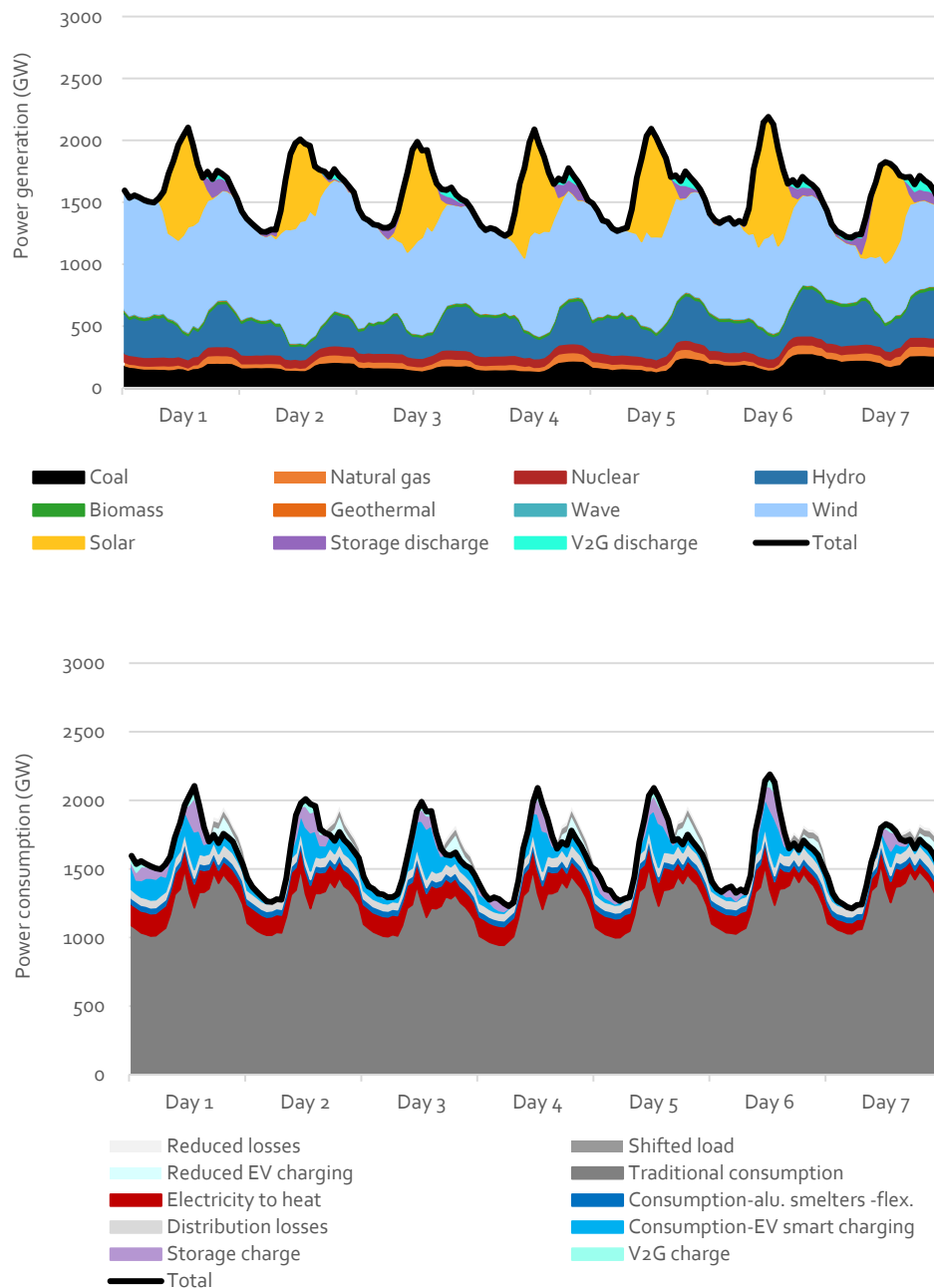
The 14th FYP should include targets and measures to support technologies an incentive to unleash the benefits of an efficient power and district heating coupling. The stock of individual heat pumps should be increasing and displace individual coal boilers and stoves. The number of EVs should increase to almost 33 million by 2025, and around 14% of the vehicle stock should be new energy vehicles (NEVS) including electric, hydrogen and plugin hybrids. For EVs, this shall be accompanied by charging infrastructure, with around 1 normal charging stations for every 10 EV's and around 1 fast charging stations per 100 EVs. Programmes and/or retail tariffs for EV charging should expose users to changing prices, such that smart charging is motivated.

Electrification should move to exceed 42% of the final energy consumption in industry, and industries should be exposed to fluctuating market prices, and motivated towards providing cost-efficient demand respond. Key energy intensive industries should be at the forefront. Scrap-based electric arc furnace steel should reach 30-32% by 2025.

By the end of the 16th FYP, the penetration levels of variable renewable energy will be high, and the availability of traditional thermal assets for maintaining the system balance including ancillary services shall reduce. Smart energy services, demand response from industrial and residential loads and electric vehicles must be deployed at scale. The district heating sector has achieved the tipping point, where large-scale replacements of thermal heating capacity, including CHPs are being replaced/supplemented by power-to-heat technologies. The energy internet becomes a reality, with data and digitisation supporting the timing, scheduling, adjustments and power

based on a comprehensive system of data on loads, prices, assets locations. This becomes possible with the introduction of smart meters as well as home energy management systems, etc.

Figure 14: Example of supply (top) and demand (bottom) side dispatch and flexibility in 2035.



Strengthened energy efficiency targets needed for the next era

The importance of energy efficiency in the energy transition cannot be overstated. The rapid pace required for scaling-up clean energy investments on the supply side is only sufficient, given that energy consumption is significantly decoupled from the economic growth targets.

In the 14th FYP energy efficiency measures must be defined such that the primary energy consumption per unit of GDP should decline by at least 19%. The measures shall support the transitioning of consumption from their current energy carriers towards electricity. Final energy consumption should remain below 3400 Mtce/year and primary energy consumption not grow above 4610 Mtce.

Energy efficiency shall take place both in the point of energy use and in the supply-chain. It can be achieved through better insulation and technology improvement in buildings (e.g., electric heaters will reach an efficiency of 98.1% by 16th FYP) as well as the promotion of efficient processes in industry (e.g., in steelmaking, EAF process will contribute up to 29% in steelmaking production by 16th FYP). Furthermore, the energy efficiency benefit of renewables should be recognized in setting targets for primary energy consumption. Until 2035, the final energy consumption increases to around 3,350 Mtce/year, while primary energy consumption should be contained below 4,025 Mtce/year.

Strict coal controls to halve consumption by 2035

While in the long run, the expanded national ETS system could be the preferred mode of coal and carbon containment, administrative measures are needed in the short-term.

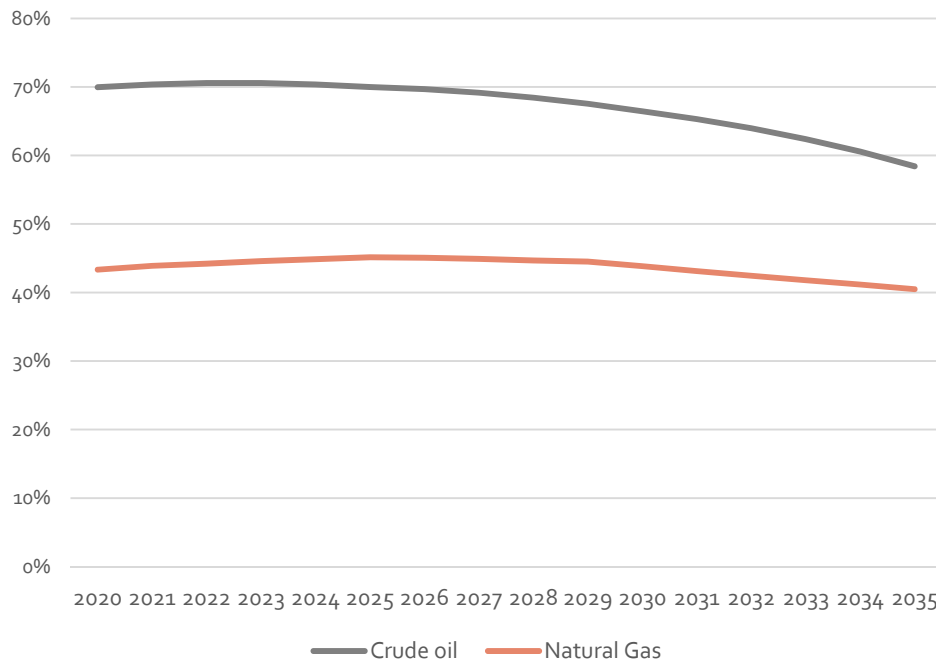
In the 14th FYP, the coal consumption should be reduced by 10%. The 15th FYP should implement further 24% reduction, and in the 16th five-year plan period the reduction should be 37%. Thereby the coal share of primary energy consumption is reduced to 47%, 36% and 23% by the end of the 14th, 15th and 16th five-year plans respectively. Preserving energy security by the energy transition

The energy transition must ensure that safe and stable energy fuels the economy in the next era of economic development. The rapid growth of oil consumption is potentially destabilising, as oil imports have been accounting for increasing percentages of the country's supply. While oil and gas imports will increase in absolute terms during the 14th five-year plan by at least 8%, the import percentage of oil can be stabilised.

The efforts to expand indigenous natural gas supplies are merited and necessary, provided that environmental safeguards are forcefully upheld. China must avoid the economy is significantly dependent on imported foreign fuel. Natural gas imports, which grow by almost 70%, see an estimated increase in the import share by at least 6 %-points during the 14th five-year plan. Hereafter, the by a combination of increased domestic production and a slowdown in growth of gas consumption in favour of other clean energy sources, implies that the import share of natural gas can decline in the 15th FYP.

By 2035, the import share of oil and natural gas can be lower than today, as a result of the energy transition.

Figure 15: Import shares of fossil fuels in the Below 2 °C scenario



Breaking the curve of energy related CO₂-emissions

Despite an uncertain, and at times tense, geopolitical environment, there is strong active cooperation on energy and climate issues, which benefits all parties.

Carbon intensity levels should be reduced in the 14th five-year plan by 27% to 67 g/RMB – a cumulative reduction of 66% since 2005 (in real terms).

In the 14th five-year plan, the carbon market should be reformed to include self-adjusting mechanisms, such as a flexible cap, floor price, and stability reserve, to prevent a collapse in carbon prices leading to undesired investment signals in favour of high-carbon investments. The carbon quota allocation scheme must be adjusted to not provide indirect subsidy for (efficient) coal-fired generation over clean energy sources.

Policy emphasis in the 14th Five-Year Plan

The 14th five-year plan period 2021-2025 will be a watershed in China's energy transition history. A confluence of developments provides risks and opportunities. It is critical that policy guidance is consistent and that measures ensure policy continuity during a period of upheaval and policy driven energy revolution.

Ambitious, but realistic end-targets for the period should be set

Achieve 19% non-fossil energy (by physical energy content), target a reduction of energy intensity of the real GDP by 21%, reduce CO₂ emissions targeting a reduction of real GDP CO₂ intensity by 27%, reduce coal consumption by 11%.

Clear guidance for power sector needed in 14th Five-Year Plan period

Conduct integrated long-term planning

Given the boundary conditions, such as national targets of non-fossil fuel energy and electricity consumption growth predictions, a proper planning model and a standard planning procedure should help evaluating and coordinating the development of infrastructure, power sources, and flexibility investments. With a clear long-term vision, potential risks and uncertainties can be examined through the model and reduced by improving the policy framework. By fitting into the long-term strategy, short-term targets can better facilitate the long-term visions to yearly action plans without adverse impacts from short-term incidents. An integrated long-term planning process will become increasingly important when administrative approval procedures are replaced by power markets driven incentives. Experiences from the European integrated planning processes could be inspiration for a planning process in a Chinese context.

Give priority focus to power system flexibility

Flexibility is an essential element for the successful integration of renewable electricity in the power system. It is important that the policy design promotes flexibility. The power market should facilitate flexibility services for existing flexible sources to be discovered and better utilized. Compensation through reservation of flexible sources should attract investments in flexibility and to maintain a stable level of flexible capacity.

As fossil-fuel plants face increasingly face insufficient operating hours they should have focus on providing flexibility, and inefficient and unclean plants should be phased out in an orderly manner.

Continue to foster good market environment for renewable integration

It is important to continue to complete and consolidate existing spot markets and focus on mobilizing flexible sources in current power system to better integrate renewable energy, including transmission, thermal and hydro power plants, industrial demand response and storage. Better use of the Mandatory Renewable Electricity Consumption Mechanism¹⁸ is key to ensure the renewable share in electricity consumption and to motivate consumption of renewable energy. The national carbon market must be enhanced and expanded to better reflect the external cost of emissions. Furthermore, an effective administrative monitoring system during the power sector reform process should be established to maintain the market rules.

Development of wind and solar requires improved grid integration and uptake of RE

To enable healthy wind and solar development, grid companies and third-party organizations should be required to annually publish five-year electricity demand forecasts, including forecasts for absorption of new wind and solar output, establish a mechanism for regularly publishing forecast results, and use this as the basis for wind and PV development and policies. The market should guide the timing and location of new wind and solar projects via competitive allocation of construction quotas. When China's wholesale power markets mature, wind and PV additions will more depend on market forces.

As wind and solar become increasingly competitive with coal, policymakers may temporarily need to limit annual wind and PV additions in specific regions to prevent new grid bottlenecks. Policymakers must manage the risk of stop-go situations in renewables investments market and industry. Policies must prevent grid and market constraints on renewable development, ensuring bottlenecks do not lead to a collapse of the renewable energy industry. Policy must support China's transition to clean energy, ensure the sound development of manufacturing industry, while also ensuring integration of electricity demand and absorption of renewable output.

Adding new coal power capacity should be avoided

Adding new coal power capacity, with a lifetime of 40 years or more, would be counterproductive for the energy transition, introducing risks for stranded investments in a competitive power market. Investments in new coal capacity should be avoided or limited as much as possible. The institutional mechanisms for accelerating a smooth retirement of old and inefficient coal plant needs to be put in place. Limiting the share of coal in the electricity generation mix is critical for the reduction CO₂ emission and structural enhancement of power supply, especially during 14-FYP, when renewable energies' cost-competitiveness is just emerging, and the carbon price incentive is weak.

The 14th Five-Year Plan is key to reform of renewable energy policy

Early in the 14th Five-Year Plan period, the feed-in tariffs for onshore wind and PV generation will be withdrawn since these have become mature industries with rapid market development and large-scale manufacturing.

Industry expects PV costs on par with coal power early in the 14th Five Year Plan

In 2019, the weighted average difference between the tariffs for coal-fired power generation and onshore wind is RMB 0.1/kWh and RMB 0.14/kWh for PV, and the feed-in tariff for new onshore wind projects will be completely withdrawn by 2021. In 2019, the average subsidy level of PV auction projects is only RMB 0.065/kWh.

New policies will support renewable energy and guide the RE industry's development.

After a decade of feed-in tariff and subsidy compensation to support the renewable energy deployment, policy supports will shift during the 14th Five-Year Plan period. Even though the subsidy for onshore wind power and photovoltaic power will phased out in 14-FYP, new mechanisms and regulations are necessary to continue to drive the cost down, by improving the investment and utilisation environment as well as enhancing regulations and monitoring systems.

New support policies will continue to both support prior renewable energy deployment and operation, as well as guiding the renewable energy industry's development. These changes coincide with wholesale power market reform, for which the 14th Five-Year Plan period will be critical. The challenges of regulatory transformation are, multifaceted and uncertain in terms of their design and implication from the support of renewable energy.

Removal of subsidies does not imply removal of economic policies

Reducing or eliminating non-technical costs remains critical. International experience indicates that economic policies related to non-technical costs, such as regulatory expenses, marketing costs, land use fees, and financing costs, become more important as renewable energy reaches cost-competitive levels and participates in power markets. For example, in 2016 a PV generation project in the United Arab Emirates bid a price of USD 0.0242 per kWh in a power auction, and this price was only possible due to the country's land tax exemption policy, consumption tax exemption policy, long-term low-interest loans, and summer tariff policies.

The 12 measures proposed by the National Energy Administration in 2018 to reduce the regulatory cost burden on renewable energy companies should be sustained and strengthened in the post-subsidy era to reduce non-technical costs, especially unreasonable non-technical costs. On land policy, some regions still violate national regulations or collect unreasonable renewable energy resource fees and urban land use taxes. The basic principles of land availability and land cost for renewable energy development should be clarified and national policies should be fully implemented.

Consumption guarantees for renewable energy remain essential over the long-term

China issued its most recent policies guaranteeing the consumption of renewable energy power in May 2019. The policy establishes mandatory consumption targets and responsibilities, along with indicators in order to guide the consumption of renewable energy power. The policy includes aspects that promote both supply and demand of renewables, both in the near-term and long-term. After wind and PV prices fall below present grid tariffs for coal and subsidies are withdrawn, renewable uptake will be the most important factor affecting annual installations of wind and solar. To meet China's need to continue wind and solar installations and thereby achieve long-term national clean energy targets, renewable demand responsibility should at least remain stable or grow over time, to create space for sustainable growth of renewable energy.

Supportive policies are still needed for some renewable energy sources

Considering the renewable energy industry's development and diversity, it is important to continue the support of other kinds of renewable energy than wind and PV, such as biomass, CSP, geothermal, marine, as well as related technologies in battery storage, hydrogen, etc. For biomass power from agricultural and forestry residues, raw materials account for at least two-thirds of the generation cost. Prohibition of straw burning via education, agricultural transfer payments, and subsidies for procurement of biomass would support development of biomass power. For large-scale solar thermal plants, such as utility-scale concentrating solar, these remain in the initial stage of industrial development, but the energy storage and flexibility aspects of the technology suggest they will have value in the world's future renewable-based energy system. For CSP technologies, competitively-set tariffs for new projects combined with annual installation targets would ensure continued development. Either grid companies should be required to enter PPAs and the cost premium may be covered by the end-users through the retail electricity price, or a differential price should still be offered for these technologies through the renewable energy development fund. If such technologies participate in power markets, they could do so under a contract-for-difference arrangement.

Renewable energy participation in the power market

A dynamic power system is needed for cost efficient VRE integration

China's electricity market should be able to mobilize existing flexibility through efficient price signals and market services; and guide investments to bring flexibility sources through the market design.

The power system should be structured to efficiently dispatch so fluctuations and uncertainties can be handled without interfering with system security. This requires integrated market operation, deep participation in spot, balancing and ancillary service markets; and a process to connect, provincial, regional and national resources seamlessly.

A clear market design target model is needed, which will enable operating the power system of the future.

Figure 16: Timeline of regional spot power market establishment



Market design should gradually have renewable energy participate in the market

Renewable energy's participation in the power market will be a gradual process according to the direction of China's power system reform, as has also been the international experience. In the early stage, renewable energy power can participate in the power markets by bidding a production curve without quoting a price and take priority in market clearing as a price taker, to enable priority for renewable consumption. When the spot market is mature and stable, newly added renewable energy projects will likely participate in the power markets by bidding both quantity and price.

Renewable energy market participation should take many forms

For new projects, participation in the power market can be diversified by referring to international experience and domestic demand, including power purchase agreements signed with power consumers or trading companies, medium- and long-term contracts, competitive bidding by the government or trading companies, direct participation in the spot market, and combination of the aforesaid models.

For existing projects that previously had feed-in tariffs set as benchmark tariffs, set via competitive bidding, or tariffs including a subsidy, as well as benefitting from the full purchase guarantee policy, China should encourage their participation in the power market. Before a switch is made from the feed-in tariff model to the market premium model or the contract for difference (CFD) model, preconditions should be established. This includes that the spot market should be a well-functioning market creating a robust reference price for such contracts to settle against.

Renewable energy should not partake in imperfect power market competition

Before the market is well-functioning, and effective competition is achieved, it is unhelpful for wind and PV to participate. It is recommended to continue the benchmark tariff parity pricing or auction-based pricing policies for wind and PV for a period. In 2019, China implemented a new auction system for PV generation. The major elements of this system, such as competitive allocation, national ranking, amended tariff, and forewarning management, are also applicable after the complete removal of subsidy for wind and PV. The feed-in tariff will be lower than the price of coal power through auction or bidding (in August 2019, the final bid prices for PV in projects auctioned were lower than the respective local coal benchmark prices).

Clean heating with a central role for district heating

With a supply of around 2,300 TWh, district heating is responsible for around 50% of the all heating demand in 2020. Heating sector reforms in China deserves attention due to large energy consumption, low cost options for decarbonization including reducing pollution and high potential for providing flexibility regarding renewable electricity integration.

Renewable heating development and planning needs priority

Renewable heating should have priority over other sources in urban heating networks for connection and utilisation. Regional energy transformation demonstration projects should include renewable heating targets, incorporate renewable heating into unified regional planning, and include renewable heating as an indicator in the regional ecological civilisation construction evaluation system. Solar energy, biomass and geothermal energy technologies should be included in the preferred technology catalogue for air pollution, energy conservation and emission reduction.

Overall RE heating development goals should be put forward for the country and for key provinces. In the planning and construction process of new urban district construction, reconstruction of old city and construction of industrial parks (areas), China should combine the regional energy planning with urban development planning and prioritize the simultaneous development of renewable power and heating.

Promote the market competitiveness of renewable heating

Restrictions should be lifted on access to heating systems and encourage private enterprises to enter the clean heating sector. Market-oriented approaches such as competitive bidding should be incorporated in the sector. For users not covered by district heating, China should promote the development of decentralized renewable heating through the combination of user investment and government subsidies.

Support technology development and demonstration

Research and design optimization of new systems should be supported, including a multi-energy complementary system for renewable energy—which involves the integration of renewable energy and conventional energy systems, and can include combining renewable heating with other energy sources and storage.

Combined with the reformation of the power system and the construction of the power market, China should establish an information platform to coordinate energy flow and other data from the electric power grid and the heat networks.

Strengthen environmental supervision of renewable heating projects

For projects that may affect surface water, underground water, soil, or air quality, China should improve the overall supervision system before, during, and after the renewable heating project's initiation. This entails monitoring geothermal energy development and utilization, including real-time monitoring and dynamic evaluation of the exploration, development, utilization and

environment condition of geothermal energy resources. Regulators should fully implement requirements for reinjection of geothermal tail water and ensure the balance of extraction and injection. Technical standards should be developed for biomass heating and NO_x emissions from large biomass boilers shall be reduced. China should promote the manufacturing of standardized, serialized and complete set of equipment, and formulate standards for biomass heating engineering design, briquette-fuel products, moulding equipment, biomass boilers and emissions.

Improve the standard system for renewable heating

The testing and certification system for the renewable heating products should be strengthened, third-party testing and certification institutions should be established, and quality certification system for renewable heating equipment and engineering services should be developed and improved.

Renewable energy gas

Renewable gases can displace fossil gas while reducing methane emissions

Development of this industry requires coordinated management across departments and fields, especially the sorting and integration of upstream raw materials and promotion of consumption of renewable energy gas.

A collaborative management system for the biogas industry must be established

The responsibilities of the leading authorities and departments for the biogas industry shall be clarified and coordinated across the multiple departments of finance, development and reform commissions, agriculture, environmental protection, energy, housing and construction, taxation and quality inspection. Industrial goals, plans, policies, and standards shall be formulated jointly.

Supervision and management shall be strengthened

Professional third-party evaluation agencies should assess projects upon completion according to project feasibility report, implementation plan and operational impact of the project. A project grading evaluation mechanism considering environmental impact, technical advancement, sustainable operating capacity, and innovation shall be established, and grading linked with subsidy and tax policies to ensure the construction quality and actual production impact of the projects. The blacklist or credit system should also apply to such projects, to notify and penalize companies with records of multiple ineffective projects.

Private capital should participate in establishing collection, storage and transportation systems for agricultural organic wastes

Policymakers can establish investment subsidies, co-equity investments, long-term off-take contracts, and public-private partnerships. New ways should be explored to integrate private investment together with government investment in waste regulation, prohibitions on straw burning, fees for sewage and waste disposal, and environment taxes for livestock and poultry farms.

Preferential tax policy should be improved and include agricultural organic waste collection and treatment services in the scope of VAT refund and marginal relief.

Gas network companies should fully purchase biogas in accordance with the RE Law

The supportive policy for the construction of gas supply networks in rural areas shall be improved, and it shall be ensured that biogas and marsh gas power generation and central gas supply are treated equally in the market.

Biofuels

Bioethanol production should match reasonable rates of consumption

The official plans state that China should promote biofuel ethanol nationwide by 2020¹⁹. To ensure a stable supply of biofuel ethanol raw materials, policymakers should set production and consumption policies in accordance to avoid situations where biofuel ethanol producers cannot meet demand.

Increase research and development of biofuel ethanol from non-grain raw materials

Due to limits on raw material availability, should focus be on the research and development of biofuel ethanol from non-grain raw materials, realize nationwide use of biofuel ethanol.

Raw material management and regulation of the biodiesel upstream industry system should be strengthened. It is urgent for China to standardize the collection, transshipment, disposal and supervision of the upstream raw materials of biodiesel such as gutter oil. A long-term management mechanism should be established, and the regulation of the industry management system should be enforced through local legislation, to ensure the safe flow of raw materials such as gutter oil and provide a raw material guarantee for biodiesel production.

- ¹ “习近平：决胜全面建成小康社会 夺取新时代中国特色社会主义伟大胜利——在中国共产党第十九次全国代表大会上的报告,” The State Council, 27 October 2017, accessed at http://www.gov.cn/zhuanti/2017-10/27/content_5234876.htm.
- ² Si Jiming, Qiu Bo, Zhang Xiaofeng, “能源环境政策：2018 全回顾 2019 抢鲜看！”, Huaneng Institute of technology and Economics, 12 April 2019, accessed at <http://news.bjx.com.cn/html/20190412/974542.shtml>.
- ³ “2018 国民经济和社会发展统计公报,” National Bureau of Statistics, 28 February 2019, accessed at http://www.stats.gov.cn/tjsj/zxfb/201902/t20190228_1651265.html.
- ⁴ Coal consumption in 2018: “《2018 煤炭行业发展年度报告》发布：电力行业全年耗煤 21 亿吨左右,” China National Coal Association, 15 March 2019, accessed at <http://news.bjx.com.cn/html/20190315/969088.shtml>; coal consumption in 2017: “中国能源统计年鉴-2017,” National Bureau of Statistics of China, 13 June 2018, Pg74.
- ⁵ “2018 国民经济和社会发展统计公报,” National Bureau of Statistics, 28 February 2019, accessed at http://www.stats.gov.cn/tjsj/zxfb/201902/t20190228_1651265.html.
- ⁶ “2018 国民经济和社会发展统计公报,” National Bureau of Statistics, 28 February 2019, accessed at http://www.stats.gov.cn/tjsj/zxfb/201902/t20190228_1651265.html.
- ⁷ “中国能源发展报告 2018,” China Electric Power Planning & Engineering Institute, 23 April 2019, P6.
- ⁸ “World Energy Investment 2018,” International Energy Agency, July 2018, accessed at iea.org/wei2018.
- ⁹ “World Energy Investment 2019,” International Energy Agency, May 2019, accessed at iea.org/wei2019.
- ¹⁰ “Notice of the National Development and Reform Commission on matters related to speeding up the key projects of interconnection of natural gas infrastructure in 2018,” Wall Street Stories, 19 June 2018, accessed at <https://wallstreetcn.com/articles/3340448>.
- ¹¹ “中汽协：2018 全年汽车销量自 1990 年来首次年度下滑,” sina.com, 14 January 2019, accessed at <http://finance.sina.com.cn/chanjing/cyxw/2019-01-14/doc-ihqfskcn6997845.shtml>.
- ¹² “董扬：去年中国电动车销量占全球 62.5%你还认为电动车不行么？” sohu.com, 1 April 2019, accessed at https://www.sohu.com/a/305260389_680702.
- ¹³ “2018 年中国储能行业细分市场现状及发展前景分析 抽水储能仍将是未来发展重点,” Prospective Industry Research Institute, 23 July 2019, accessed at <https://www.qianzhan.com/analyst/detail/220190404-54463c2a.html>.
- ¹⁴ Zhang Yousheng, Ga Hu, Liu Jian, “我国新能源技术进步超过预期 推动新能源发展步入新阶段,” Energy Research Institute of National Development and Reform Commission, July 2019.
- ¹⁵ “权威数据证实：去年我国蓝天白云更多了！主要空气污染物下降明显,” China Weather Fan, 12 May 2019, accessed at <https://baijiahao.baidu.com/s?id=1632953003474884541&wfr=spider&for=pc>.
- ¹⁶ “国务院关于印发打赢蓝天保卫战三年行动计划的通知, 国发〔2018〕22 号,” State Council, 27 June 2018, accessed at http://www.gov.cn/zhengce/content/2018-07/03/content_5303158.htm.
- ¹⁷ “国家发展改革委办公厅国家能源局综合司关于开展电力现货市场建设试点工作的通知, 发改办能源〔2017〕1453 号,” National Development and Reform Commission and National Energy Administration, 28 August 2017, accessed at http://www.ndrc.gov.cn/qzdt/201709/t20170905_860117.html.
- ¹⁸ “关于建立健全可再生能源电力消纳保障机制的通知, 发改能源〔2019〕807 号,” National Development and Reform Commission and National Energy Administration, 10 May 2019, accessed at http://www.ndrc.gov.cn/zcfb/zcfbtz/201905/t20190515_936170.html.
- ¹⁹ Implementation Plan on Expanding the Production of Biofuel Ethanol and Promotion of Ethanol Gasoline for Vehicles (FGNY [2017] No. 1508) and the Overall Layout Plan of the National Biofuel Ethanol Industry (FGNY [2018] No. 1271)