China's Renewables Curtailment and Coal Assets Risk Map

Research Findings and Map User Guide

Yiyi Zhou

Sophie Lu

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ClimateWorks FOUNDATION

Bloomberg New Energy Finance

Contents

Executive Summary

With the support of ClimateWorks Foundation, Bloomberg New Energy Finance has created the **China Renewables Curtailment and Coal Stranded Assets Risk Map.** The aim is to cast light on the issues central regulators will have to weigh up as they steer the power system through fundamental restructuring.

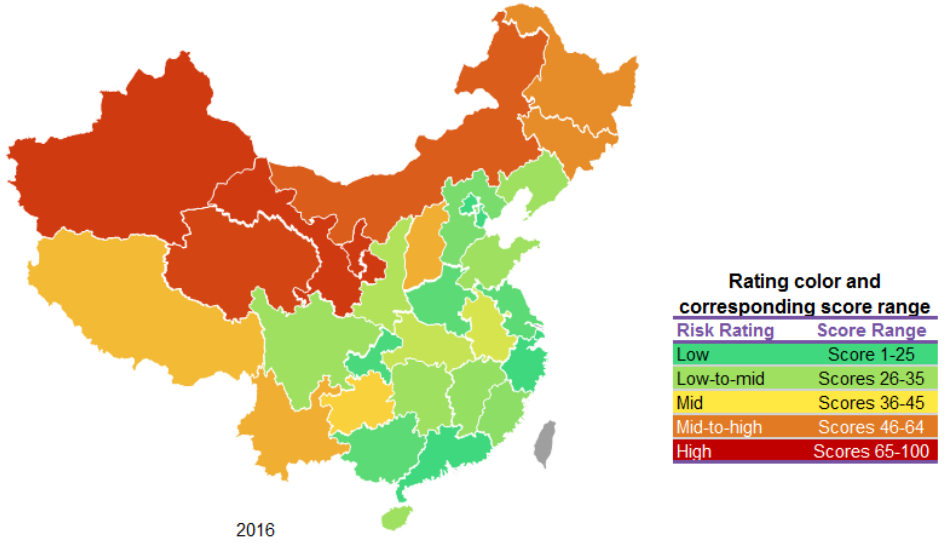
- The world's largest power system will face serious challenges in the next few years. China's power generators, both renewable and coal, experience increasing competition for dispatch. Renewable power generators face the worst curtailment rates in the world, with the national average curtailment ratio in 2016 at 17% for wind and 10% for solar. Coal power generators are entering an unprecedented period of uncertainty as regulators tighten environmental regulations and cancel new projects.
- A slowdown in new build, and additions of long-distance transmission lines to export electricity, will play a major role in alleviating the curtailment for northern regions. Some non-curtailed provinces might see the issue emerging by 2020, including Hunan, Sichuan, Guizhou and Fujian. This is partially due to weaker power demand growth and accelerated build-out of new generation capacity.
- The five provinces with the highest exposure to coal asset performance risk are Inner Mongolia, Gansu, Shanxi, Jilin, and Yunnan. All will see their coal risk worsen or stay high going into 2020. Wholesale market liberalization will have a profound impact on the performance of coal power plants, especially in over-supplied provinces with significant competition from non-coal base-load capacity, such as hydro and nuclear.

$237 billion Estimated value of coal stranded assets

35% Amount of oversupply in generation capacity

56.2TWh Total curtailed wind and solar generation in 2016

China Renewables Curtailment Risk Map (2016)



Source: BNEF China Renewable Curtailment and Coal Stranded Assets Risk Map

Bloomberg New Energy Finance

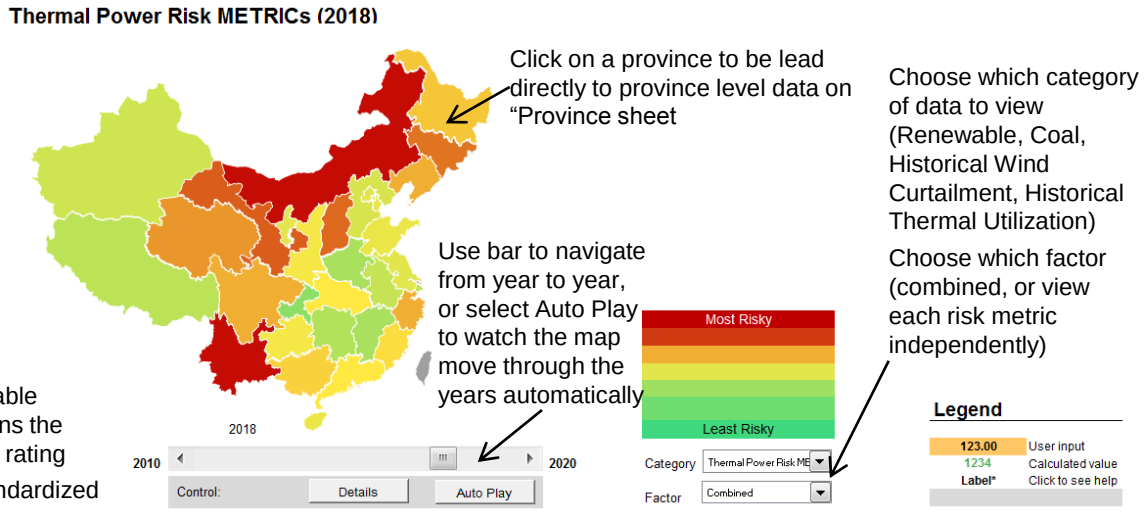
Introduction to the Risk Map tool

Currently, China's central regulators are designing new regulations that impact many companies' licenses to operate. However, the new regulations lack transparency on what factors are being considered, exactly how these factors are being measured, and how they weigh in regulators' minds. Bloomberg New Energy Finance designed this tool to capture what factors may be considered by regulators, provide data transparency on the metrics, and a view on how conditions in the industry will evolve over the course of the 13th five-year plan period.

The **China Renewables Curtailment and Coal Stranded Assets Risk Map** highlights the cross-sector, sub-national dynamics of China's power sector challenges during the 13th five-year plan (FYP) period (2016-20). Built in Microsoft Excel, this tool allow users to understand the changing nature of China's power demand and overcapacity issues at a province level. The resulting map would provide a visual comparison tool for the risk of stranding coal and renewable power generation assets across China. The tool includes three areas for analysis:

- **Factors that impact utilization:**
  - **Province-by-province supply and demand balances**, including overall electricity demand for all provinces, historical since 2010 and forecast by BNEF through 2020. Installed capacity by province, based on historical figures and BNEF forecasts for wind, solar, coal, nuclear, hydro, and gas.
  - **Province-to-province export and import capabilities,** approximated by ultra-high voltage (UHV) long-distance transmission line connections between provinces. This is in order to account for opportunities for power exports to neighboring provinces (which can help to lower curtailment risk in some key provinces).
  - **Technical constraints,** as intermittent renewable penetration increases, regional grid need greater flexibility and balancing response from other technologies, including base-load technologies. We track this as the systems evolve over time.
- **Factors that impact financial performance of assets**, including coal fuel costs; the impact of power market reforms and increased competition on wholesale power prices; and other potential environmental costs , including carbon prices.
- **The relative ambition and potential effectiveness of central and local government policies**, including specific subsidies for renewables, available guaranteed purchase levels for renewables, and renewable portfolio standards. It would also take into account environmental restrictions on coal generation or moratoria on new coal build. We consider the newest limitations on new coal build, including financing assessment and return requirements, by province.

Model user guide: heatmap



This table contains the metric rating (a standardized score)

Weightings for each metric: reflect the default BNEF settings, but at the User Input bar below, users can manually adjust metric weightings. To deactivate one metric, set weighting to zero.

Thermal Power Risk METRICs

Year:2018	15.00	10.00	5.00	15.00	10.00	15.00	10.00	5.00	5.00	5.00	5.00			
Province	Supply-demand balance	Transmission constraints (coal)	Flexibility requirement	Competition from baseload	Loss of dispatch quota	Power price risk	Earlyretire risk	Carbon costs	REC obligation	Water risk	Fuel risk aggregated			Overall risk metric
Beijing	16	7	12	71	70	17	11	90	100	80	80			42
Tianjin	29	36	14	27	60	17	100	20	83	80	60			43
Hebei	31	24	60	8	60	33	99	20	0	100	60			41
Shanxi	80	67	43	4	50	100	92	0	5	80	20			56
Inner Mongolia	100	100	68	1	50	100	100	0	0	100	20			64
Liaoning	47	28	34	13	60	81	91	0	60	80	40			50
Jilin	78	44	45	15	60	82	87	0	38	80	40			55
Heilongjiang	57	45	45	7	60	81	83	0	32	60	20			48
Shanghai	20	13	13	27	70	17	59	60	33	100	80			38
Jiangsu	32	37	31	20	70	17	99	30	25	80	60			42
Zhejiang	36	33	28	33	70	73	68	30	46	60	60			50
Anhui	48	46	37	6	50	17	96	0	23	60	60			39
Fujian	46	42	20	39	70	33	86	40	10	60	40			46
Jiangxi	44	38	44	15	50	33	53	0	0	60	60			36
Shandong	43	35	37	7	60	33	78	20	44	100	60			43
Henan	41	36	23	8	50	17	73	0	40	80	60			36
Hubei	47	78	24	51	60	17	52	30	40	40	60			45
Hunan	39	37	36	33	50	43	34	0	0	60	60			37
Guangdong	30	27	17	40	70	68	59	0	47	60	60			45
Guangxi	50	35	21	41	50	100	31	0	0	40	80			47
Hainan	43	38	24	38	50	74	3	0	66	40	80			43
Chongqing	29	34	7	37	60	17	10	12	41	60	80			33
Sichuan	71	67	11	78	60	17	32	10	31	60	80			50
Guizhou	89	61	21	34	50	17	42	0	13	40	80			44
Yunnan	91	67	32	70	60	100	40	0	18	40	80			64
Tibet	39	38	48	57	0	17	94	0	12	20	80			38
Shaanxi	64	58	34	6	60	17	99	0	58	60	40			44
Gansu	61	54	81	17	60	100	65	0	0	100	60			57
Qinghai	53	37	82	40	60	100	28	0	0	80	60			52
Ningxia	76	51	73	3	60	33	37	0	0	80	60			42
Xinjiang	60	55	66	9	60	0	59	0	35	100	40			40

Overall score combining weighted average of standardized scores of all metrics considered.

Rating color and corresponding score range color key

Rating	Score Range
Low	Score 1-25
Low-to-mid	Scores 26-35
Mid	Scores 36-45
Mid-to-high	Scores 46-64
High	Scores 65-100

Model user guide: raw data

Users can manually adjust weightings for each metric. User Input automatically overrides Default Weight

Users have options to create custom factors to add to scoring. Enter your factor value for each province and adjust the weighting in the "User Input Weights" to accommodate your new factor (so that weights add up to 100)

User Input Weight: *													
Default Weight: *	15.00	15.00	10.00	10.00	10.00	10.00	10.00	5.00	5.00	5.00	5.00		

Back to Top

This table contains the raw data behind each metric score (expressed in the unit of their calculation). Please refer to "Reference" sheet for definitions of each metric, data source, and calculation method

Thermal Power Risk METRICs- Raw Data

Province	Supply-demand balance	Transmission constraints (coal)	Flexibility requirement	Competition from baseload	Loss of dispatch quota	Power price risk	Earlyretire risk	Carbon costs	REC obligation	Water risk	Fuel risk aggregated	Custom Factor #1	Custom Factor#2
Beijing	46.1%	113.3%	7.2%	71.2%	8	0.0%	88.9%	CNY 45.00	8.3%	4	4		
Tianjin	84.5%	10.5%	9.6%	27.8%	7	0.0%	0.0%	CNY 10.00	6.0%	4	3		
Hebei	93.6%	38.9%	31.8%	8.4%	7	-1.0%	0.5%	CNY 20.00	-4.2%	5	3		
Shanxi	238.2%	-64.5%	22.8%	3.5%	6	-5.0%	8.3%	CNY 00.00	-0.4%	5	1		
Inner Mongolia	360.8%	-143.4%	32.7%	1.1%	6	-5.0%	0.0%	CNY 00.00	0.4%	5	1		
Liaoning	142.3%	29.2%	17.5%	15.0%	7	-4.0%	8.5%	CNY 00.00	5.0%	4	2		
Jilin	219.2%	-9.3%	22.7%	14.8%	7	-3.8%	13.3%	CNY 00.00	3.5%	5	2		
Heilongjiang	165.2%	-12.5%	22.8%	7.6%	7	-4.0%	17.2%	CNY 00.00	2.7%	3	1		
Shanghai	59.4%	65.4%	6.6%	27.5%	8	0.0%	41.0%	CNY 30.00	2.9%	5	4		
Jiangsu	94.2%	7.1%	17.6%	20.1%	8	0.0%	1.1%	CNY 25.00	1.6%	4	3		
Zhejiang	105.1%	18.4%	16.2%	33.0%	8	0.0%	32.2%	CNY 25.00	3.5%	3	3		
Anhui	142.3%	-15.2%	18.7%	6.2%	6	0.0%	4.0%	CNY 00.00	2.0%	4	3		
Fujian	137.3%	-4.8%	11.9%	38.0%	8	-1.0%	14.0%	CNY 30.00	-0.5%	2	2		
Jiangxi	127.7%	5.6%	23.1%	14.4%	6	-1.0%	46.9%	CNY 00.00	-1.7%	3	3		
Shandong	125.2%	12.5%	20.4%	6.7%	7	-1.0%	22.0%	CNY 20.00	3.1%	5	3		
Henan	119.0%	10.8%	12.5%	8.0%	5	0.0%	27.1%	CNY 00.00	3.0%	5	3		
Hubei	135.1%	-80.4%	12.7%	50.3%	7	0.0%	48.0%	CNY 15.00	3.5%	3	3		
Hunan	121.7%	7.3%	20.2%	31.3%	6	-4.8%	66.3%	CNY 00.00	-1.3%	3	3		
Guangdong	87.4%	31.5%	10.3%	39.4%	8	-4.8%	40.5%	CNY 00.00	3.3%	2	3		
Guangxi	144.0%	12.3%	12.7%	40.4%	6	-5.0%	69.0%	CNY 00.00	-1.5%	2	4		
Hainan	123.2%	4.6%	13.2%	38.2%	5	-3.6%	96.5%	CNY 00.00	5.5%	2	4		
Chongqing	85.4%	15.7%	6.4%	35.8%	7	0.0%	90.0%	CNY 15.00	2.4%	4	4		
Sichuan	214.1%	-64.9%	6.8%	77.7%	7	0.0%	68.1%	CNY 10.00	2.1%	3	4		
Guizhou	253.7%	-52.8%	11.3%	34.1%	6	0.0%	58.4%	CNY 00.00	1.1%	2	4		
Yunnan	267.9%	-66.1%	16.9%	69.5%	6	-1.5%	60.4%	CNY 00.00	1.2%	2	4		
Tibet	113.5%	5.0%	25.0%	55.9%	0	0.0%	6.0%	CNY 00.00	1.2%	1	4		
Shaanxi	185.0%	-44.7%	19.5%	6.3%	7	0.0%	1.0%	CNY 00.00	4.6%	4	2		
Gansu	177.0%	-34.1%	40.9%	16.9%	7	-5.0%	34.6%	CNY 00.00	-2.2%	5	3		
Qinghai	153.3%	7.3%	42.5%	39.0%	7	-5.0%	72.2%	CNY 00.00	-17.6%	4	3		
Ningxia	223.7%	-27.2%	37.0%	3.1%	7	-1.0%	63.0%	CNY 00.00	-2.5%	5	3		
Xinjiang	182.0%	-17.4%	31.7%	8.6%	7	1.0%	41.4%	CNY 00.00	3.6%	5	3		

Back to Top

Button to go back to top of "Main" sheet

Model user guide: province detail

Dataset **Provincial Detail**
Subject to terms and conditions

Select Provinces to view detailed data

Beijing
Tianjin
Hebei
Shanxi
Inner Mongolia
Liaoning
Jilin
Heilongjiang
Shanghai
Jiangsu
Zhejiang
Anhui
Fujian
Jiangxi
Shandong
Henan
Hubei
Hunan
Guangdong

Go ← Select "Go" to populate charts below with provinces selected

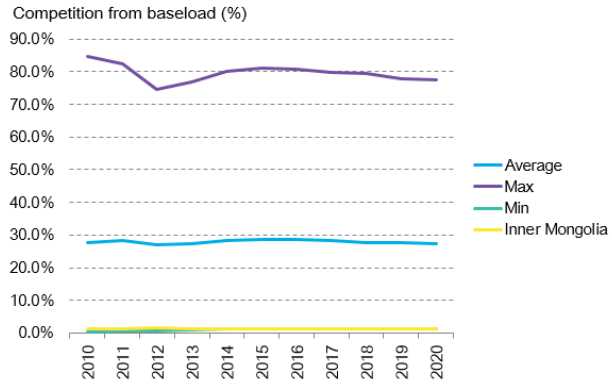
Go Back ← Select "Go Back" to go back to Main page

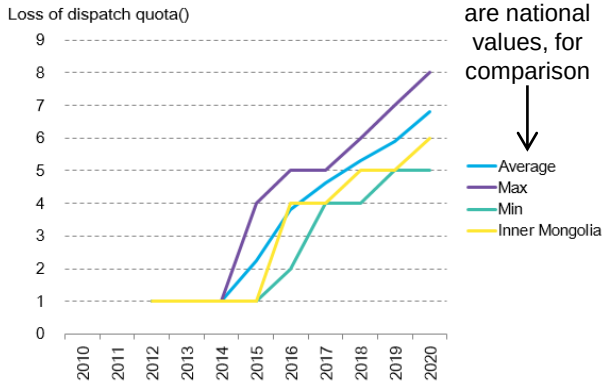
Show Data Table ← Select "Show Data Table" to jump to data tables below charts

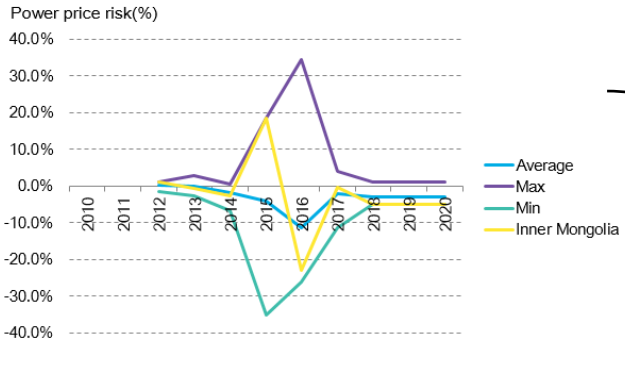
Click on "Go" to render data on this sheet.
Select multiple provinces to compare.
Click on "Show Data Table" to see underlying data.

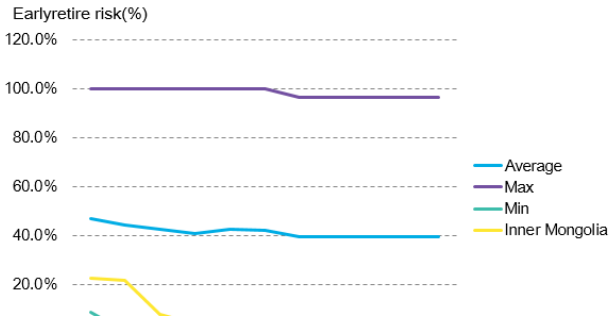
Charts

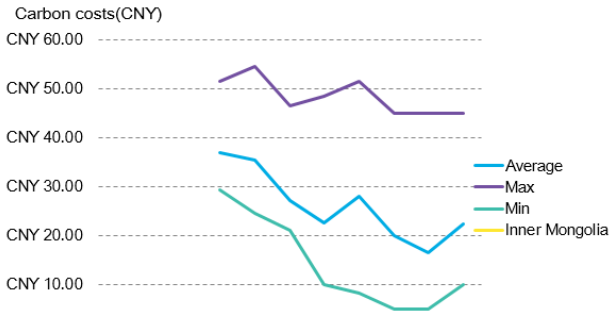
Average, Max, and Min are national values, for comparison

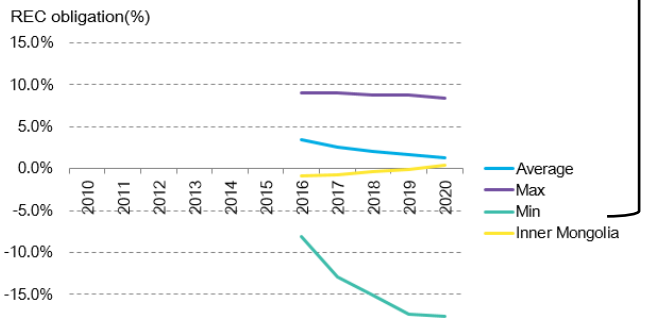












Charts exhibit raw data for each metric evolution over time

Bloomberg New Energy Finance

Glossary of key terms

Acronym	Definition
NDRC	National Development and Reform Commission
NEA	National Energy Administration
BNEF	Bloomberg New Energy Finance
NBS	National Bureau of Statistics
CEC	China Electricity Council
PV	photovoltaic
FYP	Five-year plan
RPS	Renewable Portfolio Standards
REC	Renewable Energy Credits
DPP	Direct Power Purchasing program
LCOE	Levelized Cost of Electricity
MEIO	Multi-energy integration and optimization program
UHV (DC/AC)	Ultra high voltage transmission (Direct Current / Alternating current)
CHP	Combined heating and power
KSOE	Key State-owned Enterprise (coal suppliers that report sales data, including Shenhua, China Coal, Datang, Guodian, Huaneng, etc.)
IPPs	Independent power producers

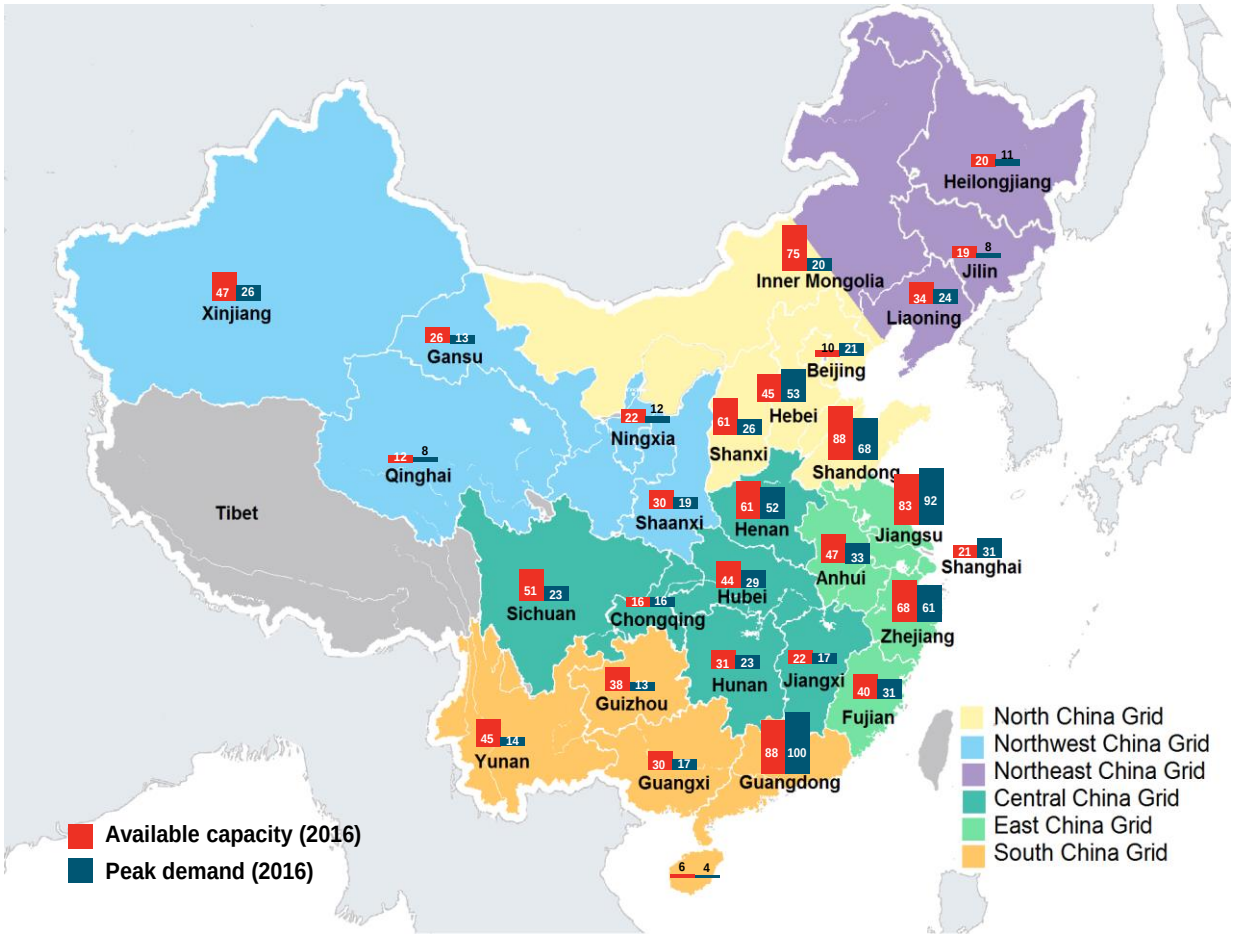
Term	Definition
Curtailment	Unplanned reduction of renewable energy generation output to the grid, whether due to technical or non-technical limitations.
Available capacity	Amount of installed capacity that can reliably be called upon during peak demand periods. In this study, it is calculated as the total installed capacity de-rated by a capacity credit that varies by technology.
Peak Demand	The highest point demand load reaches at any given year in a provincial market.
Ancillary service	Services necessary to support the transmission of electric power in a certain control area or market in order to maintain reliable operations of the interconnected transmission system.
Base load (power source)	Power stations which can economically generate the electrical power needed to satisfy the minimum demand in a regional electrical grid.
Interconnection	Grid connections between regional power markets that are used to assist with system balancing and inter-regional power export and imports.
Non-dispatchable	Generation capacity that needs to maintain relatively constant generation profile and can not be called up to fluctuate output to accommodate grid flexibility.
Reserve rate	Amount of reserve capacity margin a certain power region needs (defined by system operator)
Intermittent renewables	Renewable energy that is not continuously available and outside direct control of the grid, may be predictable but cannot be dispatched to meet grid needs.

Current challenges in China's power market

A system in transition

Oversupply is prominent issue for many provinces

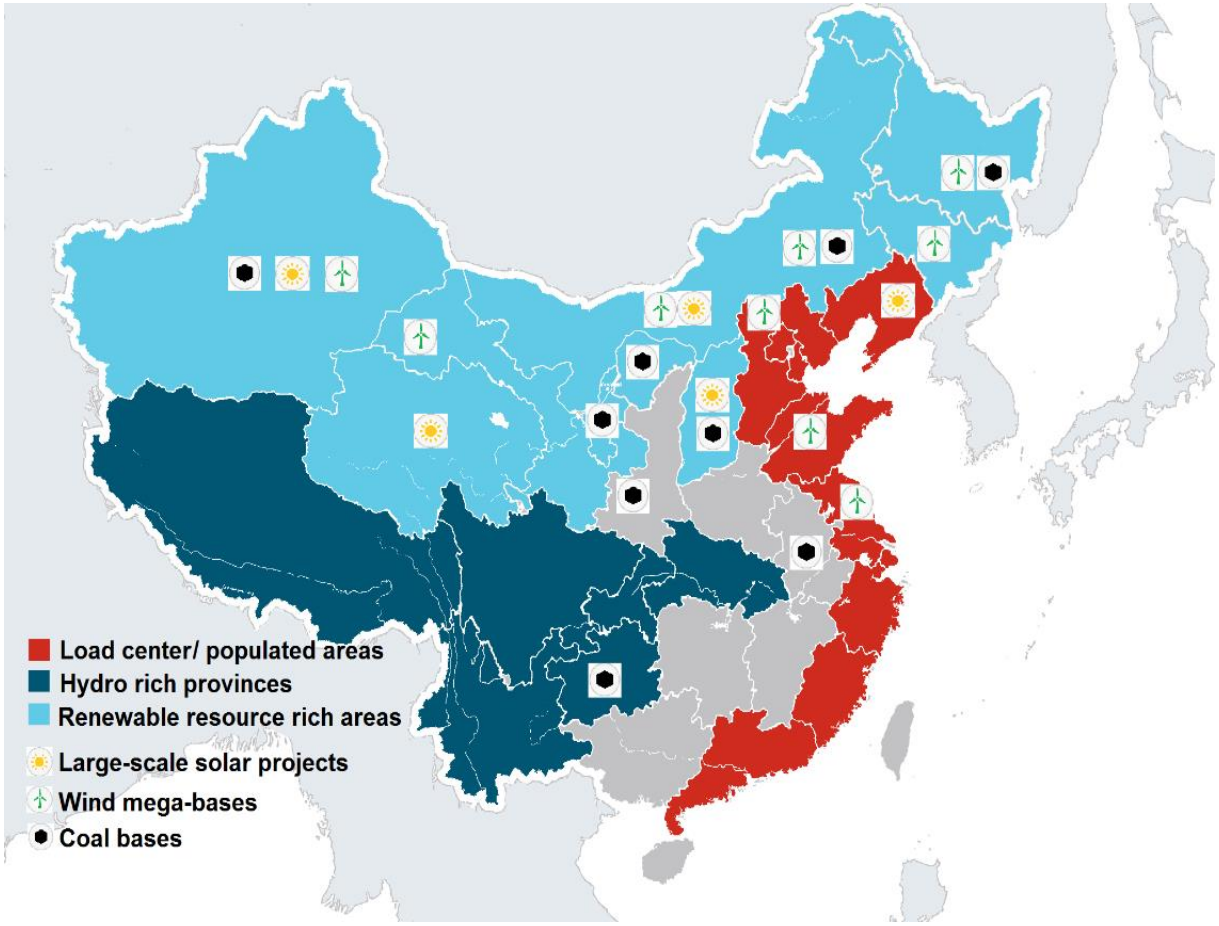
Available capacity versus peak demand by province, 2016 (GW)



Source: Bloomberg New Energy Finance, CEC. Note: Based on the global standard, we assumed available load factor of hydropower =50%, pumped hydro =100%, coal 90%, gas 90%, nuclear 80%, wind 10%, solar 30%, biomass 70%.

- China has the largest power generation fleet in the world, with 1,614GW of installed capacity, of which over two thirds was built in the last decade. From 2005-2015, power capacity grew by an average of 11.5% per year. This rapid build-out continued even as power demand growth slowed over the last five years.
- As of the end of 2016, the national power oversupply was 35%.
- In this analysis, we define supply and demand balance as available capacity (total installed capacity de-rated by each technology's availability factor) versus the peak demand load of said province.
- According to the data, in 2016, only four coastal provinces and cities, Beijing, Jiangsu, Shanghai, and Guangdong, exhibited deficits in electricity supply. And those were all small deficits.
- Inner Mongolia stands out as being the most oversupplied provincial power market in China, with 75GW of available capacity versus only 20GW of peak demand.
- Most of the provinces facing severe over-capacity are located inland, notably Xinjiang, Gansu, Sichuan, and Yunnan, where renewable resources (wind, solar, and hydro) are the most abundant.

China's geographical mismatch between resources and load centers



Source: Bloomberg New Energy Finance

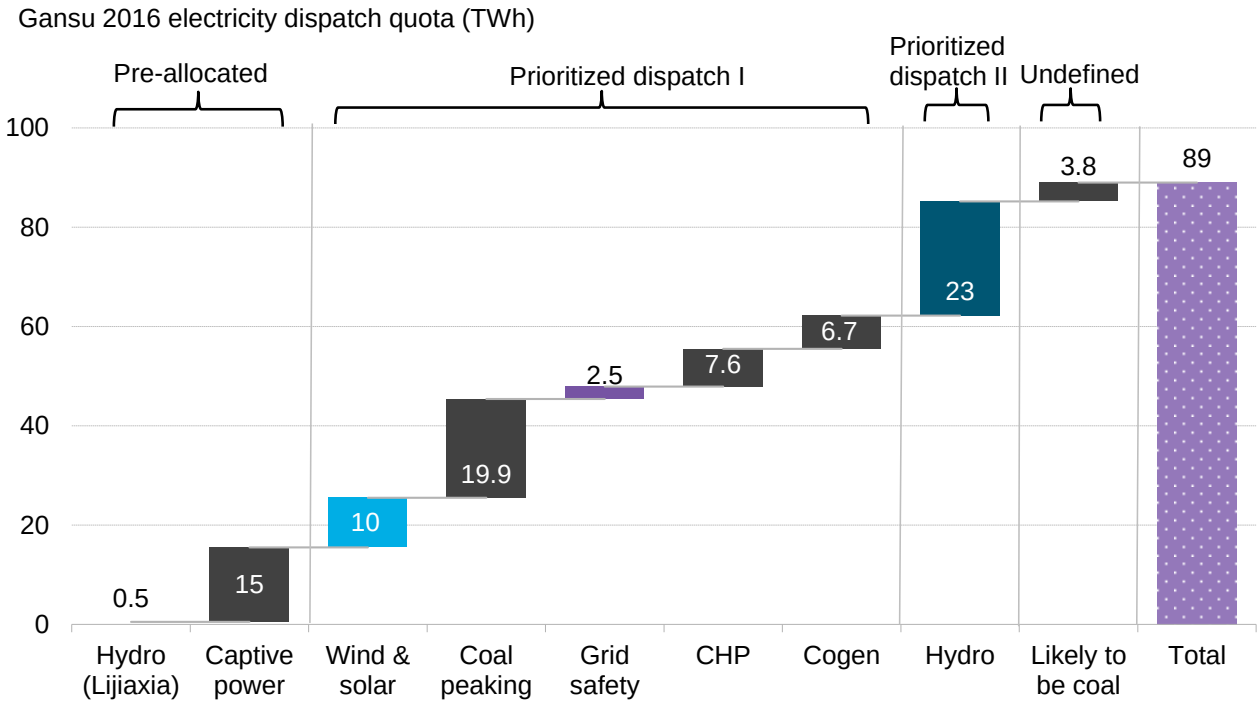
- In China, there's a geographical mismatch between generation resource-rich areas and load consumption centers. The former are located in northern regions and the latter in the east coastal provinces.
- Over 70% of China's large-scale wind and solar projects have been installed in the resource-rich northern regions featuring low electricity demand and low export capacity.
- Adding to the pressure, regions strong in wind resources are also abundant in coal. More than half of China's coal reserves are located in Inner Mongolia and Shanxi. Both provinces are also key solar and wind resource regions.
- Due to an excess of electricity supply over local demand, resource-rich northern regions have to export their renewable and thermal electricity to other regions.
- However, the construction of inter-regional transmission capacity in China has consistently lagged behind the growth of generation assets.
- A lack of transmission lines to export electricity from the renewable energy mega-bases has been the major cause of renewables curtailment in the past.

Transmission bottleneck eases with inter-provincial transmission build-out

- To export the surplus electricity to the load consumption center, various ultra-high voltage transmission lines are planned. As of 2016, eight UHV DC lines with a total length of 11,900km were in operation. Some 16 UHV DC lines are planned to be brought online by 2020. However, less than half of these lines are designated to transmit renewable electricity. The ones that are focus on Gansu, Inner Mongolia, and Xinjiang.
- In this analysis, we assume that even if UHV lines are not allocated to export specifically renewable generation, the addition of this export capacity will still benefit local renewables performance. This is because it can help to alleviate oversupply pressures on the local grid, exporting competing generation (especially coal).
- Another major factor that impacts whether or not UHV transmission capacity can help to reduce renewables curtailment is the level of utilization of these lines. Currently, many long-distance transmission lines are underutilized (around 30%). In this analysis, we consider not only how much additional transmission capacity will be built, but whether improving utilization of these lines can help to reduce regional congestion challenges.

Source: Bloomberg New Energy Finance, State Grid

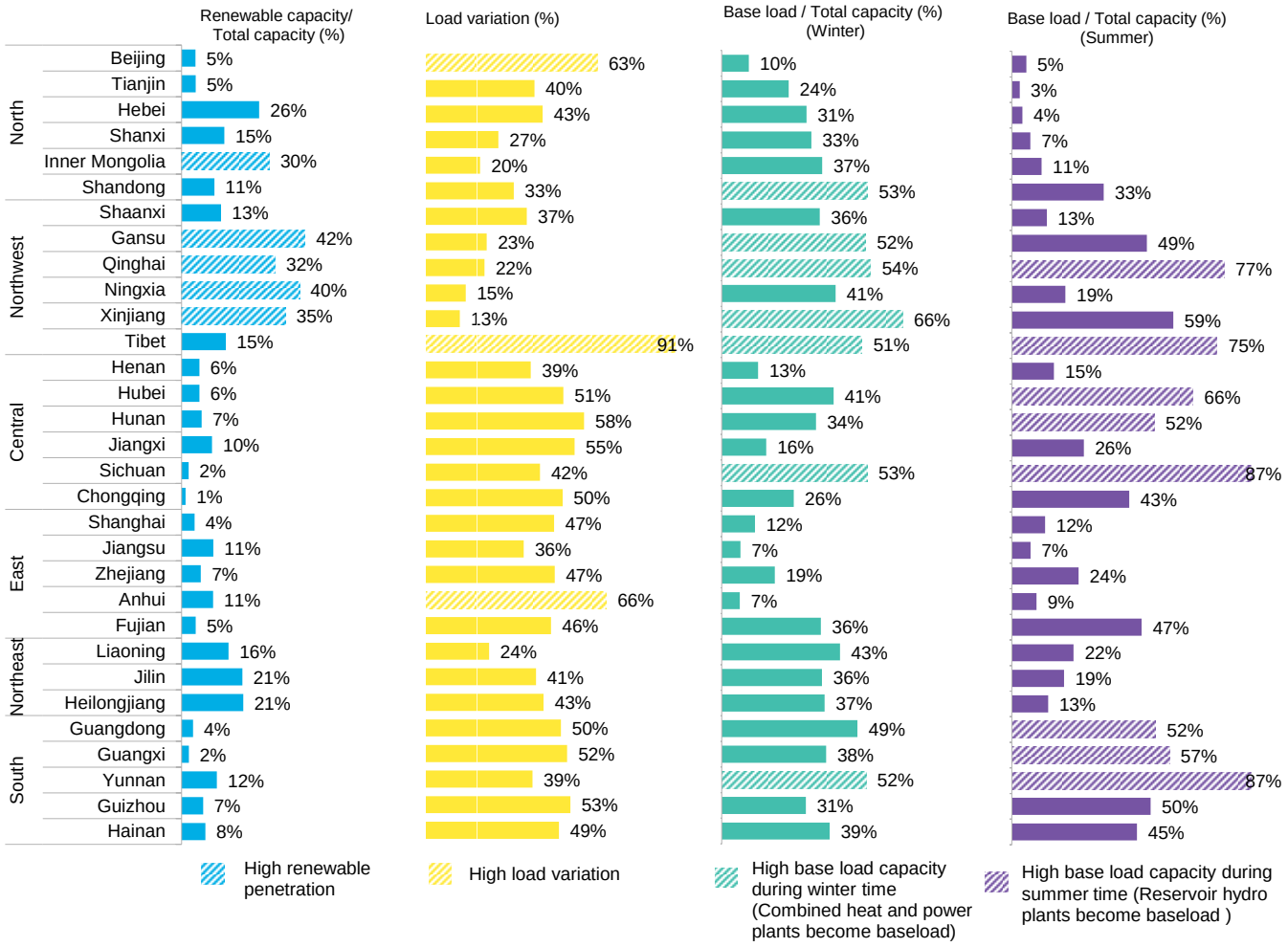
China's current market design results in inefficient dispatch



- China's power market is currently designed in a way that does not allow for economically rational dispatch – i.e. dispatching generation based on the marginal cost of those plants. In rational dispatch, zero-cost wind and solar would be prioritized ahead of other forms of generation.
- Generation used to be mostly sold to the grid companies under long-term contracts at prices set by the government. Inter-provincial power sales happen via tightly planned transactions.
- A regulated, technology-differentiated power pricing system is revised on an annual basis and is intended to reflect project LCOEs.
- Grid companies pay the same price to renewable and thermal plants. This form of dispatch does not reward lower marginal costs, which is a characteristic of renewable power plants.
- A pre-set allocation system is determined by the government on a yearly basis. The order of plant dispatch is based on a combination of regulated power prices and a pre-arranged number of hours that the plant is expected to run over the year.

System flexibility is a challenge with high renewables penetration

Provincial power flexibility key parameters, 2016



Source: NEA, Bloomberg New Energy Finance. Note: Captive power capacity, run-of-river hydro, combined heat and power (CHP) during winter time, 30% of the reservoir hydro during summer time, nuclear power plants are considered as non-dispatchable (baseload) in our calculation.

- The power system's lack of flexibility is the major technical barrier hindering the full utilization of renewables, especially in provinces with a high percentage of intermittent renewable penetration.
- China's power mix is dominated by coal, which has limited flexibility to reduce output.
- An ancillary service (load-following) market is not available. China's generators are paid at regulated prices that do not fluctuate throughout the day or respond to supply and demand signals. As a result, power generators lack financial incentives to upgrade their load-following capability.
- Northern provinces, such as Xinjiang and Shandong, have a large number of captive power plants directly owned and operated by end-users. They operate as a baseload and are not required to do load following.
- In addition, China's balancing area is typically at the provincial level. The small balancing area can mean that renewables curtailment occurs at low penetration rates.
- Interconnection can provide flexibility for electric power system operation. However, China's inter-provincial power transmission normally takes the form of fixed bilateral contracts, and this does not benefit overall power system flexibility.

New normal for power sector regulations

China’s policy-makers set up investment risk mechanisms

New regulations for the 13th FYP

- The crux of China's challenge in managing its power generation system for the next few years is: will low-carbon generation be appropriately prioritized over coal-fired power, or will it be economically 'stranded'? Additionally, as the country moves toward higher renewables penetration of the power supply and more liberalized market design, what will the impact be on China's coal-fired power assets? What is the risk of economic impairment on these assets?
- The focus during the 13th FYP period is no longer stimulating the rapid build-out of new generation capacity but rather, on how to streamline investment planning and operation of the overall power system while avoiding incurring significant social and capital costs. Since 2015, the National Energy Administration (NEA), along with related regulatory agencies, has instituted a series of mechanisms, including:
  - To promote more efficient operation of power dispatch, the government has begun directing a new round of reforms since March 2015, aiming to establish a market-based mechanism to determine volumes and pricing for wholesale markets. Most notable are the changing priorities of dispatch, expanding on regional pilots that have been under development for several years. (See slides 14 and 15 for a more detailed discussion)
  - To promote grid-integration of wind and solar, the NEA launched Renewable Portfolio Standards (RPS), requiring individual province-level utilities (grid operators) to meet targets for lower-carbon generation. This policy has not been fully implemented yet. Another policy, the Minimum Guaranteed Dispatch of Renewables, ensures minimum utilization hours for wind and solar assets in various provinces, in an attempt to address curtailment issues.
  - In order to discourage over-investment in new wind and solar capacity in provinces plagued with severe curtailment, the NEA also announced a new investment risk metric system to guide provincial regulators and project developers. (See slides 16 and 17 for more details.)
  - In order to control over-investment in coal capacity, the NEA announced a similar investment risk metric system . This allocates different investment risk thresholds for new coal capacity planned in each province. (See slide 15 for more details)
- However, a major challenge for market operators is the lack of transparency on how central regulators decided investment risk ratings for each province. All of these policies rely on overlapping sets of metrics which China's regulators will continue to monitor over the course of the 13th FYP period in order to assess the evolving conditions of the power market.

Reforms are pivotal moment for market design

Illustration of dispatch planning, pre-reform

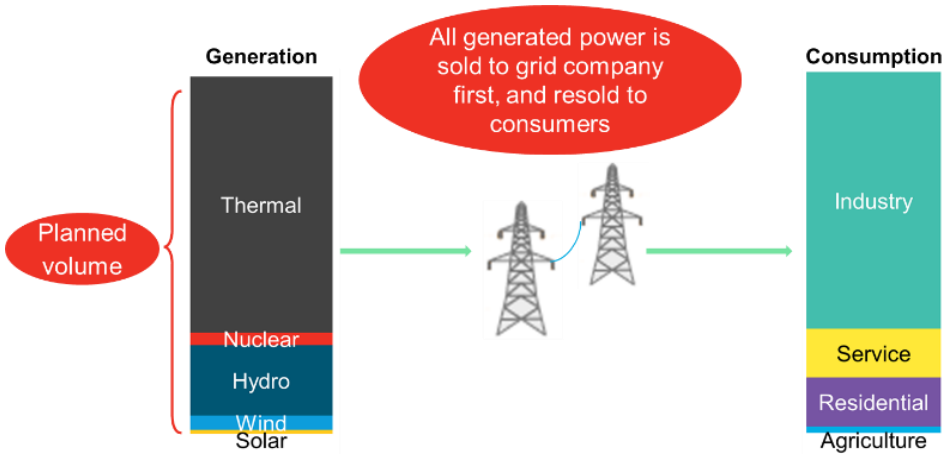
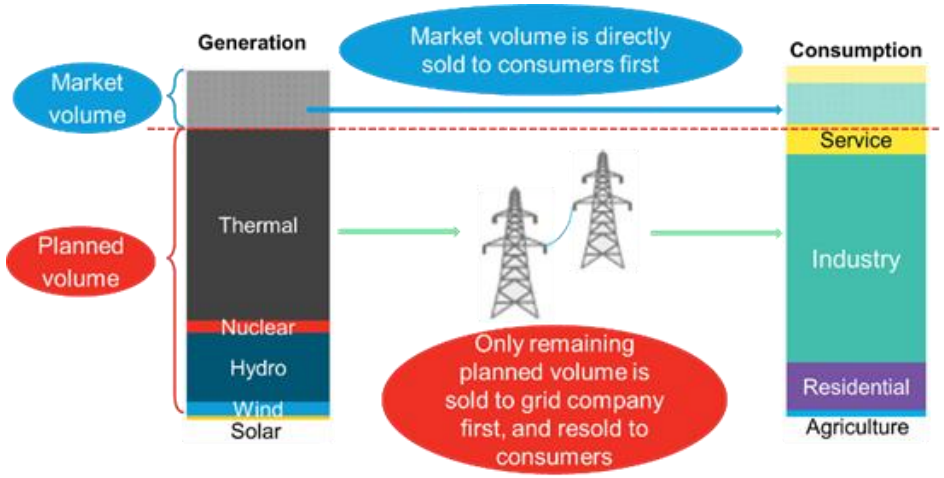


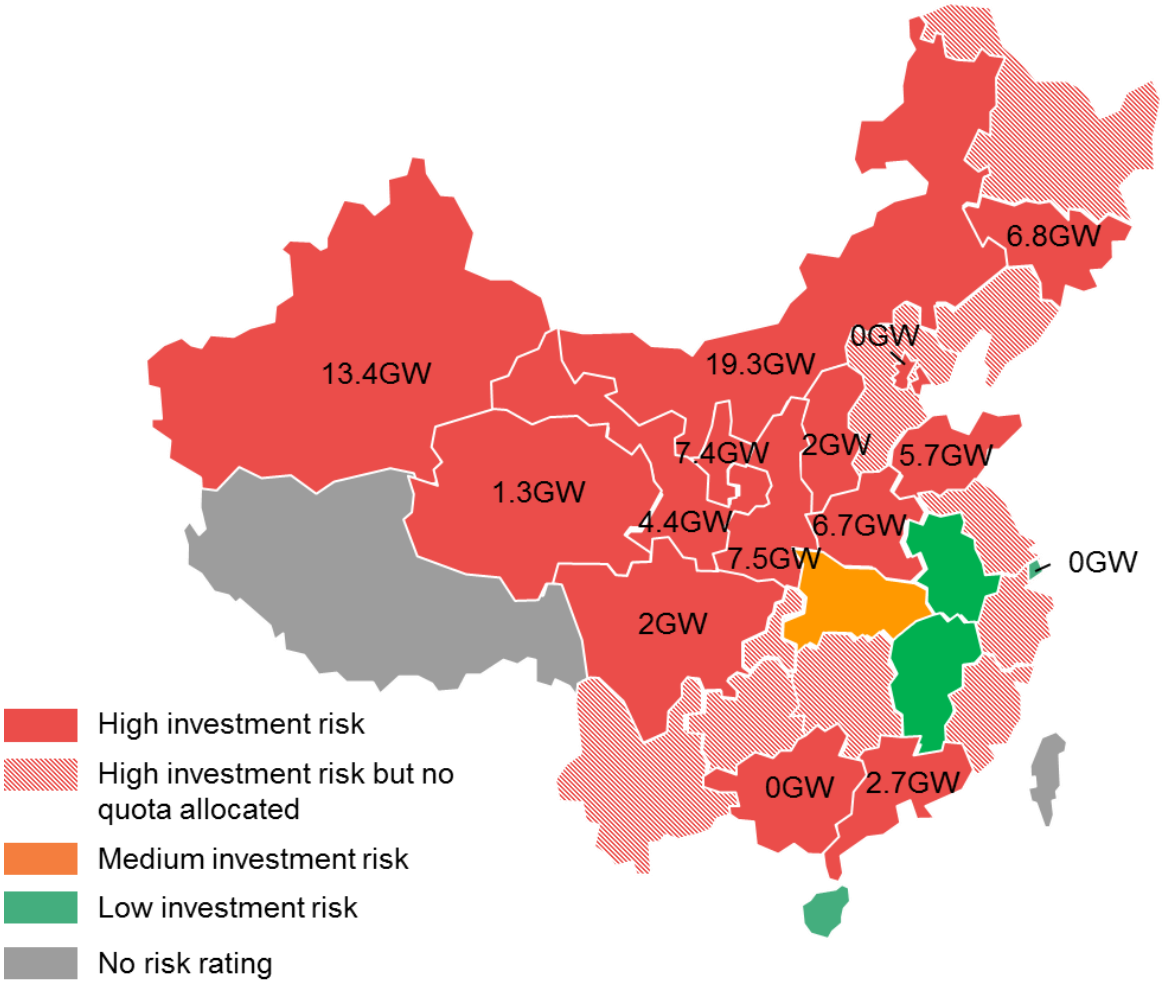
Illustration of dispatch planning, post-reform



- To build a more efficient and greener power market, the government has been directing a new round of reforms since March 2015, aiming to establish a market-based mechanism to determine volumes and pricing for both wholesale and retail.
- Since 2015, China's power sector reforms have progressed rapidly, with every province in the country (except Tibet) now piloting some form of wholesale and/or retail liberalization.
- Regulators have begun price discovery for transmission costs, piloting more transparent fees for several regions across China. This paves the way for the eventual de-regulation of wholesale and retail power prices.
- Additionally, on March 29, 2017, the National Development and Reform Commission (NDRC) and the NEA jointly issued a "Notice to orderly deregulate power generation and consumption dispatch" (the "Notice"), which lays out how future liberalized wholesale power markets will be structured and dispatch priorities established.
  - **Before reforms**, local governments were responsible for determining at the beginning of each year the generation dispatch order of all the power plants in their jurisdiction, matching supply and demand. Each coal plant was also given a minimum dispatch to ensure it could operate without a loss. The local regulators also determined wholesale power prices at which power plants could sell their generation to the grid company and the retail prices at which grid companies could sell power to customers.
  - **Following reforms**, the wholesale power market will be split in two, with a portion of it (supplied by wind, solar, nuclear, and hydro) continuing to be dispatched and priced by regulators, while the majority of the market, supplied by coal-generation, will be traded. Regulators will lower guaranteed generation quotas for existing coal power plants by 20% in 2017 with further reductions each following year. All new coal power plants that receive NEA approval for development after March 15, 2015, will not be allocated any planned generation hours. Instead, they must compete in markets to contract for 100% of their generation dispatch.

To read more, see our theme page: China Electricity Market Reforms

Official new-build coal generation investment risk forecast (2019) with 2017-2020 quotas



- In March 2016, the NEA announced the first investment risk map for new-build coal-fired generation capacity. The investment risk alert mechanism assesses the potential performance of planned coal-fired power plants, assuming they were to come online in 2019. Hence, the rating is allocated for all provinces to consider when planning for new-build coal power.
- Ratings are based on three key factors:
  - Estimated internal rate of rate (IRR) for new coal capacity, assuming it is commissioned in 2019 (this takes into account various factors including expected on-grid coal benchmark power price and coal fuel costs).
  - Estimated "reasonable" reserve rate (i.e. amount of reserve capacity margin a certain power region needs).
  - Other factors including environmental resource restrictions (air and water pollution) and other policy considerations.
- All markets rated red (high risk) are not allowed to approve new-build coal power plants.
- According to this rating, only four provinces are still allowed to plan for new capacity. However, out of the 29 provinces that are rated high-risk, only 14 were given specific quotas for how many new coal plants they can commission from 2017 to 2020. The remaining provinces were not given any quotas, which could mean that they are not allowed any new build at all, or that there is no specific limit on how much can be built.

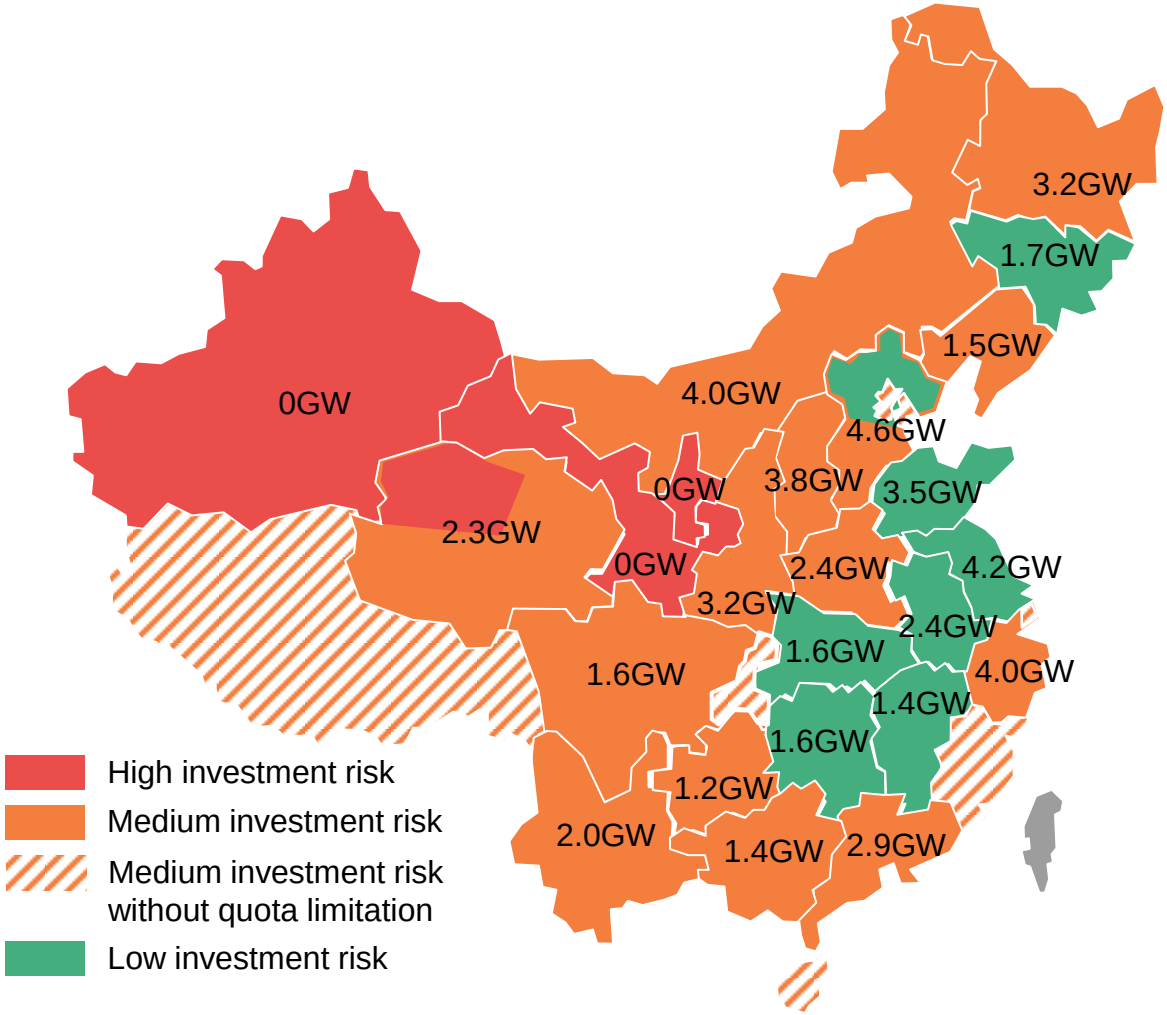
Source: NEA, Bloomberg New Energy Finance. Note: Provinces that are blank were not given a specific limit on how much new coal capacity they can bring online.

Official onshore wind investment risk map (2017) with 2017-2020 new-build quotas

Source: NEA, Bloomberg New Energy Finance

- China's NEA announced an onshore wind investment risk alert mechanism in July 2016, effectively putting a hold on wind development in provinces with high curtailment.
- Updated annually, the mechanism assigns one of three ratings – red (high risk) / orange (medium risk) / green (low risk) to each region (defined as 29 provinces and four sub-province regions).
- For setting ratings, regulators consider historical curtailment, the speed of project development, the local policy environment, power system flexibility, retail prices, and wind company profitability.
- NEA's 2017 assessment flags the following provinces with red alerts: East Inner Mongolia, West Inner Mongolia, Jilin, Heilongjiang, Gansu, Ningxia and Xinjiang. No new-build quotas have been allocated for any of these markets from now until 2020.
- When a province is under a red alert, it will not receive a "development" quota from the NEA for the following year. This means the local government cannot approve new wind projects to add to the pipeline. Projects need this "development" quota acknowledgement to qualify to receive subsidies. Additionally, local grid companies cannot connect new capacity into the grid (even if the project is completed).

Official utility-scale solar PV investment risk map (2017) with 2017-2020 new-build quotas



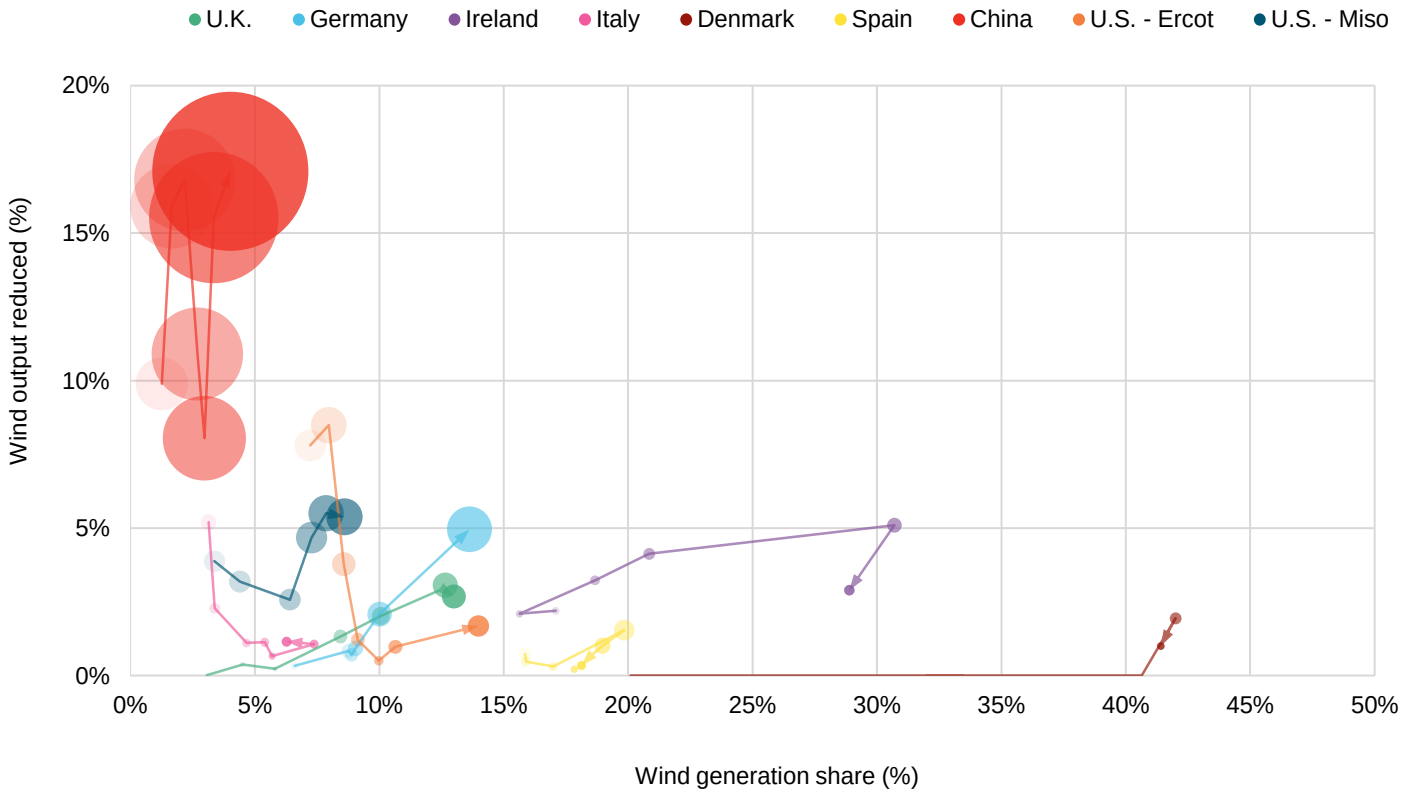
Source: NEA, Bloomberg New Energy Finance

- After releasing a similar evaluation for wind and coal, the NEA released a set of investment risk evaluation metrics for utility-scale PV in August 2017. The solar industry is much more fragmented than coal and wind, and therefore more difficult to evaluate.
- Only eight out of the 38 regions evaluated were considered “low” risk, 24 are medium-risk, and six are high-risk. But even the low-risk provinces may prove risky for investors. New-build quotas allocated for many regions with low risk ratings are already oversubscribed by existing announced or under-construction projects. Projects must obtain quota approval in order to qualify for subsidies.
- The risks are defined by major factors that can negatively affect the cash flow of a project. These are the risk of curtailment of electricity output, and other local factors such as high land costs, negative attitudes from grid companies toward renewable energy deployment and unfavorable local regulation (i.e. complex permitting processes, local governments asking for kickbacks to grant access, etc.).
- In August 2017, China approved a new quota of 86.5GW for new utility-scale PV capacity from now until 2020. According to this investment rating map, 76% of planned utility-scale PV build is located in regions with considerable curtailment and project development risk.

Renewables curtailment

Current status

China’s renewables curtailment

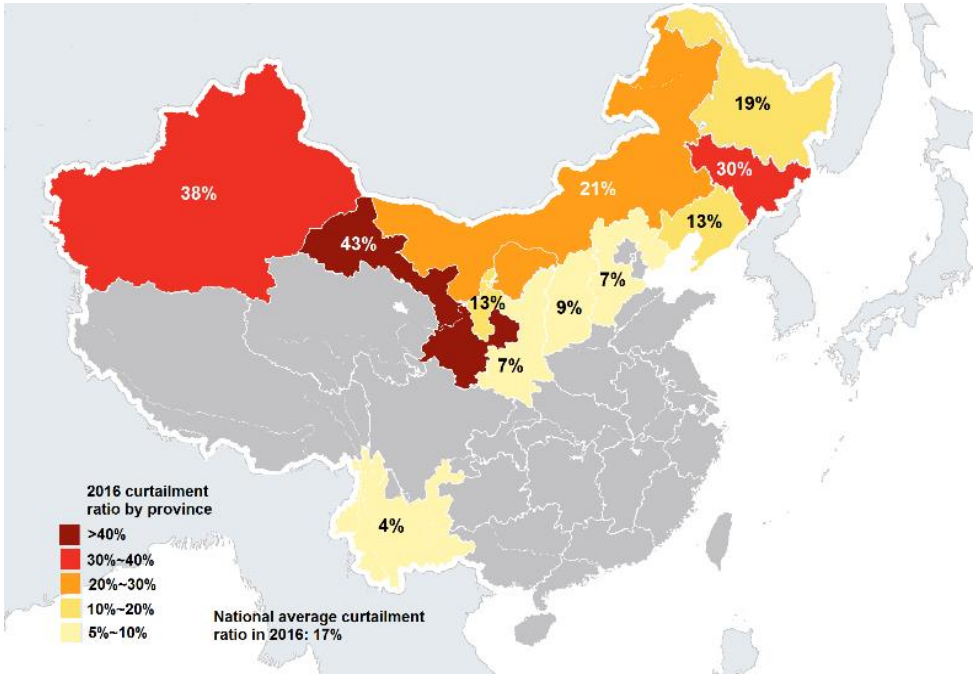


- Curtailment – wind farms and solar plants are forced to reduce their output.
- Even though variable renewable electricity penetration is still at a low level (less than 5% of the total electricity generation) in China, the country’s wind and solar curtailment is the worst in the world. China’s annual average wind curtailment exceeded 17% in 2016 largely due to the record number (30GW) of wind projects built in 2015.
- As curtailment goes uncompensated, China’s renewable energy asset owners bear big financial uncertainties.

Source: Bloomberg New Energy Finance, NEA, ENTSO-E, U.S. DOE. Note: The size of the bubbles reflects the absolute level (in GWh) of wind output reductions. Higher transparency indicate earlier years. Arrows indicate direction of time. No 2016 data available for Germany or U.S. – Miso; no 2010 data available for Ireland. 2015 was the first year where Denmark had measurable wind output reductions. This was driven by an agreement with Germany to reduce wind output at certain moments to avoid overloading the internal German grid. For details, please see Research Note - Flexibility Series: the Many Faces of Curtailment (Web|Terminal)

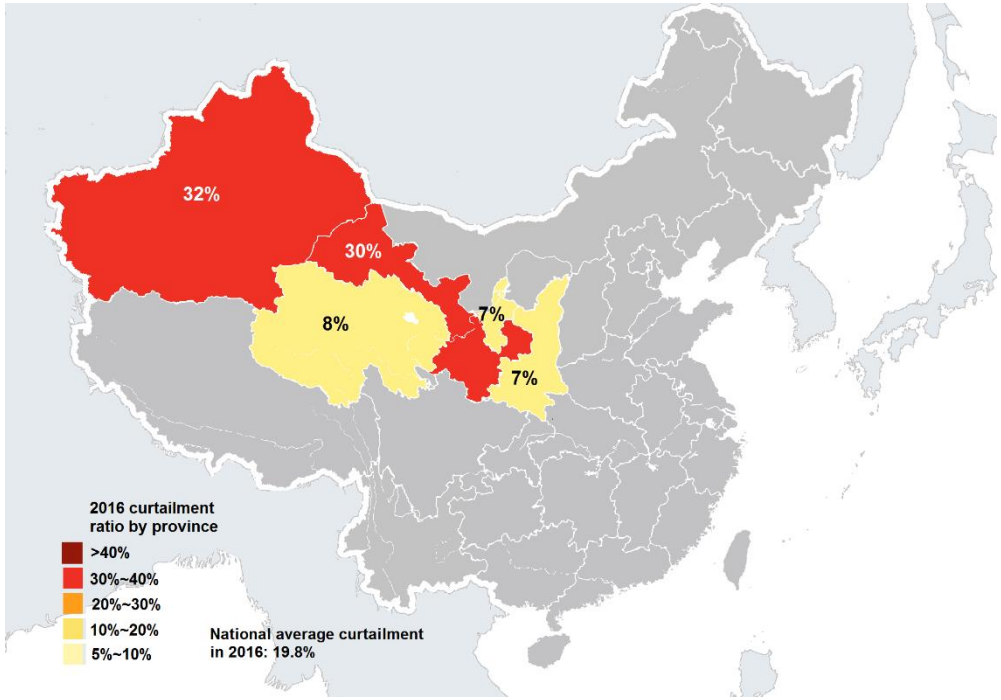
Provincial curtailment rate: current conditions

2016 provincial wind curtailment ratio in China



Source: Bloomberg New Energy Finance, National Energy Administration (NEA).

2016 provincial solar curtailment ratio in China

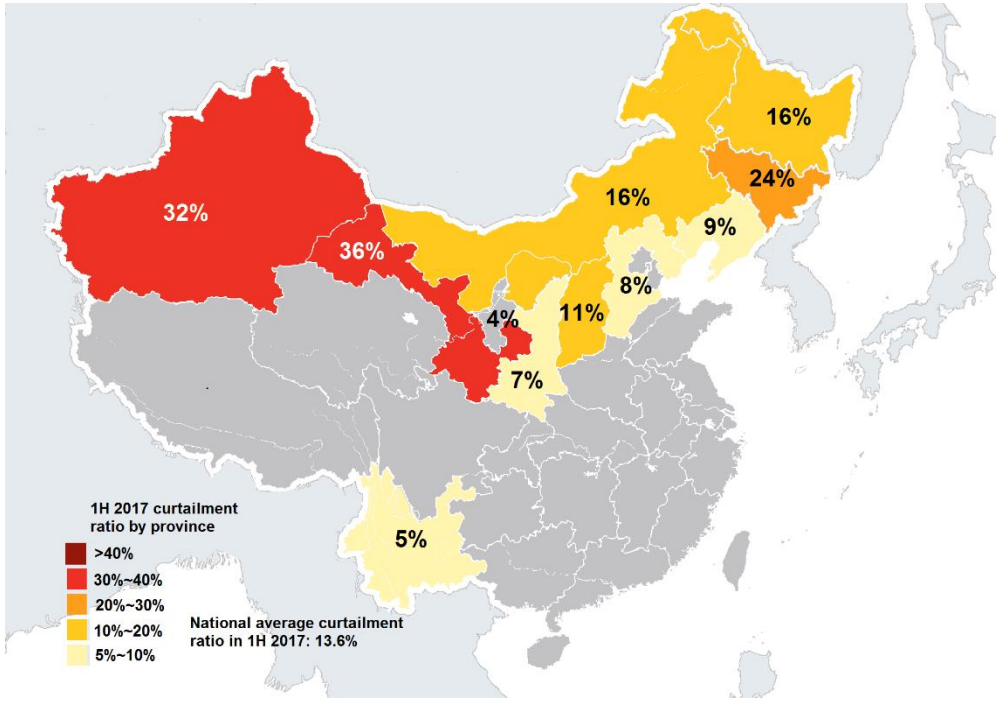


Source: Bloomberg New Energy Finance, National Energy Administration (NEA).

Northern regions are subject to the most severe curtailment, as a majority of the existing variable renewable energy plants are there. The northwest provinces, Gansu and Xinjiang, saw some of the worst grid congestion for both wind and solar. In 2016, Gansu's wind and solar curtailment surged to 43% and 30% respectively, while Xinjiang's curtailment rate remained above 30%. China's 2016 national average curtailment ratios for wind and solar amounted to 17% and 19.8% respectively.

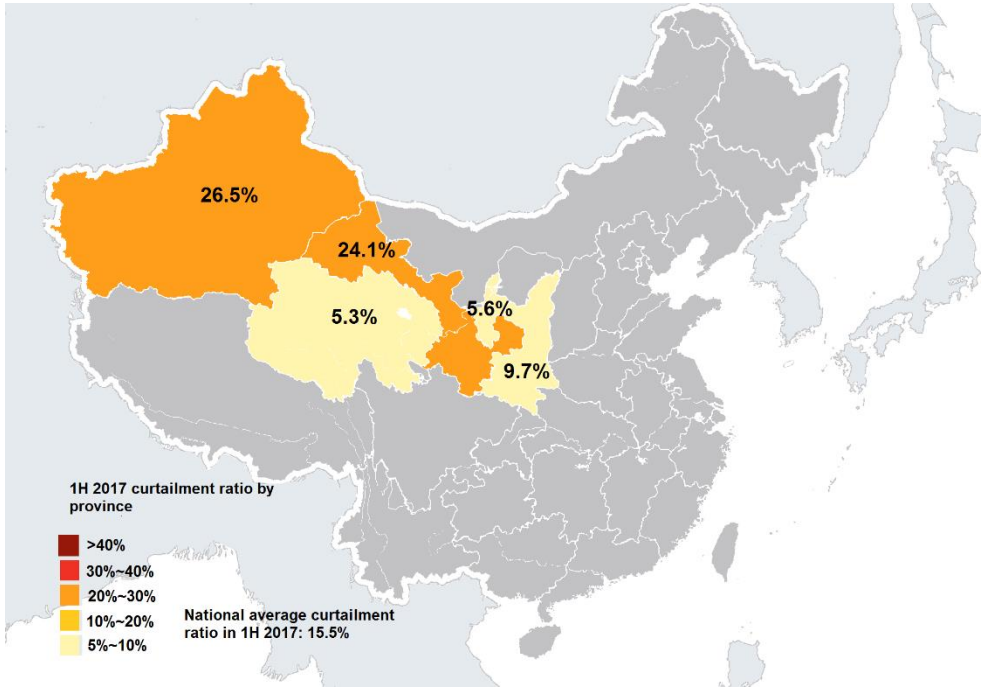
Provincial curtailment rate: current conditions

1H 2017 wind curtailment ratio in China



Source: Bloomberg New Energy Finance, National Energy Administration (NEA).

1H 2017 solar curtailment ratio in China

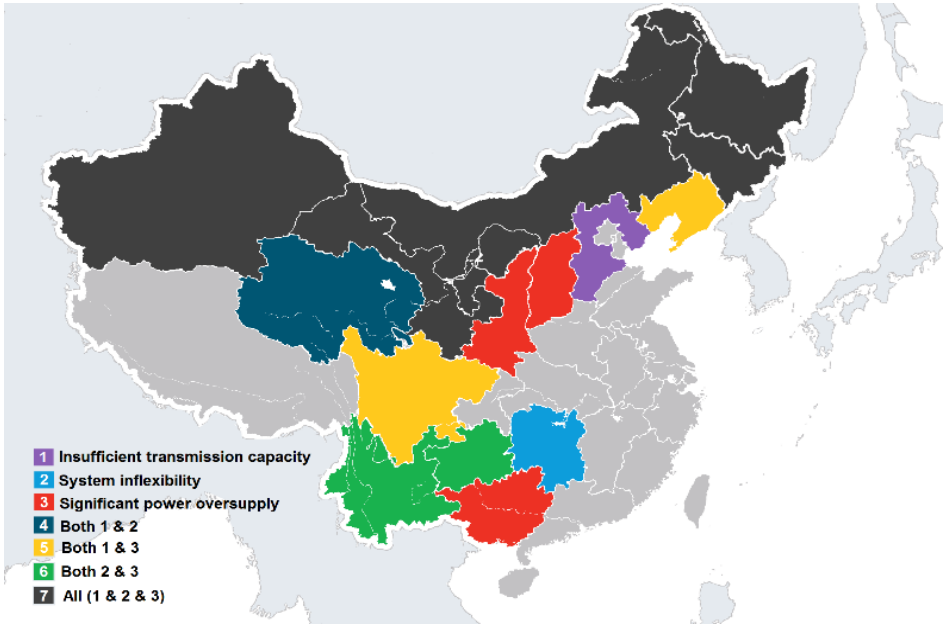


Source: Bloomberg New Energy Finance, National Energy Administration (NEA).

The surge of China's renewables curtailment in 2016 was largely driven by wind developers' rush-to-build in the northern regions to qualify for the higher feed-in tariffs. Regulatory measures controlling the rate of new build in high-curtailment provinces kicked in from 2016, and since then there has been a slight easing in curtailment for the most affected provinces, particularly Inner Mongolia and Gansu. China's wind and solar curtailment dropped to 13.6% and 15.5% respectively in 1H 2017, from 17% and 19.6% in 2016.

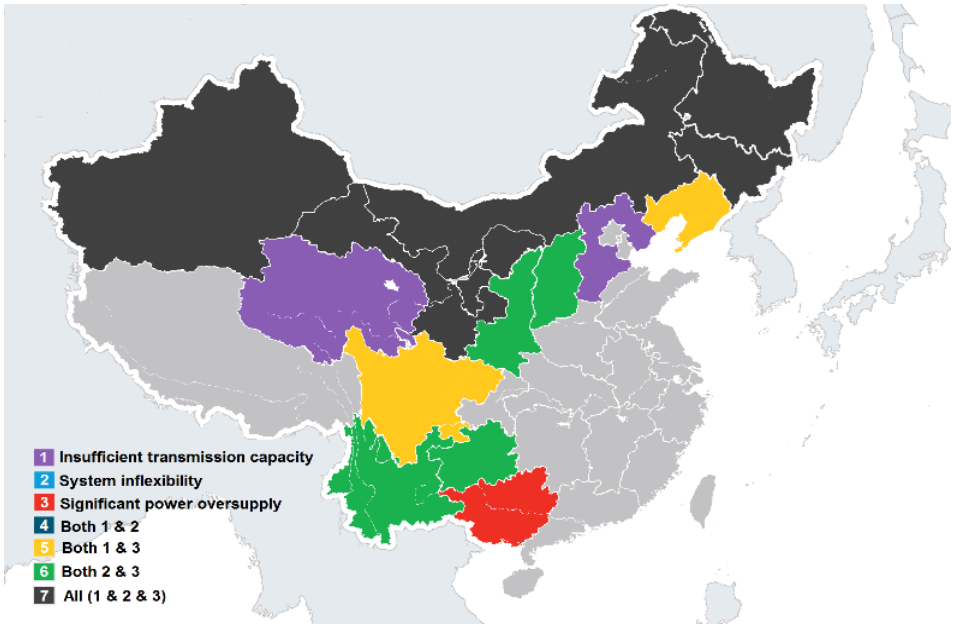
Curtailment risks: summary

Current causes of renewables curtailment during warm (wet) season



Source: Bloomberg New Energy Finance. Note: We assume captive thermal power capacity, run-of-river hydro, 30% of the reservoir hydro and nuclear power plants are base load during summer time.

Current causes of renewables curtailment during cold (dry) season



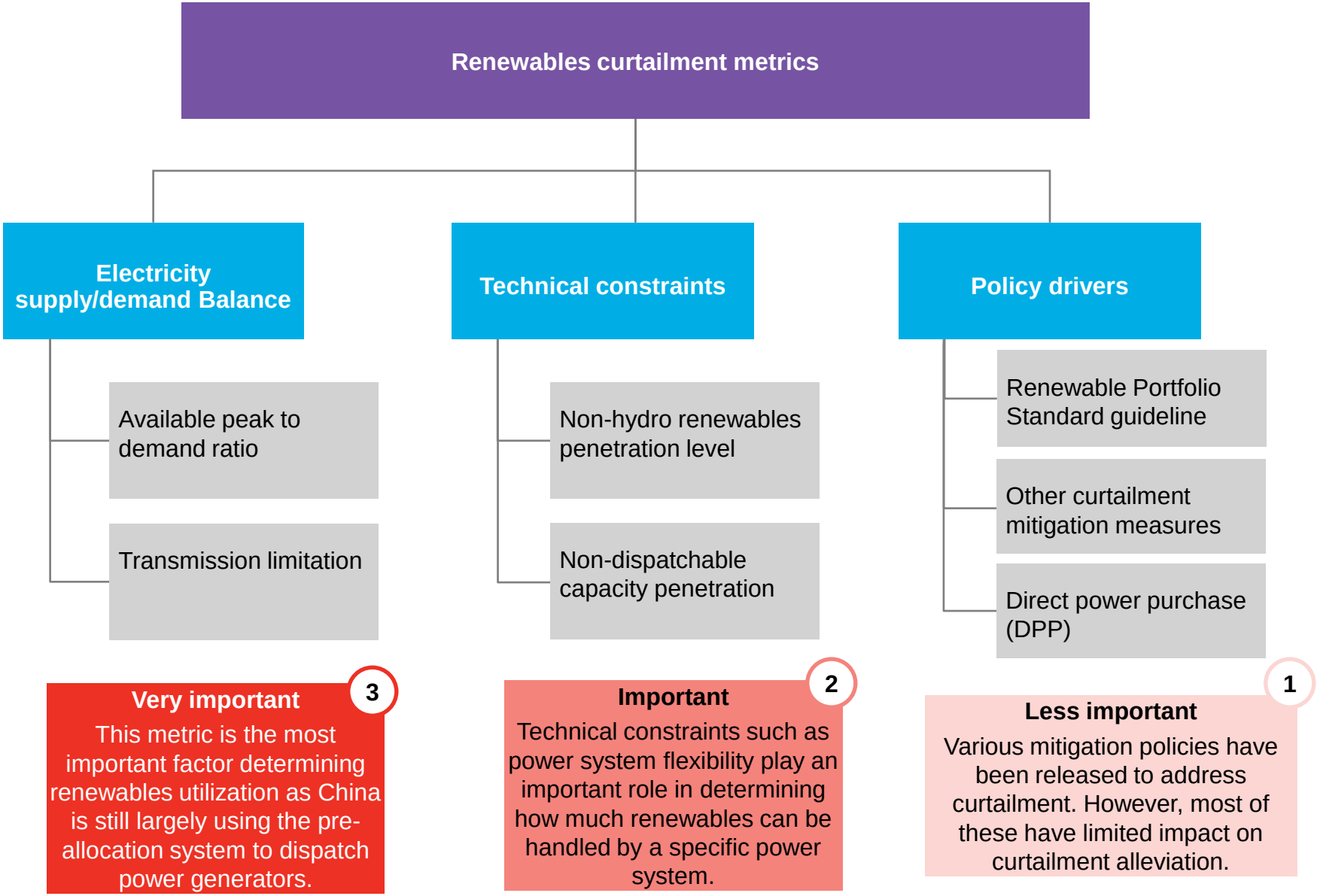
Source: Bloomberg New Energy Finance. Note: We assume captive thermal power capacity, run-of-river hydro, CHP and nuclear power plants are base load during winter time.

The causes of curtailment vary significantly between different Chinese provinces. Grid congestion, poor market dispatch design, and power oversupply are all key factors. Another issue is seasonal curtailment, related to seasonal variation in the amount of flexible capacity available to a local grid. For instance, during the cold season, the overall power system flexibility becomes worse in northern China as the combined-heat-and-power (CHP) power plants from thermal plants operate as base load capacity to deliver heat. Meanwhile, the southern parts of China will see worse power-system flexibility during the summer as hydro power becomes the base load. We account for this by calculating variation in the amount of non-dispatchable power from season to season.

Renewables curtailment assessment

Metrics and methodology

Renewables curtailment metrics



Source: Bloomberg New Energy Finance. Note: The number identified in the circles above represents the weight of importance assigned to each factor.

Renewables curtailment metrics

Category	Metrics	Description	Comments
Electricity supply/demand	**Available capacity to peak demand ratio**	*Available capacity/ local peak demand* Indication of the electricity oversupply level. The higher the available capacity to peak demand ratio, the higher the curtailment risks.	The provincial power excess level and estimated export capacity are two major drivers determining how much capacity factor will be allocated to renewable power generators.
	Transmission limitation	(*Net export capacity minus available capacity)/ available capacity* Grid congestion plays a significant role in renewables curtailment. This ratio provides a pointer to provincial-level transmission export capacity sufficiency.	
Technical constraints	**Non-hydro renewable penetration level**	*Wind and solar cumulative grid-connected capacity/ Total cumulative grid-connected capacity* Intermittent renewable energy requires other power generators to be flexible enough to adjust their output. The higher the renewable capacity penetration, the greater need for other generators to be flexible.	Power system flexibility is a major influence on how much renewables capacity can be accommodated in the system. We picked two major metrics to evaluate the current level of power system flexibility – the percentage of capacity that cannot provide load peaking and the percentage of renewables capacity that has already been integrated.
	Non-dispatchable capacity penetration	*Baseload capacity/ Total cumulative grid-connected capacity* Non-dispatchable capacity (or baseload) is the power plants that will run at full capacity and will not adjust their output to accommodate renewables. The more baseload, the less flexible the power system will be, which might result in renewables curtailment even when there is not a lot of green energy capacity in the system.	
Policy drivers	**RPS guideline gap (2016 vs 2020)**	(*Targeted 2020 non-hydro renewable penetration minus Current level)/ Current level* The proposed Renewable Portfolio Standard (RPS) requires each province to have a certain portion of total electricity demand supplied by non-hydro renewables by 2020. However, the RPS is still pending approval from the State Council and faces opposition.	We split various policy drivers into three major categories – the renewable portfolio standard, the various initiatives aimed at increasing renewable generation, and the direct power purchase (DPP) mechanism.
	Alternative approaches	*Rating determined by numbers of initiatives* Various alternative approaches to increase local renewable consumption, including energy storage for renewables (renewables + batteries, wind-to-heat, wind-to-hydrogen, and others); Dispatching and managing local generation and demand – microgrids, multi-energy optimization and integration (MEIO) and others.	
	Direct power purchase	*Rating determined by the stage of implementation and the amount of renewables participating in this mechanism* As part of China's power market reform, power generators are encouraged to conduct power transactions directly with end-users. Some provinces have encouraged renewables to participate in the DPP as well.	

Source: Bloomberg New Energy Finance

Metrics scoring

Category	Metrics	Description	Rating
Electricity supply/demand	**Available capacity to peak demand ratio**	*Available capacity/ local peak demand*	• Low risk: 0% (Score: 0) • High risk: 500% (Score: 100)
	Transmission limitation	(*Net export capacity minus available capacity)/ available capacity*	Electricity export provinces: • Low risk: 0% (Score:40) • High risk: -120% (Score: 100) Electricity import provinces: • Low risk: -160% (Score: 0) • High risk: -40% (Score: 60)
Technical constraints	**Non-hydro renewables penetration level**	*Wind and solar cumulative grid-connected capacity/ Total cumulative grid-connected capacity*	• Low risk: 0% (Score: 0) • High risk: 60% (Score: 100)
	Non-dispatchable capacity penetration	*Baseload capacity/ Total cumulative grid-connected capacity* *In our calculation, we assumed that captive power capacity, run-of-river hydro, combined heat and power (CHP) during winter time, 30% of the reservoir hydro during summer time and nuclear power plants are all baseload and non-dispatchable.*	• Low risk: 0% (Score: 0) • High risk: 90% (Score: 100)
Policy drivers	**RPS guideline gap (2016 vs 2020)**	(*Targeted 2020 non-hydro renewable penetration minus Current level)/ Current level*	• Low risk: 1000% (Score: 0) • High risk: <=0% (Score: 100)
	Alternative approaches	*Rating determined by numbers of initiatives*	• Low risk: 5 (Score: 0) • High risk: 0% (Score: 100)
	Direct power purchase	*Rating determined by the stage and scale of renewable participating market transaction*	• Low risk: 5 (Score: 0) • High risk: 0% (Score: 100)

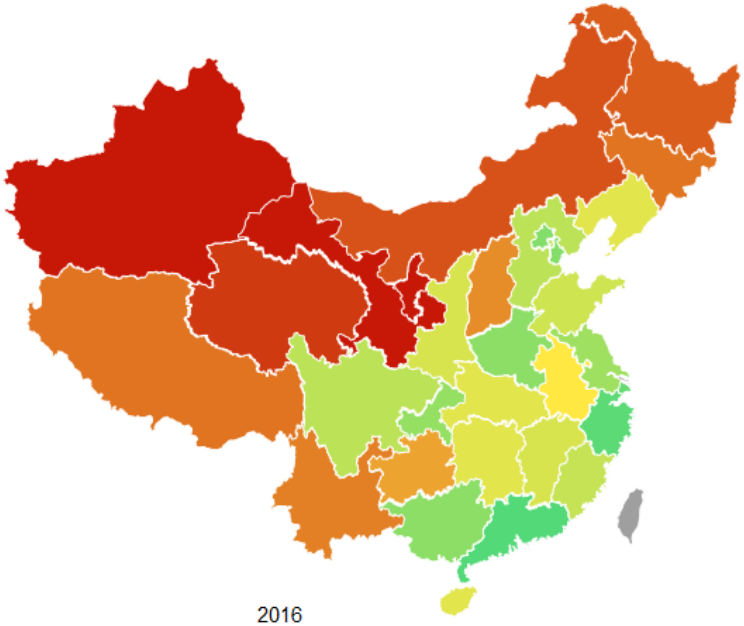
Source: Bloomberg New Energy Finance. Note: Ratings are mainly determined by the maximum and minimum values of a specific metric ranging between 2015 and 2020. Given the lack of predictability of policy drivers, we employ 2016 rating for 2017-20 unless there are clear government plants for the evolution of these policies.

Provincial curtailment risks assessment

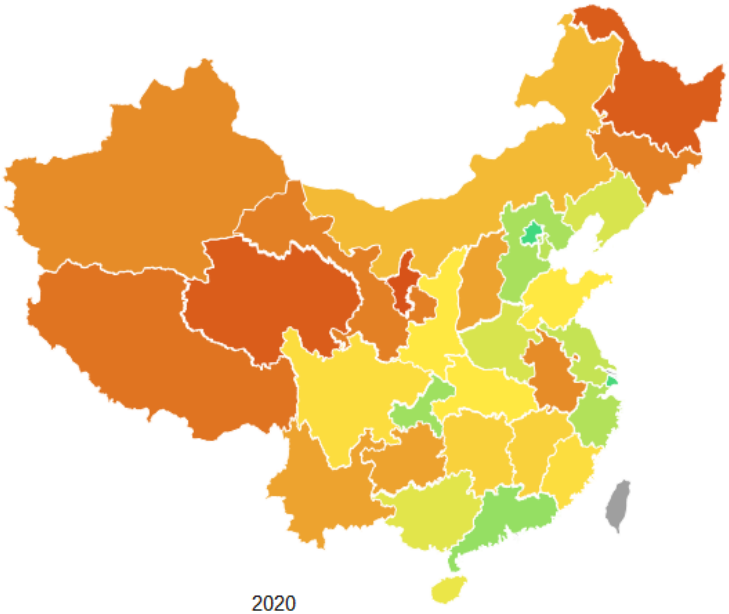
Risk assessment of provinces with renewables curtailment

Provincial curtailment risk forecast overview

Renewable curtailment metrics (2016)



Renewable curtailment metrics (2020)



Based on the previous analysis, we provide an overview of the provincial curtailment risks in 2020 below.

Category	Provinces
Curtailment may worsen	Shaanxi
Curtailment may improve significantly	Xinjiang, Gansu, Ningxia, Inner Mongolia, Yunnan, Shanxi
Curtailment may remain at about the same level	Hebei, Jilin, Heilongjiang, Qinghai, Liaoning
Curtailment may emerge for currently non-curtailed provinces	Hunan, Sichuan, Guizhou, Fujian

Source: Bloomberg New Energy Finance. Note: We only include province seeing renewable curtailment risks in this table.

Provincial curtailment risks assessment – Hebei

Category	Metrics	Current status (2016)	Forecast (2020e)	Weight	Notes
Electricity supply/demand	Available capacity to peak demand ratio	Low	Low	3	Power oversupply remains about the same
	Transmission limitation	Low	Low	3	Currently, Hebei lacks transmission lines to dispatch wind electricity from the mega-base at Zhangjiakou, causing curtailment in only that one region. On average, curtailment in the province is low. A new UHV AC is planned specifically for the Zhangjiakou asset and we expect transmission constraints to ease by 2020.
Technical constraints	Renewables penetration level	Mid	Mid-high	2	Renewables capacity penetration rate is likely to increase from 26% to 32% by 2020.
	Non-dispatchable capacity penetration	Low	Low	2	The non-dispatchable capacity will see a slight drop in Hebei from 2016-20.
Curtailment risk mitigation drivers	RPS guideline gap (2016 vs 2020)	High	High	1	Hebei is close to its RPS target of 10% by 2020. The RPS guideline is unlikely to have a major impact on renewables dispatch prioritization in Hebei.
	Alternative approach	Mid	Mid	1	Initiatives include using renewables for heat, a micro grid pilot project, and a MEIO system pilot. However, their impact might be limited given the early stage of development.
	Renewable DPP	High	Mid	1	Hebei currently does not have renewable energy generators participating in DPP schemes. However, we expect this to change over the next few years, helping to improve renewables integration.
Overall curtailment		**30**	**31**		Overall curtailment risks are likely to stay at about the same level.

Source: Bloomberg New Energy Finance. Note: The number in the bracket represents curtailment alleviation score. The higher the number, the lower the curtailment risks.

Provincial curtailment risks assessment – Shanxi

Category	Metrics	Current status (2016)	Forecast (2020e)	Weight	Notes
Electricity supply/demand	Available capacity to peak demand ratio	Mid-high	Mid-high	3	Power oversupply to slightly increase
	Transmission limitation	High	High	3	Shanxi's first 8GW UHV DC line connecting to Jiangsu is currently under construction and is expected to come online in late 2017. However, given the local available capacity, the transmission limitation is likely to persist.
Technical constraints	Renewables penetration level	Low	Mid	2	We expect Shanxi's renewables capacity penetration to increase noticeably, based on our forecast.
	Non-dispatchable capacity penetration	Low	Low	2	Shanxi's non-dispatchable capacity penetration rate is low. We anticipate it to slightly decrease, based on our forecast.
Curtailment risk mitigation drivers	RPS guideline gap (2016 vs 2020)	High	High	1	Shanxi will exceed its RPS target in 2020.
	Alternative approach	Mid	Mid	1	Initiatives include using renewables for heat, micro grid pilot project, MEIO system pilot. Impact might be limited given the early stage of development.
	Renewables DPP	High	Mid-high	1	Currently, renewables direct power purchase has not been established in Shanxi yet. Only coal generators now participate in DPP. We expect that in the future, Shanxi will allow for wind and solar to participate, but that renewables participation volumes will remain low in a market dominated by coal generation.
Overall curtailment		50	48		Overall curtailment risk is likely to improve by 2020.

Source: Bloomberg New Energy Finance. Note: The number in the bracket represents curtailment alleviation score. The higher the number, the lower the curtailment risks

Provincial curtailment risks assessment – Inner Mongolia

Category	Metrics	Current status (2016)	Forecast (2020e)	Weight	Notes
Electricity supply/demand	Available capacity to peak demand ratio	High	High	3	Currently, Inner Mongolia's power oversupply is high. It will drop slightly in the coming years.
	Transmission limitation	High	Mid	3	Three UHV DC lines connecting Inner Mongolia to load consumption centers Shandong and Jiangsu are currently under construction and are expected to come online by 2017 year-end. The province's fourth UHV line connecting to central province Hubei has been permitted and is expected to commission by 2020, bringing Inner Mongolia's total UHV DC export capacity to 40GW. Besides UHV DC lines, Inner Mongolia has also a UHV AC lines development plan. The development of the transmission lines may significantly reduce curtailment.
Technical constraints	Renewables penetration level	Mid-high	Mid-high	2	We expect Inner Mongolia's renewables capacity penetration to slightly increase, based on our forecast.
	Non-dispatchable capacity penetration	Low	Low	2	Its non-dispatchable capacity penetration rate is low and it may slightly decrease in the coming years.
Curtailment risk mitigation drivers	RPS guideline gap (2016 vs 2020)	High	High	1	Inner Mongolia exceeded its RPS target in 2016. This guideline is unlikely to have a big impact on the growth of renewable generation.
	Alternative approach	Mid	Mid	1	Inner Mongolia is currently looking into initiatives, including using wind/solar for heat, a micro grid pilot project, an Internet + smart grid project, and an MEIO system pilot project. But all these are currently at an early development stage. Given the early stage, we expect the impact of these pilots on renewables integration to be limited.
	Renewables DPP	Mid-high	Low	1	Inner Mongolia's renewables can participate in DPP, however, participation is very limited right now. We expect over the next few years, volume of participation will increase for both wind and solar.
Overall curtailment		57	49		The overall curtailment risk may ease noticeably, largely due to the multiple UHV transmission lines development.

Source: Bloomberg New Energy Finance. Note: The number in the bracket represents curtailment alleviation score. The higher the number, the lower the curtailment risks

Provincial curtailment risks assessment – Shaanxi

Category	Metrics	Current status (2016)	Forecast (2020e)	Weight	Notes
Electricity supply/demand	Available capacity to peak demand ratio	Low-mid	Mid	3	Power oversupply in this province may significantly increase.
	Transmission limitation	Mid	Mid-high	3	Shaanxi's first UHV DC transmission line with total capacity of 10GW has been announced, however, its commission timeline has not been confirmed. However, its transmission line development will be slower than its local power plants new build, resulting in increasing grid curtailment risks.
Technical constraints	Renewables penetration level	Low	Low-mid	2	We expect Shaanxi's renewable capacity penetration to noticeably increase based on our installation forecast.
	Non-dispatchable capacity penetration	Low	Low	2	Shaanxi's non-dispatchable capacity penetration rate is low and will further decrease.
Curtailment risk mitigation drivers	RPS guideline gap (2016 vs 2020)	Mid-high	High	1	Shannxi's renewable penetration rate is lower than the RPS guideline, but we expect it will close this guide, eventually reaching RPS target by 2020. This means there won't be much pressure to integrate more renewables in order to meet the RPS target.
	Alternative approach	Mid-high	Mid-high	1	Shaanxi is currently looking into initiatives including micro grid pilot project, Internet+ Smart Grid project, MEIO system pilot project. But all these projects are currently at early development stage. The effectiveness of these initiatives remains to be seen.
	Renewables DPP	High	Mid-high	1	Thermal plants can participate in DPP, and currently no renewables are allowed. In the future, renewables may be allowed to participate but we do not expect high rates of wind and solar participation.
Overall curtailment		37	41		Overall, we anticipate the province to see increasing renewable curtailment risk, reflecting the new projects build-out.

Source: Bloomberg New Energy Finance. Note: The number in the bracket represents curtailment alleviation score. The higher the number, the lower the curtailment risks

Provincial curtailment risks assessment – Gansu

Category	Metrics	Current status (2016)	Forecast (2020e)	Weight	Notes
Electricity supply/demand	Available capacity to peak demand ratio	Mid	Low-mid	3	With severe curtailment, Gansu's renewables new build is currently on halt. We expect to see a slight reduction in its available capacity to peak demand ratio in the coming years.
	Transmission limitation	High	High	3	Gansu's first 8GW UHV DC transmission line will be commissioned in 2017. This line will export Gansu's excess renewable and thermal electricity to Hunan. However, its export capacity is still lagging far behind its local power capacity.
Technical constraints	Renewables penetration level	High	High	2	Gansu's renewable capacity penetration will see a slight decrease due to project new build halt.
	Non-dispatchable capacity penetration	Low	Low	2	We expect Gansu's non-dispatchable capacity penetration rate to slightly decrease.
Curtailment risk mitigation drivers	RPS guideline gap (2016 vs 2020)	High	High	1	Gansu's renewable penetration rate is close to its RPS guideline. This means the RPS target provides little incentive for further renewable generation dispatch and integration.
	Alternative approach	Mid-high	Mid-high	1	Gansu is currently looking into initiatives including a micro grid pilot project. But all these are currently at an early development stage.
	Renewables DPP	Mid-high	Low	1	Renewable generators can participate in DPP, albeit on a limited scale. We expect this to improve over time, with higher volumes of wind and solar participating in DPP in Gansu.
Overall curtailment		60	53		Gansu has set its target to reduce its renewables curtailment to below 5% by 2020, a task that might be challenging. The increasing renewable generation quota, a slowdown in renewables new build and the operation of the UHV line could reduce moderately its curtailment.

Source: Bloomberg New Energy Finance. Note: The number in the bracket represents curtailment alleviation score. The higher the number, the lower the curtailment risks

Provincial curtailment risks assessment – Qinghai

Category	Metrics	Current status (2016)	Forecast (2020e)	Weight	Notes
Electricity supply/demand	Available capacity to peak demand ratio	Low-mid	Low-mid	3	Qinghai's power oversupply issue will get worse with a significant increase in its renewables new build.
	Transmission limitation	High	High	3	Qinghai has limited export capacity. No new high-capacity export transmission line development plan during the 13th FYP has been announced. Therefore, Qinghai's lack of export capacity may remain a bottleneck.
Technical constraints	Renewables penetration level	Mid-high	High	2	Based on our project bottom-up forecast, Qinghai's renewable capacity penetration level will surge from 32% in 2016 to 42% in 2020.
	Non-dispatchable capacity penetration	Mid-high	Mid	2	To address the lack of load-following capability, about 6GW of pumped hydro capacity will be added to the Northwest region. The rate of non-dispatchable capacity penetration will drop noticeably.
Curtailment risk mitigation drivers	RPS guideline gap (2016 vs 2020)	High	High	1	Qinghai has substantially exceeded its RPS guideline target. This means the RPS target provides little incentive to assist with improving the integration of renewable generation.
	Alternative approach	Mid	Mid	1	Qinghai is currently looking into initiatives including a micro grid pilot project, and a hybrid project. But all these are currently at an early development stage
	Renewables DPP	Mid	Low	1	Renewables can participate in DPP, but currently only do so on a limited scale. We expect this to increase over time.
Overall curtailment		59	58		To sum up, we expect Qinghai's curtailment to remain high, despite various measures attempting to improve conditions. In the coming years, given the surge in renewables new build (especially solar PV), and the lack of a grid infrastructure development plan, renewables in Qinghai will have to compete for local demand.

Source: Bloomberg New Energy Finance. Note: The number in the bracket represents curtailment alleviation score. The higher the number, the lower the curtailment risks

Provincial curtailment risks assessment – Ningxia

Category	Metrics	Current status (2016)	Forecast (2020e)	Weight	Notes
Electricity supply/demand	Available capacity to peak demand ratio	Mid	Mid	3	We expect Ningxia's power oversupply issue to continue to pose moderate risks.
	Transmission limitation	High	High	3	Ningxia's first 8GW UHV DC lines connected to east province Zhejiang was commissioned in late 2016. We expect this transmission line to play a role in addressing Ningxia's grid congestion issue. However, the utilization rate for this transmission line remains uncertain, as Zhejiang province has signalled its unwillingness to import further electricity from other provinces that might squeeze its local generators' utilization hours.
Technical constraints	Renewable penetration level	High	Mid-high	2	Based on our project bottom-up forecast, Ningxia's renewable capacity penetration level will slightly decrease from 40% in 2016, to 37% in 2020.
	Non-dispatchable capacity penetration	Low	Low	2	To address the lack of load-following capability, about 6GW of pumped hydro capacity will be added to the Northwest region. The rate of non-dispatchable capacity penetration will drop, in turn improving overall power system flexibility.
Curtailment risk mitigation drivers	RPS guideline gap (2016 vs 2020)	High	High	1	As with other northern provinces, Ningxia has substantially exceeded its RPS guideline target.
	Alternative approach	Mid-high	Mid-high	1	Ningxia is currently investigating curtailment mitigation measures, including micro grid pilots.
	Renewables DPP	High	Mid	1	Only thermal power plants can participate in DPP currently, but we expect that renewables will eventually be allowed, especially if curtailment persists. However, we do not expect high volumes of renewables participation, due to competition from local coal generation.
Overall curtailment		60	56		Overall, we expect Ningxia's curtailment to ease slightly, due to the new project development slowdown.

Source: Bloomberg New Energy Finance. Note: The number in the bracket represents curtailment alleviation score. The higher the number, the lower the curtailment risks

Provincial curtailment risks assessment – Xinjiang

Category	Metrics	Current status (2016)	Forecast (2020e)	Weight	Notes
Electricity supply/demand	Available capacity to peak demand ratio	Mid	Mid	3	We expect Xinjiang's power oversupply issue to improve slightly as its wind capacity new build is halted.
	Transmission limitation	High	High	3	Xinjiang's grid congestion issue will be eased thanks to the expansion of its export transmission lines – about three UHV DC lines with total capacity of 32GW are expected to be brought online within the 13th FYP period. However, compared with available local capacity, its transmission limitation risk remains high.
Technical constraints	Renewables penetration level	Mid-high	Mid-high	2	Xinjiang's renewable capacity penetration rate will slightly decrease in the coming years.
	Non-dispatchable capacity penetration	Low-mid	Low-mid	2	Non-dispatchable capacity penetration will also slightly decrease, thanks to the addition of new flexible capacity.
Curtailment risk mitigation drivers	RPS guideline gap (2016 vs 2020)	High	High	1	Compared with its RPS guideline, Xinjiang is only facing roughly a two-percentage-point shortage.
	Alternative approach	Mid-high	Mid-high	1	Xinjiang is looking into various risk mitigation measures including an MEIO system pilot project and renewable energy hybrid projects. All of these pilots are still at an early development phase.
	Renewables DPP	High	Low	1	DPP is launched in Xinjiang but currently does not allow wind and solar to participate. They will be allowed to do so in the future.
Overall curtailment		60	53		Xinjiang's overall power system flexibility will improve slightly, with the new flexible resources build-out and the use of existing capacity to provide load following. Overall, we expect Xinjiang's curtailment pressures to ease by 2020.

Source: Bloomberg New Energy Finance. Note: The number in the bracket represents curtailment alleviation score. The higher the number, the lower the curtailment risks

Provincial curtailment risks assessment – Liaoning

Category	Metrics	Current status (2016)	Forecast (2020e)	Weight	Notes
Electricity supply/demand	Available capacity to peak demand ratio	Low-mid	Low-mid	3	Liaoning's power oversupply will remain at about the same level during the 13th FYP period.
	Transmission limitation	Low	Low	3	Without an announced UHV line new build plan within the 13th FYP period, the region's power export capacity is likely remain at about the same level.
Technical constraints	Renewables penetration level	Low-mid	Low-mid	2	Liaoning's renewable capacity penetration ratio is likely to see a slight increase. Its ancillary market pilot might help alleviate its power system inflexibility if carried out successfully.
	Non-dispatchable capacity penetration	Low	Low	2	Non-dispatchable capacity penetration remains at about the same level from 2016-2020. Liaoning has relatively flexible generation mix and does not face major technical constraints when integrating intermittent renewables.
Curtailment risk mitigation drivers	RPS guideline gap (2016 vs 2020)	High	High	1	Compared with its RPS guideline, Liaoning is still facing shortage. This could promote renewables local generation.
	Alternative approach	Mid-high	Mid-high	1	Liaoning is investigating into using wind/solar for heat.
	Renewables DPP	High	Mid-high	1	Currently, the DPP market is only open to conventional technologies. Over time, wind may participate in DPP.
Overall curtailment		34	34		As Liaoning suffer lower nuclear plant utilization, a significant increase in renewable generation could be challenging. But the region is not likely to see significant new renewable build. We expect curtailment conditions to stay about the same in this province.

Source: Bloomberg New Energy Finance. Note: The number in the bracket represents curtailment alleviation score. The higher the number, the lower the curtailment risks

Provincial curtailment risks assessment – Jilin

Category	Metrics	Current status (2016)	Forecast (2020e)	Weight	Notes
Electricity supply/demand	Available capacity to peak demand ratio	Mid-high	Mid	3	Jilin's power oversupply will ease during the 13th FYP period.
	Transmission limitation	High	High	3	Its transmission constraint will remain an issue. Without an announced UHV line new-build plan within 13th FYP period, the region's power export capacity is unlikely to grow significantly in the coming years.
Technical constraints	Renewables penetration level	Low-mid	Low-mid	2	Jilin's renewable capacity penetration ratio is likely to remain about the same.
	Non-dispatchable capacity penetration	Low	Low	2	Non-dispatchable capacity penetration will remain at about the same level based on our forecast.
Curtailment risk mitigation drivers	RPS guideline gap (2016 vs 2020)	High	High	1	Jilin has a small gap compared with its RPS guideline target. Therefore, this mechanism is unlikely to provide much assistance in reducing wind and solar curtailment pressures.
	Alternative approach	Mid-high	Mid-high	1	Jilin is investigating using wind/solar for heat and Internet + smart grid initiatives.
	Renewables DPP	Mid-high	Mid	1	Currently, the DPP market is open to conventional technologies. Over time, we expect renewables participation will be allowed but their volumes will likely be low as there is much local coal competition.
Overall curtailment		52	52		As Jilin's local thermal generators currently are experiencing low utilization, it could be difficult to increase substantially renewable generation. Its renewables curtailment may ease slightly.

Source: Bloomberg New Energy Finance. Note: The number in the bracket represents curtailment alleviation score. The higher the number, the lower the curtailment risks

Provincial curtailment risks assessment – Heilongjiang

Category	Metrics	Current status (2016)	Forecast (2020e)	Weight	Notes
Electricity supply/demand	Available capacity to peak demand ratio	Mid	Low-to-mid	3	We expect Heilongjiang's available capacity to peak demand ratio to drop during the 13th FYP period.
	Transmission limitation	High	High	3	Its transmission constraint will continue to remain an issue. Without an announced UHV line new-build plan within the 13th FYP period, the region's power export capacity is unlikely to grow significantly in the coming years.
Technical constraints	Renewables penetration level	Low-mid	Low-mid	2	Heilongjiang's renewables penetration level will slightly increase, from 21% in 2016 to 23% in 2020.
	Non-dispatchable capacity penetration	Low	Low	2	Baseload capacity penetration will slightly decrease but not by much.
Curtailment risk mitigation drivers	RPS guideline gap (2016 vs 2020)	High	High	1	Heilongjiang has already reached its RPS guideline target. So this mechanism is unlikely to provide much incentive to improve renewable energy integration in this market.
	Alternative approach	High	High	1	We are not aware of any alternative measures Heilongjiang is investigating.
	Renewables DPP	Mid-high	Mid-high	1	Heilongjiang has DPP but whether renewables can participate is unclear and, if allowed, they will probably do so in low volumes.
Overall curtailment		53	52		Its renewable curtailment risk may ease slightly.

Source: Bloomberg New Energy Finance. Note: The number in the bracket represents curtailment alleviation score. The higher the number, the lower the curtailment risks

Provincial curtailment risks assessment – Yunnan

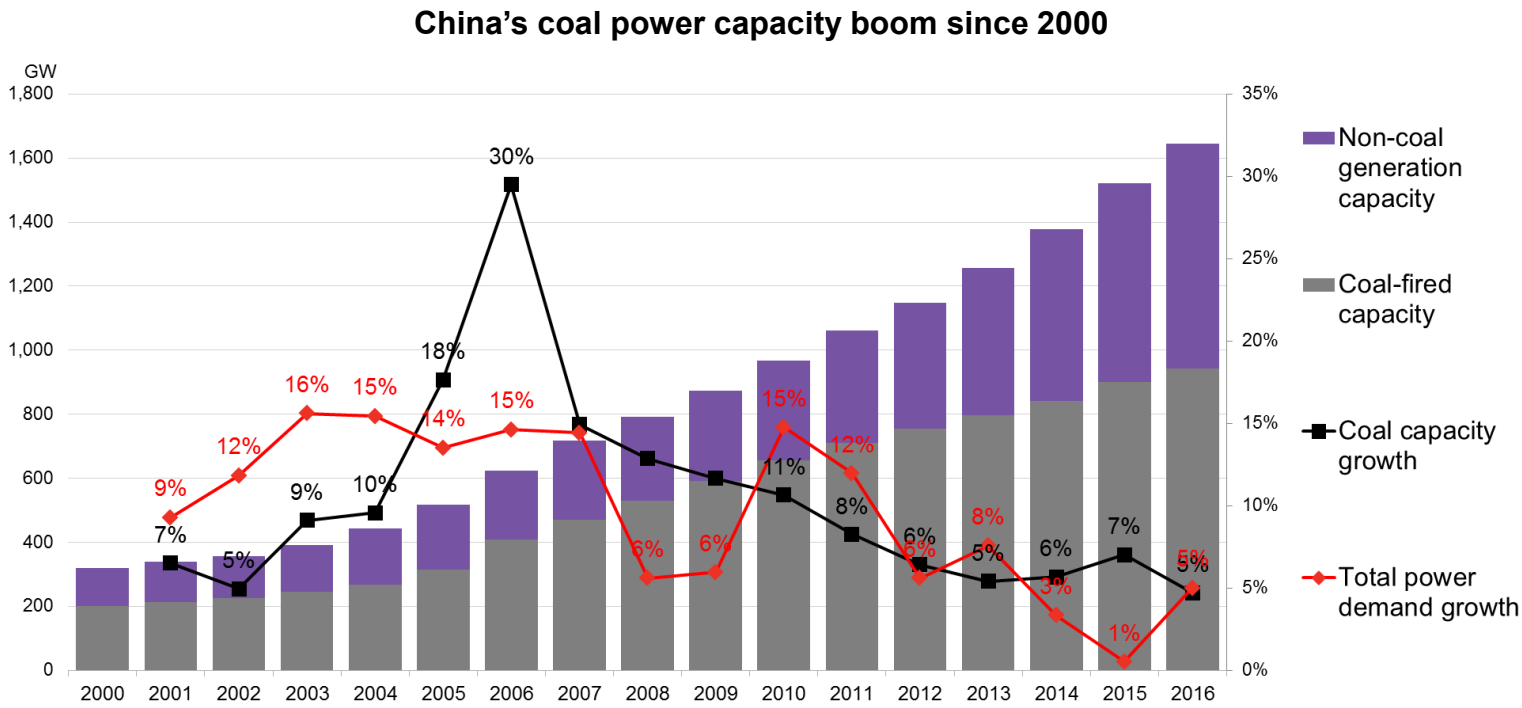
Category	Metrics	Current status (2016)	Forecast (2020e)	Weight	Notes
Electricity supply/demand	Available capacity to peak demand ratio	High	Mid-high	3	We expect Yunnan's available capacity to peak demand ratio to drop slightly.
	Transmission limitation	High	High	3	An additional UHV line will commission by 2020. However, the province's export capacity still remains an issue compared with its significant local power capacity.
Technical constraints	Renewables penetration level	Low	Low-mid	2	Yunnan's renewables penetration level will increase from 12% to 17%.
	Non-dispatchable capacity penetration	Low	Low	2	Non-dispatchable capacity penetration will slightly decrease.
Curtailment risk mitigation drivers	RPS guideline gap (2016 vs 2020)	High	High	1	Yunnan still has a gap compared with its RPS guideline target.
	Alternative approach	High	High	1	Yunnan has not announced an alternative plan.
	Renewables DPP	Mid-high	Mid	1	Yunnan's DPP market is up and running, but renewables DPP trading is very marginal. Over time, we expect renewables participation in DPP to increase, although focused primarily on hydro.
Overall curtailment		50	47		With abundant hydro resources, Yunnan is a major electricity exporting province in the southern region. We expect Yunnan's curtailment to ease, but still persist at a moderate level due to overall overcapacity and a lack of power system flexibility during wet season

Source: Bloomberg New Energy Finance. Note: The number in the bracket represents curtailment alleviation score. The higher the number, the lower the curtailment risks

Coal power assets

Current status

China’s decade of coal capacity boom

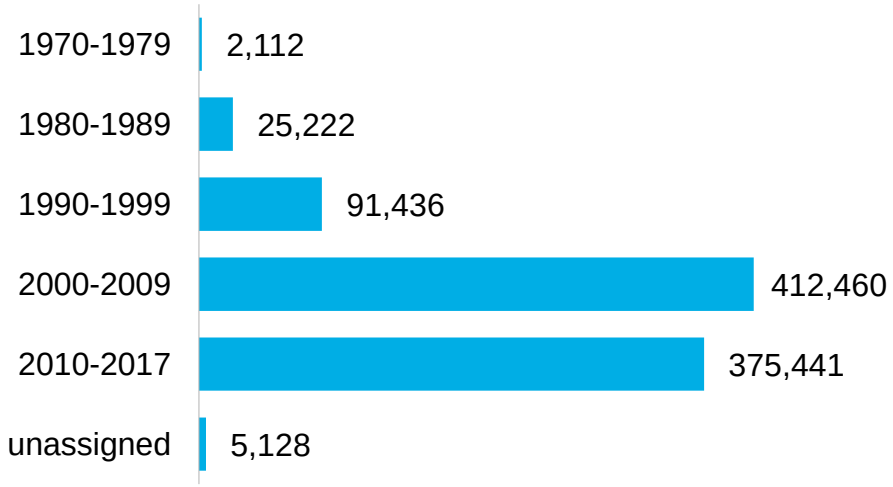


Source: BNEF, NEA, CEC

- Since 2002, when China unbundled generation from transmission and distribution, installed capacity more than quadrupled, from 357GW to 1,646GW. Coal capacity grew even faster than overall capacity, from only 200GW in 2000 to 943GW in 2016.
- Total capacity growth averaged 7% annual growth over the last decade (2007-2016) while coal capacity grew 9%.
- Even as capacity continued to grow, China’s power demand began a structural shift to slowing growth after 2010. For the last five years, generation capacity growth has far outpaced demand growth.
- This has resulted in severe overcapacity for all generation technologies, but most notably for coal-fired assets.

Coal's past, present and future

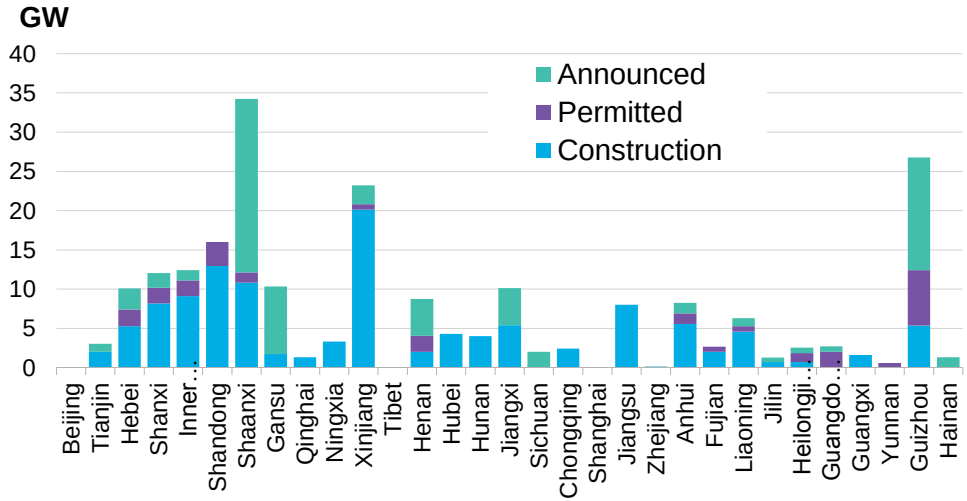
Age of China's coal fleet (MW), by year of commissioning



Source: BNEF, CEC

- Reflecting historical build trends, more than half of China's coal-fired generation fleet was built in 2000-09. Many of these plants also utilize less efficient, higher-emitting sub-critical technologies. Some of these plants will be subject to closures over the next 10-15 years, before finishing their economic life, because they will not be cost-competitive with cleaner new build. These plants show the significant social costs of overbuilding coal in the near term, when they turn out not to be economically viable or usable for the entirety of their planned lifetime.

Near-term coal build pipeline, by province and by project status



Source: BNEF, Coal Swam Tracker

- Although over-capacity is already a significant challenge, China still has around 220GW of new coal-fired power plants in the investment pipeline. Of these, 122GW are currently under construction, expected to commission in the next five years (2017-2022).
- Interior provinces, particularly Shaanxi, Xinjiang, Guizhou, and Inner Mongolia, face the highest risks of impaired coal investments, based on their pipeline of new-build projects under construction, permitted, and announced.

New normal for coal

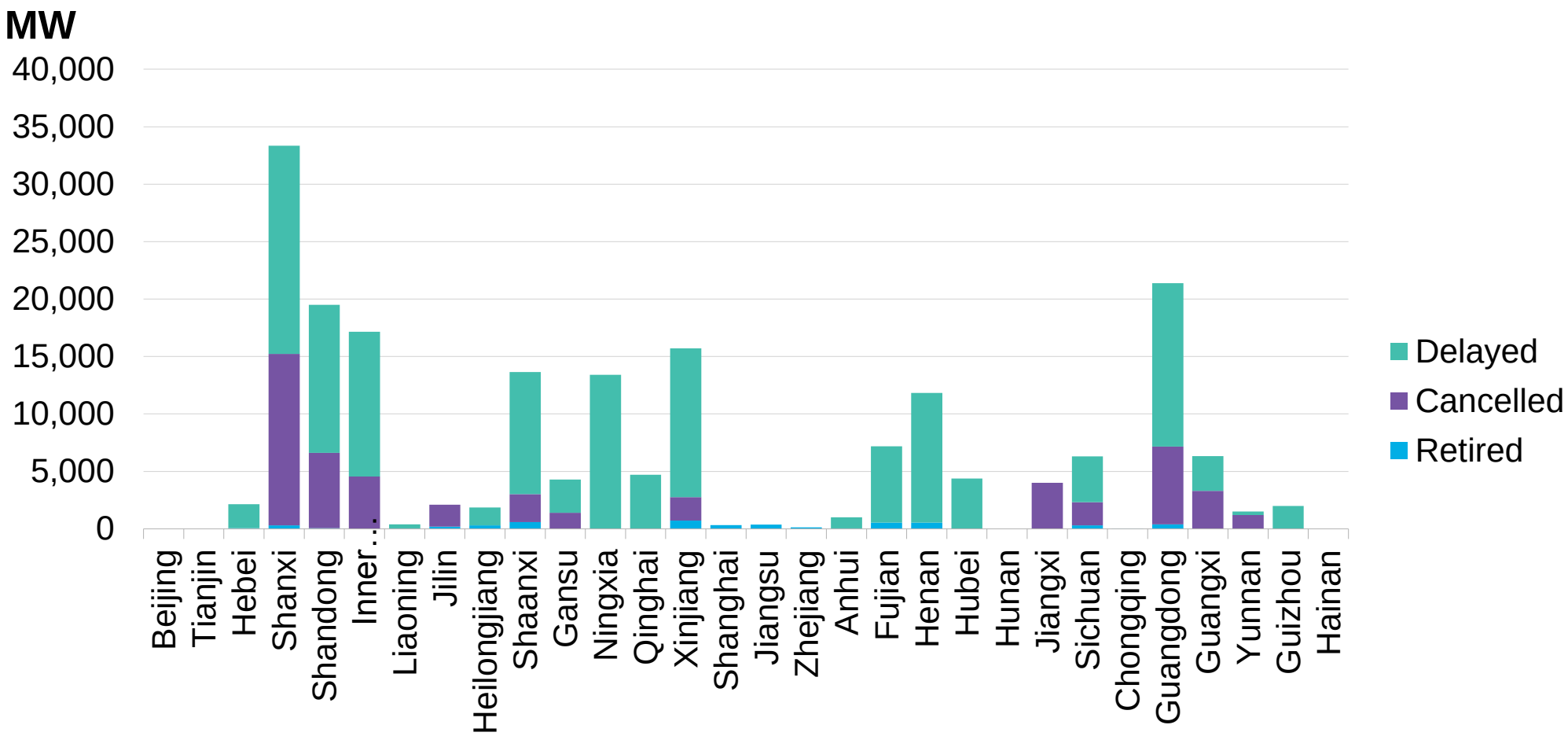
- Starting from 2015, the NEA reports all of the existing coal-fired plants to be retired each year. This is in part to assist with tracking its target of retiring 20GW of coal by 2020, at the end of the 13th FYP period.
- Starting March 2016, a raft of new coal pipeline review policies were implemented by the NEA. Whereas before, regulators were increasing standards and requirements for new projects to be permitted and included in the new capacity pipeline. These new emergency measures put current pipeline projects, including those permitted and under construction since 2012, on the chopping block for potential cancelation. Most notably, the NEA published an investment risk rating for all provinces regarding new planned coal-fired generation capacity. (See table below for summary of the policies and slide 17 for details on the investment risk rating system.)
- In September 2016, the NEA announced the cancelation of 15 coal power projects, totaling 12.4GW.
- Then in January 2017, the NEA issued a list of another 103 coal power plants totaling 114GW under construction that are to be cancelled or delayed until after 2020. More than half of these impaired projects belong to China's top seven power generation companies. Huaneng, Datang, Huadian, and Shenhua have the biggest exposure to stranded coal investments.
- On September 26, 2017, the NDRC, State-owned Assets Supervision and Administration Commission of the State Council (SASAC), and the NEA announced a further updated list of coal power projects that are to be canceled or delayed in what should be the full, formal list for 2017. In total, 29 projects totaling 35.2GW and 146 billion yuan of investment, which were currently under construction, have been ordered to stop. Another 50 projects totaling 55.2GW and representing around 243 billion yuan of investment have been delayed until further notice. This expands on the previous list from January, with 15 plants overlapping with that earlier list.
- In total, regulators have announced the cancelation or delay of over 190GW of coal power projects (see next slide for summary).

Emergency coal project pipeline review policies implemented in 2016

Chinese name (w link to original policy document)	Release date	English name
《关于进一步做好煤电行业淘汰落后产能的通知》	March 17, 2016	Notice regarding the further elimination and retirement of underperforming, old coal power capacity
《关于促进我国煤电有序发展的通知》	March 17, 2016	Notice regarding improving the orderly development of coal power industry
《关于建立煤电规划建设风险预警机制暨发布2019年煤电规划建设风险预警的通知》	March 17, 2016	Notice regarding the establishment of the coal power planning, investment and construction risk early warning mechanism, for all planed capacity out to 2019

195GW of projects canceled, delayed or retired in 2016-2017

Projects cancelled, delayed, retired

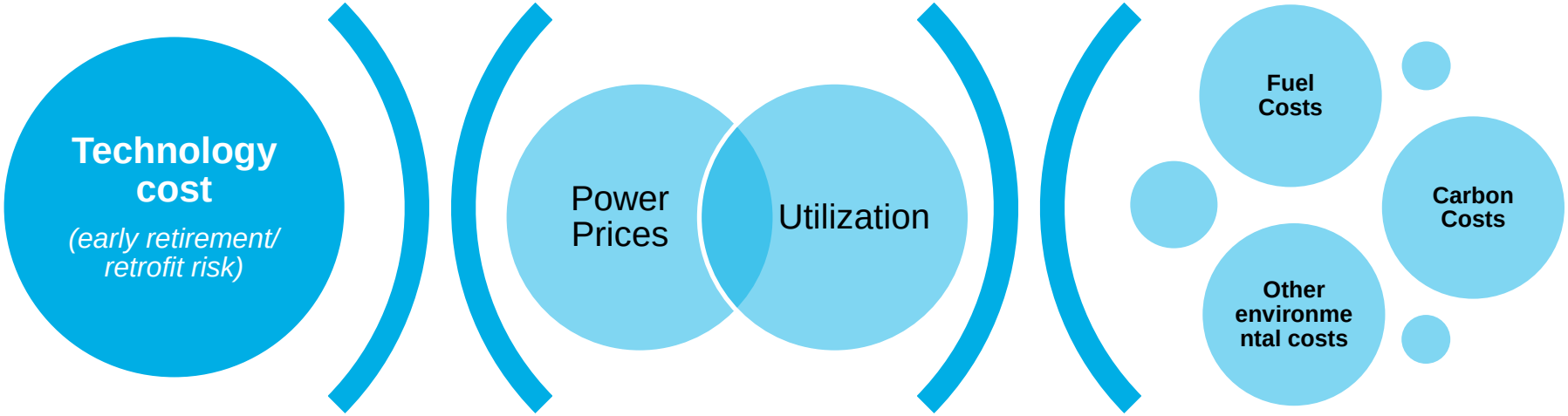


Source: BNEF, NEA

Coal asset risk assessment

Metrics and methodology

Identifying the factors that impact coal asset performance



Capex

- **Technology costs**
  - Mature technology means costs for thermal generation equipment are relatively stable
  - China already has some of the world's cheapest thermal generation equipment
  - **Key risk:** Being forced to retire early or retrofit to meet higher emissions/efficiency standards will increase mid-life capital expenditures

Revenue

- **Utilization rate**
  - Demand decreasing, oversupply
  - Transmission constraints
  - Competition from other baseload
  - Flexibility demands of high renewables penetration (impact on load factors)
  - Utilization threatened by power market reforms (loss of dispatch quota)
- **Power price risk**
  - Exposure to decreasing wholesale power prices

Variable Costs

Fuel costs

- Availability of local coal production
- Dependency on one coal supplier/contract
- Potential transport bottlenecks

Environmental/political costs

- Carbon/environmental taxes and other fees
- Obligation to support renewables (RECs and RPS targets)
- Water risks

Metrics ratings and weightings

We have assigned weightings to each risk metric, based on its potential importance and impact on coal assets. In the model, users may adjust these weightings to reflect their own custom assumptions.

Factor	Metric	Weighting	Potential impact on coal asset performance
Utilization rate	Supply-demand balance	15%	The ratio of available capacity in a local power market to the local peak demand. This is a rough estimation of reserve margin. The higher the ratio, the more oversupplied a market is, the more competition for dispatch.
	Competition from non-coal baseload	10%	Proportion of total capacity that is nuclear, large hydro, gas and biomass. These baseload technologies compete with coal for dispatch and often may take priority because they are cleaner technologies.
	Transmission limitation	15%	Amount of net exporting transmission capacity as a proportion of available power generation capacity in the province. Higher export capacity can help performance of coal plants by relieving pressure on oversupplied local markets.
	System flexibility needs	10%	The degree of penetration of intermittent renewables impacts on the flexibility needs of the local grid. High penetration means a need for higher flexibility from coal power plants, potentially reducing their overall utilization or operational efficiency due to frequent ramp-up, ramp-down.
	Loss of dispatch quota	10%	As market reforms continue, coal power plants will lose an increasing proportion of their government-planned dispatch quota, and must compete in wholesale markets for dispatch.
Power price	Risk of reduced wholesale power prices	10%	Risk of wholesale power price decline due to increasing market liberalization and competition. Also, this takes account of regions' industrial growth and economic performance.
Fuel risk aggregated	Reliance on supplier	1%	Higher reliance on a key state-owned enterprise (KSOE) coal-supplier means less flexibility in fuel prices (signing longer-term contracts, locking in prices) and inability to take advantage of potentially cheaper coal supplies from spot markets.
	Reliance on rail transport	1%	Higher reliance on rail transport (owned and operated by the KSOE) adds to fuel costs and, especially for coal generators located in inland provinces, reduces options in terms of fuel supplies.
	Share of coal reserves	3%	Higher share of national coal reserves means more local production of resource, easier and cheaper access to fuel.
Environment and political risks	Early retirement risk	10%	Measured by the proportion of existing coal generation fleet that are low-efficiency sub-critical units or are captive plants. These assets are being targeted by regulators for early-closure, and increases risk for underperforming coal assets.
	Carbon costs	5%	Impact of carbon market launches, and carbon price movements, on coal IPPs.
	REC obligation risk	5%	The risk for coal IPPs risk of being obligated to purchase RECs to meet an RPS obligation. This metric measures how close is a province to meeting its RPS target with its own non-hydro renewable generation.
	Water risk	5%	Rating of stress on baseline water. Higher water risks equal potentially higher environmental and resource costs for coal generators.

Utilization rate

Various factors that impact future utilization rates of coal-fired plants in China:

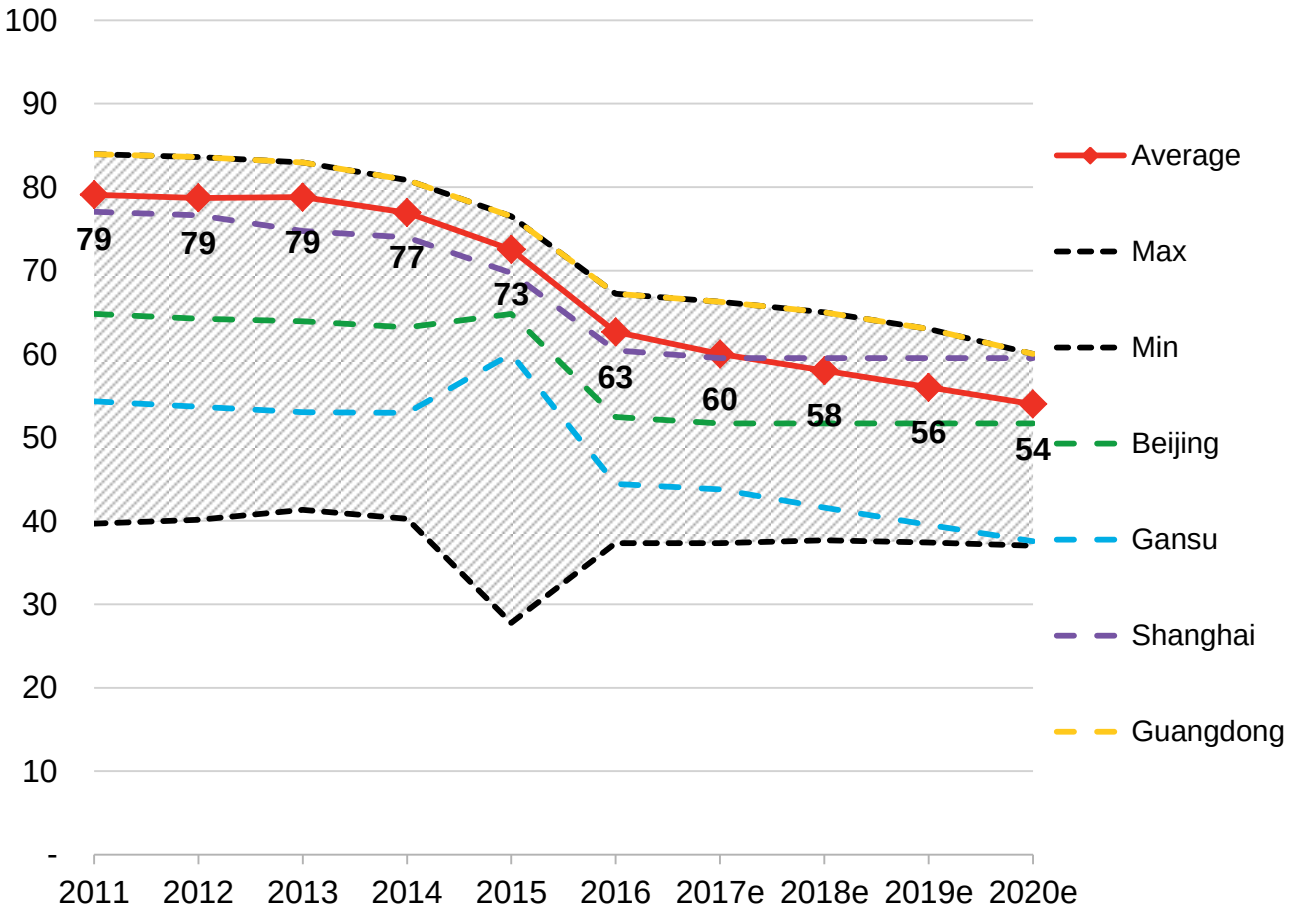
- Demand-supply balance and transmission constraints essentially approximate a coal asset's exposure to competition. When a market is oversupplied and has limited export options, the result is that coal load factors face downward pressure, often times competing with other coal plants.
- Competition from other baseload, and impact on load factors from needing to be more flexible to accommodate higher renewables penetration, are both factors that determine how coal assets' role in the power grid is changing. Currently, China prioritizes dispatch of other baseload, especially hydro and nuclear, before coal. At the same time, as the power grid transitions to higher renewables penetration, the demand on baseload is for plants to be more flexible and able to accommodate grid-balancing needs. These factors all impact future coal asset performance.
- Finally, loss of dispatch quota is a regulatory risk. With the newest policy changes as of 2016, coal power generators will have a decreasing share of their annual generation hours allocated to them by the government. All new coal generators coming online after 2016 must compete in the wholesale power markets for the majority of their generation. Existing generators will have their dispatch quota reduced incrementally each year.

	Demand-supply balance	Transmission constraints	Competition from other baseload	Flexibility demands	Loss of dispatch quota
High risk of reduced utilization	High oversupply (capacity surpasses peak demand)	Importer (assume around 40% of utilization on UHV lines)	High hydro/nuclear penetration	High local wind/solar penetration	Wholesale reform risk high (About 80% reduction in dispatch quota by 2020)
Medium risk of reduced utilization	Balanced or only slightly oversupplied	Exporter/importer balanced	Average hydro/nuclear penetration	Average wind/solar penetration	Wholesale reform risk average (About 50% reduction in dispatch quota by 2020)
Low risk of reduced utilization	Under Supplied (peak demand surpasses local supply)	Exporter (assume around 40% of utilization on UHV lines)	Low hydro/nuclear penetration	Low wind/solar penetration	Wholesale reform risk low (About 30% reduction in dispatch quota by 2020)

Power price risk

China's coal benchmark on-grid price (i.e. wholesale power price), historical and forecast

$/MWh, nominal

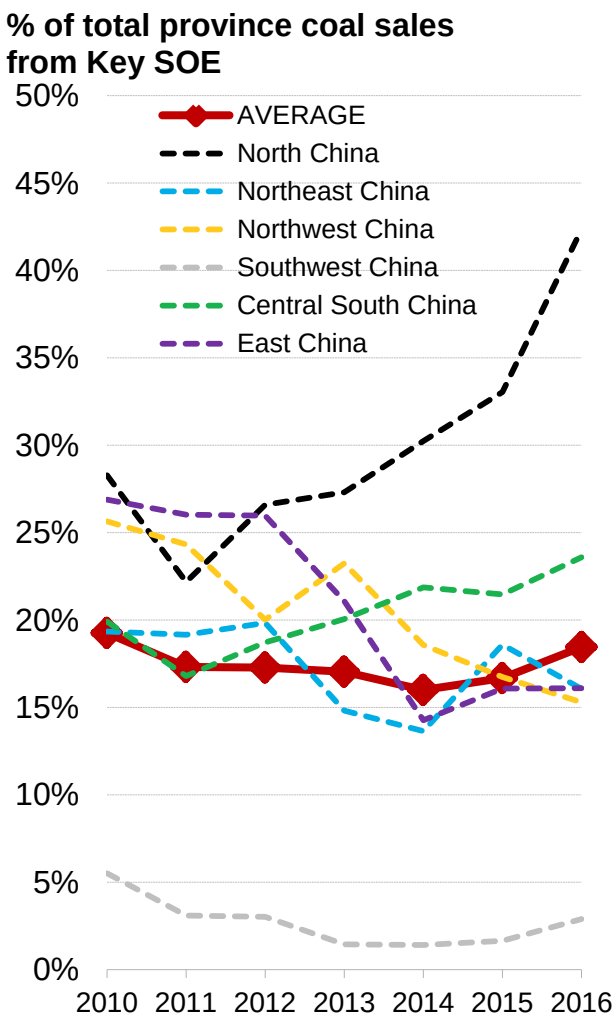


Source: BNEF, historical National Energy Administration

- As wholesale power market reforms progress in the provinces, coal generators will increasingly have to compete for dispatch – either via PPAs negotiated with customers through the Direct Power Purchasing mechanism, or on wholesale power exchanges.
- The resulting price for contracted power is expected to be lower than the current on-grid coal benchmark price, set by the government.
- Each province has varying degrees of wholesale market liberalization, often depending on the province's industrial economic performance.
- Here, we use projected provincial annual growth in industrial value-added, as well as our view of the degree of wholesale market liberalization, to forecast wholesale power prices for each province.
- Notably, we expect Guangdong will see one of the largest expected reductions in wholesale industrial and commercial power prices. But it remains still the most expensive power market in China, followed by Shanghai.
- Provinces with extremely high curtailment of renewables, like Gansu, will also experience a rapid decline in wholesale prices.
- The lowest power-price markets, like Xinjiang and Inner Mongolia, will not drop much more from their current levels, despite expected overcapacity pressures and curtailment. However, wholesale power prices are already pushing the bottom in terms of viability for coal generators. Unless coal prices drop significantly for these markets in coming years, it will be difficult for regulators to reduce benchmark wholesale power prices much more.

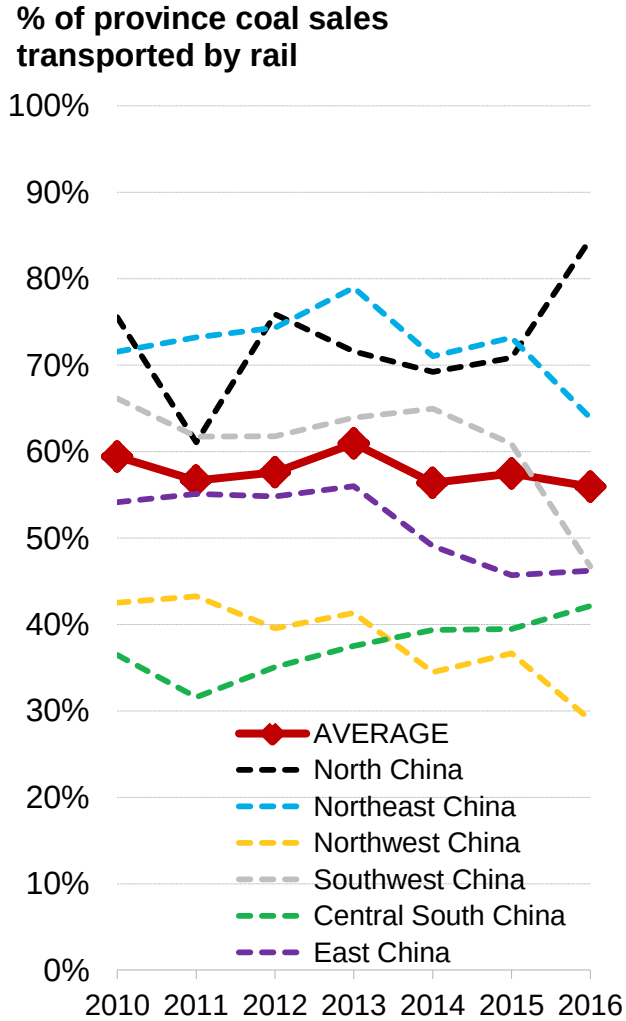
Fuel risks

Dependency on supplier



Source: China Coal Resources via Bloomberg Terminal

Dependency on rail



Source: China Coal Resources via Bloomberg Terminal

Share of coal reserves

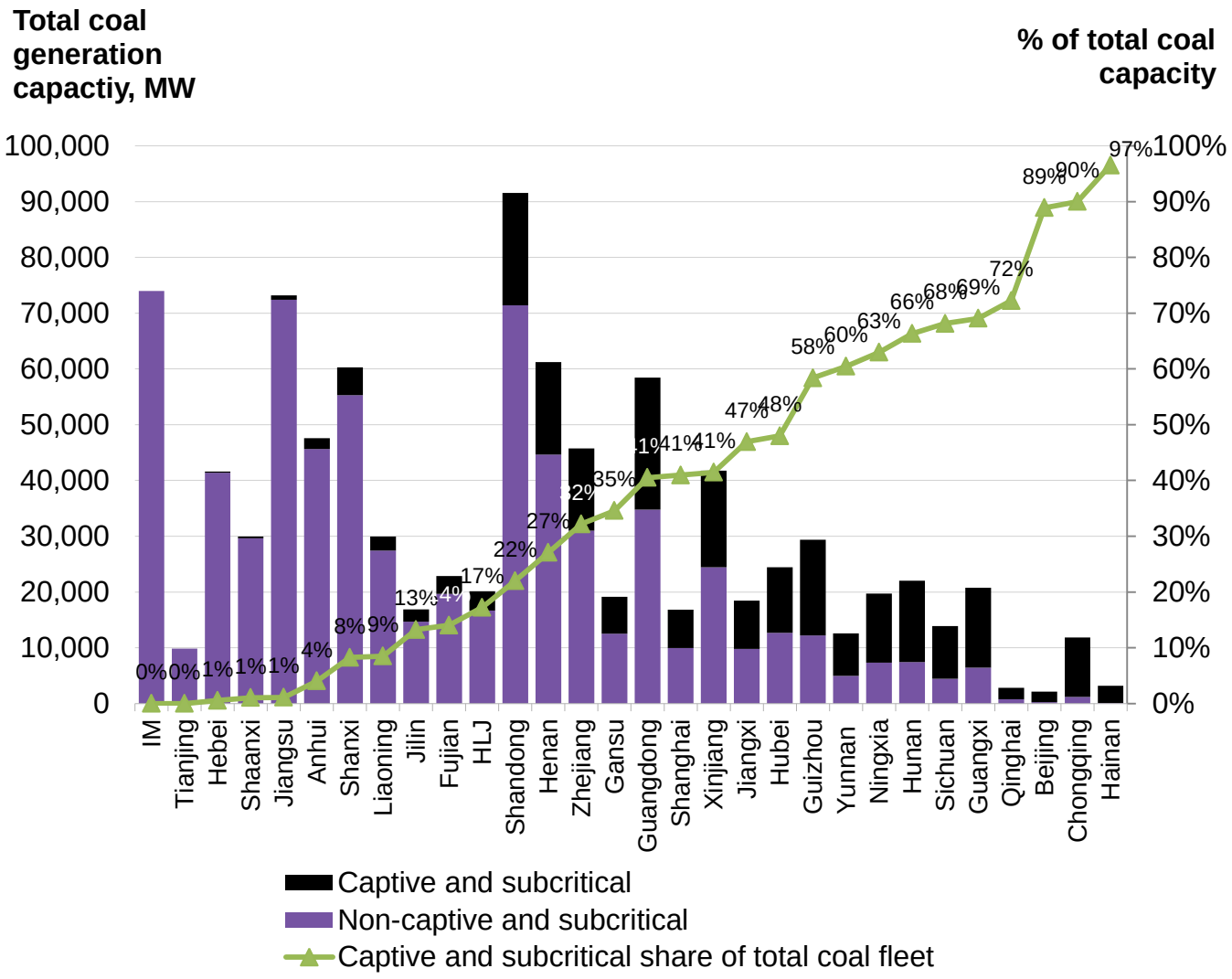
Top 10 provinces share of national coal reserves	2016
Shanxi	37.76%
Inner Mongolia	20.20%
Xinjiang	6.50%
Shaanxi	5.19%
Guizhou	4.17%
Henan	3.52%
Anhui	3.44%
Shandong	3.18%
Heilongjiang	2.52%
Yunnan	2.44%
Others	11%

Source: National Bureau of Statistics

Fuel risks – explanation

- China is targeting the closure of 150 million metric tons of excess or illegal coal production capacity. Between 2017 and 2020, it is aiming for the closure of 500 million metric tons of output, and pushing for consolidation of production and coal logistics (storage, transport, processing) capacity under a few key state-owned enterprises. The objective is to promote more efficiency in production, as well as higher environmental standards and better returns on investments in the sector. Many of the upstream and mid-stream reforms for China's coal sector started in 2014-2015, when the industry was suffering from record-low prices and depressed demand (particularly in thermal coal).
- By the end of 2017, total coal production capacity in China will be around 3.75 to 4.03 billion metric tons per year. However, there has been more rapid closure of capacity than originally anticipated and higher power sector demand for coal than estimated. As a result, China's thermal coal markets in 2017 are now slightly undersupplied for the short term. This means that thermal coal prices have increased from around 300-400 yuan/ton to 500-570 yuan/ton in the last year.
- At the same time, regulators are encouraging coal generators to enter into longer-term, stable coal procurement contracts with the KSOE suppliers, rather than relying on spot markets. They are also encouraging coal IPPs to better manage and maintain back-up inventory. Overall, this means that coal power generators are becoming increasingly reliant on a smaller group of fuel suppliers. Furthermore, as non-KSOE suppliers dwindle, inland generators have limited access to the coal spot market (which currently is tight and prices are high) and even if they were able to contract for cheaper coal (including importing seaborne), they would face bottlenecks in terms of transporting that coal. Most coal transported inland must access rail that is also operated by the KSOEs.
- Therefore, to reflect these risks, we assess exposure to fuel price risk not according to how expensive the coal is in a said market, but by how dependent a regional market is on the following: (1) access to locally produced coal (represented by their share of total national coal reserves); (2) what proportion of local thermal coal sales is transported by rail lines controlled by the KSOEs; and (3) whether or not provinces are supplied by KSOEs. We take these three different factors into account, as well as specific conditions of a local market, and set an overall fuel risk score for the province. Scores are weighted heavily towards whether or not a province has local thermal coal production capacity.
- In China, the provinces that are most dependent on KSOEs for suppliers are Northeast provinces (like Liaoning), Northwest provinces (like Shanxi, Inner Mongolia) where the KSOEs biggest production basins are located, and Central southern provinces (like Anhui and Hunan) that are landlocked. Coastal regions like Shandong, Guangdong, and Jiangsu have more options because they can also access seaborne coal. Similarly, interior regions are also the most dependent on coal rail. Northwest regions are an exception to this because the majority of the coal produced in these regions is consumed locally, close to mine mouth, so does not have to be transported via long distance rail.
- Shanxi and Inner Mongolia together account for more than half of the coal reserves available in China. They are the best supplied provinces and have access to some of the cheapest fuel for coal-fired generation.

Early retirement risk

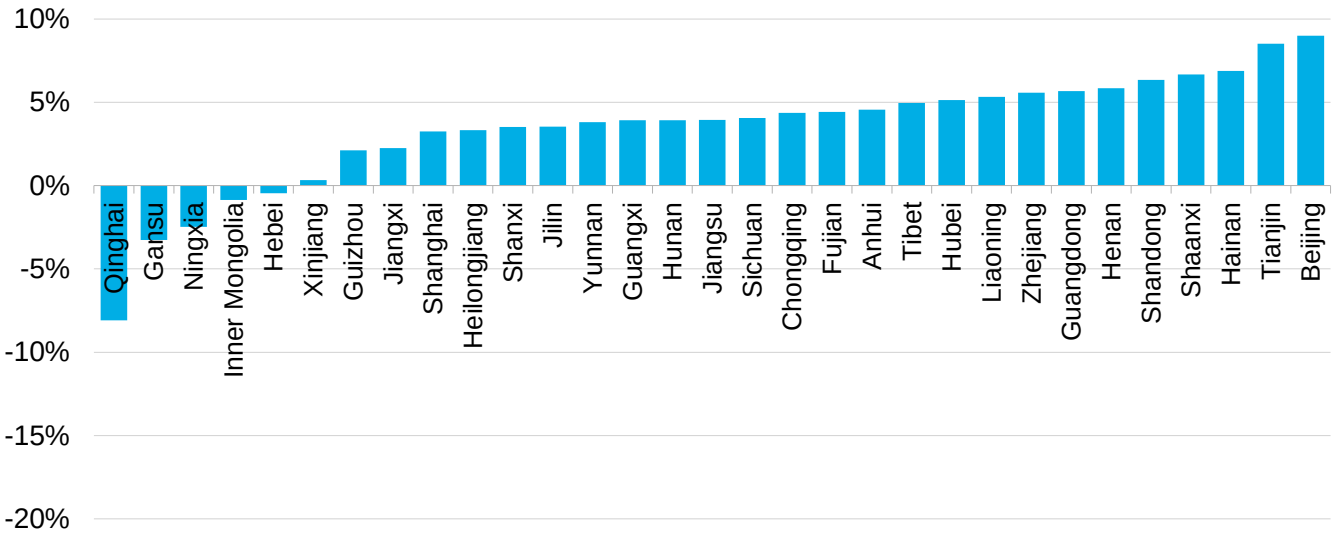


- Between 2012 and 2015, China's regulatory focus was on getting accurate data on the prevalence of small, inefficient coal generation assets, especially those that are "behind-the-fence" captive power plants for industrials.
- Regulators then used tightening energy efficiency and emissions reduction standards, as well as subsidies, to incentivize owners of old coal-fired assets to retrofit or face forced closure. Regulators also attempted to retire as much of the existing capacity as possible. Originally, plans to retire capacity (especially captive power) were more aggressive.
- However, in 2016, the regulatory approach shifted towards canceling new plants rather than forcing existing plants to close. The likely reason was that regulators found it too difficult to incentivize closure, especially of captive plants.
- However, the risk still exists of forced early-retirement (i.e. closure before economic life) for coal-fired assets. In the chart, we estimate the amount of existing coal-fired assets in each province that are captive or subcritical, and calculate that as a proportion of its total future coal-fired capacity. This signals the risk that coal asset operators in these provinces may face forced early-retirement.
- Some regions have a small and shrinking fleet of coal-fired plants that have little potential for new capacity growth, so appear to be at very high risk of early retirement (like Hainan, Chongqing). However, in reality, the provinces with the largest fleets of captive power plants are probably those at the highest risk, notably Shandong, Guizhou, Henan, and Guangdong.

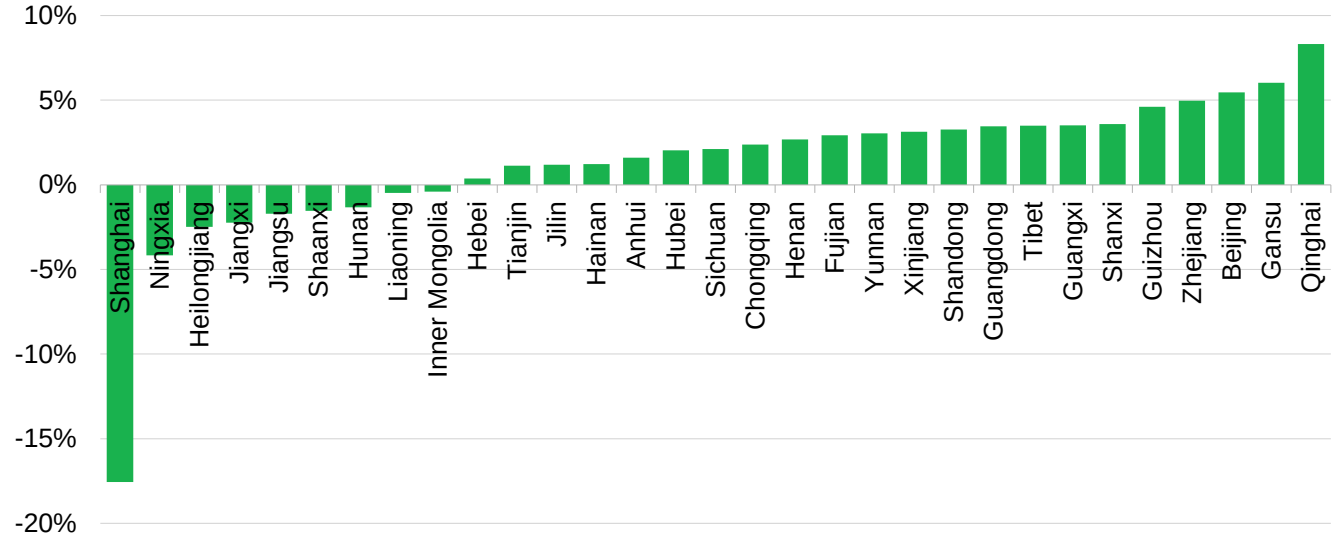
Source: BNEF NEO 2017

REC obligation forecast

Gap between RE penetration and RPS target by province, 2016



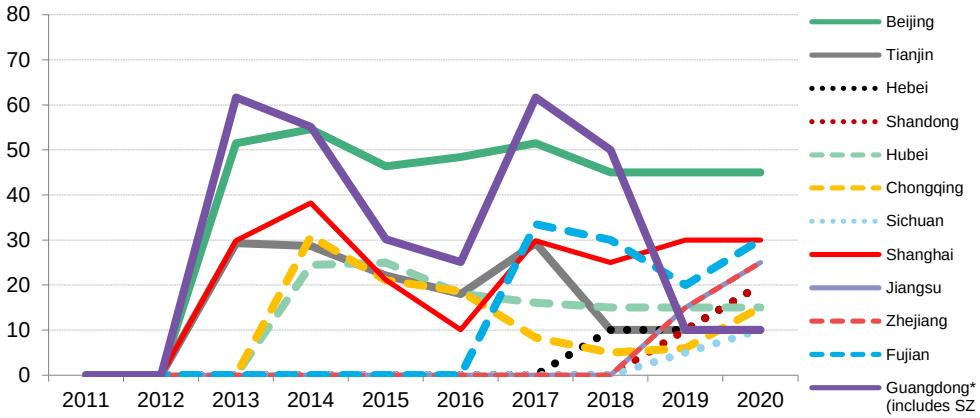
Gap between RE penetration and RPS target by province, 2020



- China launched the Renewable Energy Credits (REC) market in July 2017. The first few months are for voluntary commitments, but regulators have indicated that by early 2018, they will establish a mandatory purchasers' market.
- Who exactly will be defined as mandatory purchasers of RECs has not been confirmed. National regulators have already defined province-level renewable portfolio standards (RPS). These determine how much power demand in each province must be supplied by non-hydro renewables.
- Currently, the most likely mandatory purchasers may be China's coal IPPs and the power distribution utilities (State Grid and Southern Grid).
- This metric measures the potential compliance costs for coal IPPs in each province, if they become liable to meet the province RPS target via REC purchases.
- For each year starting from 2016, we estimate what portion of total generation will come from non-hydro renewable energy (mostly wind and solar) in each province. These estimates use average load factors for wind and solar and do NOT assume curtailment.
- Then, we estimate how much total power each province may consume from now until 2020. And we use the NEA's 2020 RPS targets for each province to calculate how much power must be procured from non-hydro renewables each year.
- The difference, or gap, between each province's estimated RPS obligation and potential realizable generation from non-hydro renewables represents our best estimate of the potential REC obligation for each province.
- Overall, by 2020, the regions that are in deficit and face the highest REC obligation risk are Shanghai and Ningxia.

Environment and political costs

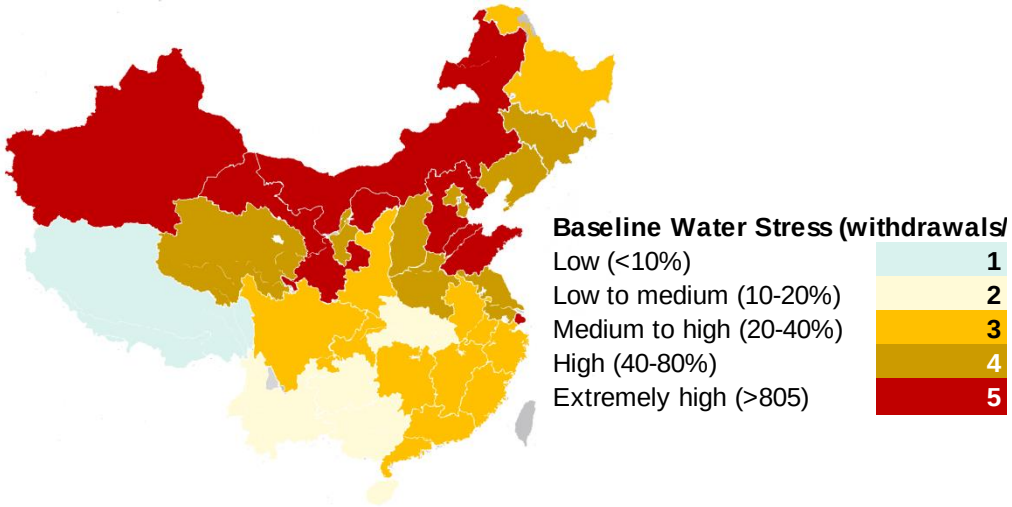
Carbon price forecast (CNY/carbon allowance)



Source: BNEF

- This metric captures the emergence of carbon prices (in nominal terms) for various markets around China.
- Starting with the seven pilots (Beijing, Tianjin, Hubei, Chongqing, Shanghai, Guangdong and Shenzhen) that are currently already in operation, we list their historical annual average carbon price. We forecast forward their carbon prices until 2020, mostly reflecting our view of the supply-demand balance for each market.
- Gradually, between 2017 and 2020, we expect that new carbon markets will launch in Hebei, Shandong, Sichuan, Jiangsu, Zhejiang, and Fujian. This reflects our base-case analysis of current regulatory progress towards establishing carbon markets in these regions.
- Our underlying assumption is that China will not launch a fully centralized national carbon market before 2020. So carbon prices in each region will still vary depending on the demand-supply balances expected in their respective local markets, with only minor amounts of inter-regional cross trading.

Water risk



Source: World Resources Institute Aqueduct Dataset

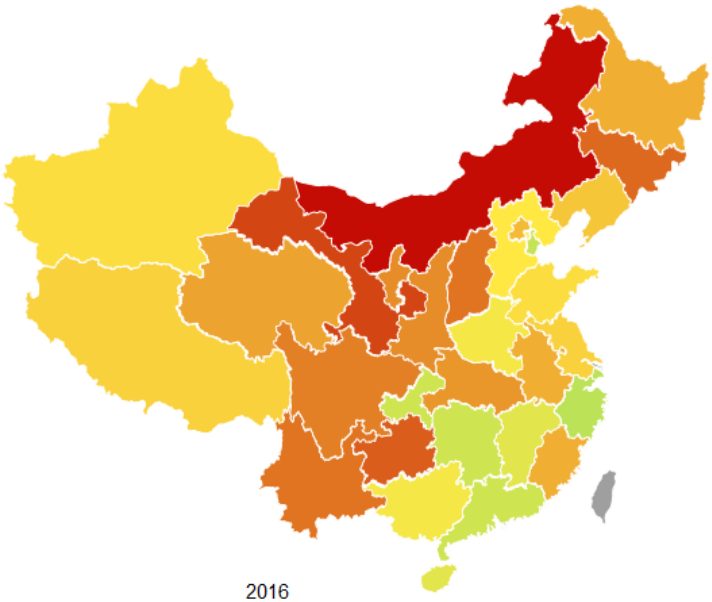
- This metric is sourced from the World Resources Institute Aqueduct Baseline Water Stress dataset.
- Baseline water stress is defined as the amount of water withdrawals expected from a water resource basin measured against the amount of available flow.
- Provinces in the northwest and north central regions (Inner Mongolia, Hebei, Shandong, Gansu, Xinjiang) which will have the highest levels of new coal capacity additions in the next few years, are also the regions with the highest baseline water stress risk.
- Water stress should represent a significant risk to both existing coal assets and new assets, with the price of usage adjusted by regulators to reflect the pressure on local resources. Unfortunately, in the current regulatory structure and at current water usage fees, true resource scarcity costs are not reflected properly. Thus we give water risk a low weighting of only 2% in our overall risk metric. This can be adjusted to be more important should policy attitudes harden towards this issue.

Provincial coal asset risk assessment

Assessment of provinces with highest coal asset risk scores

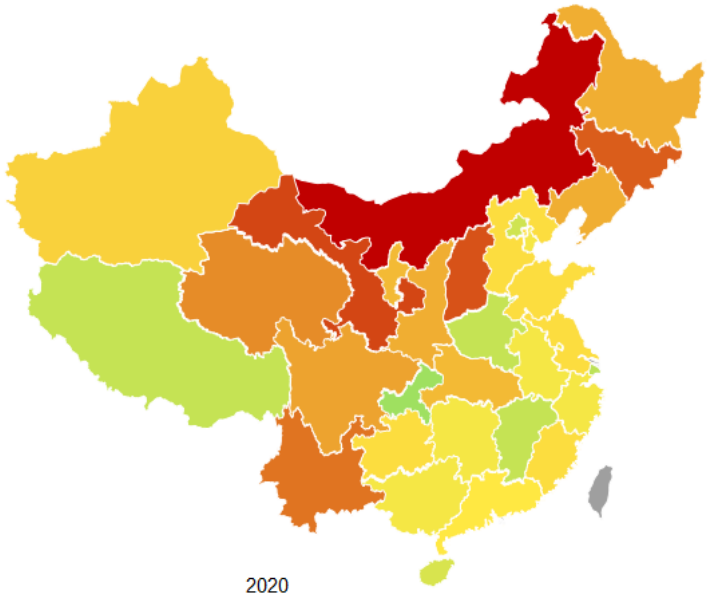
Provincial coal risk forecast overview

Thermal Power Risk METRICs (2016)



2016

Thermal Power Risk METRICs (2020)



2020

An overview of change in scores for provinces in relation to coal asset performance between 2016 and 2020.

Category	Provinces
Coal asset performance may worsen	Tianjin, Shanxi, Inner Mongolia, Liaoning, Zhejiang, Hunan, Guangdong, Qinghai
Coal asset performance may improve	Beijing, Anhui, Fujian, Jiangxi, Henan, Hubei, Chongqing, Sichuan, Guizhou, Tibet, Shaanxi, Ningxia
Coal asset performance mostly stays the same *(score changes by less than 1)*	Heilongjiang, Jiangsu, Hebei, Jilin, Shanghai, Shandong, Guangxi, Hainan, Yunnan*, Gangsu*, Xinjiang (*Although Yunnan and Gansu scores do not change, they continue to rank as in the top five worst provinces for coal asset performance)

Source: Bloomberg New Energy Finance.

Provincial coal asset risk assessment – Inner Mongolia

Category	Metrics	Current status (2016)	Forecast (2020e)	Notes
Utilization rate	Demand supply balance	High	High	Inner Mongolia is the most oversupplied province in China, with capacity (de-rated for resource availability) at 461% of peak demand load in 2016.
	Transmission constraints	High	High	The province is a net power exporter with poor access to outbound transmission capacity, and the transmission constraints are expected to worsen over time.
	Competition from other baseload	Low	Low	Most of the baseload in Inner Mongolia is coal, very little competition from other technologies like hydro and nuclear.
	Flexibility demands	Mid-high	High	Wind (and increasingly solar) capacity penetration will increase from 30% to 33% from 2016 to 2020, requiring more flexibility from the province's power system.
	Loss of Dispatch Quota	Mid	Mid-high	As market reforms progress, Inner Mongolia's coal-fired power plants can expect to face decreasing dispatch quota allocations.
Power prices	Risk of decreasing wholesale prices	High	High	The province faces downward pressure on wholesale power prices due to competition and an expected slowdown in industrial activity.
Fuel costs	Fuel aggregate risk	Low	Low	Inner Mongolia has the second largest reserves of coal in China. The province utilizes rail to transport the coal it produces and consumes. Generators face little risk to fuel price as they are located close to the mine mouth.
Environmental/ political costs	REC obligation risk	Low	Low	The province is close to meeting its RPS target with its high amount of wind generation.
	Early retirement risk	Low	Low	Most coal generation assets in the province are newer and larger-scale, with relatively low risk of being forced into early retirement.
	Carbon price exposure	Low	Low	We do not expect the province to move quickly to establish a meaningful carbon market.
	Water Risk	High	High	Inner Mongolia is very arid, with severe water resource stress.
Overall risk		64	69	Inner Mongolia currently ranks the highest in China for exposure to bad coal assets. Although most of its coal power fleet is new, they face a constrained local market and limited opportunities to export power. In 2020, conditions are expected to worsen as power market reforms come into effect, and coal power plant utilization may worsen.

Provincial coal asset risk assessment – Gansu

Category	Metrics	Current status (2016)	Forecast (2020e)	Notes
Utilization rate	Demand supply balance	High	High	Gansu is extremely oversupplied, with enough de-rated capacity to meet peak demand 2.5 times over in 2016 alone. Conditions are expected to stay the same.
	Transmission constraints	Mid-high	Mid-high	Gansu is a net exporter. It is dependent on transmission capacity to export at least a quarter of its generation capacity.
	Competition from other baseload	Low	Low	About 16-17% of the baseload in Gansu is from non-coal generation, representing a relatively low level of competition.
	Flexibility demands	High	High	42% of Gansu's capacity is expected to be wind and solar by 2020, a very high penetration requiring a greater degree of flexibility from the local grid.
	Loss of Dispatch Quota	Mid-high	High	Gansu faces increasing risk through wholesale market reforms, resulting in loss of dispatch quota to coal-fired assets.
Power prices	Risk of decreasing wholesale prices	High	High	Gansu faces a very high risk of declining wholesale power prices.
Fuel costs	Fuel aggregate risk	Mid-high	Mid-high	Gansu has very few local coal reserves so must rely on imports, mostly via rail. About a quarter of Gansu's coal suppliers are from key SOEs. Less than half of Gansu's coal is transported by rail.
Environmental/ political costs	REC obligation risk	Low	Low	According to its current new-build pipeline, even assuming curtailment, Gansu will be able to meet its RPS targets, so faces little risk from REC obligations.
	Early retirement risk	Low-mid	Low-mid	Only about a third of Gansu's coal capacity is captive or sub-critical.
	Carbon price exposure	Low	Low	We do not expect Gansu to set up a meaningful carbon market by 2020.
	Water Risk	High	High	Gansu has the highest water stress rating in China.
Overall risk		59	59	Gansu ranks the second worst in terms of coal asset risk, driven primarily by high oversupply conditions and exposure to decreasing wholesale power prices. Despite local conditions not really changing, Gansu is projected to drop to third rank for worst exposure to coal asset risk, overtaken by Yunnan.

Provincial coal asset risk assessment – Shanxi

Category	Metrics	Current status (2016)	Forecast (2020e)	Notes
Utilization rate	Demand supply balance	High	High	Shanxi starts off with lower risk of oversupply, but by 2020 will become oversupplied.
	Transmission constraints	High	High	Shanxi is heavily dependent on exporting transmission capacity (more than 30% of available capacity is for export)
	Competition from other baseload	Low	Low	Shanxi baseload consists primarily of coal, with very little from competing technologies.
	Flexibility demands	Low-mid	Mid	Shanxi's grid starts off with relatively low penetration by wind and solar but, by 2020, the proportion will grow sufficiently to increase the need for flexibility.
	Loss of Dispatch Quota	Low-mid	Mid-high	The province currently faces minimal exposure to loss of dispatch quota via wholesale market reforms, but will likely face increased risk by 2020 as reforms progress.
Power prices	Risk of decreasing wholesale prices	High	High	Due to an expected slowdown in industrial output and to potential competition between generators, Shanxi faces a high risk of future decline in wholesale power prices.
Fuel costs	Fuel aggregate risk	Low	Low	Shanxi is one of China's largest coal-producing provinces and is also primarily supplied by a key state-owned coal enterprise. It primarily dependent on rail for moving around the coal it produces and consumes. Shanxi is home to the highest proportion of China's national coal reserves.
Environmental/ political costs	REC obligation risk	Mid	Low	Shanxi faces some pressure to meet its RPS targets now, but our capacity forecasts indicate that it will easily do so by 2020.
	Early retirement risk	Low	Low	Much of coal generation capacity in Shanxi is newer and not at risk of early retirement.
	Carbon price exposure	Low	Low	We expect that Shanxi will be slow to start a carbon market.
	Water Risk	High	High	Shanxi is relatively water-scarce and resource pressure is expected to worsen.
Overall risk		55	58	Shanxi currently has the fourth-highest exposure to coal assets risk, and conditions are expected to worsen, giving it the third-highest exposure by 2020.

Provincial coal asset risk assessment – Jilin

Category	Metrics	Current status (2016)	Forecast (2020e)	Notes
Utilization rate	Demand supply balance	High	High	Currently, Jilin is nearly 270% oversupplied (de-rated capacity is 2.7 time higher than the peak load of that province). This problem will persist until 2020.
	Transmission constraints	Mid-high	Mid	Jilin has medium reliance on transmission to export, with about 9% of its generation capacity depending on long-distance transmission for utilization.
	Competition from other baseload	Low	Low	Only about 20% of Jilin's baseload capacity comes from non-coal, implying little competition for local grid utilization.
	Flexibility requirement	Mid	Mid	Jilin will have about 23% of generation capacity from wind and solar by 2020, which gives it about a middling need for greater flexibility.
	Loss of Dispatch Quota	Mid	High	The province is already very involved in wholesale market reforms and its coal generation assets face increasing risk of losing their dispatch quota.
Power prices	Risk of decreasing wholesale prices	High	High	Due to anticipated slow industrial economic growth and increasing competition, Jilin faces a high risk of decreasing wholesale prices.
Fuel costs	Fuel aggregate risk	Mid	Mid	Less than 20% of Jilin's coal is supplied by the key SOEs (neighboring provinces like Heilongjiang have local producers as well as imports from Korea and Russia, and seaborne from Qinghuangdao). About 40-43% of the province's coal is transported by rail. Jilin has almost zero local thermal coal reserves.
Environmental/ political costs	REC obligation risk	Low-mid	Mid	We anticipate Jilin will be a net REC importer by 2020. It may fall slightly short of its 2020 RPS target and local coal generators may have to purchase RECs to make up the shortfall.
	Early retirement risk	Low	Low	Most of the province's coal generation assets were developed later, only about 13% are captive or sub-critical (not including CHP plants, which we count differently).
	Carbon price exposure	Low	Low	We do not anticipate Jilin will be proactive in setting up a carbon market.
	Water Risk	High	High	Jilin is relatively arid, with high water risk.
Overall risk		56	57	Overall, Jilin ranked in the top 3 for highest exposure to coal asset risk as of 2016, and conditions basically stay about the same.

Provincial coal asset risk assessment – Yunnan

Category	Metrics	Current status (2016)	Forecast (2020e)	Notes
Utilization rate	Demand supply balance	High	High	Yunnan is the second-most oversupplied province in China, with de-rated power capacity equal to 350% of peak demand by 2020.
	Transmission constraints	High	High	Yunnan is a net power exporter, similar to Inner Mongolia, reliant on transmission capacity to export about half of its available generation.
	Competition from other baseload	High	High	More than 72% of Yunnan's baseload is from non-coal (mostly hydro). This implies a lot of competition for coal generation in the local grid.
	Flexibility demands	Low	Low-mid	By 2020, we forecast about 17% of Yunnan's generation capacity will come from wind and solar, up from 12% in 2016, meaning there will be increasing need for flexibility.
	Loss of Dispatch Quota	Mid	Mid-High	Yunnan's exposure to wholesale market reforms will increase over the next few years.
Power prices	Risk of decreasing wholesale prices	Low	Mid	Yunnan already has some of the lowest wholesale power prices in China (due to hydro), and therefore, although there is some downward pressure, wholesale prices may not decrease as much as those in other provinces.
Fuel costs	Fuel aggregate risk	High	High	Yunnan has very little local reserves of coal. About 18% of Yunnan's coal supplies are transported by rail, a smaller figure than for other provinces. Less than 1% of Yunnan's coal supplies are from one of the key SOEs.
Environmental/ political costs	REC obligation risk	Mid	Low	Yunnan is in slight deficit now, but is on track to easily meet its RPS goal by 2020.
	Early retirement risk	Mid-High	Mid-High	About 60% of the existing coal assets are captive or sub-critical plants, giving it a relatively high risk of coal early retirement or retrofits.
	Carbon price exposure	Low	Low	We do not expect Yunnan to set up a meaningful carbon market before 2020.
	Water Risk	Low-mid	Low-mid	Yunnan has relatively low stress on baseline water resources.
Overall risk		55	55	Yunnan in 2016 was tied with Shanxi for fourth-highest coal asset risk exposure but, by 2020, it becomes the second-highest coal risk exposure nationally. This is driven by competition from growing hydro generation, transmission constraints and worsening oversupply. These will, through wholesale market competition, force down power prices.

Provincial coal asset risk assessment – Qinghai

Category	Metrics	Current status (2016)	Forecast (2020e)	Notes
Utilization rate	Demand supply balance	Mid	Mid-high	Qinghai is about 1.5 times oversupplied, which is bad but not as severe as some other provinces, putting it in the middle range.
	Transmission constraints	Mid-high	Mid	Qinghai currently is not very dependent on transmission capacity to help with exporting excess generation. It also has little access to long distance lines. The expectation is that Qinghai will handle most of its own generation and balance locally.
	Competition from other baseload	Mid-high	Low-mid	Abut 39% of Qinghai's baseload generation come from non-coal technologies.
	Flexibility demands	Mid-high	High	Qinghai will have over 42% penetration of wind and solar capacity by 2020, requiring a high degree of flexibility from coal-fired assets to balance the local grid.
	Loss of Dispatch Quota	Mid	High	The province will have increasing exposure to market reforms that may require falling dispatch quota for coal-fired assets.
Power prices	Risk of decreasing wholesale prices	High	High	The province faces a very high risk of decreasing wholesale power prices, especially as direct power purchasing pilots expand.
Fuel costs	Fuel aggregate risk	Mid-high	Mid-high	Qinghai has very little local coal reserves and is reliant on imported coal from neighboring provinces. Mostly via rail transport.
Environmental/ political costs	REC obligation risk	Low	Low	Qinghai is set to overshoot its RPS target by more than 17.6% and will be a net REC exporter. It will be the most REC-abundant province in China by 2020.
	Early retirement risk	High	High	About 72% of Qinghai's coal-fired fleet is captive or sub-critical, representing a very high risk of early retirement or forced retrofits.
	Carbon price exposure	Low	Low	We do not expect Qinghai will set up a meaningful carbon price by 2020.
	Water Risk	High	High	Qinghai ranks very high in baseline water stress.
Overall risk		51	53	Qinghai ranks sixth highest nationally for coast asset risk exposure in 2016 and conditions are expected to stay about the same.

Provincial coal asset risk assessment – Sichuan

Category	Metrics	Current status (2016)	Forecast (2020e)	Notes
Utilization rate	Demand supply balance	High	High	Sichuan is highly oversupplied, with de-rated capacity more than twice its peak demand load. This issue continues into 2020.
	Transmission constraints	High	High	Sichuan relies on transmission capacity to export nearly three quarters of its generation, so is heavily reliant on long-distance transmission.
	Competition from other baseload	High	High	More than 80% of Sichuan's baseload generation is from non-coal (especially hydro), so the province ranks highest in China for competition from non-coal baseload.
	Flexibility requirement	Low	Low	Sichuan has some wind and solar, but the flexibility requirement is relatively low compared to other provinces.
	Loss of Dispatch Quota	Mid-high	High	The province is highly involved in power market reforms and faces a relatively high risk of changes to its dispatch quota system.
Power prices	Risk of decreasing wholesale prices	Low	Low	Similar to Yunnan, Sichuan already has very low wholesale power prices due to hydro. So there is not a lot of room for wholesale power prices to go down further.
Fuel costs	Fuel aggregate risk	High	High	Sichuan has very little in the way of local coal reserves. About 43% of the province's coal is transported by rail, giving it a middling risk. Only about 2% of Sichuan's coal is supplied by one of the key SOEs. It faces risk as the coal industry consolidates and smaller mines are closed.
Environmental/ political costs	REC obligation risk	Mid	Low-mid	Sichuan is currently slightly short of meeting RPS targets (which do not include hydro). But with its planned pipeline for wind and solar, it will likely meet its targets by 2020.
	Early retirement risk	High	High	68% of Sichuan's coal fleet is captive or sub-critical, giving it a high risk of additional costs from early-retirement or forced retrofits.
	Carbon price exposure	Low	Low	Sichuan is the only one of the high coal-risk provinces that may have a carbon market launched by 2020. But we expect those carbon prices to be very low.
	Water Risk	Mid-high	Mid-high	Sichuan faces mid-to-high baseline water stress.
Overall risk		54	51	Overall, Sichuan improves from seventh-worst coal asset risk exposure in 2016 to 10th national ranking in 2020. Competition and oversupply conditions in the market are expected to improve and downward pressure on wholesale power prices should ease over time.

Conclusions

Key findings

Key conclusions: renewables curtailment

- **Curtailment to decline nationally, but it may emerge in southern provinces:** We expect the national curtailment ratio to fall in the coming years, driven by progress in the severely curtailed northern regions. A slowdown in new capacity development and the addition of ultra-high voltage transmission lines to export electricity will play major roles in alleviating the curtailment in those northern provinces. On the other hand, some province that currently experience little curtailment might see the issue emerging by 2020, including Hunan, Sichuan, Guizhou and Fujian. This may reflect weaker demand growth and accelerated build-out of new generation capacity.
- **Long-distance transmission does help alleviate some curtailment risk, but this depends highly on line utilization:** UHV lines should boost renewable electricity consumption in the export provinces, even for those not planning to export renewable energy. This is because the export of other types of electricity will relieve the tension between renewables and non-renewables in the power output province and raise green energy consumption locally. However, the impact of the UHV transmission on curtailment mitigation will depend on the utilization rate of those UHV lines.
- **Importance of enforcing efficient market dispatch:** China's 13th FYP calls for efficient allocation of resources and a market producing the right signals. It includes establishing a competitive wholesale market based on economic dispatch. This should allow renewables to be dispatched first, and should reduce curtailment significantly. Under the existing system, a protected portion of dispatch is supposed to guarantee minimum utilization for wind and solar. In the absence of economic dispatch, each provinces' ability to reduce curtailment depends heavily on whether or not this guaranteed dispatch on grid operators is enforced.
- **Government-set investment risk indicators for onshore wind are too generous:** Our risk map shows that the provincial investment risk ratings the NEA allocated for onshore wind earlier this year are far too lenient, ranking only six northwest and northeast provinces as being high-risk (red). Instead, our risk maps both for 2016 and for 2020 are better aligned with the NEA's investment risk ratings for utility-scale solar. Over 30GW of wind and 24GW of solar new build are planned for provinces with medium-to-high curtailment risk ratings.

Key conclusions: Coal Asset Risk

- **Provinces with highest coal asset risk are concentrated in western and central regions of China:** The five provinces with the worst exposure to coal asset performance risk are Inner Mongolia, Gansu, Shanxi, Jilin, and Yunnan. Most of these provinces will see their coal risk worsen or stay high from now until 2020. Only Jilin sees some improvement, dropping from fourth highest risk province coal performing province, to seventh. Our map shows that two hydro-rich provinces, Yunnan and Sichuan, have particularly poor coal asset performance. This is due to increasing competition from hydro for base load, and liberalizing power markets and direct power purchasing programs that may force wholesale power prices down.
- **There are no provinces in China where new coal generation capacity is needed:** According to our analysis of supply and demand balances at end-2016, no province in China needs to build any more new coal generation capacity. Beijing, Shanghai, Jiangsu and Hebei are the only provinces where local generation fleet, de-rated for availability, is not equal to or higher than the peak demand load. However, these provinces can rely on imports as well as cleaner new build (like nuclear) to meet the shortfall. These regions are also severe air pollution control areas, so should not be building more coal-fired capacity for that reason.
- **For operating coal generators, the biggest risks stem from market reform:** In our analysis, four metrics approximate the impact of market reforms on coal asset performance: (1) loss of dispatch quota is a feature of current market reforms, and means coal power plants must rely increasingly on direct bidding into wholesale markets and have less guaranteed dispatch; (2) competition from non-coal base-load plants becomes increasingly important as wholesale markets are liberalized and coal plants have to compete with other technologies, particularly hydro and nuclear, directly for dispatch; (3) power prices can be expected to decrease in markets that are oversupplied and very competitive – especially as liberalization allows the market to determine wholesale prices, removing guarantees that coal generators can sell power at government regulated benchmark prices.
- **China faces a potential hit of $237 billion from at-risk coal assets:** Most recent investment data show that China is still constructing over 120GW of new coal generation capacity. These plants are all, according to our analysis, highly risky investments that will under-perform. Along with the 195GW of projects that have been cancelled since 2016, and another 100GW of projects awaiting regulatory approval that China still may bring on after 2020, we estimate that the country faces a social cost of $237 billion from risky coal investments.

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- Tao Wang, Casey Cronin, Jan Mazurek, Dan Plechaty, Surabi Menon

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sales.bnef@bloomberg.net
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Sophie Lu
slu117@bloomberg.net

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