SUSTAINABLE FINANCE PROGRAMME

SMITH SCHOOL OF ENTERPRISE AND THE ENVIRONMENT

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Stranded Assets and Thermal Coal in China:

An analysis of environment-related risk exposure

Working Paper

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The Sustainable Finance Programme at the University of Oxford Smith School of Enterprise and the Environment aims to be the world's leading centre for research and teaching on sustainable finance and investment. The Programme was established in 2012 (originally as the Stranded Assets Programme) to understand the requirements, challenges, and opportunities associated with a reallocation of capital towards investments aligned with global environmental sustainability.

We seek to understand environment-related risk and opportunity across different sectors, asset classes, and geographies; how such factors are emerging and how they positively or negatively affect asset values; how such factors might be interrelated or correlated; their materiality (in terms of scale, impact, timing, and likelihood); who will be affected; and what affected groups can do to pre-emptively manage risk.

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Key Findings

- We examined the environment-related risks facing current and planned coal-fired power stations owned by the top 50 coal-fired power utilities in China (which together comprise 89% of China's coal-fired capacity). We measured each power station's exposure to seven local risk hypotheses and 12 national risk hypotheses. This asset-level analysis, which was then aggregated to the parent company level, can help to inform specific investor actions related to risk management, screening, voting, engagement, and disinvestment. We also prepared in-depth case studies of exposure to environment-related risks and potential stranding for the five largest coal-fired utilities in China: 1) Huaneng; 2) Datang; 3) Guodian; 4) Huadian; and 5) State Power Investment Corp.

- We examined the financial structure and market value of Chinese utilities over time. This was done to help to determine the performance, stability, and health of our sample companies. This also provides insight into their ability to finance future generating capacity, as investors also seek this information to determine expected rates of return. Utilities in good financial health may also be better able to adapt to stranded assets created by the risks we identify and analyse in this report. If the sample is found to be under considerable financial stress, investors may consider the sector non-investment grade and be hesitant to commit capital, or demand higher rates of return on their investment. Access to capital is also crucial to facilitate investment in China's low carbon transition.

- We found that the financial position of the top 50 coal-fired power utilities in China is generally getting worse. First, between 2008 and 2015, the industry has impaired CN¥13.8 billion of assets. Second, Chinese utilities have a large reliance on short-term debt (current liabilities), which may introduce additional financial risk and risk of bankruptcy if market conditions were to rapidly deteriorate. Third, profit margins have been declining over time, from 23% in 1995 to 9% in 2015. Fourth, the companies in our sample have made efforts to increase their financial leverage, inducing higher financial risk to operations. Fifth, China's coal-fired utilities have typically held low levels of cash reserves, which diminishes their ability to satisfy debt commitments using cash or near-cash equivalents. Sixth, the proportion of debt to earnings is growing, increasing the time taken to repay debt.

- To examine the upper bound and potential scale of stranded coal assets in China, we used four illustrative scenarios where all existing and planned coal-fired power stations are completely stranded over 5-year, 10-year, 15-year, and 20-year periods. These scenarios are suitable time horizons to consider given the pace of change in the global energy system. Disruption appears to be accelerating as tipping points are reached and the idea that the power sector will remain relatively static and 'safe' for new thermal coal assets is counter to the evidence we see internationally across the G20. They are also reasonable time horizons in terms of keeping within the carbon budget constraints associated with the Paris Agreement on climate change.

- The four scenarios reflect the different speeds and scales at which the environment-related risk factors identified in this report could realistically materialize. While highly illustrative, these scenarios highlight the maximum potential impact of stranded coal assets on the utility sector in China. These scenarios estimate that stranded coal assets could be as much as CN¥3,086–7,201bn (US$449-1,047bn), equivalent to 4.1–9.5% of China's 2015 GDP. Given the scale of this potential stranding, it might be prudent for financial regulators to examine which parts of China's financial system are more or less exposed to these risks and to consider taking steps to mitigate this exposure.

- Given growing overcapacity, competition from renewables, carbon emissions curtailment, and falling demand growth; a failure to examine the exposure of China's existing and proposed coal-fired power plants to the risk of asset stranding may have significant consequences. Stranded coal assets would affect utility returns for coal-fired utilities investors; impair the ability of utilities to service outstanding debt obligations; and create stranded assets that have to be absorbed by taxpayers and ratepayers.

Executive summary

To our knowledge this is the most up-to-date and comprehensive analysis of the exposure of coal-fired power stations in China to environment-related risks that can create ‘stranded assets’. Stranded assets are assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities.[1] The environment-related risks facing coal-fired power stations are substantial and could be significant drivers of asset stranding. They span physical environmental impacts, the societal responses to such environmental impacts (for example, new policies and technological change), and new legal liabilities that may arise from either of the former.

By examining the environment-related risks facing coal-fired power stations, creating appropriate measures to differentiate the exposure of different assets to these risks, and linking this analysis to company ownership, debt issuance, and capital expenditure plans, our research is designed to help inform decision-making in relation to China’s power sector. In particular, our research can help to inform specific investor actions related to risk management, screening, voting, engagement, and disinvestment. The datasets that underpin our analysis, as well as the analysis itself, also enable new lines of academic research and inquiry.

The government is currently overseeing a significant increase in coal generation capacity, from 978 GW with 227 GW under construction, and 563 GW at various stages of planning. This compares with 99 GW of intermittent renewables and 88 GW of non-coal thermal genearation under construction (187 GW total non-coal), and 421 GW of intermittent renewables and 164 GW of non-coal thermal generation currently planned (585 GW total non-coal). Although the government has taken some proactive measures in 2016 and 2017 to reduce the amount of new coal capacity, growing environment-related risks mean that companies, investors, and policymakers should more thoroughly examine the exposure of China’s existing and proposed coal-fired power plants to the risk of asset stranding. Stranded coal assets would affect utility returns for investors (including the state); impair the ability of utilities to service outstanding debt obligations; and create stranded assets that have to be absorbed by taxpayers and ratepayers. Moreover, new coal-fired power stations will generate significant negative externalities for the duration of their shorter than anticipated lives, particularly in terms of carbon emissions that cause climate change, as well as air pollution that harms human health.

Methodology

The approach we have used here is based on the methods developed in a previous report of the Sustainable Finance Programme of the University of Oxford’s Smith School of Enterprise and the Environment (the ‘Oxford Smith School’) from March 2015, entitled *Stranded Assets and Subcritical Coal: the risk to companies and investors.*[2] This methodology was significantly expanded in the publication *Stranded Assets and Thermal Coal: An analysis of environment-related risks*[3], published by the Oxford Smith School in January 2016, and further refined in *Stranded Assets and Thermal Coal in Japan: An analysis of environment-related risk exposure.*[4] published in May 2016. This report uses similar data and methods to these publications to provide a high-resolution examination of the environment-related risks facing China’s thermal coal assets.

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[1] See Caldecott, B., et al. (2013). *Stranded Assets in Agriculture: Protecting Value from Environment-Related Risks*.
[2] See Caldecott, B., Dericks, G., & Mitchell, J. (2015). *Stranded Assets and Subcritical Coal: The Risk to Companies and Investors*.
[3] See Caldecott, B., Kruitwagen, L., Dericks, G., et al. (2016). *Stranded Assets and Thermal Coal: An Analysis of Environment-Related Risk Exposure*.
[4] Ben Caldecott et al., “Stranded Assets and Thermal Coal in Japan: An Analysis of Environment-Related Risk Exposure,” 2016.

Understanding how environment-related factors interact and affect a company requires a detailed examination of the company's specific asset base. For all Chinese utilities with coal-fired generation, we have analysed the attributes of their coal-fired power stations and integrated and cross-referenced this data with indicators of environment-related risk to develop asset-specific analyses of risk exposure. We then aggregate these analyses to the company level to provide company-wide assessments of environment-related risk exposure. We also integrate capital expenditure pipeline and company debt issuance into these analyses to identify companies with the greatest risk exposure in their capex pipeline. The datasets used to underpin our analysis are described in the Appendix.

Our approach requires us to take a view on what the environment-related risks facing coal-fired power stations could be and how they could affect asset values. We call these Local Risk Hypotheses (LRHs) or National Risk Hypotheses (NRHs) based on whether the risk factor in question affects all assets in China in a similar way, or if risk exposure is specific to the local environment. Water stress, for example, varies across the country and so is an LRH, whereas country-wide changes to renewables policy support is an NRH. A description of these LRHs and NRHs is provided below.

Utility exposure to LRHs

The Local Risk Hypotheses we apply and measure China's coal-fired power stations against are outlined here:

LRH-1: Carbon Intensity
The more carbon intensive a coal-fired power station, the more likely it is to be negatively impacted by climate policy, whether carbon pricing, emissions performance standards, or other similar measures. More carbon-intensive power stations are more exposed to transitional risk from climate change mitigation policy. Carbon intensity is assessed for each power station in kg.CO_2/MWh.

LRH-2: Plant Age
Older power stations create risks for owners in a number of ways. First, ageing power stations are more vulnerable to regulations that might force their closure. Second, utilities with significant ageing generation portfolios have a higher risk of being required to cover site remediation costs after power station closures and outstanding worker liabilities (i.e. pension costs). Finally, older power stations are more susceptible to unplanned shutdowns and maintenance needs, resulting in the costs of repairs and secondary losses or opportunity costs of underperformance on contracted power delivery. Plant age is taken as the year of completed construction.

LRH-3: Local Air Pollution
Coal-fired power stations in locations with high population density and serious local air pollution are more at risk of being regulated and required to either install emission abatement technologies or cease operation. Thus, owners of assets in areas of high population density and high local pollution will have a greater risk of bearing the financial impacts of such possibilities. Local air pollution is assessed using $PM_{2.5}$ as a proxy and is measured in $\mu g/m^3$.

LRH-4: Water Risks
The hypothesis is that power stations located in areas with; (1) higher physical baseline water stress, (2) more severe droughts, and (3) more frequent flooding are at higher risk of being forced to reduce or cease operations.

LRH-5: Quality of Coal
The hypothesis is that coal-fired power stations that use lignite are more at risk than those that use other forms of coal. This is because their greater CO_2 and SO_2 emissions makes them more exposed to regulatory risk.

LRH-6: CCS Retrofitability

Coal-fired power stations not suitable for the retrofit of carbon capture and storage (CCS) technology may be at more risk of premature closure. These power stations do not have the option of CCS retrofit in the case of strong GHG mitigation requirements on coal-fired power utilities, enforced either by targeted policy or carbon pricing. CCS retrofitability is assessed based on a number of criteria given in Section 2.2.1.

LRH-7: Future Heat Stress

The hypothesis is that physical climate change will exacerbate heat stress on power stations. Higher ambient local temperatures decrease power station efficiency and exacerbate water stress, which causes physical risks, such as forced closure or reduced operation, and social risks, such as unrest and increased potential for regulation. Future heat stress is measured in ^{o}C in 2035 above preindustrial levels.

Table 1: Units of measurement of LRHs

	Hypothesis	Unit
LRH-1	Carbon intensity of generated electricity	[kg.CO_2/MWh]
LRH-2	Plant age, year constructed	[year]
LRH-3	Local air pollution exposure with $PM_{2.5}$ as a proxy	[$\mu g_{PM2.5}/m^3$]
LRH-4	Water risk	[Rank (1=lowest,50=highest]
LRH-5	Quality of coal	[Per cent burning lignite]
LRH-6	CCS Retrofitability described by criteria in Section 2.2.1	[Per cent retrofitable]
LRH-7	Average temperature change in 2035 above preindustrial levels	[Δ^oC by 2035]

Table 2: Summary of financial and environment-related risk exposure

SUMMARY OF RISK EXPOSURE	COAL-FIRED CAPACITY			DEBT / EQUITY	CURRENT RATIO	(EBITDA-CAPEX) / INTEREST	LRH-1: CARBON INTENSITY	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLLUTION	LRH-4: WATER RISK	LRH-5: QUALITY OF COAL	LRH-6: CCS RETROFITABILITY	LRH-7: FUTURE HEAT STRESS
	OPR [MW]	CON [MW]	PLN [MW]				Local Risk Hypothesis						
China Huaneng Group	124,928	22,720	49,180	0.59	0.34	3.79	878	2005	40	22	9%	39%	1.02
China Guodian Corporation	103,512	11,140	60,550	1.19	0.21	3.40	867	2006	42	18	4%	35%	1.02
China Datang Corporation	102,035	16,200	58,243	1.36	0.30	3.76	880	2005	44	10	4%	37%	1.03
China Huadian Corporation	90,525	18,150	49,218	0.66	0.36	3.50	878	2006	42	12	3%	36%	1.01
State Power Investment Corporation	76,416	13,310	46,239	0.06	0.42	3.11	888	2006	41	19	26%	35%	1.03
China Shenhua Energy Co. Ltd.	69,475	20,880	60,590	8.38	1.19	0.29	868	2009	38	26	3%	43%	1.04
China Resources Power Holdings Co. Ltd.	39,358	5,300	21,430	5.56	0.43	1.06	865	2008	56	12	0%	44%	0.94
Guangdong Yudean Group Co., Ltd.	33,336	3,200	14,860	4.53	0.93	0.75	882	2006	28	42	0%	51%	0.85
Zhejiang Provincial Energy Group Company Ltd.	22,410	900	5,320	2.58	1.04	0.57	846	2007	37	23	0%	0%	0.88
State Development & Investment Corporation	14,636	9,660	8,885	0.50	1.00	1.73	863	2008	42	34	0%	48%	0.99
Beijing Energy Investment Holding Co., Ltd.	13,720	10,860	6,890	-	0.74	1.08	880	2007	35	23	0%	32%	1.12
Shandong Weiqiao Pioneering Group Co., Ltd.	13,100	10,080	0	1.53	1.76	0.58	870	2013	72	2	0%	0%	0.92
HeBei Construction & Investment Group CO., Ltd.	9,722	1,400	2,000	-	1.14	1.16	860	2002	66	11	0%	19%	1.04
Jiangsu Guoxin Investment Group Limited	9,365	1,000	8,393	-	-	-	863	2009	60	15	0%	73%	0.92
Wenergy	8,880	2,440	3,980	6.09	0.57	0.41	849	2007	54	19	0%	45%	0.96
CLP Holdings Ltd.	8,352	1,320	0	4.14	0.58	0.55	874	1999	42	30	0%	40%	0.90
State Grid Corporation of China	8,145	0	7,020	-	0.30	0.54	868	1999	45	6	0%	26%	1.00
Shanxi International Energy Group Co., Ltd.	7,290	7,170	3,900	-	-	-	881	2008	36	28	0%	17%	1.07
CITIC Group Corporation	7,010	0	375	-	-	-	860	2002	68	46	0%	18%	0.95
China Coal Energy Company Limited	6,660	5,550	1,960	-	0.92	1.13	869	2010	34	23	0%	13%	1.12
Henan Investment Group	5,870	3,180	2,000	-	-	-	848	2007	77	3	0%	71%	1.00
Shenzhen Energy Group Co., Ltd.	5,628	1,140	5,300	-	0.88	1.01	850	2002	26	39	0%	55%	0.84
Shenergy (Group) Company Limited	5,184	0	0	-	0.89	0.13	842	2005	57	44	0%	76%	0.90
China Petroleum & Chemical Corp.	5,099	300	0	6.77	0.72	0.33	869	2000	53	5	0%	34%	0.97
Shandong Xinfa Aluminum & Electricity Group	4,815	350	2,200	-	-	-	886	2012	25	28	46%	7%	1.22
Cheung Kong Infrastructure Holdings Ltd.	4,610	0	0	4.46	2.52	0.25	874	1994	30	48	4%	9%	0.74
Xinjiang Tianfu Energy Co., Ltd.	4,500	2,160	2,640	-	0.53	1.40	872	2012	12	17	0%	0%	1.27
East Hope Group Company Limited	4,300	0	1,050	-	-	-	873	2014	9	47	0%	100%	1.32
Aluminum Corporation Of China Limited	4,195	2,370	1,360	-	0.79	2.15	900	2008	41	16	0%	69%	1.09
Formosa Plastics Corporation	4,050	0	0	9.77	2.50	0.30	845	2002	22	49	0%	89%	0.76
Xingfa	4,040	1,320	750	2.82	0.85	1.41	832	2014	85	4	0%	0%	0.92
Gansu Province Electric Power Investment Group Co., Ltd	3,940	2,700	660	0.55	1.52	1.16	869	2009	10	19	0%	33%	1.17
Huainan Mining Group Power Generation Co., Ltd.	3,540	0	0	-	-	-	868	2011	64	27	0%	0%	0.90
Hangzhou Jinjiang Group Co., Ltd.	3,020	1,332	3,690	-	-	-	935	2013	16	8	79%	9%	1.22
Xishan Coal & Electricity (Group) Co., Limited	3,000	1,320	2,000	-	-	-	908	2008	61	32	0%	0%	1.04
Jiuquan Iron & Steel (Group) Co., Ltd.	2,950	0	1,632	-	0.33	1.80	858	2011	7	34	0%	0%	1.19
GCL-Poly Energy Holdings Ltd.	2,648	0	1,000	-	0.81	2.54	865	2006	60	37	0%	13%	0.90
Inner Mongolia Guodian Energy Investment Co., Ltd.	2,400	680	4,560	-	-	-	911	2007	15	32	50%	25%	1.23
Fujian Energy Group Co., Ltd.	2,012	0	1,758	0.79	1.00	1.35	855	2013	21	39	0%	15%	0.83
Chongqing Energy Investment Group Co. Ltd.	1,920	2,680	4,300	-	0.69	1.89	882	2011	53	34	0%	100%	0.90
Sichuan Qiya Aluminium Industry Group Co., Ltd.	1,800	1,800	0	-	-	-	841	2014	9	45	0%	100%	1.32
Power Construction Corporation of China	1,610	0	6,000	-	-	-	851	2010	25	37	0%	100%	1.12
Qinghai Province Investment Group Limited	1,595	0	1,920	-	-	-	868	2007	9	9	0%	0%	1.14
Guangdong Baolihua New Energy Stock Co., Ltd.	1,470	0	3,800	2.30	1.02	0.84	953	2009	30	6	0%	41%	0.91
Guangdong Pearl River Investment Co., Ltd.	1,320	0	0	-	-	-	834	2013	30	50	0%	0%	0.76
Wanji Holding Group Graphite Product Co., Ltd.	1,140	0	1,200	-	-	-	868	2008	61	1	0%	0%	1.05
Shaanxi Coal and Chemical Industry Group Co., Ltd.	950	2,600	3,653	-	0.66	2.79	881	2012	29	30	0%	32%	1.16
Datong Coal Mine Group Co.,Ltd.	500	2,100	2,000	-	1.19	4.19	863	2009	38	12	0%	0%	1.13
Shaanxi Provincial Investment (Group) Co., Ltd.	300	2,320	11,000	-	-	-	868	2008	20	43	0%	100%	1.20
Inner Mongolia Asset Management Bureau	0	700	4,020	-	-	-	849	2017	15	41	0%	0%	1.20

For LRH-4, companies are ranked by exposure, with '1' being the most exposed
For more details, see tables in Appendix C.

There is little variation in average coal generation CO2 intensity across major Chinese utilities, which are generally just within the threshold for supercritical efficiency (880 kg CO2/MWh). China's MW-weighted average coal-fired power CO_2 intensity is 873 kg.CO_2/MWh, which compares favourably with the United States and Europe, whose plants are on average considerably older and less efficient.

On a MW-weighted basis there is also little variation among the top 50 utilities with respect to average coal plant age – which on average were built in 2007. China's coal generation fleet is among the world's youngest.

Air pollution, measured as atmospheric particulate matter of less than 2.5 µm (PM 2.5), is extremely high. Only 16 out of the 50 companies (32%) comply on a MW-weighted basis with China's national annual average limit of $\mu g_{PM2.5}/m^3$, and only two comply with the WHO's annual limit of 10 $\mu g/m^3$.

Water Risk (LRH-4) incorporating Water Stress, Frequency of Flooding, and the Severity of Drought is displayed above as a rank among the 50 companies in order to aggregate these variables into a single metric: 1 = [highest risk, 50 = lowest risk].

As can been seen from Figure 21: CCS geological suitability, China has excellent CCS potential along its heavily populated coasts, as well as certain areas in the northeast, central China, and Xinjiang (western-most province). The potential CCS suitability of Chinese utilities reflects this pattern, however many potential reservoirs are near population centres which could object to local CCS adoption.

Figure 20: Chinese coal deposits by type shows that China's major lignite deposits are primarily located in central and southern China. However, lignite only comprises a significant portion of the generation portfolios of a handful of Chinese power companies.

Projected increases in heat stress by 2035 is shown in Figure 22 and follows a slow increase as one travels north. Therefore, levels of future heat stress increases show little variation, all averaging around 1^oC.

Utility exposure to NRHs

The hypotheses below affect all coal-fired generating assets in China. A simple traffic-light method has been used to conduct analysis for these risk hypotheses. Criteria are developed below for each hypothesis, with conclusions as to whether coal-fired utilities are at high risk (red), medium risk (yellow) or low risk (green). Based on each of these criteria, an aggregate risk outlook is given after scoring each (+2 for high risk criteria, +1 for medium risk criteria). Comparator countries are also given based on the analysis conducted in *Stranded Assets and Thermal Coal: An analysis of environment-related risks* and *Stranded Assets and Thermal Coal in Japan: An analysis of environment-related risk exposure.* These comparisons are important for contextualising risk exposure in China. This will help investors who have a global universe of investment opportunities to understand how China's utilities compare to utilities in other countries. Table 3 provides a summary of all NRHs for China's coal-fired power utilities and those in comparator countries, where directly comparable.

Table 3: Summary of National Risk Hypotheses

	China	Japan	Australia	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
NRH-1: Future Electricity Demand	Green	Red	Yellow	Red	Green	Green	Red	Yellow	Red	Yellow
NRH-2: Renewables Resource	Green	Green	Red	Green	Yellow	Yellow	Yellow	Red	Yellow	Yellow
NRH-3: Decline in Government Support for Coal	Yellow					-				
NRH-4: Renewables Policy Support	Red	Red	Yellow	Red	Green	Red	Green	Yellow	Yellow	Red
NRH-5: Growth of Decentralised Renewables	Yellow	Red				-				
NRH-6: Growth of Utility-Scale Renewables	Yellow	Green				-				
NRH-7: Gas Reserves and Production Growth	Red					-				
NRH-8 Growth of Gas-Fired Generation	Red	Yellow	Yellow	Green	Red	Yellow	Green	Green	Green	Red
NRH-9: Falling Utilisation Rates	Red	Yellow	Yellow	Green	Yellow	Red	Yellow	Red	Yellow	Yellow
NRH-10: Water Regulatory Risk	Yellow	Green	Green	Green	Red	Yellow	Green	Yellow	Green	Green
NRH-11: CCS Regulatory Environment	Red	Yellow	Green	Yellow	Red	Red	Yellow	Red	Green	Green
NRH-12: Investor Sentiment	Yellow					-				
NRH-13: Nuclear Restarts	-	Yellow				-				
TOTAL*	63%	50%	43%	36%	57%	64%	36%	64%	36%	50%

*Higher percentage equates to a worse risk outlook. Percentage is calculated based on allocating two points for every red signal and one point for every yellow signal, and then dividing this score by the total maximum points (ie if every signal was red). Total for China based on this publication. Total for comparator countries based on *Stranded Assets and Thermal Coal*[5] and *Stranded Assets and Thermal Coal in Japan*[6] reports.

The National Risk Hypotheses we apply and measure China's coal-fired power stations against are outlined below:

NRH-1: Future Electricity Demand Outlook

The hypothesis is that the greater the growth in demand for electricity, the less likely other forms for generation (e.g. solar, wind, gas, and nuclear) are to displace coal-fired power. Growth in overall electricity demand might even allow coal-fired generators to maintain or increase their current share of power generation.

NRH-2: Renewables Resource

The hypothesis is that the availability of renewable resources is a key determinant of the competiveness of renewables relative to conventional generation. Countries with larger renewable resources could see larger and faster rates of deployment. This would result in coal-fired power stations being more likely to face lower wholesale electricity prices and other forms of power sector disruption.

NRH-3 Decline in Government Support for Coal-fired Power Stations

[5] Ben Caldecott et al., "Stranded Assets and Thermal Coal: An Analysis of Environment-Related Risk Exposure," *Stranded Assets Programme, SSEE, University of Oxford*, 2016, 1–188.
[6] Ben Caldecott et al., "Stranded Assets and Thermal Coal in Japan," *Stranded Assets Programme, SSEE, University of Oxford*, 2016, 1–106.

The hypothesis is that a loss of government support for coal-fired power stations would increase the risk that these assets would be stranded.

NRH-4: Renewables Policy Support
This hypothesis examines the Chinese government's policy support for renewable power generation. The hypothesis is that countries with robust regimes for supporting renewables will see greater renewables deployment. This would result in coal-fired power stations being more likely to face lower wholesale electricity prices and other forms of power sector disruption.

NRH-5: Growth of Decentralised Renewables and the Utility Death Spiral
The hypotheses are that the growth of decentralised renewables might affect coal-fired power differently than centralised renewables by leading to a 'utility death spiral' and the rapid, unforeseen erosion of a coal-fired utility's business model. In China, decentralised renewables are almost exclusively small-scale solar PV installations. The utility death spiral is the disruption to conventional power utility companies as a result of a virtuous cycle where distributed energy resources (e.g. rooftop solar PV) are eroding the distribution network business model of the central utility, which in turn raises retail electricity prices making distributed energy resources even more competitive.[7]

NRH-6: Growth of Utility-Scale Renewables
The hypothesis is that rapid renewables deployment would result in coal-fired power stations being more likely to face lower wholesale electricity prices and other forms of power sector disruption. Since 2008, half the world's added electric generating capacity has been renewable.[8] The Chinese Government wants to increase renewables from 10% of its energy mix to 20% by 2030, reducing its reliance on gas, coal and nuclear.

NRH-7: Gas Reserves and Production Growth
The hypothesis is that the growth of gas-fired generation, particularly in markets where electricity demand growth is lower or negative, could harm the economics of coal-fired generation and result in coal-to-gas switching.

NRH-8: Growth of Gas-Fired Generation
The hypothesis is that the growth of gas-fired generation, particularly in markets where electricity demand growth is lower or negative, could harm the economics of coal-fired generation and result in coal-to-gas switching.

NRH-9: Falling Utilisation Rates
The hypothesis is that under-utilised coal-fired power stations will be financially vulnerable and more prone to stranding. The entrance of new generating options may reduce the utilisation rates of coal-fired generating assets. Competition on marginal costs, or must-run regulation for renewables, can displace coal-fired generation, reducing utilisation rates. Generating stations with falling utilisation rates are less able to cover fixed costs with operating profit.

NRH-10: Water Regulatory Risk
The hypothesis is that coal-fired power stations in countries that have strict water use requirements and an awareness of water issues are more likely to be affected by changes to water pricing or regulation.

NRH-11: CCS Regulatory Environment

[7] CTI (2015). *Coal: Caught in the EU Utility Death Spiral*. London, UK.; Graffy, E. and Kihm, S. (2014) 'Does disruptive competition mean a death spiral for electric utilities', Energy LJ, HeinOnline, 35, p. 1.; Costello, K. W. and Hemphill, R. C. (2014) 'Electric Utilities' "Death Spiral": Hyperbole or Reality?', The Electricity Journal, 27(10), pp. 7–26
[8] Lovins, A. 'How Opposite Energy Policies Turned the Fukushima Disaster into a Loss for China and a win for Germany', *Forbes*, 2014.

The hypothesis is that CCS could be a way for coal-fired power stations to keep running under stricter carbon constraints, but CCS will not happen without a supportive legal framework. Legal restrictions and regulatory uncertainties can present barriers to the development of CCS projects, which in turn present a risk to coal-fired utilities which could have CCS as an option for future GHG mitigation.
NRH-12: Investor Sentiment
The hypothesis is that investor sentiment drives asset valuations and effects the cost of capital, and therefore can influence asset stranding. At the national level investor sentiment in coal-fired power may incorporate concerns related to expanding international and national climate targets and the growth of coal divestment campaigns.

Scale of potential asset stranding

To examine the scale of potential stranded coal assets in China, we used four illustrative scenarios where existing and planned coal-fired power stations are stranded over five-year, ten-year, 15-year, and 20-year periods. We judge that the five-year, ten-year, 15-year, and 20-year scenarios are suitable time horizons to consider given recent timeframes of change in the Chinese and global energy systems. Renewables deployment has increased from 10% of global capacity to 15% in the last five years,[9] the cost of onshore wind and solar PV has fallen by 39% and 41% respectively over the same period, and sales of electric vehicles have grown by 1,031%.[10] Disruption appears to be accelerating as tipping points are reached and the idea that the power sector will remain relatively static and 'safe' for new thermal coal assets is counter to the evidence we see internationally across the G20. They are also reasonable time horizons in terms of keeping within the carbon budget constraints associated with the Paris Agreement on climate change.

In all four scenarios the start date is 2016 and the known installed capacity of coal-fired generation is 978 (including capacity planned for 2016). We extract capacity data from the Platts World Electric Power Plants (WEPP) Database for Q4 2016. To avoid double-counting jointly-owned capacity, we separate capacity among joint-owners. We delineate the capacities into existing and planned (or currently under construction). We use IEA data[11] to estimate build cost (in 2012$) per kW, for all coal-fired technologies in the WEPP database.[12] For circulating fluidized bed (CFB) technologies, we estimate the build cost in 2015$ per kW based on the recently built CFB plant,[13] and discount to 2012$ build cost using World Bank inflation data.[14] We assume all sunk costs – such as fees and contingency, engineering, procurement and construction services, and any additional owner costs[15] - as these represent losses in the case of asset stranding.

For each asset, we depreciate the asset using the straight-line method over an assumed useful life of 35 years since the date (or planned date) of build. We assume a salvage value of zero. As the last planned coal-fired generating asset is scheduled for 2020, our total time series covers 2016 to 2056 to include all depreciation. The series below plots, for each year, the total estimated asset stranding charge if the value of all the coal generating assets were to decline to zero. Therefore, these estimates should be interpreted as an upper bound of possible asset stranding in the case where all coal-fired power plants are prematurely shut.

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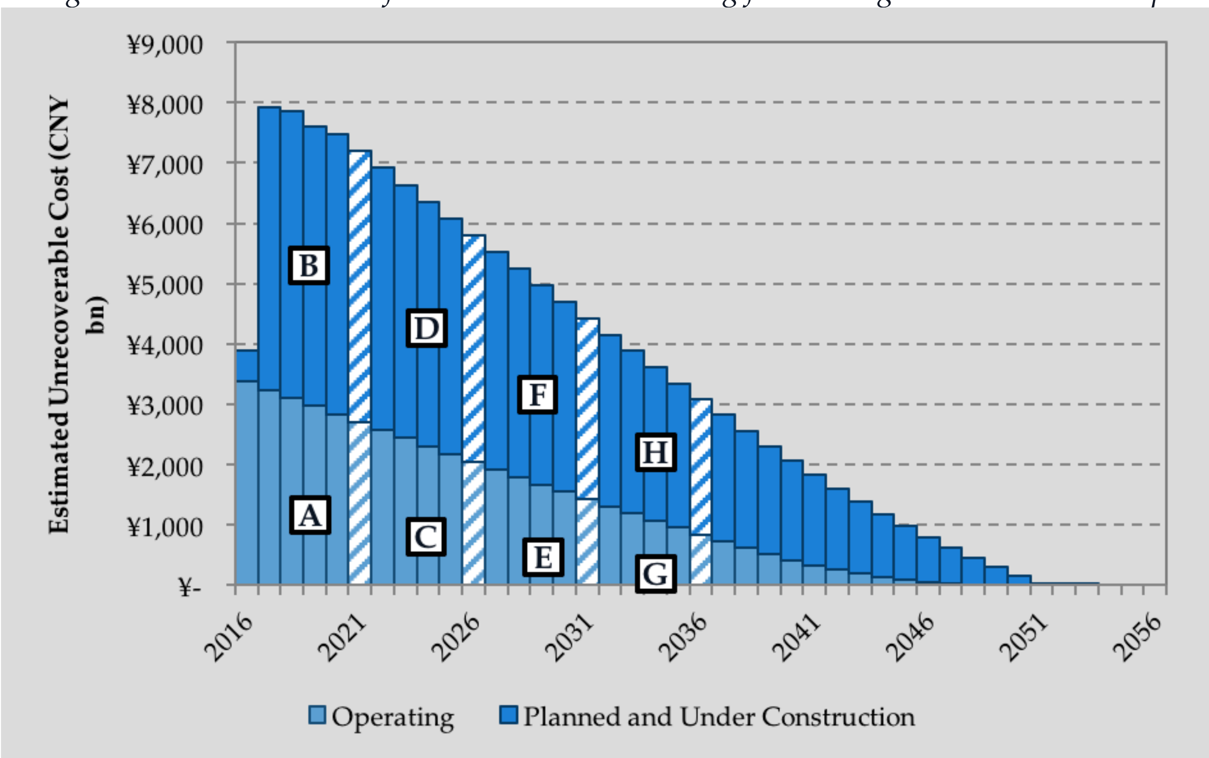
[9] BNEF, 'global trends in renewable energy investment 2015', 2015.
[10] Office of Energy Efficiency & Renewable Energy (2016) 'Fact #918: march 28, 2016 global plug-in light vehicle sales increased by about 80% in 2015' [Online] Available at: http://energy.gov/eere/vehicles/fact-918-march-28-2016-global-plug-light-vehicle-sales-increased-about-80-2015
[11] http://www.worldenergyoutlook.org/weomodel/investmentcosts/
[12] Coal technologies include: Circulating fluidized bed (CFB), integrated gasification combined cycle (IGCC), IGCC with CCS, Subcritical, Supercritical, ultracritical, and coal with CCS.
[13] http://cornerstonemag.net/china-brings-online-the-worlds-first-600-mw-supercritical-cfb-boiler/
[14] Note, we estimate the CFB cost at ~832 2012$/kW, which is marginally higher than the cost of (expensive) ultracritical technologies at 800 2012$/kW. We find the estimated CFB cost to be a reasonable assumption.
[15] Fang Rong and David G. Victor, "What Does It Cost to Build a Power Plant?," *ILAR Working Paper*, vol. 17, 2012.

For the five, ten, 15, and 20-year scenarios, the upper bound of asset stranding for new capacity is estimated using known operating capacity and capacity either planned or currently under construction. Therefore, this number could change due to currently planned projects becoming cancelled and additional planned capacity being added over upcoming years.

In the 5-year scenario, the total assets stranded are ¥7,201bn ($1,047bn), split between operating assets of ¥2,703bn ($393bn) and ¥4,498 ($654bn) of assets in the pipeline (under construction or planned). The ten-year scenario shows total asset stranding charges of ¥5,797bn ($843bn), of which ¥2,051bn ($298bn) is derived from stranded assets that are currently operating and ¥3,746bn ($545bn) is from assets currently in the pipeline. The estimates of stranded assets in the 15-year scenario are considerably lower, at ¥4,420bn ($643bn), of which ¥2,994 ($435bn) or 68% comprises pipelined projects. Finally, the stranded asset charges in the 20-year scenario total ¥3,086bn ($449bn), of which 73% (¥2,243bn|$326bn) would fall on pipelined capacity. These scenarios estimate that stranded coal-fired assets could be as much as ¥3,086–7,201bn ($449–1,047bn), equivalent to 4.1-9.5% of China's 2015 GDP[16]. This compares with a recent Carbon Tracker Initiative (2016) report which found that China does not need to build any more coal plants, and that it risked misallocating half a trillion US dollars in capital if it did.[17]

Figure 1: Estimated scale of maximum asset stranding for existing and new build coal plants



NB: The difference between the value on the y-axis and zero represents estimated stranded assets charge.
Letters in the chart correspond to the labels in Table 6.

Table 4: Estimates of total asset stranding charges in CN¥bn (US$bn)

Coal Offline in:	Operating Assets	Planned and Under Construction	Total

[16] The World Bank, "World Bank National Accounts Data."
[17] Carbon Tracker Initiative, "Chasing the Dragon? China's Coal Overcapacity Crisis and What It Means for Investors," 2016.

2021 (5 Years)	**[A]** ¥2,703 ($393)	**[B]** ¥4,498 ($654)	**[A+B]** ¥7,201 ($1,047)
2026 (10 years)	**[C]** ¥2,051 ($298)	**[D]** ¥3,746 ($545)	**[C+D]** ¥5797 ($843)
2031 (15 Years)	**[E]** ¥1,426 ($207)	**[F]** ¥2,994 ($435)	**[E+F]** ¥4,420 ($643)
2036 (20 Years)	**[G]** ¥843 ($123)	**[H]** ¥2,243 ($326)	**[G+H]** ¥3,086 ($449)

Utility case studies

At the company-level, we prepared case studies of five utilities selected because they comprised the former national State Power Corporation and currently dominate coal generation in China, controlling over half of all coal-fired generation assets. These company case studies are for: 1) Huaneng 2) Datang; 3) Guodian; 4) Huadian; and 5) State Power Investment Corp. In these case studies we examine the sensitivity of these companies to the risks outlined in this report, and estimate potential scale of asset stranding specifically attributable to them following the national methodology used earlier in this section.

Table 5: Breakdown of the five utilities' operating, under construction, and planned coal capacity

		Coal Generating Capacity* [MW] (per cent of total capacity)			
Rank	**Company**	**OPR**	**CON**	**PLN**	**Total**
1	HUANENG	124,928 (63%)	22,720 (12%)	49,180 (25%)	196,828 (100%)
2	DATANG	102,035 (58%)	16,200 (9%)	58,243 (33%)	176,478 (100%)
3	GUODIAN	103,512 (59%)	11,140 (6%)	60,550 (35%)	175,202 (100%)
4	HUADIAN	90,525 (57%)	18,150 (11%)	49,218 (31%)	157,893 (100%)
5	STATE POWER INVESTMENT CORP	76,416 (56%)	13,310 (10%)	46,239 (34%)	135,965 (100%)

Table 6: Units of measurement of LRHs for power plants

	Hypothesis	Unit
LRH-1	Carbon intensity of generated electricity	[kg.CO_2/MWh]
LRH-2	Plant age, year constructed	[year]
LRH-3	Local air pollution exposure with $PM_{2.5}$ as a proxy	[$\mu g_{PM2.5}/m^3$]
LRH-4	Water stress	[% Renewable resource]
LRH-5	Quality of coal	[Per cent burning lignite]
LRH-6	CCS Retrofitability described by criteria in Section 2.2.1	[Per cent retrofitable]
LRH-7	Average temperature change in 2035 above preindustrial levels	[Δ^oC by 2035]

Table 7: Financial Ratios, Local Risk Hypotheses (LRH) 1-7 for operating and planned plants, and Estimates of total asset stranding (¥bn)

	Ratio Analysis[i]				Env.-Related Risks[i]							Stranded Assets[ii]			
	DEBT / EQUITY	**CURRENT RATIO**	**(EBITDA - CAPEX)/ INTEREST**	**OPR / PLN[iii]**	**LRH-1**	**LRH-2**	**LRH-3**	**LRH-4**	**LRH-5**	**LRH-6**	**LRH-7**	**2021 (5 year)**	**2026 (10 year)**	**2031 (15 year)**	**2036 (20 year)**
HUANENG	3.79x	.34x	0.6x	**OPR**	878	2005	40	28%	9%	39%	1.02	¥322 ($47)	¥239 ($35)	¥161 ($23)	¥91 ($13)
				PLN	861	2017	26	48%	3%	47%	1.13	¥406 ($59)	¥337 ($49)	¥268 ($39)	¥200 ($29)
DATANG	3.76x	.30x	1.4x	**OPR**	867	2006	42	30%	4%	35%	1.02	¥253 ($37)	¥187 ($27)	¥125 ($18)	¥67 ($10)
				PLN	856	2017	37	47%	0%	38%	1.02	¥471 ($68)	¥392 ($57)	¥313 ($46)	¥234 ($34)
GUODIAN	3.40x	.21x	1.2x	**OPR**	880	2005	44	42%	4%	37%	1.03	¥282 ($41)	¥214 ($31)	¥149 ($22)	¥88 ($13)
				PLN	848	2017	41	47%	0%	31%	1.03	¥368 ($54)	¥306 ($45)	¥244 ($36)	¥182 ($26)
HUADIAN	3.50x	.36x	0.7x	**OPR**	878	2006	42	37%	3%	36%	1.01	¥239 ($35)	¥180 ($26)	¥123 ($18)	¥71 ($10)
				PLN	847	2017	42	27%	0%	27%	1.04	¥365 ($53)	¥305 ($44)	¥244 ($36)	¥184 ($27)

STATE POWER	3.11x	.42x	0.1x	**OPR**	888	2006	41	47%	26%	35%	1.03	¥204 ($30)	¥155 ($23)	¥110 ($16)	¥66 ($10)
				PLN	858	2017	30	54%	14%	38%	1.05	¥315 ($46)	¥262 ($38)	¥209 ($30)	¥156 ($23)

i) Ratio risk presented as follows: $N_{D/E}$, $N_{Current\ Ratio}$ = 45; $N_{(EBITDA-CAPEX)/INT}$ = 35; N_{OPR} = 40; N_{PLN} = 34
ii) Environment-related risk is presented according to Table 6
iii) Stranded Assets expressed in bn¥ and as a fraction of total utility assets
iv) OPR: Operating plants; PLN: Planned and under construction plants

Table 7 above shows the existing and pipelined capacities potentially at risk of asset stranding in the baseline (now), five, ten, 15, and 20-year caol phase-outscenarios. All five companies will be subject to stranded assets in each of the four scenarios. As we can also note in Table 7, the five major Chinese utilities have broadly similar risk exposures to all LRHs. These characteristics are on average; (LRH-1) comparatively low CO_2 intensity of coal generation (at or slightly superior to supercritical efficiency), (LRH-2) young coal plant fleets around a decade in age, (LRH-3) $PM_{2.5}$ pollution levels close to the national annual limit of 35 μg/m^3, (LRH-4) plants located in areas of relatively low levels of water stress (water usage to availability ratios of around 35%), (LRH-5) low levels of lignite use, (LRH-6) moderate levels of CCS retrofitability (around 40%), and (LRH-7) uniform projected temperature changes of about 1^{o}C by 2035.

There are however some interesting trends that can be noted between existing and planned capacities. For example, each of the planned coal generation fleets of all five companies have the same or lower air pollution levels than those currently operating, suggesting a deliberate move across the five companies to mitigate or at least contain local air pollution levels. All five companies are also pursuing less carbon intensive generation in their planned fleets, which will all exceed supercritical efficiency thresholds on average. Like the nation as a whole, in all five companies the greatest potential asset stranding occurs in the first 5-year scenario, decreasing steadily thereafter. This result is caused by the heavy front-loading of expected completion dates of the coal plants in the generation pipeline. Estimates of potential asset stranding correspond closely with total generating capacity. The only time that this pattern is broken is for Huadian in the 20-year scenario, where due to high levels of under construction plants its potential asset stranding in this scenario exceeds Guodian.

We briefly evaluate each company below on the basis of 1) their existing coal-fired power station portfolio, 2) the coal-fired generation capacity they are constructing or planning to construct and 3) their financial condition with regard to DEBT/EQUITY, CURRENT RATIO, and EBITDA-CAPEX/INTEREST ratios, and 4) the extent their existing and planned portfolios are exposed to local environment-related risks. Table 6 provides guidance on the interpretation of LRH exposure.

Huaneng

Huaneng has the most coal generation (124,928 MW) of all utilities in China. It also has the greatest capacity under construction at 22,720 MW. Its planned capacity is nearly double this at 49,180 MW, however Guodian Datang, and Huadian have planned coal generation capacities that exceed this. Given its high combined operating, under construction, and planned capacities, it is not surprising that Huaneng generally has the greatest potential asset stranding losses in all stranding scenarios.

It is notable that Huaneng's planned capacity is markedly more CCS compatible (LRH-6) than its existing capacity (39% operating versus 47% planned), and that Huaneng's planned plants are also located in areas with significantly lower $PM_{2.5}$ air pollution (LRH-3): 40 μg/m^3 for existing versus 26 μg/m^3 for planned plants. Lignite use (LRH-5) is also expected to fall from 9% in existing plants to just 3% of planned capacity. CO_2 intensity (LRH-1) is additionally expected to fall marginally from 878 to 861 kg CO_2/MWh. On the other hand water stress (LRH-4) and heat stress is expected to rise in planned plants, from 28% to 48% and 1.02 to 1.13^{o}C, respectively.

Datang

Datang has the third highest coal generation capacity (102,035MW) of all utilities in China, but the second greatest capacity planned at 58,243 MW. Its coal capacity under construction represents the second smallest fraction of total capacity of all the five companies studied, at 9% (16,200 MW).

As evident from Table 7 above, Datang's existing and planned fleets only vary significantly with respect to water stress (LRH-4), with planned water stress averaging 47% compared to 30% for existing plants, indicating an substantial increase in vulnerability to water shortages. Datang's LRHs are otherwise similar to the other five companies, and there are only marginal expected decreases in CO_2 intensity (LRH-1, from 867 to 856 kg CO_2/MWh) and air pollution (LRH-3, from 42 to 37 μg/m^3), and marginal increases in CCS retrofitability (LRH-6, from 35 to 38%) and hard coal use (LRH-5, lignite falling from 4% to 0%).

Guodian

Guodian has the second highest coal generation capacity (103,512 MW) of all utilities in China, but the greatest capacity planned at 60,550 MW. It also has the greatest proportion of plants planned at 35%, however its coal capacity under construction represents the smallest fraction of operating capacity of all the five companies studied, at only 6% (11,140 MW).

Guodian's LRHs are similar to the other five companies, and there are little appreciable change between currently operating and planned capacities, with $PM_{2.5}$ levels (LRH-3) only falling marginally from 44 to 41 μg/m^3 within a 100km radius of planned plants, and water stress (LRH-4) increasingly slightly from 42% to 47% usage rates. On the other hand they do expect CO_2 intensity (LRH-1) to fall from 880 to 848 kg CO_2/MWh, which is the second lowest level among the five companies.

Huadian

Huadian has the fourth highest coal generation capacity at 90,525 MW, and among the five major companies has the second highest percentage of its total capacity under construction at 11% (18,150 MW). Although Huadian ranks fourth in total potential asset stranding in the five, 10, and 15 years scenarios, because of its high level of plants under construction, it surpasses Guodian and ranks third in asset stranding in the 20 year scenario.

Across the five companies Huadian's planned capacity expects to achieve notable reductions in water stress (LRH-4, from 37% to 27%), and its planned plants are the most efficient at 847 kg CO2/MWh (LRH-1). On the negative side it also expects stagnant air quality improvements (LRH-3, holding at 42 μg/m^3), and declining CCS retrofitability (LRH-6, from 36% to 27%).

State Power Investment Corp

State Power Investment Corp (SPIC) has the fifth highest coal generation capacity in China at 76,416 MW. Notably, among the five major companies SPIC has the highest percentage of total capacity that is under construction or planned at 44% (13,310 MW under construction and 46,239 MW planned). Because of its smaller size, total potential asset stranding in the five, 10, 15, and 20 year scenarios is also the lowest of the five companies.

The most notable characteristic of SPIC's LRHs is its abnormally high percentage of operating capacity that uses lignite fuel (LRH-5, 26%). However this is expected to decline to only 14% in planned plants. Still, the CO_2 intensity (LRH-3) of its planned plants is expected to decrease slightly overall from 888 to 858 kg CO_2/MWh. Across the five companies SPIC is also noteworthy for having the highest water stress (LRH-4) for operating plants (47%), and planned plants are expected to have even greater water stress (54%). Local air pollution (LRH-3) is expected decline however, from 41 to 30 μg/m^3 in planned plants.

1 Introduction

The principal aim of this report is to conduct a comprehensive analysis of the exposure of coal-fired power stations in China to environment-related risks which can generate 'stranded assets'. Stranded assets are assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities.[18] By examining the environment-related risks facing coal-fired power stations, creating appropriate measures to differentiate the exposure of different assets to these risks, and linking this analysis to company ownership, debt issuance, and capital expenditure plans, our research can help inform decision-making in relation to China's power sector by investors, policymakers, and civil society. The datasets that underpin our analysis, as well as the analysis itself, also enables new lines of academic research and inquiry. The typology of potential environment-related risks is described in Table 8.

Table 8: Typology of environment-related risks

Set	Subset
Environmental Change	Climate change; natural capital depletion and degradation; biodiversity loss and decreasing species richness; air, land, and water contamination; habitat loss; and freshwater availability.
Resource Landscapes	Price and availability of different resources such as oil, gas, coal and other minerals and metals (e.g. shale gas revolution, phosphate availability, and rare earth metals).
Government Regulations	Carbon pricing (via taxes and trading schemes); subsidy regimes (e.g. for fossil fuels and renewables); air pollution regulation; voluntary and compulsory disclosure requirements; changing liability regimes and stricter licence conditions for operation; the 'carbon bubble' and international climate policy.
Technology Change	Falling clean technology costs (e.g. solar PV, onshore wind); disruptive technologies; GMO; and electric vehicles.
Social Norms and Consumer Behaviour	Fossil fuel divestment campaign; product labelling and certification schemes; and changing consumer preferences.
Litigation and Statutory Interpretations	Carbon liability; litigation; damages; and changes in the way existing laws are applied or interpreted.

The approach used in this report is based on the methods pioneered in a previous report of the Sustainable Finance Programme of the University of Oxford's Smith School of Enterprise and the Environment (the 'Oxford Smith School') from March 2015, entitled *Stranded Assets and Subcritical Coal: the risk to companies and investors.*[19] This methodology was significantly expanded in the landmark publication *Stranded Assets and Thermal Coal: An analysis of environment-related risk exposure,*[20] also published by the Oxford Smith School in January 2016. This report uses similar data and methods to provide a high-resolution examination of environment-related risk to Chinese thermal coal assets.

[18] See Ben Caldecott, Nicholas Howarth, and Patrick McSharry, "Stranded Assets in Agriculture : Protecting Value from Environment-Related Risks," *Stranded Assets Programme, SSEE, University of Oxford*, 2013.
[19] Ben Caldecott, Gerard Dericks, and James Mitchell, "Stranded Assets and Subcritical Coal: The Risk to Companies and Investors," *Stranded Assets Programme, SSEE, University of Oxford*, 2015, 1–78.
[20] Caldecott et al., "Stranded Assets and Thermal Coal: An Analysis of Environment-Related Risk Exposure."

China is the fourth biggest country in the world by area (behind Russia, Canada, and the US) but has the largest population at 1.38 billion (or 18 per cent of world population). Since it began freeing markets in 1978, China has experienced perhaps the most remarkable episode of economic growth in human history, expanding GDP at an average rate of 10 per cent per year for over three decades.[21] In recent years however this growth level has declined significantly, and there is concern that industry has continued to expand at former rates which no longer reflect current economic realities, leading to significant overcapacity. The future of China's electricity supply is therefore now substantially uncertain, with fundamental drivers like new carbon emissions and air pollution targets, competition from renewables, and macroeconomic factors like declining GDP growth and increasing worries about the solvency of the financial system all likely to affect the demand for power and its supply.

Understanding how these and other environment-related factors interact and affect companies requires a detailed examination of the company's specific asset base. For Chinese utilities, we analyse the attributes of their coal-fired generating stations and integrate and cross-reference this data with indicators of environment-related risk to develop asset-specific analyses of risk exposure. We then aggregate these analyses to the company level to provide company-wide assessments of environment-related risk. We also integrate company debt issuance into these analyses to identify companies with the most significant risk exposure.

This approach requires us to take a view on what the environment-related risks facing thermal coal assets could be and how they could affect asset values. The environment-related risks facing the thermal coal value chain are substantial and span physical environmental impacts, the transition risks of policy and technology responding to environmental pressures, and new legal liabilities that may arise from either of the former. From this horizon-scanning exercise we develop risk hypotheses. The hypotheses are categorised into Local Risk Hypotheses (LRHs) and National Risk Hypotheses (NRHs) based on whether the risk factor in question affects all assets in a particular country in a similar way or not. For example, water stress has variable impacts within a country and so is an LRH, whereas a country-wide carbon price is an NRH. In this report, we apply this bottom up, asset-specific approach to Chinese coal-fired power stations.

The remainder of Section 1 introduces the Chinese power market and the use of coal-fired power in China. Section 2 presents analysis of environment-related risk exposure of Chinese coal-fired power stations and their utility owners. Section 3 examines stranding risks to Chinese coal-fired power plants across four decommissioning scenarios (5, 10, 15 and 20 years) and provides breakdowns of the risks associated with these for five major utilities. Section 4 concludes.

1.1 Chinese Electricity Market Structure

China's electricity market is both the world's largest, having surpassed the US in 2011, and one of the world's most dynamic, having grown at record speeds for several decades. According to the most recent data, China produced 5,500 TWh of electricity in 2015, having more than doubled from 2,475 TWh only a decade prior.[22] The vast majority of this power is used for non-residential (i.e. industrial) purposes, in 2013 this share was 86%.[23] China's current electric generation capacity is also the world's largest totalling 1,525 GW, with 978 GW (64 per cent) of coal, 259 GW (17 per cent) of hydropower, 129 GW (8 per cent) of wind,

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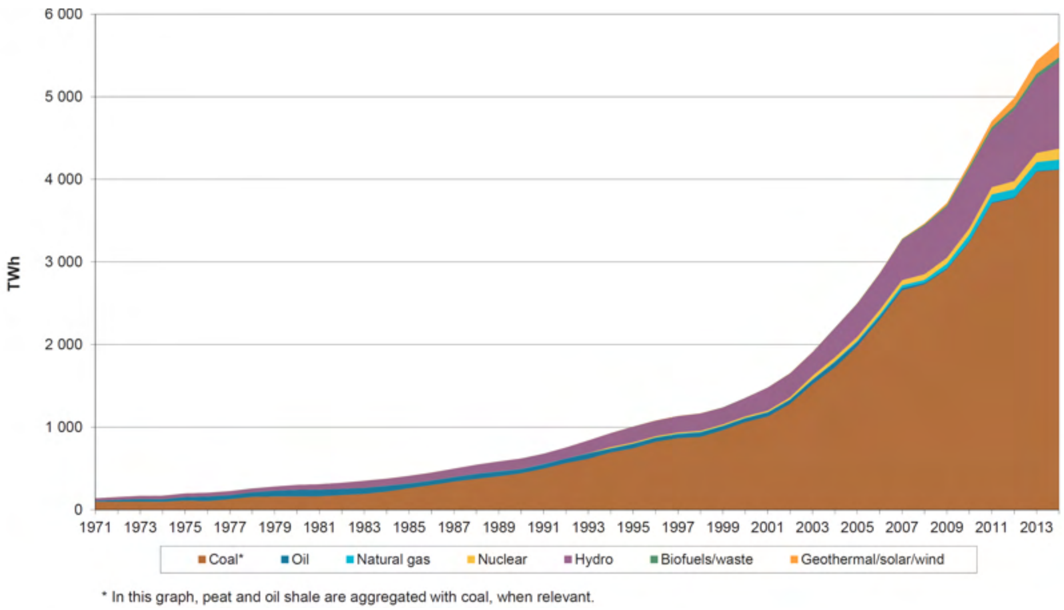
[21] Nelson Schwartz and Rachel Abrams, "Even the Most Pessimistic Observers Think China Will Still Grow by 4 or 5 Percent," *The New York Times*, n.d.

[22] Enerdata, "Global Energy Statistical Yearbook 2016."

[23] Department of Energy Statistics and National Bureau of Statistics, *China Energy Statistical Yearbook 2014* (China Statistics Press, 2014), http://data.cnki.net/yearbook/Single/N2015110114.

43 GW (3 per cent) of solar, 43 GW of gas, and 30 GW (2 per cent) of nuclear power. This represents the world's largest national coal[24], hydro[25], wind[26], and solar power capacities.[27]

Figure 2: China's electricity generation by fuel[28]



China's electricity market is primarily controlled by the state, but efforts to increase competition and introduce market pricing are on-going. The modern structure of the Chinese power system was established in 2002 when the state council authorized three major liberalisations which broke up the vertical integration of the Chinese power supply; (1) the separation of power transmission and generation; (2) the separation of distribution from transmission and construction of wholesale power markets; (3) the separation of retail sales from distribution and construction of retail power markets.[29]

At the same time the former national State Power Corporation was divided into two electric grid companies and five power generating companies. These two grid companies, Southern Grid and State Grid, manage over 90% of the country's power transmission and distribution. Southern Grid is responsible for the construction, operation and maintenance of electricity transmission assets in the southern provinces, i.e. Yunnan, Guangxi, Guangdong, Guizhou and Hainan. State Grid is responsible for all other provinces, autonomous regions, and municipalities directly under the central government. State grid is further operated through five regional grid companies, i.e. Northeast, Northwest, North, East and Central. The geographical distribution of the regional power grids corporations is depicted in Figure 3 below.

[24] Statista, "Installed Capacity of Coal Power Plants Worldwide as of 2016."
[25] World Energy Council, "World Energy Resources: 2013 Survey."
[26] Scientific American, "China Blows Past the U.S. in Wind Power."
[27] Reuters, "China's Solar Capacity Overtakes Germany in 2015, Industry Data Show."
[28] IEA, "People's Republic of China, Electricity Generation by Fuel," 2016, http://www.iea.org/stats/WebGraphs/CHINA2.pdf.
[29] Xu Shaofeng and Chen Wenyin, "The Reform of Electricity Power Sector in the PR of China," *Energy Policy* 34 (2006): 2455–65.

Figure 3: China's power grid system[30]

In parallel with the divison of power distribution, China's then 46% installed electric generation capacity owned by the State Power Corporation was separated into five newly established state-owned companies, namely; China Huaneng, China Datang, China Huadian, Guodian Power and State Power Investment. These five major state-owned enterprises each own about 10% of the nation's installed coal capacity.

In spite of the major corporate break-ups in 2002, prices and output in China's power system are still primarily determined by planning and regulation. For instance, tariffs for coal power are regulated by the NDRC and set at a level to provide reasonable returns to investors under current investment and operation conditions, and the output of generators is subject to allocated generation hours by provincial planning agencies.[31] This opaque and arbitrary pricing system for power generation that has long been cited as a key distortion in the Chinese economy.[32]

1.2 China Electricity Market Reform

[30] China's Power Grid Systems map is republished with permission of Stratfor. Stratfor, "China's Power Grid Systems Map," 2012, https://www.stratfor.com/image/chinas-power-grid-systems-map.
[31] F Kahrl and X Wang, "Integrating Renewable Energy into Power Systems in China: A Technical Primer" (Beijing, China, 2014), http://www.raponline.org/wp-content/uploads/2016/05/rap-e3chinapowersystemoperations-final-2014-dec-24.pdf.
[32] The State Council, "Opinions on Further Deepening the Power System Reformation, 关于进一步深化电力体制改革的若干意见," 2015.

In order to address low levels of competitiveness and efficiency in the power sector, in March 2015 the 'Opinion on Further Deepening Power Sector Reform (the No.9 File)' targeted a new round of power sector reform. This edict's most notable change was that the central planning of the market for industrial electricity users would be gradually replaced with direct market participation and pricing. In addition, on 13th July 2016 an NDRC affiliate released a draft file on the Orderly Deregulation of Power Generation and Consumption Planning[33], which outlined a specific market reform roadmap for coal power. According to this policy, during a transitional period lasting 3 to 5 years, total coal-fired generation will be divided into two blocks which will be separately allocated by two mechanisms. The first block will be allocated through planning, which will be gradually reduced, and the second through new market trading, which will be gradually expanded. At the province level, separate pilot power exchanges will initially be set up. Furthermore, all coal power plants commissioned after 15th March 2017 will no longer be given any guaranteed planned generation hours, and renewable energy and cogeneration will be given grid priority.[34]

These changes are set to bring forth intense price competition for surviving and new coal power plants. For example, when the pilot exchange opened in Guizhou, the retail price for industrial customers fell by 0.12RMB/KWh, cutting down the generation revenues in the province by at least 100 million RMB[35]. The speed of market pricing phase-in has however been sluggish. In 2014, direct power purchases accounted for approximately 3 per cent of the total electricity consumption; in 2015, 5.4 per cent, and it is forecasted that in 2016 this percentage will have reached only 10% of total electricity consumption.[36]

1.3 Coal-Fired Power in China

Coal accounts for 73 per cent of China's total energy production, 70 per cent of China's electric power, and 93 per cent of its thermal generation.[37,38] China has pursued coal as its primary energy source due to its plentiful domestic supply (China has the world's third largest reserves behind the US and Russia) and relatively low cost. Over the past 40 years the rate of coal production growth has fluctuated with economic cycles, and has grown at a rapid average rate of 5.9% per year.[39] However, coal production and consumption fell in 2014 for the first time since the last major restructuring of state-owned enterprises which occurred the late 1990s. Coal's share of total installed capacity is scheduled to fall from 64 per cent today to 58 per cent in 2020 and 42 per cent by 2050.[40]

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[33] National Development and Reform Commission and National Energy Administration, "Orderly Deregulation of Power Generation and Consumption Planning(exposure Draft File), 关于有序放开发用电计划工作的通知（征求意见稿）," 2016.

[34] Since the marginal cost of wind and solar generation is near zero the grid would take their power before fuel-based generation anyway.

[35] Polaris transmission and distribution power net, "Guizhou Promoted the Implementation of Direct Trading of Electricity to Release the Reform Dividend of Supply Side," 2016, http://shupeidian.bjx.com.cn/news/20160816/762682.shtml.

[36] Greenpeace, "Study on Economics of Coal-Fired Power Generation Projects in China," 2016.

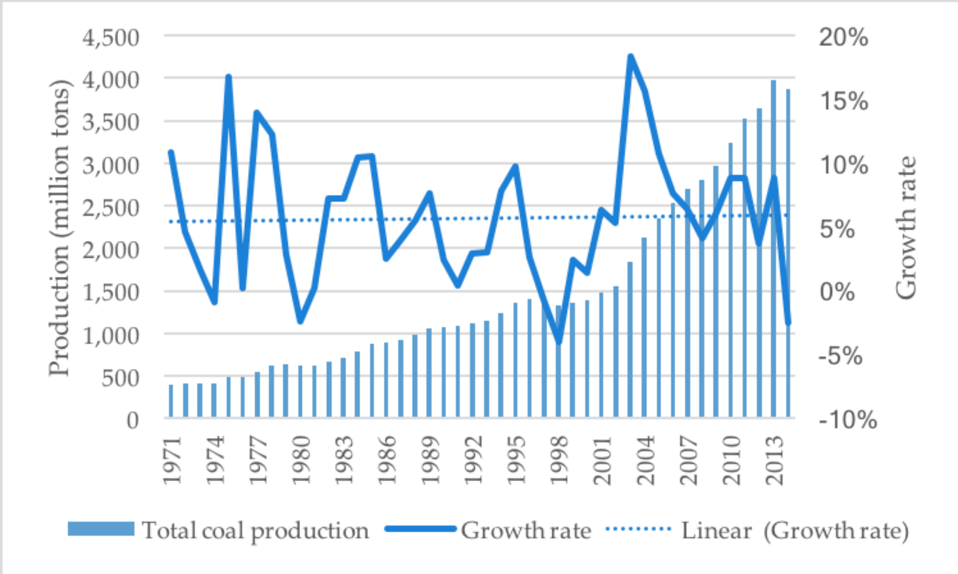
[37] Yan-Shen Zhang Zhu, Chen; Jian-Nan Wang, Guo-Xia Ma, "China Tackles the Health Effects of Air Pollution," *The Lancet* 382, no. 9909 (2013): 1959–60.

[38] National Bureau of Statistics, *China Statistical Yearbook*, 2014, http://www.stats.gov.cn/tjsj/ndsj/2015/indexeh.htm.

[39] See Figure 4.

[40] China Water Risk, "Towards a Water & Energy Secure China," 2015.

Figure 4: China's nominal coal production and growth rate (1971-2014)[41]



In addition to the 978 GW of currently operating coal-fired capacity, as of end 2016 China has another 227 GW under construction and 563 GW in various planning stages. Whereas in the past the primary concern of the government was to ensure ample power supply to meet rampant demand, with the economy now growing at its slowest rate in 25 years[42] and looming doubts over the stability of its financial system[43], government planners are now struggling to contain excess capacity arising from faltering power demand and the rapid expansion of renewables.[44]

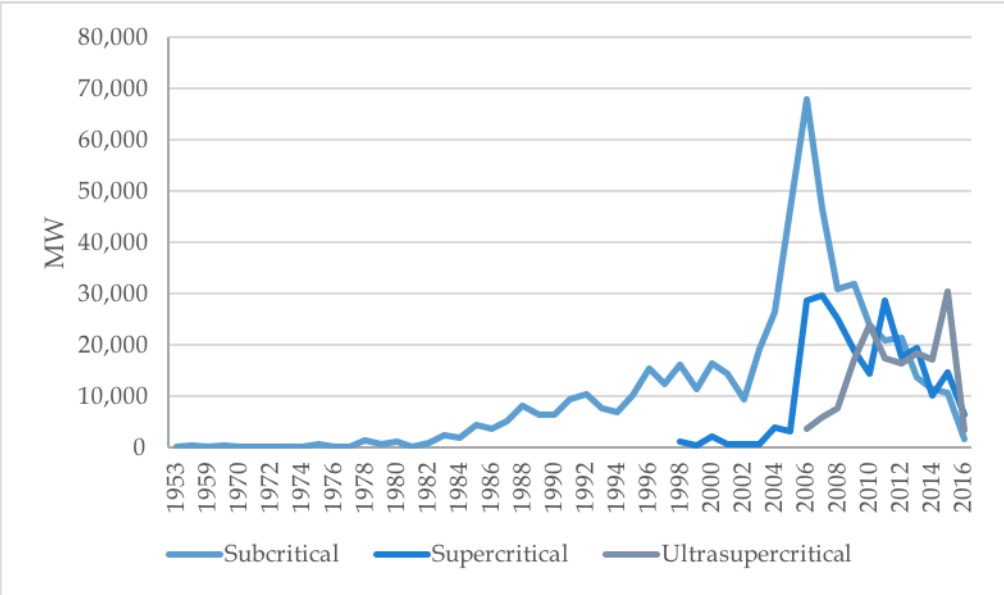
Consequently, last year thermal power utilisation rates fell to just 49.4 per cent, and in the first 5 months of 2016 was 44.8 per cent[45], which represents the lowest utilisation rate since 1969.[46] To combat these low utilisation rates the Chinese government axed 372 GW of new coal power plant construction starts in April 2016[47], and in October took the unprecendented step of postponing the construction (until the 2020s) of 17 GW of coal fired plants which had already been financed and broken ground.[48] In 2016 China also cancelled 114 GW of planned coal-fired power, which represented the single biggest annual drop in its coal pipeline history.[49] A few months later in January 2017, China then suspended a further 85 plants consisting of 29 GW under construction and 45 GW planned.

[41] Zhongguo tongji nianjian 2008-2015, *SAWS, Zhongguo Meitan Gongye Fazhan Gaiyao* (Beijing: Meitan gongye chubanshe, 2010). p.18-20.
[42] Gabriel Wildau, "China's : The State-Owned Zombie Economy," *The Financial Times*, February 2016.
[43] Gabriel Wildau, "China's Challenges and Their Global Risks," *The Financial Times*, n.d., https://www.ft.com/content/68fbf5d3-452e-3b55-8550-e83c0f1cc5bf.
[44] A. Myllyvirta, "China Keeps Building Coal Plants despite New Overcapacity Policy," *Greenpeace Energy Desk*, 2016.
[45] Reuters, "China Building 200 GW of Coal-Fired Power despite Capacity Glut: Greenpeace," n.d., http://uk.reuters.com/article/us-china-power-coal-idUKKCN0ZT09B.
[46] Greenpeace, "Study on Economics of Coal-Fired Power Generation Projects in China."
[47] Carbon Tracker Initiative, "Chasing the Dragon? China's Coal Overcapacity Crisis and What It Means for Investors."
[48] Steve Johnson, "China Axes Part-Built Coal Power Plants," *The Financial Times*, n.d., https://www.ft.com/content/78db1ca6-96ab-11e6-a80e-bcd69f323a8b?sectionid=markets.
[49] Alister Doyle, "Global Coal Power Plans Fall in 2016, Led by China, India: Study," *Reuters*, n.d., http://www.reuters.com/article/us-global-coal-idUSKCN11C2N4.

It is claimed that this excess capacity was planned to be built due to the prospect of government guaranteed operating hours and electricity tariffs.[50] Furthermore, in spite of the obvious oversupply, the excess plants had not been cancelled earlier due to the slow reaction times of China's central planning system.[51] However even with these suspensions, there is still 227 GW of coal-fired capacity under construction and further plans for a significant expansion to renewable energy. Specifically, China's National Energy Administration is targeting wind power capacity to rise from 129 to 210 GW and solar from 43 to 110 GW by 2020 as well.[52] Therefore the power generation industry and particularly coal is highly dependent on continued rapid growth in power demand.

Over the past decade there has also been a notable move by China to replace inefficient subcritical coal-fired power plants with more efficient super and ultra-supercritical plants. For instance, during the period of 2006-2011 (China's 11th five-year plan), a total of 77 GW of small coal generating units were phased out by larger supercritical (600MW) and ultra-supercritical (1000MW) units.[53] Since 2012, new coal-fired power plants are now also primarily built with either the most efficient ultra-supercritical or more efficient supercritical technologies. New subcritical capacity is now rare.[54]

Figure 5: Coal-generation capacity installations by boiler efficiency and year



[50] Kahrl and Wang, "Integrating Renewable Energy into Power Systems in China: A Technical Primer."
[51] Kahrl and Wang, "Integrating Renewable Energy into Power Systems in China: A Technical Primer."
[52] Greenpeace, "Study on Economics of Coal-Fired Power Generation Projects in China."
[53] L Wu and H Huo, "Energy Efficiency Achievements in China's Industrial and Transport Sectors: How Do They Rate?," *Energy Policy* 73 (2014): 38–46.
[54] See Figure 5.

2 Investment Risk Hypotheses

In this section, we complete a comprehensive analysis of the environment-related risk exposure facing China's coal-fired utility sector. This analysis is divided between two sub-sections: the first sub-section is a financial analysis that considers China's utilities in aggregate to explore the sector's financial health, and provides insight into its potential vulnerability (or resilience) to environment-related risks; the second is our assessment of the potential environment-related risks facing coal-fired power stations in China and how they could affect asset values. Table 9 shows the sample of 50 companies (out of 613) which we include within the financial analysis. It was decided to incorporate only these 50 companies because the vast majority of the 613 companies in the population only operated a single small plant. These 50 utilities either operate, are constructing, or have planned coal-fired power capacity in China. In total, these companies currently operate 869 GW or 89 per cent of China's coal-fired generating capacity.

1.2 Financial Analysis

This section begins with an in-depth look at the financial structure and market value of Chinese utilities over time. A thorough examination of the financial structure will help determine the performance, stability, and health of the utility sample. In this section, we examine the market capitalisation of the sample to examine how the market values of these firms have evolved over time. Second, we examine common financial ratios, including: debt, leverage, profitability, coverage, liquidity, and capital expenditure ratios. These ratios help identify investors' exposure to financial risk in the sector. Understanding the financial structure provides insight into China's ability to finance future generating capacity, as investors also seek this information to determine their expected rates of return on utility investments. Utilities in good financial health may be able to adapt to changes in operating environment, such as demand destruction, population decline, and adapting to a market with a large proportion of renewables. If the sample is found to be under considerable financial stress, investors may consider the sector non-investment grade and be hesitant to commit capital, or demand higher rates of return on their investment. Access to capital is crucial to facilitate investment in China's energy infrastructure and generating assets.

It must be noted that the majority of power utility companies in China are state-owned firms. As such, the operating environment may be considerably different to urban-collectives or foreign companies established during the reform period of 1978 to mid-1990s, which are typically more exposed to market forces. As such, we note any unusual observations and findings.

Table 9: The top 50 companies owning; operating, under construction, and planned coal plants

Rank	Company	ISIN number	Coal Generating Capacity* [MW]			
			OPR	CON	PLN	Total
1	China Huaneng Group	CNE1000006Z4	124,928	29,540	63,910	218,378
2	China Datang Corporation	CNE1000002Z3	103,512	25,360	62,880	191,752
3	China Guodian Corporation	CNE1000019J1	102,035	21,100	60,223	183,358
4	China Huadian Corporation	CNE000000K58	90,525	19,753	58,240	168,518
5	China Shenhua Energy Co. Ltd.	CNE100000767	76,416	13,310	54,758	144,484
6	State Power Investment Corporation	-	69,475	11,840	49,389	130,704
7	China Resources Power Holdings Co. Ltd.	HK0836012952	39,358	10,860	23,080	73,298
8	Guangdong Yudean Group Co., Ltd.	-	33,336	10,080	14,860	58,276
9	State Development & Investment Corporation	-	22,410	9,660	11,000	43,070
10	Beijing Energy Investment Holding Co., Ltd.	-	14,636	8,490	9,545	32,671
11	Zhejiang Provincial Energy Group Company Ltd.	-	13,720	6,250	8,693	28,663
12	Shandong Weiqiao Pioneering Group Co., Ltd.	-	13,100	6,000	8,500	27,600

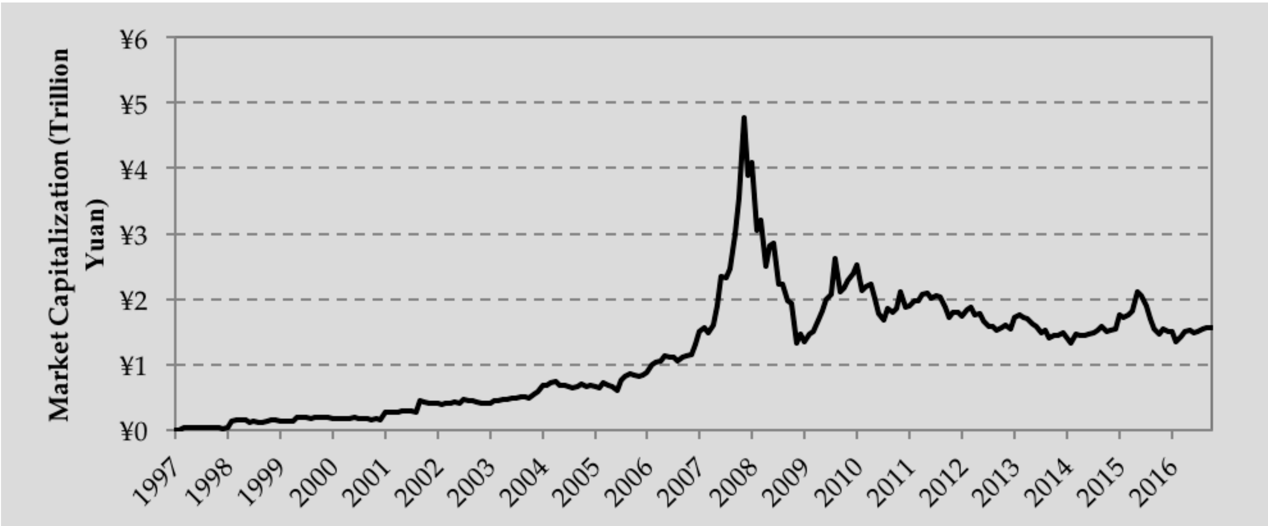
13	Shanxi International Energy Group Co., Ltd.	-	9,722	4,380	8,340	22,442
14	Jiangsu Guoxin Investment Group Limited	-	9,365	3,200	7,300	19,865
15	State Grid Corporation of China	-	8,880	2,700	6,000	17,580
16	China Coal Energy Company Limited	CNE100000528	8,352	2,680	5,320	16,352
17	Wenergy	CNE000000DF9	8,145	2,600	4,560	15,305
18	Shenzhen Energy Group Co., Ltd.	CNE000000933	7,290	2,370	4,300	13,960
19	Shaanxi Provincial Investment (Group) Co., Ltd.	-	7,010	2,320	4,020	13,350
20	HeBei Construction & Investment Group CO., Ltd.	-	6,660	2,160	3,980	12,800
21	Henan Investment Group	-	5,870	2,100	3,900	11,870
22	Gansu Province Electric Power Investment Group Co., Ltd	-	5,628	2,000	3,800	11,428
23	CLP Holdings Ltd.	HK0002007356	5,184	2,000	3,690	10,874
24	Xinjiang Tianfu Energy Co., Ltd.	CNE0000019W6	5,099	2,000	3,653	10,752
25	Chongqing Energy Investment Group Co. Ltd.	-	4,815	2,000	3,320	10,135
26	Aluminum Corporation Of China Limited	CNE1000000T0	4,610	2,000	3,165	9,775
27	Hangzhou Jinjiang Group Co., Ltd.	-	4,500	2,000	2,800	9,300
28	Inner Mongolia Guodian Energy Investment Co., Ltd.	-	4,300	1,980	2,640	8,920
29	Power Construction Corporation of China	CNE1000017G1	4,195	1,800	2,640	8,635
30	CITIC Group Corporation	CNE1000001Q4	4,050	1,400	2,620	8,070
31	Shandong Xinfa Aluminum & Electricity Group	-	4,040	1,400	2,600	8,040
32	Shaanxi Coal and Chemical Industry Group Co., Ltd.	-	3,940	1,360	2,580	7,880
33	Xishan Coal & Electricity (Group) Co., Limited	CNE0000013Y5	3,540	1,332	2,400	7,272
34	Xingfa	CNE000000ZC9	3,380	1,320	2,400	7,100
35	China Petroleum & Chemical Corp.	CNE0000018G1	3,080	1,320	2,200	6,600
36	East Hope Group Company Limited	-	3,020	1,320	2,130	6,470
37	Shenergy (Group) Company Limited	CNE0000005Q7	3,000	1,320	2,020	6,340
38	Guangdong Pearl River Investment Co., Ltd.	-	2,950	1,320	2,020	6,290
39	Inner Mongolia Asset Management Bureau	-	2,648	1,320	2,000	5,968
40	Cheung Kong Infrastructure Holdings Ltd.	BMG2098R1025	2,470	1,320	2,000	5,790
41	Datong Coal Mine Group Co., Ltd.	CNE000001MZ6	2,400	1,283	2,000	5,683
42	Jiuquan Iron & Steel (Group) Co., Ltd.	-	2,054	1,200	2,000	5,254
43	Qinghai Province Investment Group Limited	-	2,012	1,200	2,000	5,212
44	Formosa Plastics Corporation	TW0001301000	1,950	1,140	2,000	5,090
45	Fujian Energy Group Co., Ltd.	-	1,950	1,050	1,758	4,758
46	GCL-Poly Energy Holdings Ltd.	KYG3774X1088	1,950	1,000	1,632	4,582
47	Sichuan Qiya Aluminium Industry Group Co., Ltd.	-	1,930	1,000	1,450	4,380
48	Wanji Holding Group Graphite Product Co., Ltd.	-	1,920	1,000	1,400	4,320
49	Huainan Mining Group Power Generation Co., Ltd.	-	1,920	900	1,400	4,220
50	Guangdong Baolihua New Energy Stock Co., Ltd.	CNE000000P12	1,850	700	1,333	3,883

*OPR: Operating; CON: Under Construction; PLN: Planned

1.2.1 Market Capitalisation and Book Value of the Sector

The following section presents the evolution of the market and book values of the 50 companies in our sample. Figure 6 shows a dramatic increase in the total market capitalisation of our sample between 1997 and 2007, from near zero to CN¥4.76 trillion (~USD$ 690 billion). Similar to most economies globally, the value of the Chinese power industry declined rapidly from late-2007 during the global financial crisis (GFC). From November 2007, the sample saw a decline in market capitalisation of -72%to CN¥1.34 trillion.

Figure 6: Aggregate market capitalisation for the Chinese sample



This figure illustrates the monthly sum of market capitalisations across the 54 companies in the Chinese sample. Data between March 1997 and October 2016. Source: Data from S&P Capital IQ.

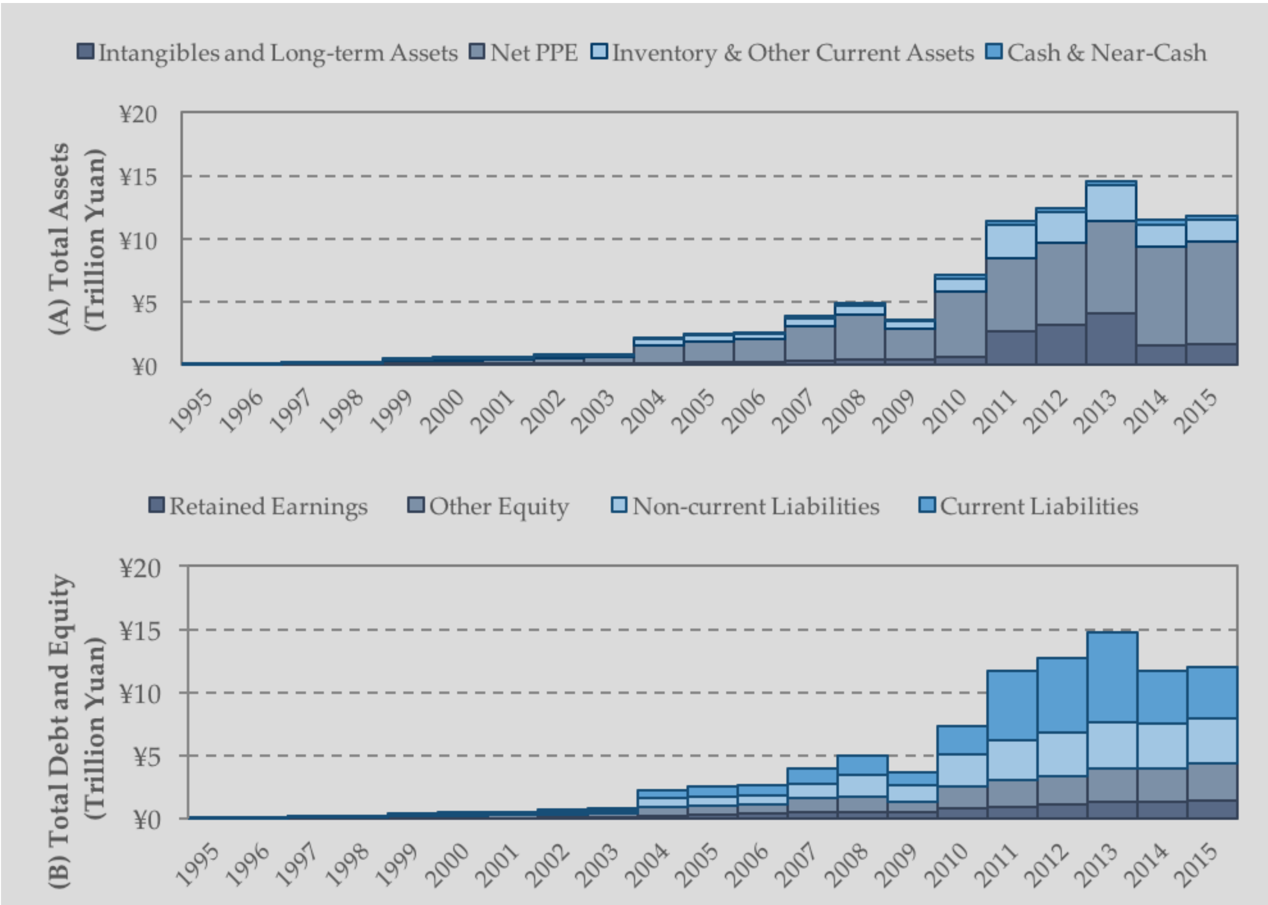
Plot (A) of Figure 7 shows that total assets of the sample was relatively low in the mid-1990s period, at the beginning of China's 'capitalist' period. Between 1995 and 2015, total assets grew from approximately CN¥41.8 billion to over CN¥1,180 billion; a compounded average growth rate of 32.59% per annum. This growth in total assets coincides with an influx of foreign-capital investment. Naturally, holdings of current and non-current assets increased over the entire period, but the relative holdings of each varied greatly.

Current assets, which represent the most liquid of assets held by the firm, typically represented 22.2% of total assets. Of this, cash and near-cash equivalents held by utilities represented around 2.7% of total assets, while inventory and other current assets represented around 19.5%. Between 1999 to 2003, Chinese utilities experienced a cash shortage and reserves fell from 3.4% to as little as 0.2% of total assets. Moreover, inventory levels declined from 31% in 2000 to only 14% in 2015. The reduction in current assets suggests that the sample became less solvent and suffered from poor liquidity, and was potentially unable to pay short-term liabilities if called upon.

Between 1995 and 2015, the majority of total asset expansion occured in long-term, non-current assets. Net investments in Plant, Property and Equipment (PPE), including generation assets naturally represented the majority of all investments, at 62.3% of total assets. Perhaps the most interesting result is the recognition of goodwill and intangibles. Goodwill, which represents the excess of purchase consideration over the total value of assets and liabilities, and other intangibles were relatively volatile over the period. In absolute terms, the book value of intangibles increased rapidly over the period, suggesting that utilities believed the fair market value of their firms (or purchases) were above historical costs. However impairment charges also began to increase in many utilities. Between 2008 and 2015, the industry has impaired CN¥13.8 billion of assets, with over CN¥6.2 billion occurring in 2010 alone. In addition, the value of long-term assets also began to decline as outstanding (long-term) investments and account recievables were settled. As such, Chinese utilities began to shift from regional monopolies towards a market model more consistent with merchant generation, with increased exposure to competitive forces and less reliance on long-term contracts.

Plot (B) of Figure 7 shows that the proportion of total debt (both current and non-current) on the balance sheet increased at a faster rate than total equity (the sum of retained earnings and other equity additions). Firms often mix both debt and equity as debt financing reduces the average cost of capital and, when used appropriately, allows firms to expand quickly. Further, debt financing allows companies to retain a greater proportion of profits within the company (or paid to shareholders). Providing market conditions are stable, Chinese utilities should be able to service their debt commitments. This latter point is of greatest concern in China. The optimal use of debt can be called into question given China's rapidly evolving market conditions and political economy. Chinese utilities have a large reliance on short-term debt (current liabilities), which may introduce additional financial risk and risk of bankruptcy if market conditions were to rapidly deteriorate. Total assets in the industry have been declining since 2013, mostly due to paying down current liabilities. Perhaps the reduction in current liabilities is recognition from either investors of Chinese utilities that this short-term debt is becoming less likely to be serviced, thus a lower amount of current liabilities is being issued (and purchased).

Figure 7: Delineation of total assets for the sample



This figure presents the aggregate total assets, total debt and total equity for the sample. Data is delineated using S&P Capital IQdefinitions. Where applicable, the utility-specific formulas defined by Capital IQ have been used.

1.2.2 Bond Issuances

To build a general picture of the financial health of the industry, we perform a financial ratio analysis. The use of financial data allows stakeholders to understand how well the industry is performing and which areas require improvements. In particular, exposure to high levels of debt increases risk for both debt and equity holders of companies as the priority of either is further diluted in the event of the company's insolvency. We examine a number of financial ratios using data extracted from *S&P Capital IQ*. The ratios include those related to: profitability, capital expenditure, liquidity, leverage, debt coverage, and the ability for utilities to service existing debt. The analyses are conducted between 1995 and 2015 to represent the last 21 (inclusive) years of data.[55] Of the 50 companies in the sample, accounting data was available for a maximum of 28 at any one time. Figure 8 presents the median ratios, with 25th and 75th percentiles to illustrate the distribution of observed ratios: 50% of companies will fall within the two percentile bands.

The first two ratios examined present the general profitability and capital expenditure in China's coal-fired power industry, both of which are relevant to the industry's ability to service its debt commitments. Profit margins, shown in Figure 8 Plot (A) have been declining over time, from 23% in 1995 to only 9% in 2015. From 2002 to 2005, there was a divergence of profit margins, where some utilities became highly profitable while the majority of the sector remained on a downwards trajectory. Although profit margins continued to decline post-2005, no companies suffered a net loss.

The second ratio in Plot (B) measures capital expenditure (CAPEX) relative to total revenue. CAPEX represents the funds required to acquire, maintain, or upgrade existing physical assets. CAPEX is scaled by revenue to show how aggressively the company is re-investing its revenue back into productive assets. A high ratio can be perceived either positively or negatively, depending on how the capital is spent and how effectively it uses the assets to generate income. Plot (B) shows that a large proportion of revenue was re-invested in companies over the period analysed. Typically, the ratio fluctuates between 8% to 35% over the period analysed, with an average ratio of 20% of revenue allocated for CAPEX. Overall, the cost of acquiring, maintaining and upgrading coal-fired utility operations has been relatively stable over time.

The current ratio and quick ratio are used as proxies for liquidity in the industry. The former measures the ability to service current liabilities using current assets, the latter measures the ability to service current liabilities using cash, near-cash equivalents, or short-term investments. In the late-1990s, Plot (C) shows that the value of current assets it typically 3 times greater than current liabilities, while Plot (D) shows that the value of cash and near-cash equivalents is typically 1.9 times higher than current liabilities. Both ratios fall quickly in the following years. From 1999, the current ratio is relatively stable, at around 0.9 times (or 90%) current liabilities. In addition, the quick ratio also fall to around 0.6 times current liabilities. Intiuitively, these ratios highlight that the utility industy does not hold enough solvent assets to service the cost of current liabilities. Overall, the industry's liquidity has been relatively low, however the fact that many utilities are state-owned implies that government can guarantee, or assist, the repayment of debt obligations. Therefore, liquidity may be less of a concern if the government is willing to extend assistance.

Two financial leverage ratios are examined: the Debt/Equity ratio in Chart (E) and the Debt/Capital ratio in Chart (F). Both ratios measure how much capital comes in the form of debt, relative to equity or all capital. Debt can be used to maximise profit growth if the rate of return available for employing debt is greater than the cost of interest payments. Further, as debt has a fixed claim, the proportion of net income available to shareholders is greater. In contrast, excessive use of debt can lead to credit downgrades, making debt an expensive form of capital, and can also magnify losses due to higher interest payments.

[55] Data were extracted from S&P Capital IQ on the 30th November, 2016.

Both Plots (E) and (F) show low leverage ratios in 1996, of 20% and 17%, respectively.[56] Both the Debt/Equity and Debt/Capital ratios increased over time, indicating that debt became a more common form of financing assets relative to equity capital. By 2015, the median ratio of Debt/Equity in the industry was 115%, with many companies having higher observations. Overall, the industry has made efforts to increase its financial leverage position, inducing higher financial risk to operations. This finding becomes important with respect to stranded assets as small changes in revenue can dramatically impact net income. Equity shareholders, who are subordinate to debt contracts, are most likely to absorb the burden of stranded assets.

Faced with increasing levels of debt, we examine three coverage ratios. Coverage ratios measure the industry's ability to meet its financial obligations. Three ratios are considered: 1) EBIT/interest, 2) EBITDA/interest, and 3) (EBITDA-CAPEX)/interest. The lack of observations induces a number of outlier observations, which typically occur between 1995 and 1999. For the most part, all three observations are above 1, indicating the industry generates sufficient earnings to cover interest expenses. Between 1999 and 2015, Plot (G) shows that operating income is typically between 7.2 and 1.8 greater than interest expense. Plot (H) examines EBITDA, which accounts for large depreciation and amortisation on assets. Over the same period, EBITDA is typically 8.1 to 2.9 times greater than interest expensive, suggest the costs of intangible and tangible assets are large. Finally, Plot (I) utilises (EBITDA-CAPEX), which considers the impact of capital expenditures on the industry's ability to cover interest expenses. The deduction of CAPEX allows comparison across capital-intensive companies, and is typically interpreted as free cash flow. This latter observation contains a large number of omissions, and thus the data is less reliable than the former two metrics. When deducting annual CAPEX, the ratios range from 4.8 to 0.8 times interest expense using free cash flow. As intimated previously, China's coal-fired utilities have typically held low levels of cash reserves, which diminished their ability to satisfy debt commitments using cash or near-cash equivalents.

The final four ratios in Plots (J) to (M) represent the industry's ability to retire incurred debt. The ratios can be broadly interpreted as the amount of time needed to pay off all debt, ignoring interest, tax, depreciation and amortisation. The ratios are divided into two groups: group 1 considers the numerators: 'total debt' and 'net debt', where net debt subtracts cash and near-cash equivalents for total debt; group 2 considers the denominators: EBITDA and (EBITDA-CAPEX), where the latter controls for capital expenditures which allows comparison between utilities and non-capital intensive industries.

[56] Note, outlier observations of Debt/Equity and Debt/Capital ratios in 1995 skewed the median observations. Thus, we omit this year from our interpretation.

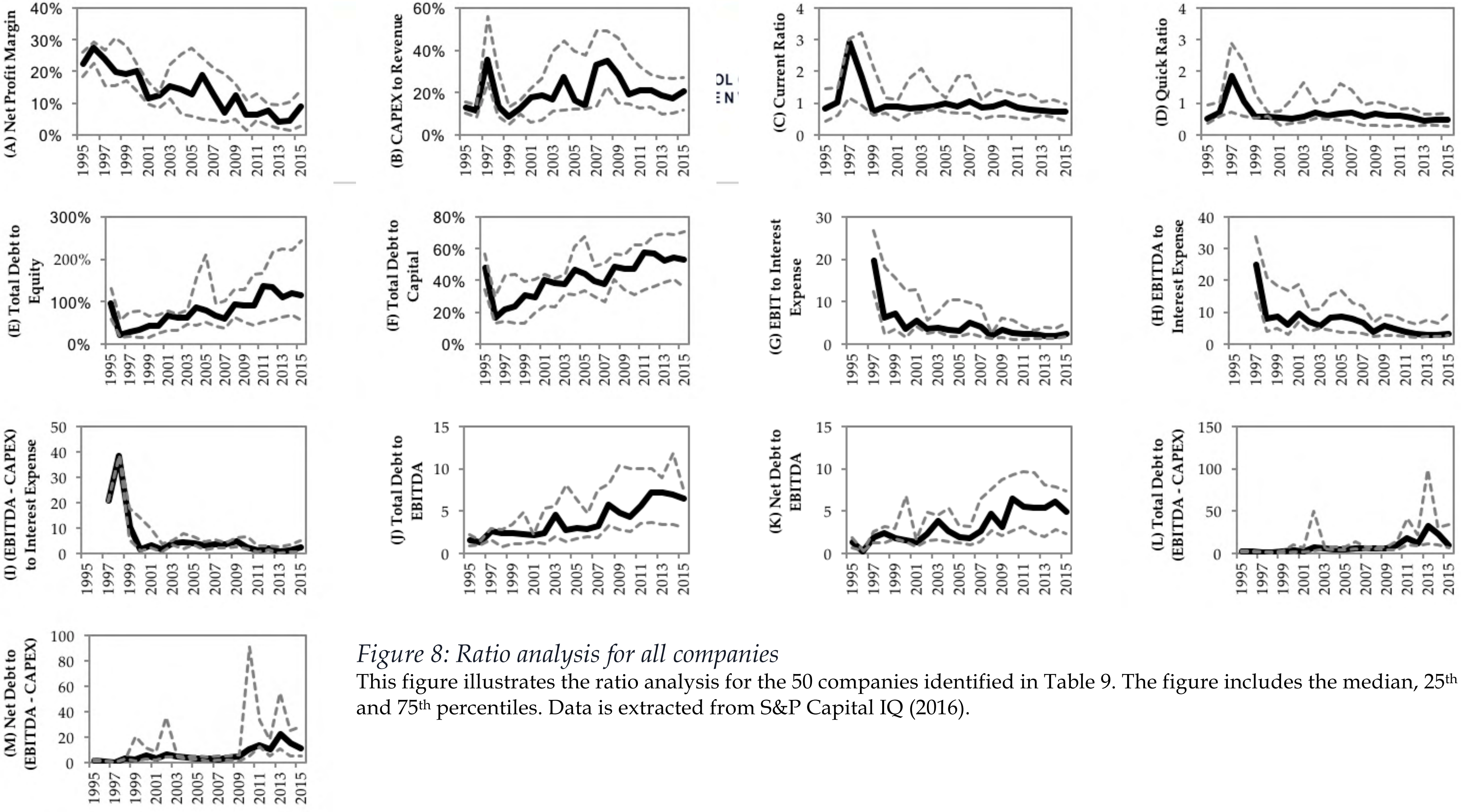


Figure 8: Ratio analysis for all companies

This figure illustrates the ratio analysis for the 50 companies identified in Table 9. The figure includes the median, 25th and 75th percentiles. Data is extracted from S&P Capital IQ (2016).

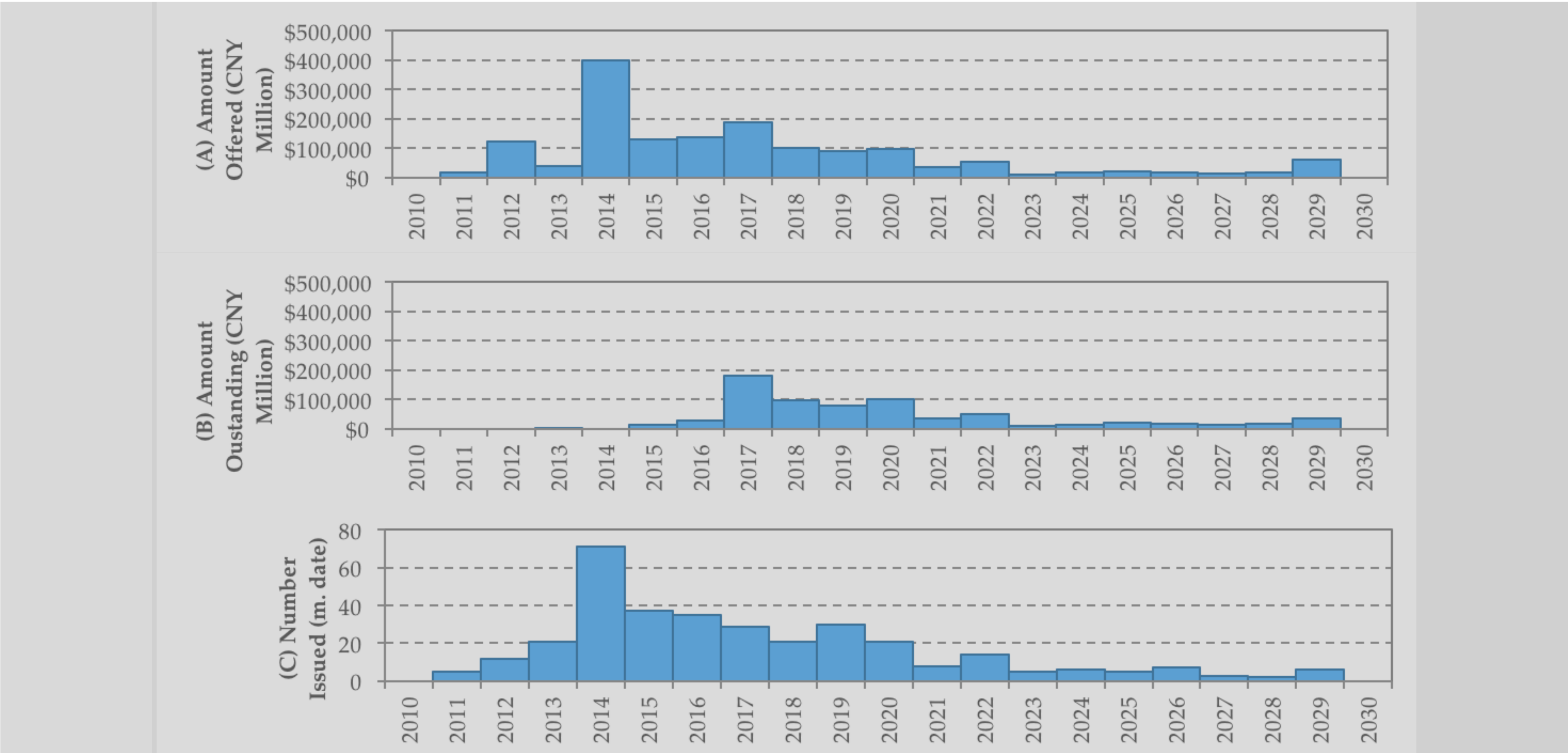
Consistent with the preceding analyses of debt, all four ratios suggest that the proportion of debt to earnings is increasing over the series, increasing the time taken to repay debt. Plots (J) shows that the time taken to repay total debt, using EBITDA, increased from 1.55 years in 1995 to 6.5 years in 2015. The relationship is relatively similar for the Net Debt value in Plot (K) as holdings of cash and near-cash equivalents was typically low. After subtracting capital expenditures, Plots (L) and (M) show that the time taken to repay debt almost doubles, to 6.65 years (Total Debt) and 11.42 years (Net Debt). In particular, the post-2009 years represent volatile years for the industry's ability to repay debt. This is consistent with the low earnings, and stable CAPEX, observed in Plot (A). In conclusion, all four ratios indicate that the sample's ability to repay debt is deteriorating.

Figure 9 illustrates the bond maturity schedule for debt securities in the Chinese coal-fired utility sample, between 2010 and 2030. Panel (A) illustrates the total amount of debt offered (CN¥ million), Panel (B) illustrates the total amount still outstanding (CN¥ million), and Panel (C) illustrates the total number of contracts offered.[57] We examine all debt contracts[58] issued by the firm and, for prudence, exclude subsidiaries which may include partial-holdings only. Of the 50 companies analysed, 33 had fixed-income data available. Only three perpetual debt contracts were issued in our sample. Two contracts issued by China Datang Corporation amounted to CN¥9.9 billion (US$1.5 billion); while one contract, issued by CK Hutchison Holdings Limited, of CN¥ 2.1 billion (US$300 million) is already inactive.

Plot (A) of Figure 9 shows that the total amount of debt offered between 2017 and 2030 is currently CN¥714.3 billion (US$103.8 billion); of this figure, Plot (B) shows that CN¥665 billion (US$93.7 billion) is still outstanding. Plot (B) also shows that the majority (73.8%) of all outstanding debt obligations are due within the next five years (2017-2021), indicating the sample shows a preference for debt which matures within five years or less. The most expensive year for retiring debt is 2017, with CN¥181.9 billion (US$26.5 billion) due – representing 27% of all outstanding debt obligation. This finding is consistent with the large proportion of current liabilities observed in the industry's balance sheet (see Figure 7). Within our debt issuance results for China's coal fired utility industry,[59] we observed debt contracts issued to 2075, which indicates some confidence that the firms would be operating at such date. However, for the Chinese sample, we observe no debt contracts beyond 2029 – indicating a more myopic perspective in the coal-fired utility industry's future or, at least, some conservativism with respect to issuing debt contracts beyond 10 to 12 years.

[57] Data are extracted in US$ millions, and converted to CNY million using an exchange rate of 1 USD = 6.87722 CNY which was appropriate at the time of analysis.
[58] Contracts include *Active* (current), *Inactive* (historical), *Rule 144A* (privately placed, two year holding period), and *Regulation S* (safe harbour, executed in another country) contracts.
[59] Caldecott et al., "Stranded Assets and Thermal Coal: An Analysis of Environment-Related Risk Exposure."

Figure 9: Bond maturity schedule and number of contracts issued



1.3 Environment-Related Risk Hypotheses

In this section, we examine the environment-related risks facing coal-fired power stations and how they could affect asset values. We call these Local Risk Hypotheses (LRHs) or National Risk Hypotheses (NRHs) based on whether the risk factor in question affects all assets in China in a similar way, or if risk exposure is specific to the local environment. Water stress, for example, varies across the country and so is an LRH, whereas a country-wide 'utility death spiral' is an NRH. The hypotheses are coded for easier reference. For example, LRH-1 refers to carbon intensity of coal-fired power stations and NRH-1 refers to the overall demand outlook for electricity.

Hypotheses for different environment-related risks have been developed through an informal process. We produced an initial long list of possible LRHs and NRHs. This list was reduced to the more manageable number of LRHs and NRHs contained in this report. We excluded potential LRHs and NRHs based on two criteria. First, we received feedback from investors and other researchers in meetings, roundtables, and through correspondence, on the soundness, relevance, and practicality of each hypothesis. Second, we assessed the data needs and analytical effort required to link the hypotheses with relevant, up-to-date, and where possible, non-proprietary, datasets.

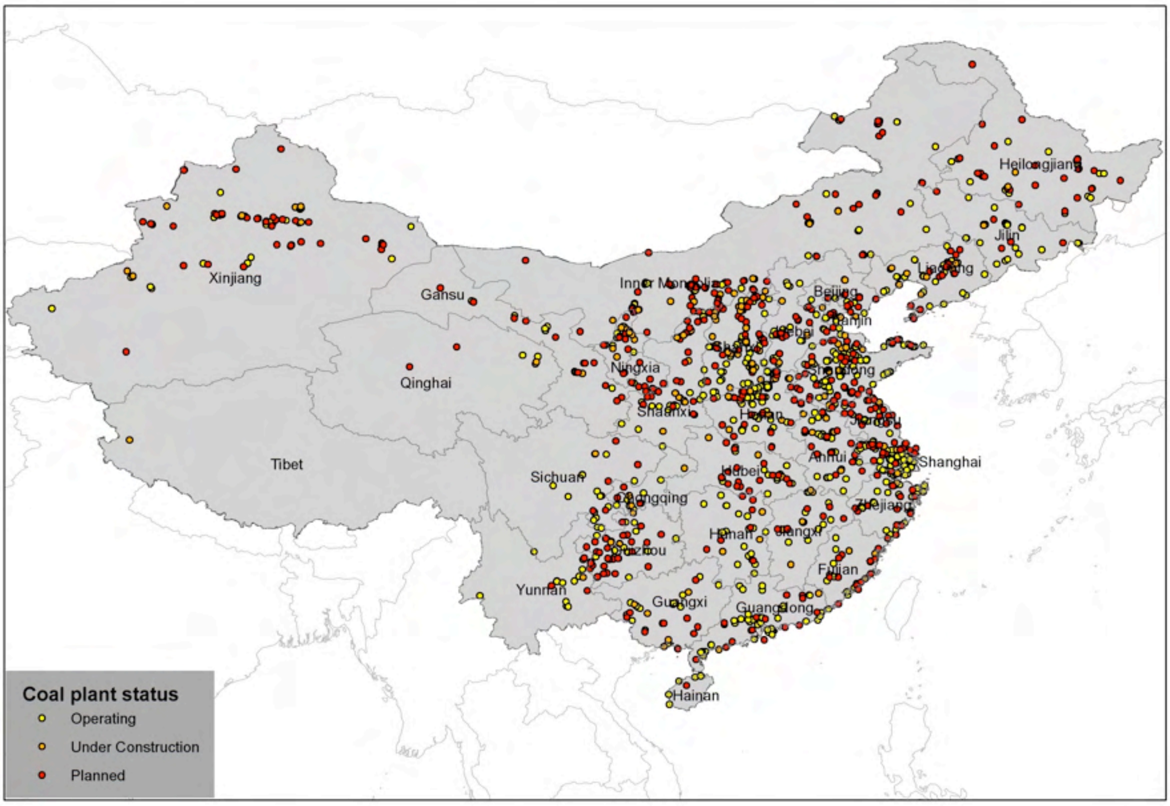
The current list of hypotheses and the datasets used to measure asset exposure to them are in draft form. Other datasets may have better correlations and serve as more accurate proxies for the issues we examine. Important factors may not be represented in our current hypotheses. We are aware of these potential shortcomings and in subsequent research intend to expand the number of hypotheses we have, as well as improve the approaches we have used to analyse them. A list of the LRHs and NRHs examined is displayed in Table 10 below, as well the sources used to investigate them.

Table 10: Local Risk Hypotheses (LRHs) and National Risk Hypotheses (NRHs)

#	NAME	SOURCE
Coal-Fired Power Utilities		
LRH-1	Carbon Intensity	CoalSwarm/Enidpedia/CARMA/Greenpeace/ Oxford Smith School
LRH-2	Plant Age	CoalSwarm/WEPP/Enipedia/CARMA/Oxford Smith School
LRH-3	Local Air Pollution	Atmospheric Composition Analysis Group, Dalhousie University
LRH-4	Water Risk/Stress	WRI Aqueduct
LRH-5	Quality of Coal	CoalSwarm/WEPP/Oxford Smith School
LRH-6	CCS Retrofitability	CARMA/CoalSwarm/WEPP/Geogreen
LRH-7	Future Heat Stress	IPCC AR5 WGII
NRH-1	Future Electricity Demand	Oxford Smith School
NRH-2	Renewables Resource	Oxford Smith School
NRH-3	Decline in Government Support for Coal-fired Power Stations	Oxford Smith School
NRH-4	Renewables Policy Support	EY's Renewables Attractiveness Index
NRH-5	Growth of Decentralised Renewables and the 'Utility Death Spiral'	Oxford Smith School
NRH-6	Growth of Utility-Scale Renewables	BP/REN21
NRH-7	Gas Reserves and Production Growth	BP Statistical Energy Review 2016
NRH-8	Growth of Gas-Fired Generation	IEA
NRH-9	Falling Utilisation Rates	Oxford Smith School
NRH-10	Water Regulatory Risk	WRI Aqueduct
NRH-11	CCS Regulatory Environment	Global CCS Institute
NRH-12	Investor Sentiment	Oxford Smith School

Figure 10 below depicts the locations of all currently operating, under construction and planned coal-fired power plants in China.

Figure 10: Coal-fired power station status

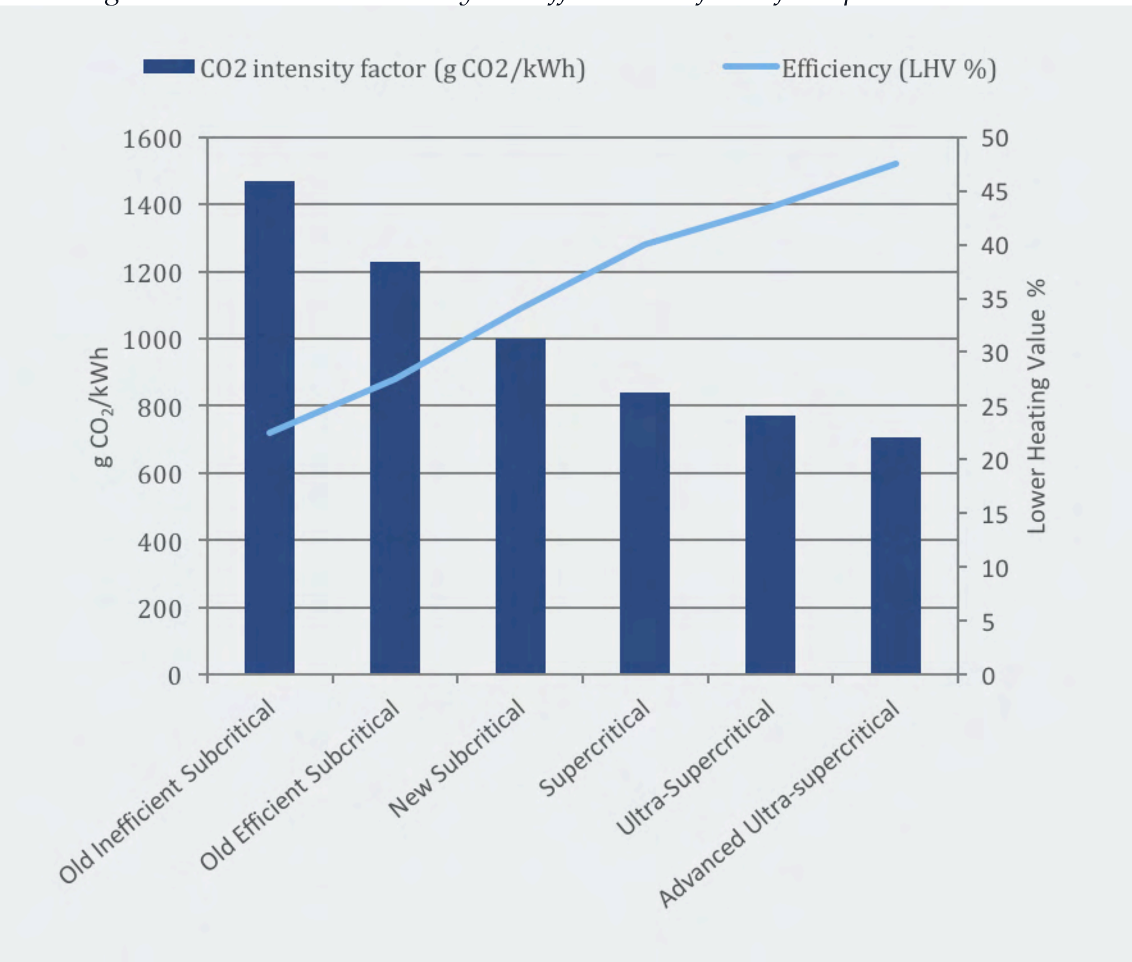


1.3.1 Local Risk Hypotheses

LRH-1: Carbon Intensity

The hypothesis is that the more carbon intensive a coal-fired power station is, the more likely it is to be negatively impacted by climate policy: whether carbon pricing, emissions performance standards, or other similar measures. Carbon intensity is directly dependent on power station efficiency, see Figure 11.

Figure 11: Emissions intensity and efficiencies of coal-fired power stations[60]



	Efficiency (LHV %)	CO2 intensity factor range (kg CO2/MWh)
Advanced Ultra-supercritical	45-50	670-740
Ultra-Supercritical	42-45	740-800
Supercritical	38-42	800-880
New Subcritical	30-38	880-1120
Old Efficient Subcritical	25-30	1120-1340
Old Inefficient Subcritical	21-25	1340-1600

The carbon intensity of power stations can vary widely based on the efficiency of the boiler technology used. Larger generating units often utilise more efficient generating technology, e.g. boiler type. The relationship between boiler technology and unit capacity in China can be seen in Table 11 below. Units with larger capacities tend to employ more advanced technologies which have higher energy efficiency.

[60] IEA, "Energy Technology Perspectives 2013`" (Paris, France, 2013).

Table 11: Boiler technology shares of Chinese coal-fired power plants by different capacities[61]

Capacity (MW)	High Pressure	Ultra-High Pressure	Subcritical	Supercritical	Ultra-supercritical
<300	5%	95%	-	-	-
300-600	-	-	96.2%	3.8%	-
600-1000	-	-	38%	50%	12%
>1000	-	-	-	-	100%

Power stations with lower thermal efficiencies are more vulnerable to carbon policies because such policies will more heavily impact inefficient power stations relative to other power stations.[62] This is highly relevant to coal-fired power generation because it is the most emissions-intensive form of centralised generation.[63] Relatively inefficient coal-fired power stations, such as subcritical coal-fired power stations (SCPSs), are the most vulnerable to carbon policies.

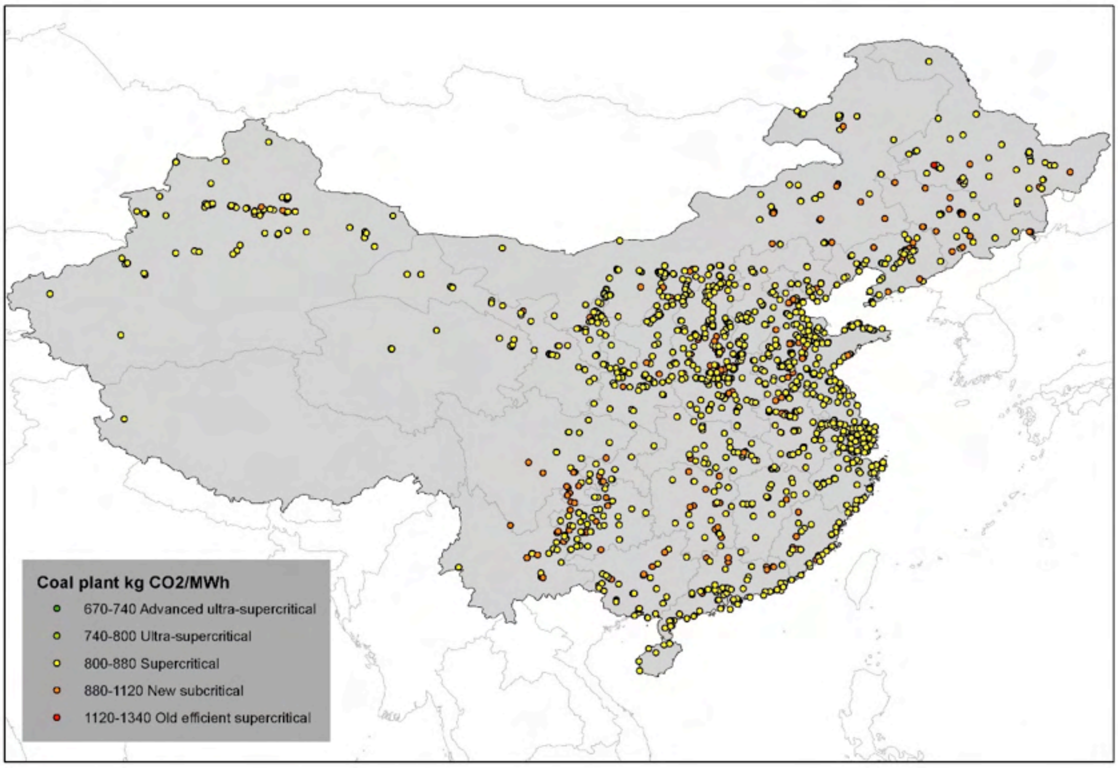
China has one of the world's most modern coal fleets, and the majority of its plants now operate at supercritical efficiencies or better. Nevertheless, even if no further coal generation capacity is built, due to the sheer size of its coal fleet it is expected that China will exceed its 2°C carbon budget by 2040.[64] For China to remain below this limit would require significant asset stranding in its current coal generation fleet or the successful adoption of CCS technology.[65] Furthermore, to reduce air pollution and coal consumption, policymakers guarantee extra hours to coal plants with higher efficiency and give them higher grid priority in ten provinces.[66] Furthermore, China is now rolling out a nation-wide Emissions Trading Scheme (ETS) which will effectively put a price on the carbon emissions of coal-power plants. Collectively these measures will make the most CO_2-intensive plants even more expensive to run and more likely to be shutdown first, as China has already done with small and inefficient units between 2006-2011.[67,68]

To identify carbon intensity risks, the emissions intensity of each coal-fired power station in China is identified in kg CO_2/MWh using data from CoalSwarm's Global Coal Plant Tracker database, Greenpeace, and North China Electric Power University. Within our population of power utilities, CO_2 intensities for 21 per cent of coal-fired power stations were not available. CO_2 intensity for these missing data points was estimated from coefficients derived from a log-log regression of matched data using plant MW capacity, coal type, combustion technology, and age as regressors. This functional form was chosen as it allows for proportional rather than absolute coefficient values, thereby corresponding more closely with the way in which our regressors should affect CO_2 intensity in practice.

Power stations were then aggregated by utility company and weighted by MW to determine the average carbon intensity of the coal-fired power stations for the 50 companies in our sample.

[61] China Electricity Council, "National 600Mw Scale Thermal Power Unit Benchmarking and Competition Dataset (in Chinese).," 2013. And China Electricity Council, "National 300Mw Scale Thermal Power Unit Benchmarking and Competition Dataset (in Chinese)," 2013.
[62] Ben Caldecott and James Mitchell, "Premature Retirement of Sub-Critical Coal Assets: The Potential Role of Compensation and the Implications for International Climate Policy," *Seton Hall Journal of Diplomacy and International Relations* 16, no. 1 (2014): 59–70.
[63] W Moomaw et al., "Annex II: Methodology," *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*, 2011, 982.
[64] Carbon Tracker Initiative, "Chasing the Dragon? China's Coal Overcapacity Crisis and What It Means for Investors."
[65] Ibid.
[66] NDRC, State Environmental Protection Administration (SEPA), and SERC and National Energy Working Group, "Pilot Measures for Implementing Energy Efficient Dispatch <节能发电调度办法实施细则（试行）No. 523," 2007.
[67] In 2007, in order to improve electricity sector's efficiency, China's state council has issued "Notice on closing down small thermal electric power generating units", requiring new Electricity Generating Units (EGUs) of large capacities to be built on the condition that a certain amount of small units be shut down. As a result, during the period of 2006-2011, China's 11th five-year, a total of 77GW of small EGUs were replaced by large supercritical (600MW) and ultra-supercritical (1000MW) EGUs.
[68] Wu and Huo, "Energy Efficiency Achievements in China's Industrial and Transport Sectors: How Do They Rate?"

Figure 12: Operational coal-fired power station CO2 emissions intensities



LRH-2: Plant Age

The hypothesis is that older power stations creates risks for owners in two ways. First, ageing power stations are more vulnerable to regulations that might force their closure, since it is financially and politically simpler to regulate the closure of ageing power stations. Power stations typically have a technical life of 40 years, though Chinese coal power plants have historically had a somewhat shorter lifespan, and recover their capital costs after 35 years.[69] Once power stations have recovered capital costs and have exceeded their technical lives, the financial need to compensate for closures is greatly reduced or eliminated.[70] Second, utilities with significant ageing generation portfolios have a higher risk of being required to cover site remediation costs after power station closures and outstanding worker liabilities (i.e. pension costs). Finally, older power stations are more susceptible to unplanned shutdowns and maintenance needs, resulting in higher repair costs and secondary losses or opportunity costs of underperformance on contracted power delivery.

The age of each generating unit within each power station is identified using data from CoalSwarm, the World Electric Power Plant (WEPP) database, Greenpeace, and North China Electric Power University. Unit ages are then aggregated to the plant level by weighting the MW capacity of each generating unit. For generating units that lack age data (16% in total), the average age of generating units in the same province is used. Power station ages are then further aggregated by utility company to determine the average age of corporate coal-fired power generation portfolios.

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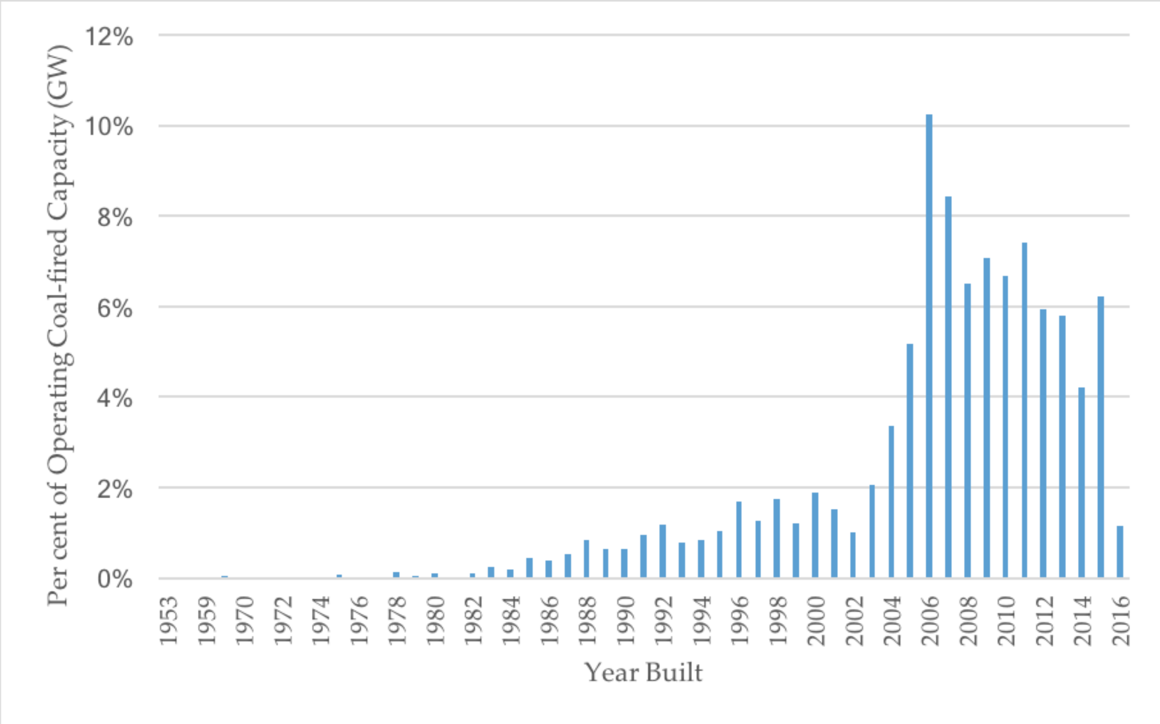
[69] IEA, "Energy, Climate Change and Environment" (Paris, France, 2014).

[70] Caldecott and Mitchell, "Premature Retirement of Sub-Critical Coal Assets: The Potential Role of Compensation and the Implications for International Climate Policy."

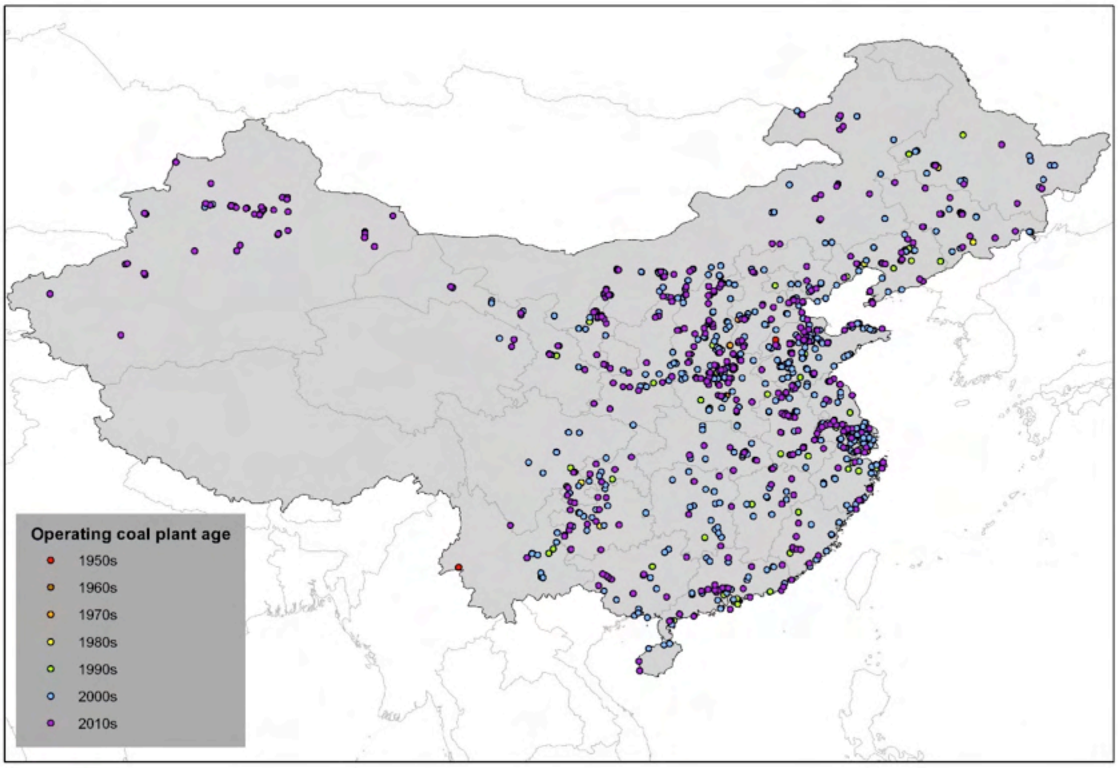
As shown in Figure 13, the age structure of China's coal power plant fleet is characterised by a step-change increase in new capacity additions which began in 2004 and continued until 2015. As a result, China's coal fleet is characterised by relative youth; with an average age[71] of just 10 years[72], and 75 per cent of built capacity having come online since 2005. Regionally, we can also notice in Figure 14 a strategic expansion of coal-fired power which occurred in the 2010s in the western-most province of Xinjiang.

Figure 13: Per cent of operating coal-fired power station capacity by year built



[71] Weighted by MW capacity.
[72] For comparision note that all of the UK's operating coal power plants have been running for over 35 years.

Figure 14: Operational coal-fired power station ages



LRH-3: Local Air Pollution

The hypothesis is that coal-fired power stations in locations with serious local air pollution are at greater risk of being regulated and required to either install emission abatement technologies or cease operation. Thus, owners of assets in areas of high local pollution will have a greater risk of bearing the financial impacts of such possibilities.

Those power stations without abatement technologies (e.g. flue gas desulphurisation units and electrostatic precipitators) installed are at greater risk of being stranded by having to make large capital expenditures in the future to fit emission abatement technologies. This risk is exacerbated by power station age because investments are harder to justify closer to the end of a power station's technical life.

The WHO estimates that 92% of the global population lives in areas where air pollution exceeds safety limits[73], and there is strong evidence from the US, EU, and China to support the hypothesis that emitting assets in polluted areas may be prematurely closed and new power stations subject to greater pollution controls. In China specifically, last year in China nearly 300 cities failed to meet national standards for air quality[74], and a number of non-GHG emission policies are forcing the closure of coal-fired power generation in the heavily polluted eastern provinces.[75] China now requires NO_x and SO_2 pollution controls on all new coal-fired power plants (see Table 12), and it is estimated that close to 90 per cent of the coal plants in China have controls for all conventional pollutants in flue gas.[76] The government wants even

[73] WHO, "Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease," 2016.

[74] Dong Liansai, "So What Happened with China's Pollution in 2015?," *Greenpeace*, 2016, http://www.greenpeace.org/eastasia/news/blog/China-pollution-2015/blog/55341/.

[75] Caldecott, Dericks, and Mitchell, "Stranded Assets and Subcritical Coal: The Risk to Companies and Investors."

[76] R Martin, "Fixing China's Coal Problem," *MIT Technology Review*, 2015, https://www.technologyreview.com/s/537696/fixing-chinas-coal-problem/.

greater coverage however, and recently issued the 'Energy saving and Emission abatement Plan of Upgrading and Transforming Coal Power in China' (2014-2020)[77], which requires even more stringent ultra-low emissions retrofits on coal plants in the east, northeast, central and west regions by 2017, 2018, 2018 and 2020, respectively.[78,79] Moreover, since January of 2016, the newly revised Atmospheric Pollution Prevention Law now gives grid priority to more efficient, and therefore less polluting coal power plants.[80]

In spite of these measures, the air pollution situation in China is still one of the world's most dire. A recent medical study found that 1.2m Chinese die prematurely due air pollution, and that $PM_{2.5}$ pollution specifically has now become the fourth biggest threat to the health of the Chinese people.[81] In addition, acid rain as a consequence of coal consumption is increasingly becoming a major constraint on agricultural production, with up to 40 per cent of China's agricultural land affected.[82] In response, the government launched a National Plan of Air Pollution Control in Key Regions with the 12th Five-Year Plan (2011-2015) that allocates \$277.5bn to the reduction of air pollution over this period[83]; and the Action Plan for Air Pollution Prevention and Control, which aims to decrease provincial $PM_{2.5}$ pollution towards the National Ambient Air Quality Standard of 35 micrograms per cubic meter ($\mu g/m^3$) by, among other policies, limiting coal consumption by power companies and industry.[84]

Table 12: Pollution control deployment on coal-fired power plants in China[85]

Pollutant	**Pollution Control Employed**
Particulate Matter (PM)	Electrostatic Precipitators now employed on 96% of coal-fired power stations
Nitrous Oxides (NO_x)	Since 2005 new coal power stations larger than 300 MW must employ Denitrification technology to reduce NO_x emissions. Coal generation capacity built since 1999 and larger than 300 MW represents 68 per cent of the total.
Sulfur Dioxide (SO_2)	Since 1999 new coal power stations larger than 300 MW must employ Flue Gas Desulpurisation (FGD) technology. Coal generation capacity built since 1999 and larger than 300 MW represents 77 per cent of the total.

Sources: Oxford Smith School; Martin, R. (2015). "Fixing China's Coal Problem." MIT Technology Review

The following approach is taken to identify risks to utilities that may be created by the co-location of coal-fired power stations with local air pollution levels.

- All coal-fired power stations are mapped against a geospatial dataset of global $PM_{2.5}$ pollution. $PM_{2.5}$ data is taken from the analysis of Boys, Martin et al. (2014), and consists of annual ground-level $PM_{2.5}$ averages between 2012 and 2014 derived from satellite observation.
- The average $PM_{2.5}$ levels measured within a radius of 100km of each power station is then identified. Typically each power plant has between 250-300 $PM_{2.5}$ measurement observations within this 100km radius.

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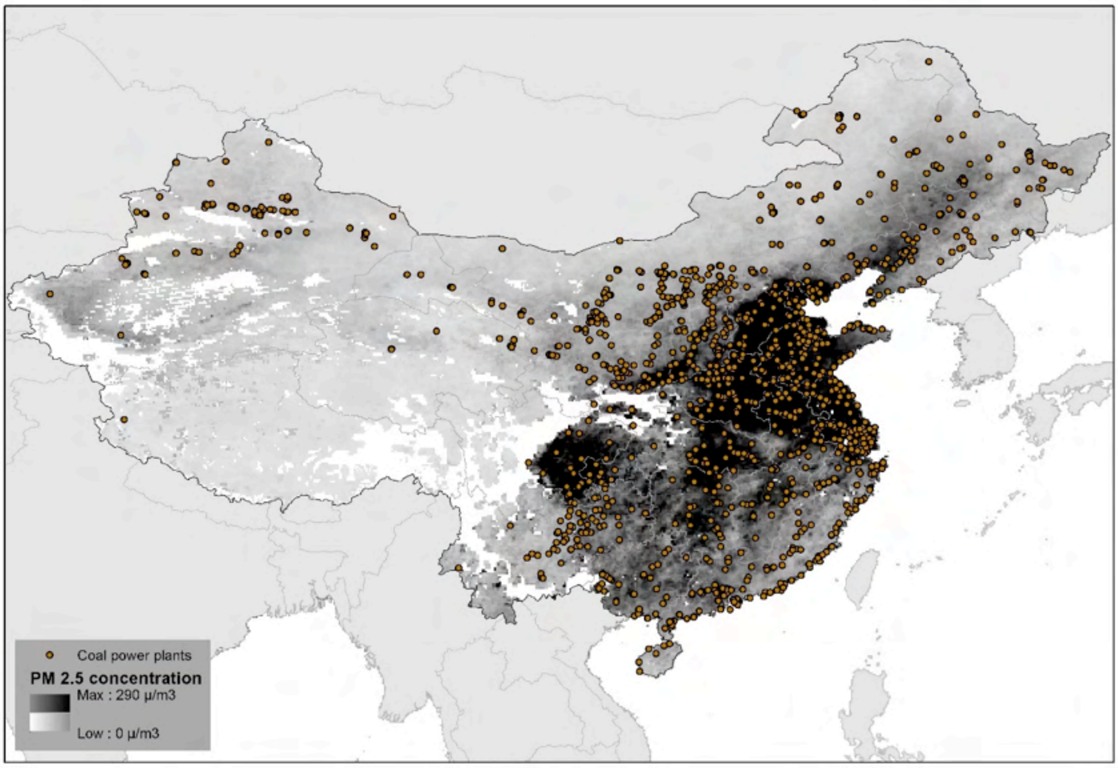
[77] National Energy Administration, "The Energy Saving and Emission Abatement Plan of Upgrading and Transforming Coal Power in China (2014-2020) <煤电节能减排升级与改造行动计划（2014-2020 年）," 2014.
[78] Ministry of Environmental Protection, "National Development and Reform Commission and National Energy Administration, The Full Implementation of Ultra Low Emission and Energy Saving Transformation of Coal-Fired Power Plants", <全面实施燃煤电厂超低排放和节能改造工作方案>," 2015.
[79] National Energy Administration, "Coordinated Development of Power Sector in Northeast China, <关于推动东北地区电力协调发展的实施意见>," 2016.
[80] Ministry of Environmental Protection, "National Development and Reform Commission and National Energy Administration, The Full Implementation of Ultra Low Emission and Energy Saving Transformation of Coal-Fired Power Plants", <全面实施燃煤电厂超低排放和节能改造工作方案>,."
[81] GH Yang et al., "Rapid Health Transition in China, 1990-2010: Findings from the Global Burden of Disease Study 2010," *The Lancet* 381 (2010): 1987–2015.
[82] C You and X Xu, "Coal Combustion and Its Pollution Control in China," *Energy* 35, no. 11 (2010): 4467–72.
[83] Zhu, Chen; Jian-Nan Wang, Guo-Xia Ma, "China Tackles the Health Effects of Air Pollution."
[84] International Energy Agency (IEA), "Energy and Air Pollution," 2016.
[85] You and Xu, "Coal Combustion and Its Pollution Control in China."

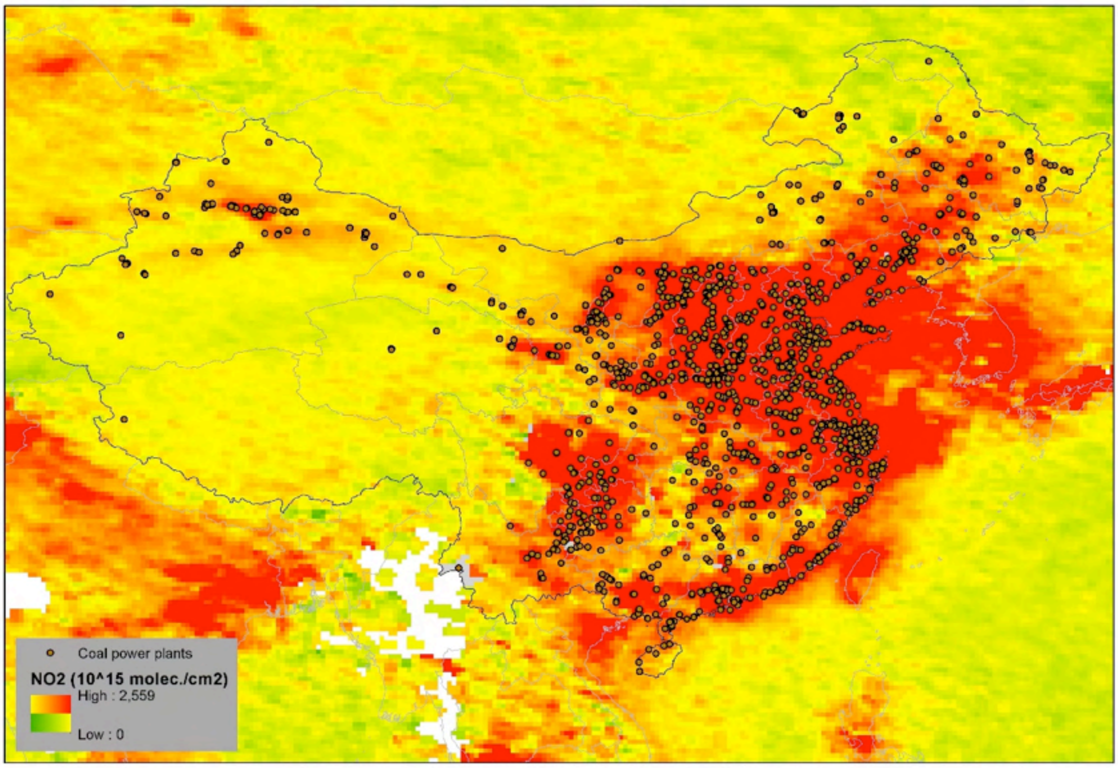
In this hypothesis, $PM_{2.5}$ is also used as a proxy indicator for other conventional air pollutants. This is because Mercury, NO_x and SO_x comprise PM pollution once suspended in the atmosphere, and are therefore included in an evaluation of exposure to $PM_{2.5}$ alone. Furthermore, although other pollutants such as Mercury have toxic neurological impacts on humans and ecosystems, $PM_{2.5}$ is responsible for a more significant range of respiratory and cardiac health impacts associated with coal-fired power.[86] MoreoverFigure 15, Figure 16, Figure 17, and Figure 18 show these air pollutant concentrations in China in relation to all operating, under construction, and planned coal power plants.

Figure 15: Average $PM_{2.5}$ concentrations, 2012-2014[87]



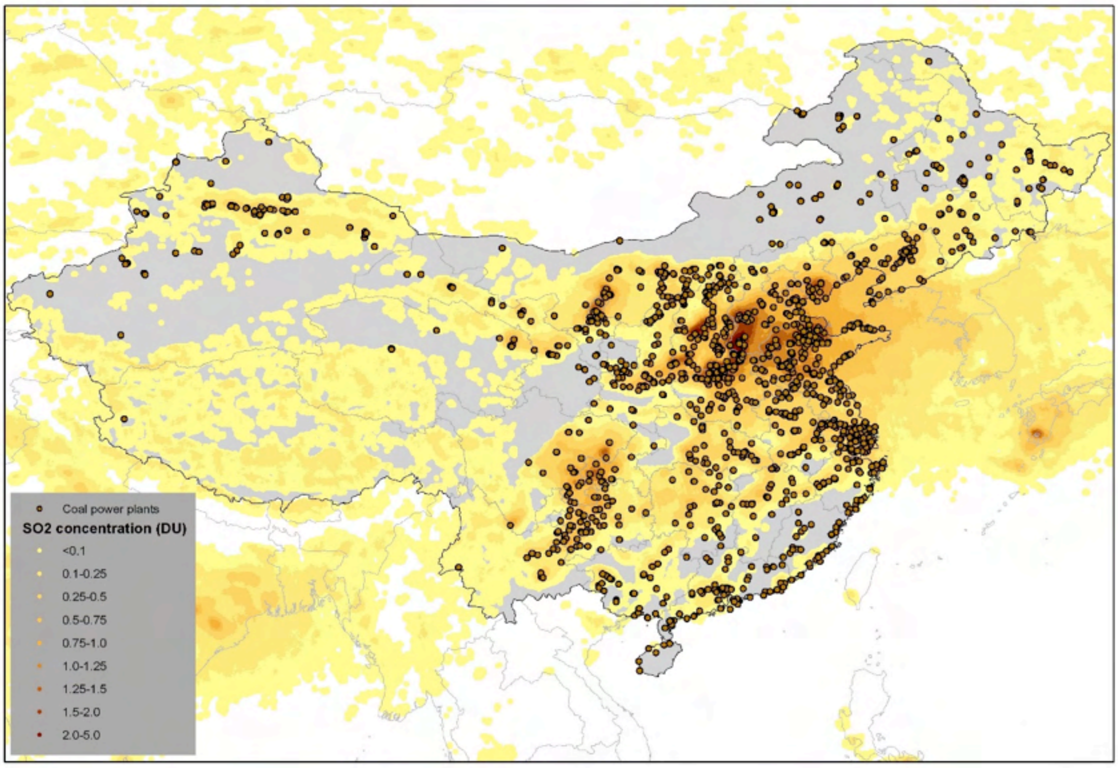
[86] Alan H Lockwood et al., "Coal's Assault on Human Health," *Physicians for Social Responsibility Report*, 2009.
[87] B L Boys et al., "Fifteen-Year Global Time Series of Satellite-Derived Fine Particulate Matter," *Environmental Science & Technology* 48, no. 19 (2014): 11109–18.

Figure 16: Average NO_2 concentrations, 2015[88]



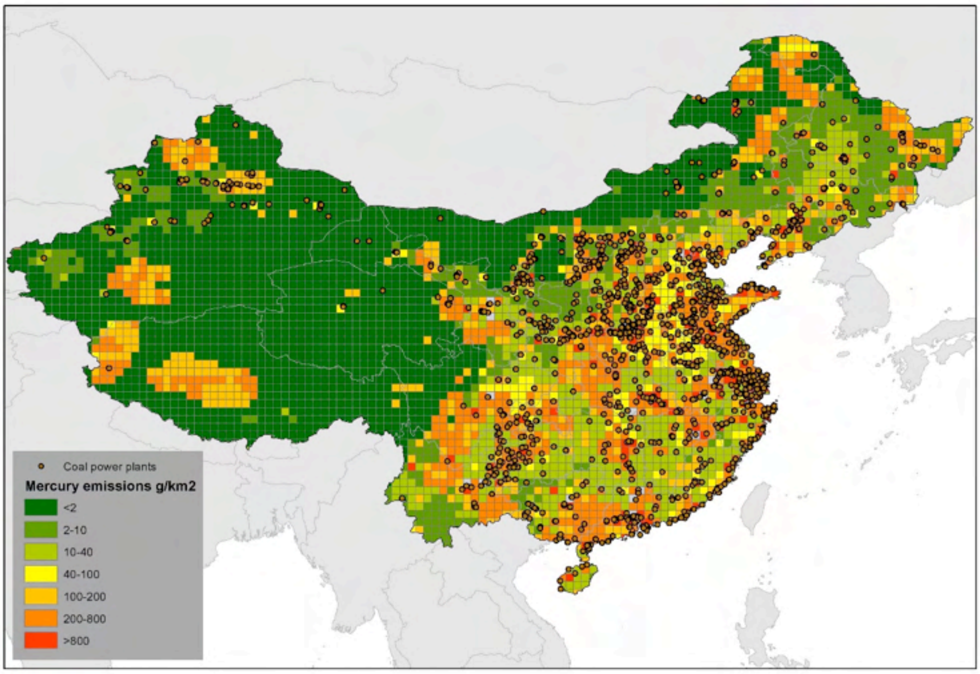
[88] K F Boersma et al., "An Improved Tropospheric NO2 Column Retrieval Algorithm for the Ozone Monitoring Instrument," *Atmos. Meas. Tech.* 4, no. 9 (September 2011): 1905–28, doi:10.5194/amt-4-1905-2011.

Figure 17: Average SO_2 concentrations, 2011-14[89]



[89] N A Krotkov et al., "Aura OMI Observations of Regional SO2 and NO2 Pollution Changes from 2005 to 2015," *Atmos. Chem. Phys.* 16, no. 7 (April 2016): 4605–29, doi:10.5194/acp-16-4605-2016.

Figure 18: Average mercury emissions, 2010[90]



LRH-4: Water Risks

The hypothesis is that power stations located in areas with; (1) higher physical baseline water stress, (2) more severe droughts, and (3) more frequent flooding are at higher risk of being forced to reduce or cease operations.

Thermal power generation is one of the most water-intensive industries and Coal-fired Rankine-cycle (steam) power stations are second only to nuclear power stations in water use. The largest factor in determining the water-efficiency of stations is the type of cooling system installed. Secondary factors are ambient temperature and station efficiency.[91] Risks from water stress can be mitigated to an extent by the use of closed-cycle, hybrid, or dry-cooling technology, though at a cost of reduced generation efficiency.[92]

Table 13: Water use in electric power generation[93]

Fuel-Type	Cooling Technology			
	Once-Through	Closed-Cycle (Wet)	Hybrid (Wet/Dry)	Dry Cooling
Coal	95,000-171,000	2,090-3,040	1,045-2,755	~0
Gas	76,000-133,000	1,900-2,660	950-2,470	~0
Oil	76,000-133,000	1,900-2,660	950-2,470	~0
Nuclear	133,000-190,000	2,850-3,420	Applicability†	Applicability†

†Use of hybrid and dry cooling only recently considered for nuclear plants.

[90] AMAP/UNEP, "AMAP/UNEP Geospatially Distributed Mercury Emissions Dataset 2010v1," 2013.
[91] Caldecott, Dericks, and Mitchell, "Stranded Assets and Subcritical Coal: The Risk to Companies and Investors."
[92] Z Guan and H Gurgenci, "Dry Cooling Technology in Chines Thermal Power Plants," in *Australian Geothermal Energy Conference*, 2009, https://www.geothermal-energy.org/pdf/IGAstandard/AGEC/2009/Guan__Gurgenci_2009.pdf.
[93] EPRI, "Water Use for Electric Power Generation" (Palo Alto, CA, 2008).

History has shown that the availability of water resources is a legitimate concern to the profitability of power stations. In India, coal-water shortages have restricted coal power plants from operating at full capacity, forced nationwide blackouts, and have been shown to quickly erode their profitability.[94] In China, attempts to limit air pollution in eastern provinces have pushed coal-fired power generation into western provinces, where there is extreme water scarcity and similar shortages are now expected.[95] In water-scarce regions China has responded by adopting dry-cooling for its power plants. As of end 2012, 112 GW or 14 per cent the country's then thermal generation capacity was dry-cooled.[96]

Flooding is also a concern for power plants in terms of both continuity of operations and potential damage to property. In February 2014 a UK power plant was inundated by groundwater flooding and forced to suspend generation for 12 weeks.[97] Later that year high water-levels on the Sava River in Serbia caused the 1,502 MW Nikola Tesla coal plant to be shut down and caused problems at the Kostolac and Morava power plants.[98] In 2015, three coal power plants on Ha Long Bay in Vietnam were also shuttered due to flooding.[99]

In order to measure the threat faced by coal-fired plants to water risks, we utilise measures of; physical water stress, drought severity, and flood occurrence from WRI AqueductWRI AqueductWRI AqueductWRI AqueductWRI AqueductWRI Aqueduct dataset. Physical water stress is defined by WRI as total annual water withdrawals (municipal, industrial, and agricultural) expressed as a percentage of the total annual available flow within a given watershed. Higher values indicate greater competition for water among users. Extremely high water stress areas are determined by WRI as watersheds with >80% withdrawal to available flow ratios, 80-40% as high water stress, 40-20% as high to medium, 20-10% as medium to low, and <10% as low.[100] WRI defines drought severity as the average length of drought times the dryness of the droughts from 1901-2008 in a given watershed. Drought length is defined as a contiguous number of months when soil moisture remains below the 20th percentile. Dryness is the average number of percentage points by which soil moisture drops below the 20th percentile. WRI defines flood occurence as the number of floods which occurred within the given watershed between 1985-2011.

Power plants are given a rank according to their level of physical water stress among the plants in our sample of 50 companies, except if the plant is dry-cooled, in which case they are given a rank value of 50 (the lowest risk rank). Power station cooling technology was taken from the WEPP database and visual inspection. It was not possible to identify the cooling technology of 22% of coal plants. Ranks were also given for levels of drought severity and flood occurrence. These rank values of physical water stress, drought severity, and flood occurence for each power plant are then averaged, and then this averaged rank is used to rank plants a further time on overall 'water risk'.

All coal-fired power stations are mapped against the Aqueduct Baseline Water Stress geospatial dataset and depicted in Figure 19 below.

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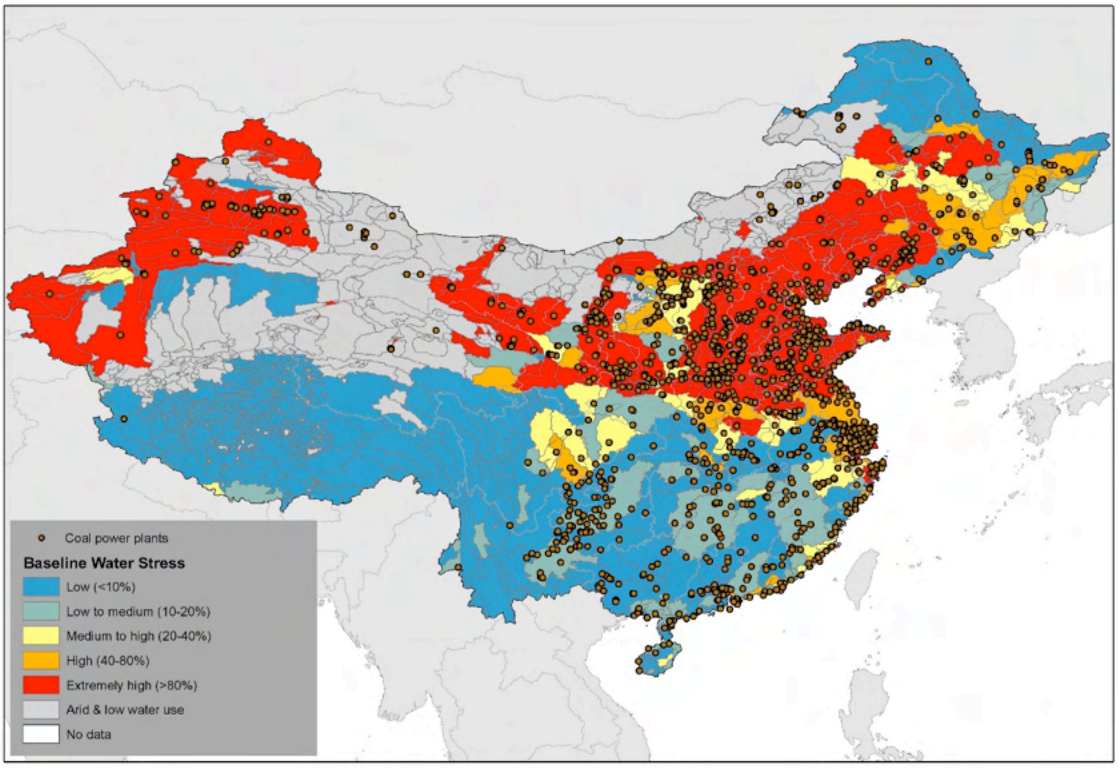
[94] International Energy Agency, "World Energy Outlook" (IEA, 2012).
[95] Carbon Tracker Initiative, "Coal Financial Trends," 2014, https://www.carbontracker.org/wp-content/uploads/2014/09/Coal-Financial-Trends-ETA.pdf.
[96] C Zhang et al., "Water-Carbon Trade-off in China's Coal Power Industry," *Environmental Science and Technology* 48, no. 9 (2014): 11082–89.
[97] EnergyUK, "A Review of Power Station Resilience over Winter 2013/2014," 2015, https://www.energy-uk.org.uk/publication.html?task=file.download&id=5021.
[98] Power Magazine, "Flooding Threatens Coal-Fired Power Plant," n.d., http://www.powermag.com/flooding-threatens-coal-fired-power-plant/.
[99] EcoWatch, "Toxic Flood from Coal Mines and Power Plants Hit Vietnam's Ha Long Bay World Heritage Site," 2015, http://www.ecowatch.com/toxic-floods-from-coal-mines-and-power-plants-hit-vietnams-ha-long-bay-1882080179.html.
[100] Francis Gassert et al., "Aqueduct Global Maps 2.1: Constructing Decision-Relevant Global Water Risk Indicators" (Working Paper. Washington, DC: World Resources Institute. Available online at: http://www. wri. org/publication/aqueductglobalmaps-21-indicators, 2014).

Figure 19: Baseline water stress, Data from WRI Aqueduct 2015



LRH-5: Quality of Coal

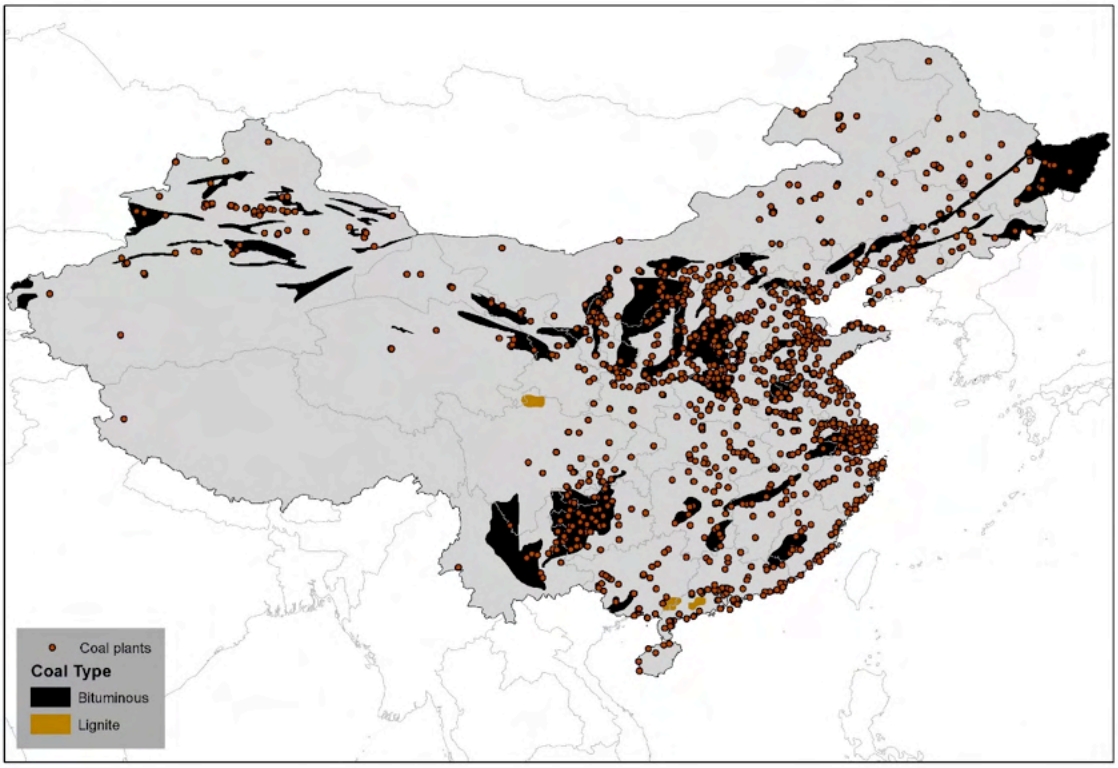
The hypothesis is that coal-fired power stations that use lignite are more at risk than those that use other forms of coal. This is because their greater CO_2 and SO_2 emissions makes them more exposed to regulatory risk.

Coal from different deposits varies widely in the quality and type of pollutants it will emit when combusted. With regards to CO_2, lignite uniformly emits the most for a given unit of power. Therefore, power stations that burn lignite are likely to be more vulnerable to carbon regulations. Similarly, lignite plants emit a greater quantity of harmful pollutants when generating electricity such as SO_2, and will consequently require more expensive retrofitting to make comparable to plants which burn bituminous coal. Compared to other major coal producing nations China's coal is generally of low quality[101], with 46 per cent of China's 114 bnt coal reserves comprising either sub-bituminous coal or lignite.[102] However, China is primarily exploiting its best quality coal reserves first while largely eschewing the mining of lignite.[103]

Data on individual power station use of lignite was compiled from CoalSwarm and WEPP. However, for 33% of coal plants the coal type could not be identified from these sources. Due to lignite's low energy-to-weight ratio, around the world power stations which burn lignite are generally collocated with their mines. Hence we classify power stations which lack coal fuel-type data as burning lignite if they are co-located with lignite reserves according to Figure 20 below.

[101] Tim Wright, *The Political Economy of the Chinese Coal Industry: Black Gold and Blood-Stained Coal*, vol. 45 (Routledge, 2012). p.20.
[102] Energy Watch Group, "Coal: Resources and Future Production," n.d., http://www.peakoil.net/files/EWG-Coalreport_10_07_2007.pdf.
[103] M Hook et al., "A Supply-Driven Forecast for the Future Global Coal Production," in *Contribtion to the ASPO*, 2008.

Figure 20: Chinese coal deposits by type[104]



LRH-6: CCS Retrofitability

Coal-fired power stations not suitable for the retrofit of carbon capture and storage (CCS) technology may be at more risk of premature closure. These power stations do not have the option of CCS retrofit in the case of strong GHG mitigation requirements on coal-fired power utilities, enforced either by targeted policy or carbon pricing. Because CCS plays a large part in in the IPCC and IEA's 2°C scenarios[105] (IPCC AR5 2DS) as well as the IEA's 2°C scenarios (IEA ETP, IEA WEO 450S), it is necessary to evaluate the retrofitability of power stations to assess the resilience of utilities' generation portfolio to policies aiming to align power generation emissions with a 2DS.

As coal contributes two-thirds of China's primary energy supply and more than 80% of electricity generation, CCS is widely recognised as a crucial technology in order to achieve deep cuts in its CO_2 emissions.[106] Notably for China, CCS would have the added benefit of helping to reduce China's high levels of local air pollution. Happily, the feasibility of CCS in China on its thermal power stations is good, as much of its coal fleet is co-located in areas geologically suitable for large-scale carbon sequestration[107]; in particular the north china plain comprising; Beijing, Tianjin, Shanghai, and Xinjiang.[108] However, these are also population centres and therefore CCS adoption could also be opposed in these locations.

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[104] Chinese coal deposits data from various sources: compiled by Oxford Smith School.
[105] Refers specifically to the IPCC AR5 430-480PPM, IEA ETP 2DS, and IEA WEO 450S.
[106] Liang Xi and David Reiner, "How China Can Kick-Start Carbon Capture and Storage," *Chinadialogue*, 2013, https://www.chinadialogue.net/article/show/single/en/6047-How-China-can-kick-start-carbon-capture-and-storage.
[107] R.T. Dahowski et al., "A Preliminary Cost Curve Assessment of Carbon Dioxide Capture and Storage Potential in China," *Energy Procedia* 1, no. 1 (2009): 2849–56. And Pacific Northwest National Laboratory, "China Shows Promise in Carbon Capture and Storage," 2012, http://www.pnnl.gov/science/highlights/highlight.asp?id=685.
[108] See Figure 21.

As is the case elsewhere, China's CCS potential is being developed slowly. It's first pilot project opened in 2008, and currently China has no large-scale CCS projects in operation, but there are seven large-scale projects now in the pipeline, with five scheduled for completion in the 2020s.[109] Nevertheless, it is projected that unless a nationwide CCS industrial policy implemented by the early 2020s, it will not be possible to retrofit enough coal-fired power plants with CCS in time to remain within a 2˚C budget.[110] A recent report also looked at retrofitting China's coal plants with CCS and found that to do so would add $34-129 to the LCOE of each MWh generated[111], which could more than double their total cost.[112] By contrast, solar PV projects which emit zero carbon, were being developed earlier this year in China for as little as $78 per MWh alone.[113]

Table 14: Large-scale Chinese CCS Project Pipeline

Project name	Operation date	Industry	Capture type	Capture capacity (Mtpa)	Transport type	Primary storage type
Sinopec Qilu Petrochemical CCS Project	2017	Chemical Production	Industrial Separation	0.5	Pipeline	Enhanced oil recovery
Yanchang Integrated CCS Demonstration Project	2018	Chemical Production	Pre-combustion capture (gasification)	0.4	Pipeline	Enhanced oil recovery
Huaneng GreenGen IGCC Project (Phase 3)	2020s	Power Generation	Pre-combustion capture (gasification)	2	Pipeline	Enhanced oil recovery
Shanxi International Energy Group CCUS Project	2020s	Power Generation	Oxy-fuel combustion capture	2	Pipeline	Not specified
Shenhua Ningxia CTL Project	2020s	Coal-to-liquids (CTL)	Pre-combustion capture (gasification)	2	Pipeline	Not specified
Sinopec Shengli Power Plant CCS Project	2020s	Power Generation	Post-combustion capture	1	Pipeline	Enhanced oil recovery
China Resources Power (Haifeng) Integrated CCS Demonstration Project	2020s	Power Generation	Post-combustion capture	1	Pipeline	Dedicated Geological Storage

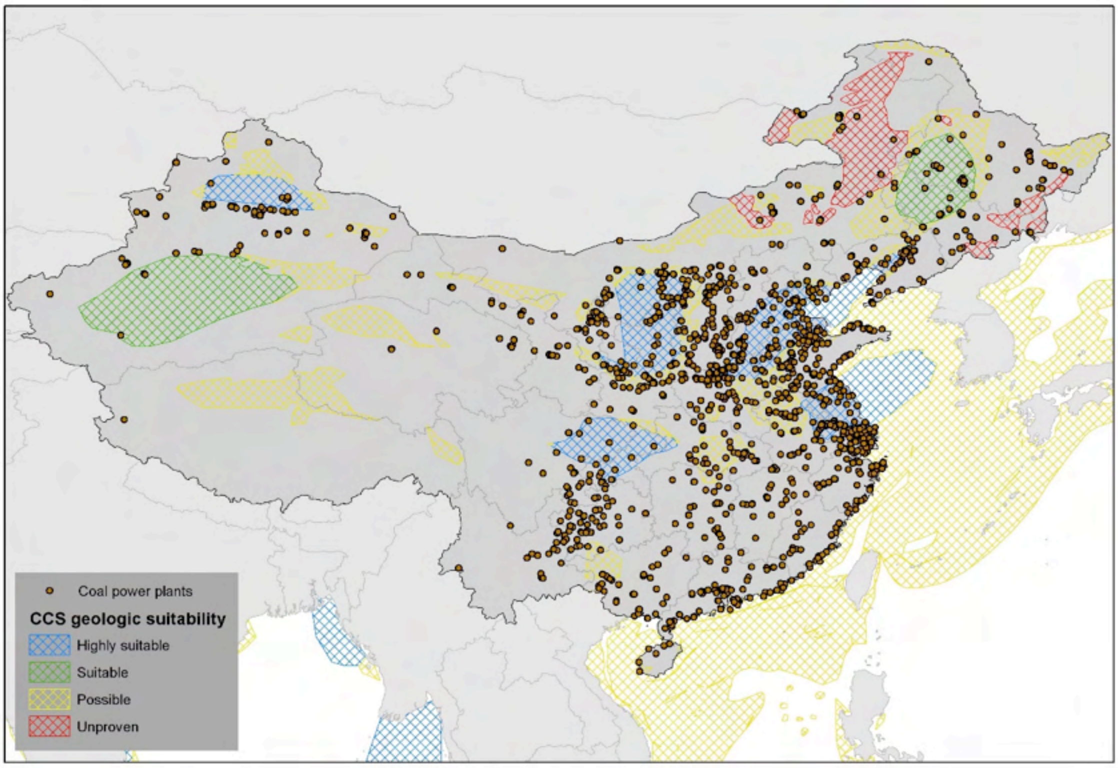
Source: Global CCS Institute[114]

No dataset exists for CCS retrofitability.[115] Instead we adopt the following approach to identify the percentage of utilities' coal-fired power generation portfolios that may be suitable for CCS retrofits. CCS policy support is considered separately as a national-level risk indicator. Power stations with generators larger than 100MW[116,117] and are younger than 20 years[118,119] are deemed technically suitable for CCS

[109] Global CCS Institute, "The Global Status of CCS," 2016, https://www.globalccsinstitute.com/projects/large-scale-ccs-projects.
[110] Carbon Tracker Initiative, "Chasing the Dragon? China's Coal Overcapacity Crisis and What It Means for Investors."
[111] IEA, "Ready for CCS Retrofit," 2016.
[112] IEA, "Projected Costs of Generating Electricity," 2015.
[113] Reuters, "Chinese Solar Power Project Developers Offer Record Low Tariff Price-Media," n.d., http://uk.reuters.com/article/china-power-solar-idUKL3N1BZ3CY.
[114] Global CCS Institute, "The Global Status of CCS."
[115] IEA, "Ready for CCS Retrofit."
[116] National Energy Technology Laboratory, "Coal-Fired Power Plants in the United States: Examination of the Costs of Retrofitting with CO2 Capture Technology" (Washington, US, 2011).
[117] Although MITei suggests that 300MW is the threshold for power stations generally, 100MW is taken as a conservative case. See MITei, "Retrofitting of Coal-Fired Power Plants for CO2 Emission Reductions," 2009.

retrofit, and are then mapped against the Global CCS Suitability geospatial dataset to determine whether they are within 40km of areas suitable for CCS, and therefore geographically suitable.[120] Power stations that are both technically and geographically suitable are aggregated by utility to identify the percentage of utilities' generation portfolio that is 'suitable' for CCS retrofit.

Figure 21: CCS geological suitability[121]



LRH-7: Future Heat Stress

The hypothesis is that physical climate change will exacerbate heat stress on power stations. Higher ambient local temperatures decrease power station efficiency and exacerbate water stress, which causes physical risks, such as forced closure or reduced operation, and social risks, such as unrest and increased potential for regulation.

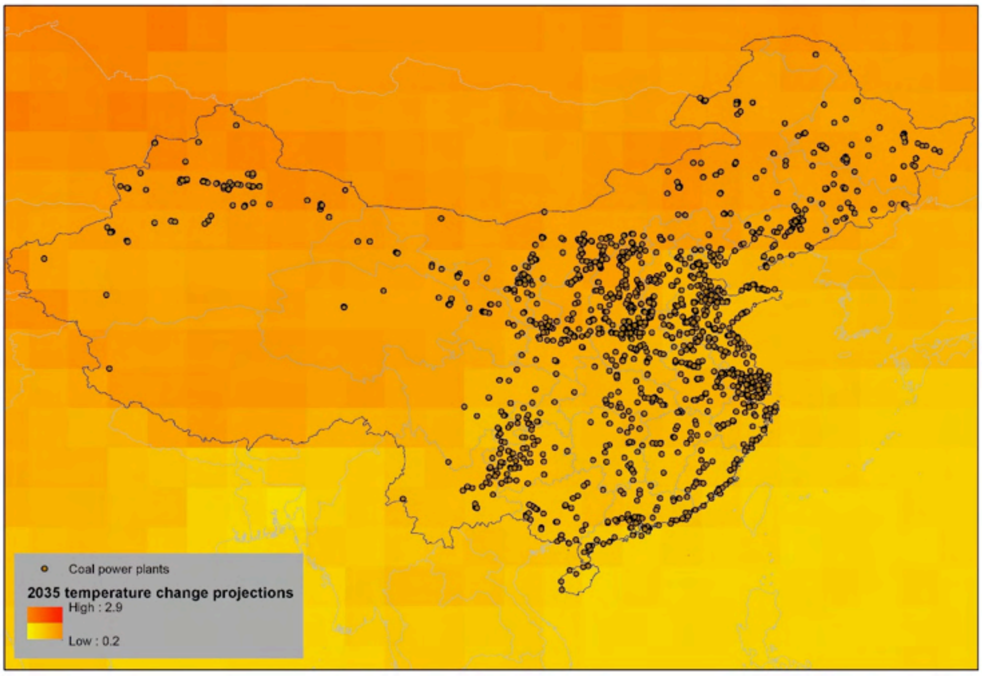
There is evidence that warming risks should be taken into account. In Australia for instance, changes in the climate pose direct water-related risks to Australian coal-fired power generation. During a heat wave in the 2014 Australian summer, electricity demand increased in tandem with water temperatures. Loy Yang power station's generating ability was greatly reduced because it could not cool itself effectively.[122] This caused the electricity spot price to surge to near the market cap price.[123] The inability to produce power at

[118] National Energy Technology Laboratory, "Coal-Fired Power Plants in the United States: Examination of the Costs of Retrofitting with CO2 Capture Technology."
[119] This is the central scenario of the OECD CCS retrofit study.
[120] 40km has been suggested as the distance to assess proximity to geological reservoirs, see National Energy Technology Laboratory, "Coal-Fired Power Plants in the United States: Examination of the Costs of Retrofitting with CO2 Capture Technology.
[121] Reproduced with permission of IEA, GHG and Geogreen.
[122] AEMO, "Heatwave 13 to 17 January 2014," *American Energy Market Operator*, 2014.
[123] Brian Robins, "Electricity Market: Heatwave Generates Interest in Power," *The Sydney Morning Herald*, 2014.

peak demand times has the potential to significantly impact power stations' profits in competitive energy markets.

To assess the vulnerability of power stations to climate-related temperature increases, the Intergovernmental Panel on Climate Change's (IPCC) AR5 2035 geospatial dataset is used. This dataset gives a spatial representation of expected temperature change by 2035. The projected average temperature change within a 50km radius is calculated from this dataset for each power station. Power stations are then ranked nationally. Those power stations in the top quintile of temperature change are identified as 'at risk'. Power stations are then aggregated by utility to identify the companies most at risk from heat stress induced by climatic changes. Figure 22 shows the IPCC's modelled near-term future temperature changes for China.

Figure 22: Projected 2016-35 temperature change[124]



1.3.2 National Risk Hypotheses

The hypotheses below affect all generating assets within China. A simple traffic light method has been used to summarise and compare the analyses for these risk hypotheses. Traffic-light methods are well suited to complex and uncertain situations where attempts at great precision are unsuitable. Such is particularly the case in environmental and sustainability analyses. Commonly, reports by other institutions such as DEFRA[125] and World Bank[126] also employ traffic-light methodologies. The hypotheses developed below draw on the IEA NPS as a conservative scenario and add extra evidence to give a more complete policy outlook for coal-fired utilities. The time horizon for these risk indicators is near to mid-term, using the IEA's 2020 projections where appropriate.

[124] Data from RCP8.5, P50 of IPCC, "Climate Change 2014: Mitigation of Climate Change," 2014.
[125] Department for Food, Environment & Rural Affairs, "Sustainable Development Indicators," 2013.
[126] The World Bank, "RISE Scoring Methodology," 2016.

An effective traffic-light method clearly describes threshold values or criteria for each colour, and such thresholds should be testable by analysis or experiment.[127] Criteria are developed below for each hypothesis, with conclusions as to whether coal-fired utilities are at high risk (red), medium risk (yellow) or low risk (green). Based on each of these criteria, an aggregate risk outlook is given after scoring each (+2 for high risk criteria, +1 for medium risk criteria). These scores can be used for an aggregate risk outlook for coal-fired power generation in China. Comparator countries are also given scores based on the analysis conducted in *Stranded Assets and Thermal Coal*[128]. These traffic-light comparisons are important for contextualising risk exposure in China. For investors who have a global universe of investment opportunities, understanding how China's utilities compare to utilities in other countries with regards to environment-related risk exposure is eminently relevant.

The analysis of NRHs below has been expanded and updated since *Stranded Assets and Thermal Coal*[129]. Changes in opinion of risk exposure are noted where appropriate. Table 15 provides a summary of all NRHs for China's coal-fired power utilities and their peers in comparator countries, where directly comparable. We underline that, over this section, the data for comparison with other peer countries come from both the *Stranded Assets and Thermal Coal*[130] and *Stranded Assets and Thermal Coal in Japan*[131] reports.

Table 15: Summary of National Risk Hypotheses

	China	Japan	Australia	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
NRH-1: Future Electricity Demand	Green	Red	Yellow	Red	Green	Green	Red	Yellow	Red	Yellow
NRH-2: Renewables Resource	Green	Green	Red	Green	Yellow	Yellow	Yellow	Red	Yellow	Yellow
NRH-3: Decline in Government Support for Coal	Yellow	-								
NRH-4: Renewables Policy Support	Red	Red	Yellow	Red	Green	Red	Green	Yellow	Yellow	Red
NRH-5: Growth of Decentralised Renewables	Yellow	Red	-							
NRH-6: Growth of Utility-Scale Renewables	Yellow	Green	-							
NRH-7: Gas Reserves and Production Growth	Red	-								
NRH-8 Growth of Gas-Fired Generation	Red	Yellow	Yellow	Green	Red	Yellow	Green	Green	Green	Red
NRH-9: Falling Utilisation Rates	Red	Yellow	Yellow	Green	Yellow	Red	Yellow	Red	Yellow	Yellow
NRH-10: Water Regulatory Risk	Yellow	Green	Green	Green	Red	Yellow	Green	Yellow	Green	Green
NRH-11: CCS Regulatory Environment	Red	Yellow	Green	Yellow	Red	Red	Yellow	Red	Green	Green
NRH-12: Investor Sentiment	Yellow	-								
NRH-13: Nuclear Restarts	-	Yellow	-							
TOTAL*	63%	50%	43%	36%	57%	64%	36%	64%	36%	50%

*Higher percentage equates to a worse risk outlook. Total for China based on this publication. Total for comparator countries based on *Stranded Assets and Thermal Coal*[132] and *Stranded Assets and Thermal Coal in Japan*[133] reports.

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[127] R G Halliday, L P Fanning, and R K Mohn, "Use of the Traffic Light Method in Fisheries Management Planning," *Marine Fish Division, Scotia-Fundy Region, Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmount, NS, Canada*, 2001.
[128] Caldecott et al., "Stranded Assets and Thermal Coal: An Analysis of Environment-Related Risk Exposure."
[129] Ibid.
[130] Ibid.
[131] Caldecott et al., "Stranded Assets and Thermal Coal in Japan."
[132] Caldecott et al., "Stranded Assets and Thermal Coal: An Analysis of Environment-Related Risk Exposure."
[133] Caldecott et al., "Stranded Assets and Thermal Coal in Japan."

The National Risk Hypotheses we apply and measure China's coal-fired power stations against are outlined below:

NRH-1: Future Electricity Demand Outlook

The hypothesis is that the greater the growth in demand for electricity, the less likely other forms of generation (e.g. solar, wind, gas, and nuclear) are to displace coal-fired power. Growth in overall electricity demand might even allow coal-fired generators to maintain or increase their current share of power generation.

According to official accounts,[134] in 2015 the Chinese economy witnessed its slowest growth rate since the Asian financial crisis in 1997, growing by only 6.9%. This result has been contested by other indicators (e.g. the industrial activity) suggesting that it was actually only half as much.[135] Nevertheless, China's electricity demand growth in 2015 performed even worse, reaching its lowest level since 1980: 0.5%.[136] The increasing gap between electricity consumption growth and GDP growth is stressed in Figure 23 below. This indicates that China's economy is starting to shift away from energy-intensive sectors, such as cement and steel, towards a more domestic- and service-oriented economy involving a less-intensive growth economy configuration. As highlighted by BNEF,[137] this phenomenon is further supported by a decrease of 2.3% in heavy industry during the first two months of 2016, contrasted by an increase of 12% in services and residential consumption over the same period.

Figure 23: China GDP & electricity demand growth (%)[138]

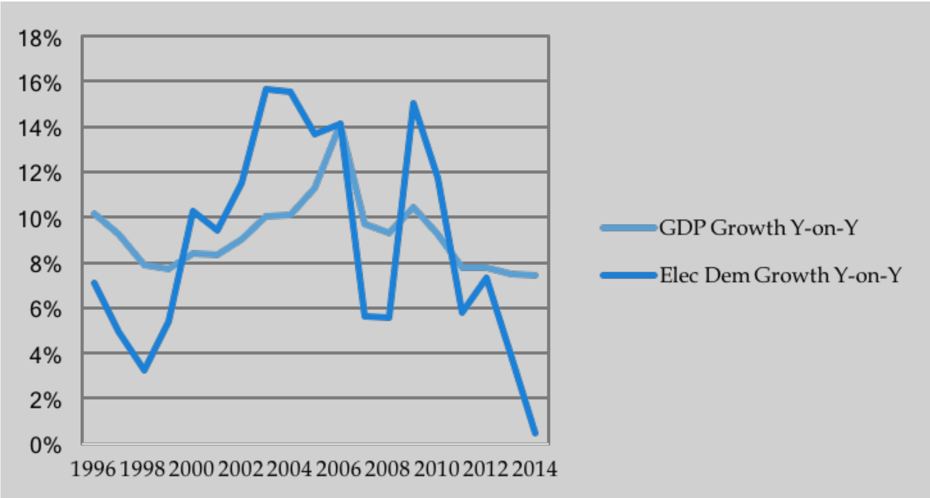


Table 16 shows the compound annual growth rates assumptions in the real GDP, population, electricity generation (TWh) and in the total final energy demand for both the IEA New Policies Scenario (NPS) and the 450 one (450S). These forecasts predict substantial GDP growth. However large gains in efficiency and the new configuration of the Chinese economy mentioned above should lead to decreasing final energy demand and power generation relative to GDP. Moreover, gas and nuclear should comprise an increasing proportion of the final energy demand as they are projected to increase by respectively 7.6% and 8.8% over the period.[139]

[134] Bloomberg New Energy Finance, "New Energy Outllook 2016," 2016.
[135] Ibid.
[136] Ibid.
[137] Ibid.
[138] Ibid.
[139] International Energy Agency, "World Energy Outlook," 2016.

Table 16: China Future Indicators Assumptions. Source: IEA WEO 2016[140]

2014 - 2040	GDP	POP	ELEC	TFED
IEA: NPS	4.6%	0.1%	2.2%	0.9%
IEA: 450S	4.6%	0.1%	1.7%	0.2%

GDP:Real GDP Growth Assumption
POP: Population Assumption
ELEC: Electricity Generation (TWh)
TFED: Total Final Energy Demand

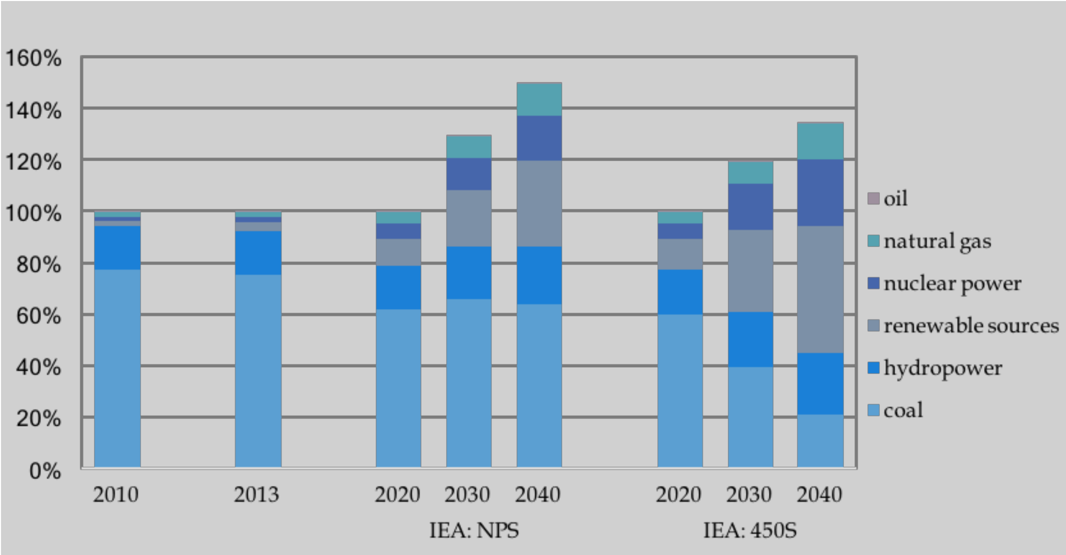
Similarly, in all scenarios, the IEA[141] predicts strong growth of gas, nuclear and renewables power to the Chinese generating mix. Figure 24 reflects the decarbonization in the electricity generation mix occurring from 2020, and therefore the increasing share of low-carbon sources in power generation, participating in decoupling electricity generation from power sector emissions. The latter is obviously more important in the 450 Scenario than in the New Policies one. Indeed, 50.8% of the electricity generation relies on fossil-fuel energies under the New Policies Scenario against only 26% under the 450 one by 2040. Moreover, the "variable renewables", such as wind power and solar power, represent 18.8% and 29.3% of the generated power by 2040 in respectively the New Policies Scenario and the 450 one. As a result China faces a decline in CO_2 emissions in both scenarios. Chinese CO_2 emissions will also peak in 2030 under the New Policies Scenario, due to a decreasing economic growth rate, while they peak before 2020 in the 450 Scenario and then decrease gradually by 2040.[142] This underlines view that in the future China will see a weakening of the relationship between global economic growth, energy demand and related CO_2 emissions.

The power generation mix in both scenarios is also a consequence of the China's carbon trading scheme for power due to come into force by the end of 2017.[143] Additionnaly, the 450 Scenario also incorporates the widespread use of carbon pricing instruments and therefore reflects a more binding price on CO_2 of $75 and $125 per tonne in 2030 and 2040 against a price of $23 and $35 per tonne for the same years in the New Policies Scenario.[144]

Finally, Figure 24 also stresses that, despite the progress to slow down the projected rise in global energy-related CO_2 emissions, those efforts are still insufficient to limit warming to 2°C, as reported by the 450 Scenario results.

140 Ibid.
141 Ibid.
142 Ibid.
143 Ibid.
144 Ibid.

Figure 24: China's Electricity Mix and its Projections[145,146]



For the purposes of evaluating risk exposure in this hypothesis, future electricity demand is considered over the period to 2020. The WEO's NPS scenario is chosen as a conservative outlook. *Table 17* shows the outlook for China in this report and comparator countries in previous reports[147,148].

Countries which have 0% projected electricity demand growth between 2013 and 2020 are considered 'high risk'. Countries with 1 or 2% growth are considered 'medium risk'. Countries with >2% growth are considered 'low risk'. China is considered 'low risk'.

Table 17: 2013-20 Compound Average Annual Growth Rate (CAAGR) in Future Electricity Demand

2013 - 2020	**China**	Other OECD Pacific	Japan	India	Other SE Asia	South Africa	EU	US
CAAGR[149]	**4%**	2%	0%	6%	4%	1%	0%	1%
Risk	(green)	(yellow)	(red)	(green)	(green)	(yellow)	(red)	(yellow)

NRH-2: Renewables Resource

The hypothesis is that the availability of renewable resources is a key determinant of the competiveness of renewables relative to conventional generation. Countries with larger renewable resources could see larger and faster rates of deployment. This would result in coal-fired power stations being more likely to face lower wholesale electricity prices and other forms of power sector disruption.

145 Ibid.
146 The World Bank, "World Development Indicators | World DataBank," 2016.
147 Caldecott et al., "Stranded Assets and Thermal Coal: An Analysis of Environment-Related Risk Exposure."
148 Caldecott et al., "Stranded Assets and Thermal Coal in Japan."
149 International Energy Agency, "World Energy Outlook," 2015.

China has an abundance of wind resources, however the available capacity normalised by China's total power consumption is not currently a threat to China's conventional generators. China has relatively abundant solar resources in the North and Southwest[150], and has had massive build-outs of solar PV generation (see NRH-6). However, nationwide China's solar irradiance does not meet standard thresholds for significant solar potential – but only just.

Table 18 shows the outlook for China in this report and comparator countries in previous reports[151,152]. Wind resource potential is drawn from Lu et al. (2009) and is normalised by 2015 total electricity generation. Solar resource potential is drawn from McKinsey & Company (2014) and SolarGIS (2016). Following analyses in these reports, where either solar resource exceeds 1400 kWh/kWP or wind resource exceeds ten times the annual electricity demand of the country, coal-fired power generation in the country is considered at 'medium risk' of displacement by renewables. Where both exceed these thresholds, coal-fired power is considered at 'high risk'.

Table 18: Renewables Resources

	China	Japan	Australia	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
Wind resource [TWh/TWh] [153,154]	**7.5**[155,156]	3.8	405.0[157]	6.5	4.4	3.3	22.0	31.7	29.8	20.5
Solar resource [kWh/kWP][158,159]	**1,300**	1,175	1,425	950	1,400	1,450	~950	1,500	875	1,250
RISK	● (green)	● (green)	● (red)	● (green)	● (yellow)	● (yellow)	● (yellow)	● (red)	● (yellow)	● (yellow)

NRH-3: Decline in Government Support for Coal-fired Power Stations

The hypothesis is that if existing subsidies for Chinese coal-fired power generation changed or are decreased, the profitably of some existing and new coal-fired capacity may be impaired or eroded entirely.

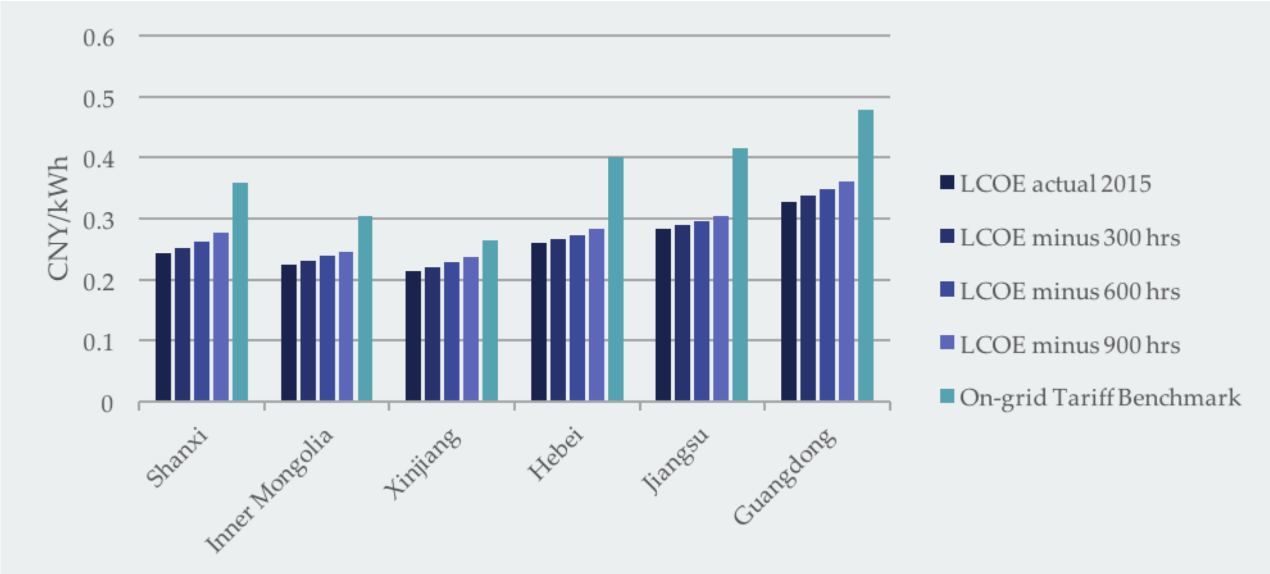
The potential of high rates of return from investments in Chinese coal-fired power generation have driven significant investment despite slowing demand growth for electricity, overcapacity of thermal generation capacity, and decreasing running hours of coal-fired power stations year-on-year. Marketization policies of the 13th five year plan pose material risks to the profitability of coal-fired power stations operating in an environment where there is overcapacity of thermal power generation, competition from renewables, and low demand growth. It is likely that such risks will materialise in the intermediate term, which is well within the payback period of existing and new coal-fired capacity.

The majority of China's coal fired generators operate under a system whereby power generators receive a power price based on provincial regulated benchmark prices. Power generators also have guaranteed run

150 "Map of Flat Plate Tilted at Latitute Resource of China," *International Maps - National Renewable Energy Laboratory*, 2016.
151 Caldecott et al., "Stranded Assets and Thermal Coal: An Analysis of Environment-Related Risk Exposure."
152 Caldecott et al., "Stranded Assets and Thermal Coal in Japan."
153 Xi Lu, Michael B McElroy, and Juha Kiviluoma, 'Global Potential for Wind-Generated Electricity', *Proceedings of the National Academy of Sciences* 106, no. 27 (2009): 10933–38.
154 BP plc, "BP Statistical Review of World Energy 2015," 2015.
155 BP plc, "BP Statistical Review of World Energy 2016," 2016.
156 Xi Lu, Michael B McElroy, and Juha Kiviluoma, 'Global Potential for Wind-Generated Electricity', *Proceedings of the National Academy of Sciences* 106, no. 27 (2009): 10933–38.
157 Although this figure is more than an order of magnitude larger than other countries investigate it is correct.
158 SolarGIS, "SolarGIS: Free Solar Radiation Maps Download Page," 2016.
159 David Frankel, Kenneth Ostrowski, and Dickon Pinner, "The Disruptive Potential of Solar Power," *McKinsey Quarterly* 4 (2014).

hours, which, combined with power prices, are designed to cover capital and operating costs, excluding costs of coal. This leaves coal price as the only real project risk.[160]

Figure 25: LCOE by utilisation hours[161]



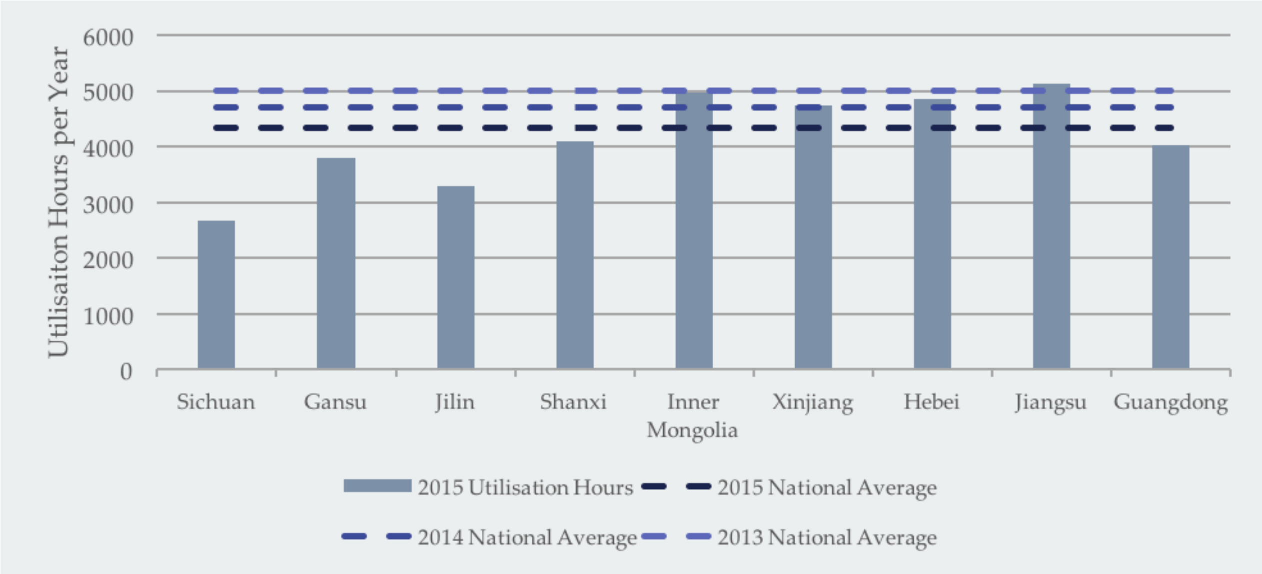
Note: 2015 utilisation hours: Shanxi 4100; Inner Mongolia 4979; Xinjang 4730; Hebei 4846; Jiangsu 5125; Guangdong 4028.

While benchmark prices are revised periodically, they are slow to react to commodity prices. The impact of this time delay is that return on investment coal-fired generators has been unduly high given the relatively low risk of the investment. As is demonstrated in Figure 25, based on 2015 running hours and provincial benchmark prices, excess returns are in the range of RMB .05-.08 per kWh.[162]

The impact of the potential of high returns is that it has driven continued investment in coal fired power generation in the face of overcapacity and slowing electricity growth. Installed capacity of thermal power generation increased from 48GW in 2014 to 72GW in 2015. This is despite electricity consumption growth slowing to just 0.5% in 2015, a marked decline from 2011 where growth was nearly 12%. Additionally, thermal power generation's share of the generation mix declined by 2.3% in 2015 because of a diversifying energy mix. These impacts can ultimately be seen in the decline of utilisation hours from 2013 to 2015.[163]

[160] International Institute for Sustainable Development, "Global Subsidies Initiative" (International Institute for Sustainable Development, 2016).
[161] Greenpeace, "Study on Economics of Coal-Fired Power Generation Projects in China."
[162] Ibid.
[163] Ibid.

Figure 26: Utilisation hours of China's coal-fired power stations[164,165]



Significant investment in Chinese coal-fired power generation continues today. While the Chinese National Energy Administration attempted to stop the permitting of building of new coal-fired capacity in March 2016, analysis suggests that this has failed, as there is still 227 GW of coal-fired power generation under construction.

This should be of significant concern to investors. China's system of provincially regulated benchmark prices is presently being unwound in favour of liberalising the consumption of power generation. Although considerable obstacles are recognised to full liberalisation,[166] the intent of the Chinese government is clear: regional energy trading platforms continue to be tested in increasing numbers and as of November 2015, over 300 well-capitalised energy retail businesses have been registered.[167]

Based on analysis by North China Electric Power University that stress tests Chinese coal-fired power generation with different electricity demand and benchmark price scenarios, it is reasonable to assume that even minor adjustments in benchmark prices may render many generators unprofitable.[168] A move towards a fully liberalised system of power generation in an environment of overcapacity, competition from renewables, and low demand growth my have truly catastrophic consequences for investors in coal fired power generation.

While investors may continue to see high returns on their investments in Chinese coal-fired power generation in the short term, it is likely that these investments will end up stranded in the intermediate term. The significant but non-imminent nature of this risk therefore warrants a 'medium' risk classification.

164 Global Risks Insight, "Under the Radar: Why China's Energy Deregulation Overshadows the Aramco IPO" (Global Risks Insight, 2016).
165 Greenpeace, "Study on Economics of Coal-Fired Power Generation Projects in China."
166 L. W. An Bo, "China's Market-Oriented Reforms in the Energy and Environmental Sectors" (Pacific Energy Summit, 2015).
167 Global Risks Insight, "Under the Radar: Why China's Energy Deregulation Overshadows the Aramco IPO."
168 Greenpeace, "Study on Economics of Coal-Fired Power Generation Projects in China."

Table 19: Decline of Government Support

Risk Level	Description	Evaluation
High	Imminent risks to investments at large scale	○
Medium	Either imminent risks to some investments or large scale risks that are not imminent	●
Low	Risks neither imminent nor large scale	○

NRH-4: Renewables Policy Support

This hypothesis examines the Chinese government's policy support for renewable power generation. The hypothesis is that countries with robust regimes for supporting renewables will see greater renewables deployment. This would result in coal-fired power stations being more likely to face lower wholesale electricity prices and other forms of power sector disruption. This hypothesis also captures the overlap of climate policy with renewable energy policy support.

The Chinese government is using every policy mechanism available to drive the uptake of renewable energy including national- and provincial-level targets, feed-in-tariffs and net metering, renewable postfolio standards, carbon markets, and government tendering, subsidies, and tax credits. These diverse policy mechanisms and any recent developments will be discussed here.

Renewable Energy Targets

The transition to renewable energy has played a large role in China's planning in both the 12th Five Year Plan and the 13th Five Year Plan. By 2020, the Chinese government plans for non-fossil energy to account for 15% of all energy consumption, a figure to increase to 20% by 2030.[169] The Chinese government has also articulated plans for the deployment of renewable generating capacity by technology, see NRH-6. The national government of China has stipulated renewables deployment targets for the 31 provinces of China, autonomous regions, and several large municipalities in order to meet their national targets. The non-fossil-fuel, non-hydro renewables integration targets for the regions range from 5 to 13% and are shown in Table 20.[170]

Table 20: Regional breakdown of non-hydro renewables targets

Region		Region		Region		Region	
Anhui	7%	Hainan	10%	Jiangxi	5%	Shanxi	10%
Beijing	10%	Hebei	10%	Jinan	13%	Sichuan	5%
Chongqing	5%	Heilongjiang	13%	Liaoning	13%	Tianjin	10%
Fujian	7%	Henan	7%	Ningxia	13%	Tibet	13%
Gansu	13%	Hubei	7%	Qinghai	10%	Xinjiang	13%
Guangdong	7%	Hunan	7%	Shaanxi	10%	Yunnan	10%
Guangxi	5%	Inner Mongolia	13%	Shandong	10%	Zhejiang	7%
Guizhou	5%	Jiangsu	7%	Shanghai	5%	**Total**	**9%**

The most recent targets for renewable generating capacity have generated some concern by environmental groups. Recent reports indicate a scaling-back of ambition on renewables targets and an increase in the coal capacity cap. The NEA's published target remains 160 GW solar, 250 GW wind, and 380 GW hydropower in 2020,[171] however these reports[172,173] indicate that these targets have dropped to 110 GW of

[169] The State Council The People's Republic of China, "China Sets Targets for Local and Renewable Energy Use," *English.Gov.CN*, 2016.
[170] Wang Cheng, "China Announces Renewables Quota, but Is It Enough?," *CNESA*, 2016.
[171] National Energy Adminstration, "China Leads the World in Renewable Energy," 2016.Na
[172] Bloomberg News, "China Scales Back Wind, Solar Ambitions as Renewables Boom Cools," *Bloomberg*, 2016.

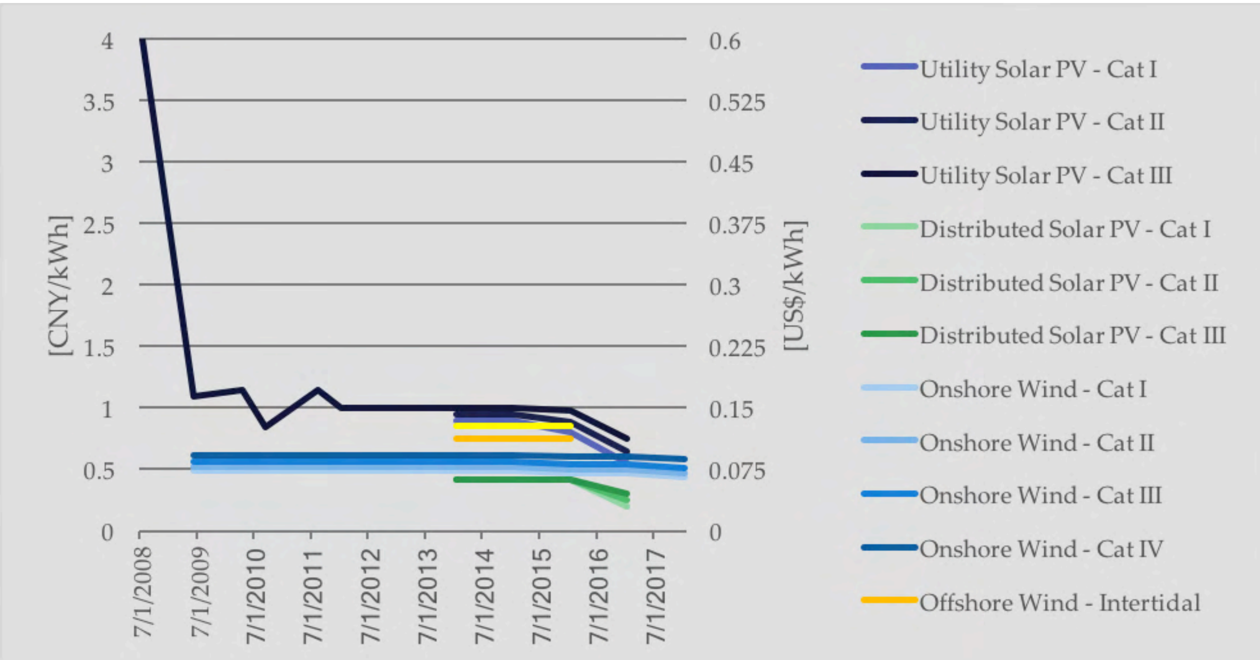
solar PV capacity, 210 GW of wind capacity, and 340 GW of hydro power. The coal power capacity cap has meanwhile increased from 960 GW to 1100 GW. These renewables generating capacity targets remain well above the historic targets of 110 GW of solar capacity and 210 GW wind which were established in an initial outline of China's 13th Five Year Plan[174] however ambitions for hydro power, which were 350 GW by 2020 in the same policy, have been further downsized.

Feed-in-Tariffs and Net Metering

China's growth in renewable energy deployment has been in-part driven by feed-in-tariffs for solar and wind power. Feed-in-tariffs were first introduced in the late-2000s and have enjoyed a period of relative stability enabling the development of a robust renewables deployment industry. More recently , decreases in the feed-in-tariff for PV have been announced as part of a shift from targetting large utility-scale solar PV installations to distributed and even residential-scale installation.[175] Chinese provinces and municipalities may give additional feed-in-tariffs on top of the national prescribed rates to support local development of renewables and meet local renewables targets.[176]

Figure 27 shows how China's feed-in-tariffs have changed over time. China's national feed-in-tariffs are segmented by category according to the availability of renewables resource in the region. Generally, the lower the category, the less renewables resource of that type (i.e. solar irradiance or wind energy) is available, and the feed-in-tariff is commensurably higher. China's newest feed-in-tariffs also contain provisions for net metering. This is discussed more in NRH-5 below.

Figure 27: China Feed-in-Tariffs[177,178,179,180]



[173] Meng Meng, Henning Gloystein, and Josephine Mason, "China to Cap Coal at 55 Percent of Total Output by 2020: NEA," *Reuters*, 2016.
[174] Du Juan, "New 5-Year Plan to Raise Goals for Renewable Energy," *ChinaDaily*, 2014.
[175] Frank Haugwitz, "China's Distributed Solar PV Ambitions - Policies and Challenges," 2015.
[176] E.g. "China Introduces Offshore Wind Feed-in-Tariffs," *Global Wind Energy Council*, 2014.
[177] Solar – past: Haugwitz, "China's Distributed Solar PV Ambitions - Policies and Challenges."
[178] Solar – future: Mark Osborne, "China's NEA Proposes Significant Solar Feed-in-Tariff Cuts for 2017," *PV-Tech*, 2016.
[179] Wind – onshore: Yang Jianxiang, "China Reduces FITs over Two-Year Period," *Wind Power Monthly*, 2016.
[180] Wind – offshore: "China Introduces Offshore Wind Feed-in-Tariffs."

Renewable Portfolio Standards

In early 2016 utility companies in China were been advised that they will be expected to have 9% non-fossil, non-hydro electricity by 2020.[181] The design of China's renewable portfolio standard policy is similar to the policies in the US and the EU. Companies will be expected to purchase and surrender an increasing number of renewable energy certificates demonstrating they meet state goals for renewable generation.

China currently has a general oversupply of electricity,[182] practices substantial idling of on-grid renewables capacity,[183] and has a large amount of renewables capacity awaiting grid connection.[184] While renewables are supposed to receive priority dispatch both in managed grids and marginal-cost dispatch, in practise many are idled in favour of incumbent fossil and nuclear generators.[185] New renewable portfolio standards will incentivise grid connection and dispatch of existing capacity and will encourage investment in new capacity.

Climate Policy and Carbon Markets

In November 2014, the United States and China released a joint statement concerning their emissions reduction goals.[186] After bilateral discussions, the Chinese and United States governments hosted a joint press conference wherein both unveiled their plans to combat climate change. China commited to deploying up to 1000 GW of new zero-emission generating capacity by 2030, also capping total emissions in the same year – the first climate policy from China to include a plan for total emissions. The announcement of the two largest greenhouse gas emitting countries gave substantial momentum towards developing a strong agreement at COP21.

China ratified the Paris Agreement in Septemeber 2016. China's Nationally Determined Contribution (NDC) largely enacted the agreement bilaterally negotiated with the United States. China's NDC commited to greenhouse gas emissions peaking in 2030, improvement of the carbon intensity of China's economy, and afforestation targets.[187] The NDC also includes the renewable energy target of 20% non-fossil energy by 2030.

China's National Development and Reform Commission has been running pilot carbon markets since 2013 in seven regions: Beijing, Tianjin, Shanghai, Chongqing, Shenzhen, Hubei Province, and Guangdong Province. The NDRC is now preparing to launch a national cap and trade programme, expected to launch in 2017.[188] A national carbon market in China will exceed the size and scope of the EU ETS and will almost double the global coverage of carbon emissions by some form of tax or trading scheme.[189]

This summary of China's renewable energy targets, feed-in-tariffs, renewable portfolio standards, and climate policy and carbon markets is far from an exhaustive or detailed list of renewables policies in China. As a summary however, this evidence indicates a robust and stable policy environment that supports a transition towards renewable energy. In order for this hypothesis to produce comparable, testable results across multiple countries, a consistent measure must be used to evaluate renewables policy support. EY's Renewable Energy Attractiveness Indicator (RECAI) provides a country-specific measure of renewables support. This measure is also useful in that it allows peer comparison of what constitutes 'strong' policy support. The NRH has been updated from previous Stranded Assets and Thermal Coal publications[190,191]

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[181] The State Council The People's Republic of China, "China Sets Targets for Local and Renewable Energy Use."
[182] Brian Spegele, "China's Coal-Plant Binge Deepens Overcapacity Woes," *Wallstreet Journal*, 2016.
[183] Bloomberg News, "China Scales Back Wind, Solar Ambitions as Renewables Boom Cools."
[184] E.g. Joshua S. Hill, "China Installed 18.6 GW of Solar PV in 2015, but Was All of It Connected?," *Cleantechnica*, 2016.
[185] Sue-Lin Wong and Charlie Zhu, "Chinese Wind Earnings under Pressure with Fifth of Farms Idle," *Reuters*, 2015.
[186] Lenore Taylor and Tania Branigan, "US and China Strike Deal on Carbon Cuts in Push for Global Climate Change Pact," *The Guardian*, 2014.
[187] climateactiontracker.org, "China," *Climate Action Tracker*, 2016.
[188] John Chung-En Liu, "Assembling China's Carbon Markets" (Ash Center for Democratic Governance and Innovation, Harvard Kennedy School, 2016).
[189] World Bank Group and Ecofys, "Carbon Pricing Watch 2016" (Ecofys, 2016).
[190] Caldecott et al., "Stranded Assets and Thermal Coal: An Analysis of Environment-Related Risk Exposure."

using EY's October 2016 publication[192] of renewable energy attractiveness. The top 20 globally attractive countries are considered at least 'medium risk' to coal-fired power utility companies. The top 10 globally attractive countries are considered 'high risk'. Relative to these previous reports, Japan has fallen in risk and South Africa has increased in risk. China, ranked second in the world for renewables investment, carries significant risk.

Table 21: Renewables policy support[193]

	China	Australia	Japan	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
EY: RECAI Rank	2	11	12	5	>40	3	36	9	14	1
RISK	Red	Yellow	Yellow	Red	Green	Red	Green	Red	Yellow	Red

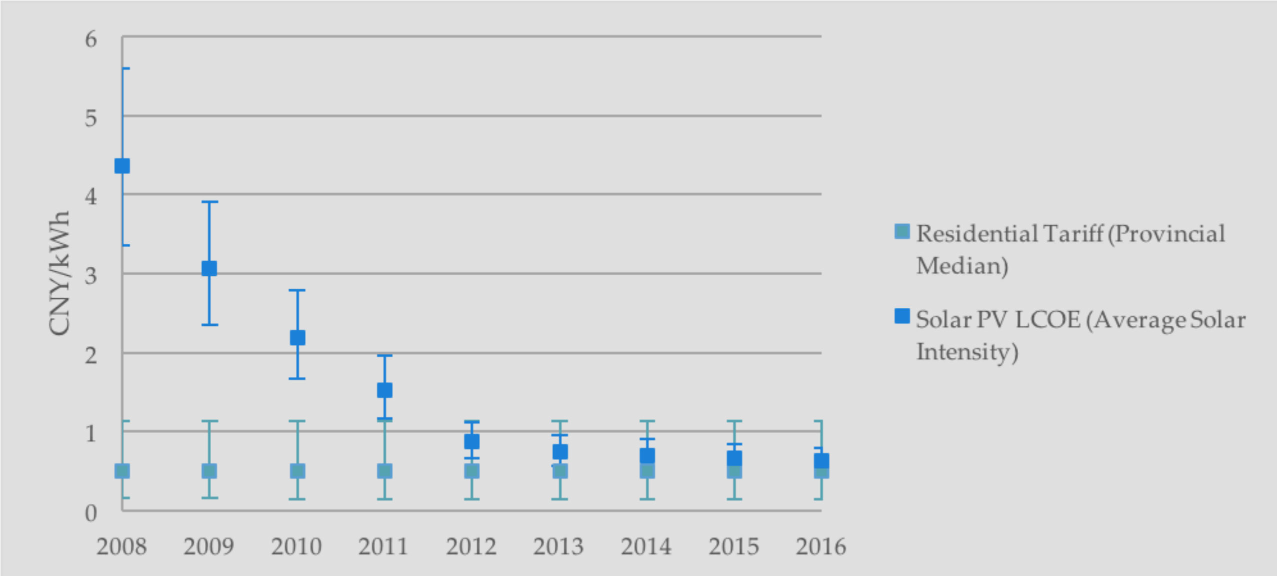
NRH-5: Growth of Decentralised Renewables and the Utility Death Spiral

NRH-5 and NRH-6 examine the growth of renewables in China's power supply. The hypotheses are separated under the consideration that the growth of decentralised renewables might affect coal-fired power differently from centralised renewables. The growth of decentralised renewables may lead to a 'utility death spiral' and the rapid, unforeseen eroision of a coal-fired utility's business model.

The 'utility death spiral' is the disruption to conventional power utility companies as a result of a virtuous cycle of distributed energy resources (e.g. rooftop solar PV) eroding the distribution network business model of the central utility, which in turn raises retail electricity prices making distributed energy resources even more competitive.[194] Figure 28 shows the levelised cost of electricity (LCOE) for PV in China and the range of residential electricity tariffs. The intersection of these two prices – where self-generated PV electricity becomes as cheap as grid power, i.e. grid parity – is one of the tipping points of the utility death spiral. For solar-rich areas of the county, this appears to have begun occuring in 2012. As the price of solar PV has fallen, parity appears to be becoming more common across the less solar-rich areas of the country.

[191] Caldecott et al., "Stranded Assets and Thermal Coal in Japan."
[192] EY, "Renewable Energy Country Attractiveness Index," 2016.
[193] Ibid.
[194] Matthew Gray, "Coal: Caught in the EU Utility Death Spiral," *Carbon Tracker. Http://www. Carbontracker. Org/wp-content/uploads/2015/06/CTI-EU-Utilities-Report-v6-080615. Pdf*, 2015; Elisabeth Graffy and Steven Kihm, "Does Disruptive Competition Mean a Death Spiral for Electric Utilities," *Energy LJ* 35 (2014): 1; Kenneth W Costello and Ross C Hemphill, "Electric Utilities' 'Death Spiral': Hyperbole or Reality?," *The Electricity Journal* 27, no. 10 (December 2014): 7–26, doi:http://dx.doi.org/10.1016/j.tej.2014.09.011.

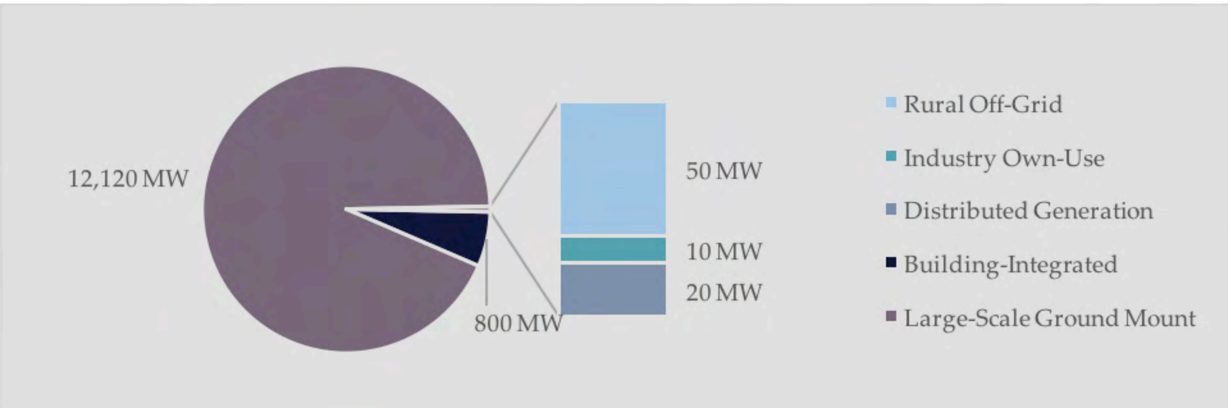
Figure 28: LCOE of Solar PV and Residential Electricity Tariff[195,196,197,198]



i. Oxford Smith School calculations assume 20 year operating life and 10% discount factor
ii. Error bars show maximum and minimum provincial tariffs and solar intensity category respectively
iii. 2012-2016 residential tariff data projected from 2008-2011. 2014 and 2015 LCOE data interpolated.

In spite of the approaching grid parity, decentralised renewables have not yet seen the same tremendous growth as centralised utility-scale renewables. Shown in Figure 29**Error! Reference source not found.**, over 93% of all solar PV capacity additions in 2013 were large-scale ground-mounted installations. To promote the development of decentralised solar PV, the government has introduced new feed-in-tariffs that specifically target distributed generation; planned for the deployment of at least 30 micro-grid sites by 2020; and developed a poverty alleviation scheme that specifically leverages distributed generation.

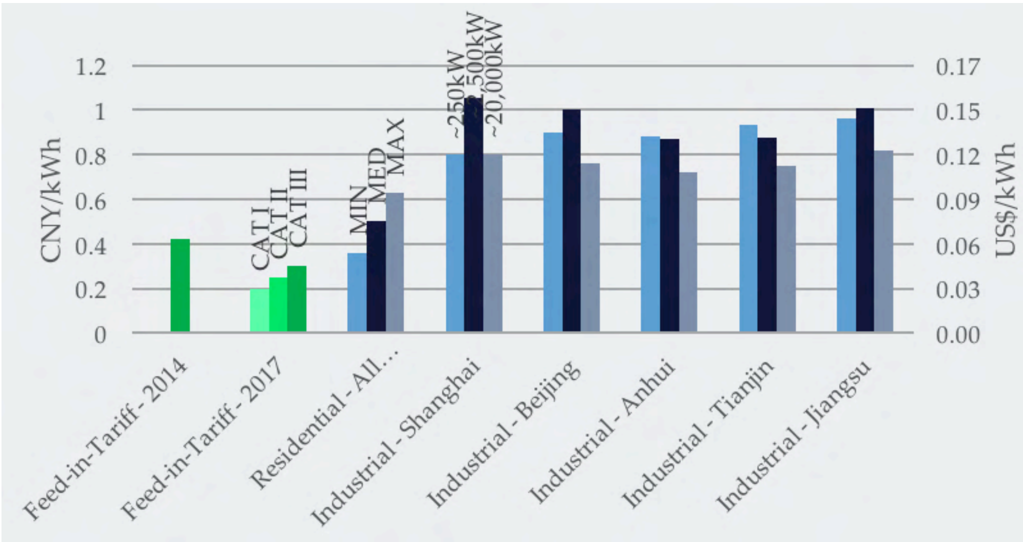
Figure 29: Annual solar PV capacity additions 2013[199]



[195] China Energy Group, "Key China Energy Statistics" (Lawrence Berkley National Laboratory, 2014).
[196] Martin Schachinger, "pvXchange Module Price Index November 2016," *Pv Magazine*, 2016.
[197] Feifei Shen, "China's Solar Prices Can Fall 38%, Become Competitive with Coal," *Bloomberg*, 2016.
[198] Mei Liao et al., "Distributed Photovoltaic Generation Systems in China: An Environmental Cost-Benefit Analysis with Social-Techno-Economic Approach" (Economics & Management School,Beijing University of Technology, 2014).
[199] Lv Fang, Xu Honghua, and Wang Sicheng, "National Survey Report of PV Power Applications in China 2013" (IEA PVPS, 2014).

The new distributed solar feed in tariff, introduced in 2014, aims to directly incentivise distributed solar PV generation. Figure 30 compares the feed-in-tariff with residential electricity prices of the various provinces and industrial rates in select regions by size of connection. It is important to note that the feed-in-tariff rate is given 'behind the meter' – that is, a prosumer consumes their own generated power first, giving an effective rate of the feed-in-tariff *plus* the local rate for electricity. Projects receiving this feed-in-tariff must be installed on rooftops, structures, or otherwise non-arable land.[200]

Figure 30: Comparison of feed-in-tariffs and electricity rates[201,202,203]



The Chinese Government is also planning on building 30 to 50 micro-grid projects by 2020. These projects must use a high (>50%) portion of renewables and be macro-grid friendly – whether by islanding certain loads entirely or providing flexibility with flexible generation and energy storage.[204] The Government has also set a target for concentrated solar thermal power – targetting 1.35 GW by 2018.[205]

In October 2016, China's National Energy Administration released the results of its first round of solar PV poverty alleviation projects. These projects are specifically designed to supply low-income areas with solar PV power to reduce energy poverty and to stimulate the local economy with the creation of solar PV and grid distribution jobs. Solar PV projects totalling 5.16 GW were announced in 14 provinces, 42% of which were distributed generation projects.[206]

While current progress hasn't favoured distributed generation, China's renewables policy direction in the 13th five year plan has clearly shifted towards favouring distributed solar PV generation. The extent to which this policy will be successful, and further will lead to a utility death spiral, are so far unclear. In previous *Stranded Assets and Thermal Coal* reports we assessed that China was at no risk of a utility death spiral. In this report we increase the risk level to 'medium' based on emerging evidence and the direction of policy, see Table 22.

[200] Haugwitz, "China's Distributed Solar PV Ambitions - Policies and Challenges."
[201] Osborne, "China's NEA Proposes Significant Solar Feed-in-Tariff Cuts for 2017."
[202] China Energy Group, "Key China Energy Statistics."
[203] Tim Comerford et al., "A Comparison of US and China Electrcity Costs" (BLS & Co. Ltd, Tractus Asia Limited, 2016).
[204] Haugwitz, "China's Distributed Solar PV Ambitions - Policies and Challenges."
[205] National Energy Adminstration, "首批 20 个太阳能热发电示范项目确定 总计装机容量 134.9 万千瓦," 2016.
[206] "China Releases First PV Poverty Alleviation Project List, Totals 5.16GW," *EnergyTrend*, 2016.

Table 22: Countries showing evidence of the utility death spiral [207]

Country	Reference	RISK
China	Low evidence of the utility death spiral	
Japan	Strong evidence of the utility death spiral	
Australia	Strong evidence of the utility death spiral	
Germany	Strong evidence of the utility death spiral	
Indonesia	No evidence of the utility death spiral	
India	No evidence of the utility death spiral	
Poland	No evidence of the utility death spiral	
South Africa	No evidence of the utility death spiral	
United Kingdom	Low evidence of the utility death spiral	
United States	Strong evidence of the utility death spiral	

NRH-6: Growth of Utility-Scale Renewables

The hypothesis is that rapid renewables deployment would result in coal-fired power stations being more likely to face lower wholesale electricity prices and other forms of power sector disruption. As explained in NRHs -4 and -5, the Chinese government has provided strong and consistent policy support for renewables deplotyment and almost all renewables deployed in China have been utility-scale. In only a few years, China has become the world leader in renewables deployment and generation. This section examines growth rates for wind and solar generating capacity and the amount of renewables generation as a portion of total generation. Table 23 first summarises growth to date and deployment targets for 2020.

Table 23: Renewables Deployment – Historic and Targets

	Historic			Targets		Growth Rates (CAAGR)		
Generating Technology	2000[208]	2010[209]	2015[210]	2020 Initial[211]	2020 Revised[212]	Historic 2010-2015	Initial Target 2015-2020	Revised Target 2015-2020
Solar PV	<1 GW	1 GW	43 GW	160 GW	110 GW	112%	30%	21%
Wind	<1 GW	45 GW	145 GW	250 GW	210 GW	26%	12%	8%
Hydropower	79 GW	213 GW	320 GW	380 GW	340 GW	8%	3%	1%
Nuclear	2 GW	11 GW	26 GW	58 GW	58 GW	19%	17%	17%
Coal[213]	212 GW	671 GW	920 GW	960 GW	1100 GW	7%	1%	4%
Gas	7 GW	35 GW	70 GW	110 GW	110 GW	15%	9%	9%

Since 2000, the growth of China's economy has driven massive increases in China's generating capacity. Until recently, this new demand was met almost exclusively by coal and hydropower. Since 2010, China has embarked on a coordinated effort to build renewable generating capacity, as well as nuclear and gas capacity to a lesser extent. These new options threaten the primacy of coal in the generating mix and of the companies who generate coal-fired power.

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207 For references for comparator countries, see Caldecott et al., "Stranded Assets and Thermal Coal in Japan"; Caldecott et al., "Stranded Assets and Thermal Coal: An Analysis of Environment-Related Risk Exposure."

208 International Energy Agency, "World Energy Investment Outlook," *International Energy Agency, Paris, France* 23 (2003): 329, doi:10.1049/ep.1977.0180.

209 International Energy Agency, "World Energy Outlook," 2012.

210 World Nuclear Association, "Nuclear Power in China," *World Nuclear Association - Country Profiles*, 2016.

211 National Energy Adminstration, "China Leads the World in Renewable Energy."

212 Bloomberg News, "China Scales Back Wind, Solar Ambitions as Renewables Boom Cools."

213 Meng, Gloystein, and Mason, "China to Cap Coal at 55 Percent of Total Output by 2020: NEA."

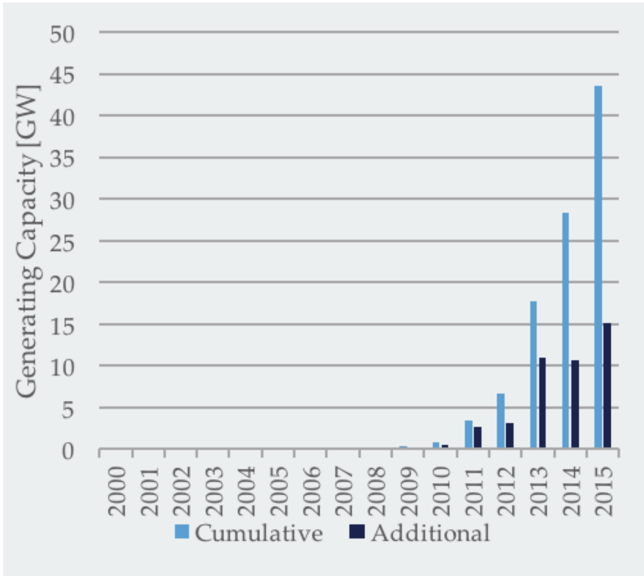
The NEA's published target still calls for 160 GW of solar PV, 250 GW of wind, and 380 GW of hydropower by 2020.[214] Revision announcements since have signalled decreased ambition for solar PV, wind, and hydropower and an increase in the cap on coal-fired power.[215,216]

Solar PV

In the last five years, the installed price per peak watt of solar PV has fallen by a factor of almost 7. In the same period, the installed capacity has increased by a factor of over 50. Almost all the new capacity has been ground-mounted and utility scale, see NRH-5. Figure 31 shows the precipitous decline of China's solar PV prices, and Figure 32 shows the increase in solar PV generating capacity.

Figure 31: Solar PV module and system prices[217,218]

Figure 32: China Solar PV Capacity[219]

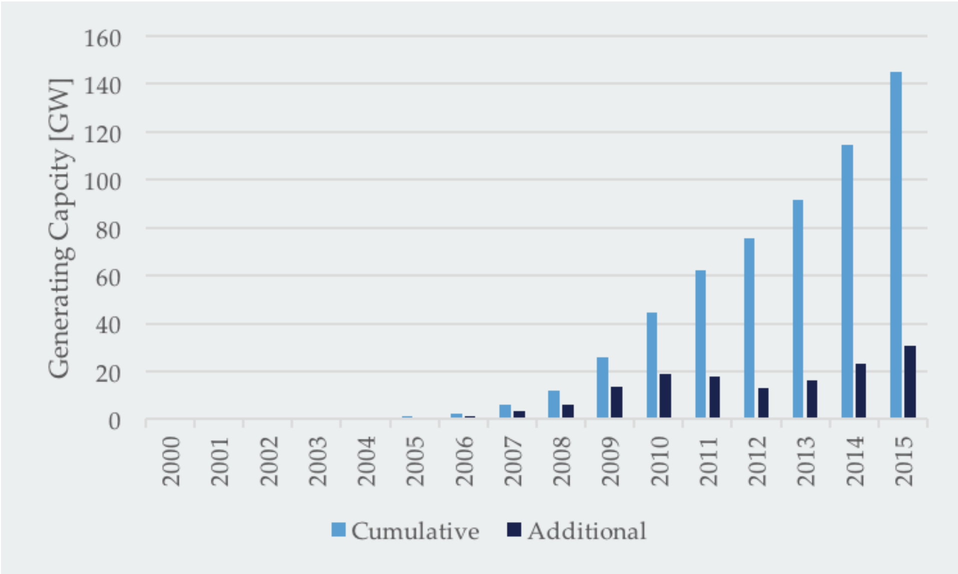


Wind

China has undergone a boom in wind power in the last 10 years. China's northern provinces are rich in wind resources and are relatively close to population centres.[220] Many of China's wind farms are either not yet grid connected or are curtailed by grid operators, and so pose less of a threat to incumbent coal generators.[221] This is captured by the second metric of this hypothesis which examines the growth in portion of renewables generation.

214 National Energy Adminstration, "China Leads the World in Renewable Energy."
215 Bloomberg News, "China Scales Back Wind, Solar Ambitions as Renewables Boom Cools."
216 Meng, Gloystein, and Mason, "China to Cap Coal at 55 Percent of Total Output by 2020: NEA."
217 Schachinger, "pvXchange Module Price Index November 2016."
218 Shen, "China's Solar Prices Can Fall 38%, Become Competitive with Coal."
219 BP plc, "BP Statistical Review of World Energy 2016."
220 *The Power of Renewables: Opportunities and Challenges for China and the United States* (The National Academies Press, 2010).
221 Liu Yuanyuan, "Wind Power Curtailment in China Expected to Increase in Second Half of 2016," *Renewable Energy World*, 2016.

Figure 33: Cumulative and Installed Wind Capacity in China (2000-15)[222]



Hydroelectric and Bioenergy

While the primary growth in renewables has been in solar PV and wind power, this hypothesis also considers growth in hydropower and other renewables like bioenergy. Since 2010, hydropower generating capacity has increased to 320 GW, up from 213 GW in 2010.[223] Approximately 10 GW of bioenergy generating capacity are now also available, up from 6 GW in 2010.[224,225]

Risk Hypothesis

This hypothesis uses the growth in installed renewables capacity (GW) and the growth in the proportion of renewable power generation to estimate risk exposure to year-on-year renewables growth. This hypothesis therefore captures both the absolute growth in generating capacity and its growth relative to total electricity demand growth, its utilisation and connectivity, and a number of other factors. As almost all renewables in China are utility-scale, renewables generation as a portion of total generation is taken from *BP Statistical Review of World Energy 2016.*[226] Where the CAGR in renewable power generation as a portion of total generation exceeds 10%, and where CAGR in renewable power capacity exceeds 10%, the country is considered 'high risk'. Where only one exceeds 10%, the country is 'medium risk'. Table 33 and Table 34 shows the risk assessment for China's utilities and the risk assessments of comparator countries from *Stranded Assets and Thermal Coal: An analysis of environment-related risks.*

Stranded Assets and Thermal Coal: An analysis of environment-related risks[227] considered all renewables collectively and did not separate them into utility-scale and distributed. These comparator countries are shown in Table 47. *Stranded Assets and Thermal Coal in Japan*[228] also broke out renewables by utility scale versus distributed scale – and therefore is also available as a comparator country for this risk hypothesis in Table 24.

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[222] BP plc, "BP Statistical Review of World Energy 2016."
[223] World Nuclear Association, "Nuclear Power in China."
[224] International Energy Agency, "World Energy Outlook," 2016.
[225] International Energy Agency, "World Energy Outlook," 2012.
[226] BP plc, "BP Statistical Review of World Energy 2016."
[227] Caldecott et al., "Stranded Assets and Thermal Coal: An Analysis of Environment-Related Risk Exposure."
[228] Caldecott et al., "Stranded Assets and Thermal Coal in Japan."

Table 24: Year-on-Year growth of utility-scale renewables capacity and generation

2010 - 2015 CAGR	China	Japan
Utility-Scale Renewables Capacity	**14.3%**	**2%**
Utility-Scale Renewables Generation	**5.1%**	**1.3%**
RISK	Yellow	Green

Table 25: Year-on-Year growth of all renewables capacity and generation

2010 - 2014 CAGR	Australia	Japan	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
All Renewables Capacity	11%	13%	14%	2%	7%	15%	14%	23%	8%
All Renewables Generation	8%	6%	12%	-8%	1%	16%	25%	30%	7%
RISK	Yellow	Yellow	Red	Green	Green	Red	Red	Red	Green

NRH-7: Gas Reserves and Production Growth

The hypothesis is that the growth of gas-fired generation, particularly in markets where electricity demand growth is low or negative, could harm the economics of coal-fired generation and result in coal-to-gas switching. Gas-fired generation is more likely to be competitive in countries where there are large domestic reserves and growing domestic gas production.

Gas can compete directly with coal in the supply of dispatchable, baseload electricity. Gas-fired electricity also has the advantage of being less carbon intensive and more efficient than coal-fired power. We examine data on proven natural gas reserves and the growth in gas production drawn from the BP Statistical Energy Review 2016[229]. Coal-fired utilities are more at risk in countries which have large reserves of gas and growing gas production. Countries which have either >1% of global reserves or a CAAGR in gas production of >0% are considered 'medium risk'. Countries with both are considered 'high risk'. Table 26 shows the outlook for China in this report and comparator countries in previous reports.[230,231]

Table 26: Natural Gas Reserves and Production Growth

	China		Australia	Japan	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
Natural gas reserves[232]	2.1%	Natural gas reserves[233]	2%	0%	0%	1.5%	0.8%	0.1%	0%	0.1%	5.2%
Production growth (2011-15	6.08%	Production growth (2010-14	5%	N/A	-8%	-4%	-11%	0%	N/A	-11%	5%

[229] BP plc, "BP Statistical Review of World Energy 2016."
[230] Caldecott et al., "Stranded Assets and Thermal Coal: An Analysis of Environment-Related Risk Exposure."
[231] Caldecott et al., "Stranded Assets and Thermal Coal in Japan."
[232] BP plc, "BP Statistical Review of World Energy 2016."
[233] BP plc, "BP Statistical Review of World Energy 2015."

CAAGR) [234]		CAAGR) [235]									
RISK	🔴	RISK	🔴	🟢	🟢	🟡	🟢	🟢	🟢	🟢	🔴

NRH-8: Growth of Gas-Fired Generation

The hypothesis is that the growth of gas-fired generation, particularly in markets where electricity demand growth is lower or negative, could harm the economics of coal-fired generation and result in coal-to-gas switching.

While the growth of renewables is expected to displace power from carbon-based fuels, it is likely that coal rather than gas-fired generating stations will be first affected, see NRH-1. The IEA WEO is chosen as a central, conservative, and comparable scenario for use in this hypothesis. If either historic or projected CAAGR of gas-fired power generation is positive, then the outlook for coal-fired power in that country is considered 'medium risk'. If both are positive, then the outlook is considered 'high risk'. Table 27 shows the outlook for China in this report (high risk) and comparator countries in previous reports[236,237].

Table 27: Natural gas-fired power generation outlook

CAAGR	**China**	Australia	Japan	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
2010-13 Historic[238]	10%	11%	10%	-13%	2%	-18%	-13%	N/A	-13%	4%
2013-20 NPS[239]	17%	0%	-4%	0%	2%	6%	0%		0%	2%
RISK	🔴	🟡	🟡	🟢	🔴	🟡	🟢	🟢	🟢	🔴

NRH-9: Falling Utilisation Rates

The hypothesis is that under-utilised coal-fired power stations will be financially vulnerable and more prone to stranding. The entrance of new generating options may reduce the utilisation rates of coal-fired generating assets. The utilisation rate of a power generating asset is the ratio of its actual annual output to its maximum potential annual output according to its nameplate capacity. Competition on marginal costs, or must-run regulation for renewables, can displace coal-fired generation, reducing utilisation rates. Generating stations with falling utilisation rates are less able to cover fixed costs with operating profit.

Thermal power utilisation rates in China are at low levels and declining due to the construction of excessive generation capacity: particularly coal-fired. Last year thermal power utilisation rates fell to just 49.4%, and in the first 5 months of 2016 was only 44.8%[240], which represents their lowest level since 1969 – due to China's chaotic Cultural Revolution (1966-1976).[241] To combat these low utilisation rates, in October 2016 China has taken the unprecendented step of halting the construction of 30 coal fired plants which had already been financed and had begun construction until at least 2019/2020.[242] However, capacity is still slated to increase substantially over this period. Combined with stagnant demand, utilisation rates should remain at historically low levels in the short and medium terms.

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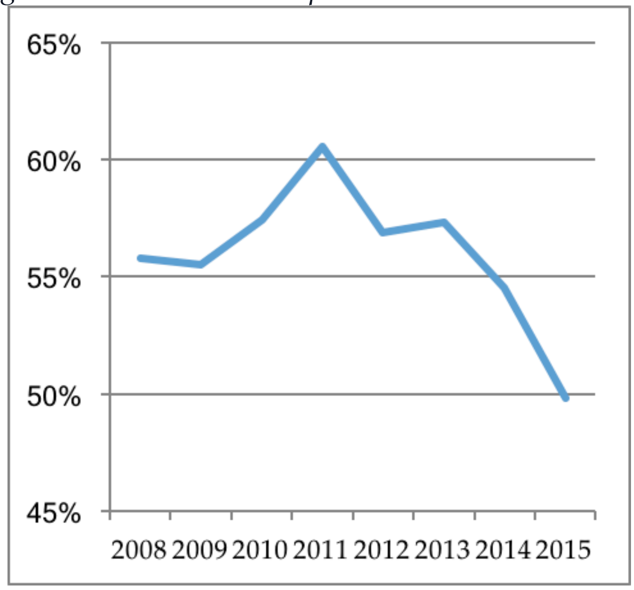
234 BP plc, "BP Statistical Review of World Energy 2016."
235 BP plc, "BP Statistical Review of World Energy 2015."
236 Caldecott et al., "Stranded Assets and Thermal Coal: An Analysis of Environment-Related Risk Exposure."
237 Caldecott et al., "Stranded Assets and Thermal Coal in Japan."
238 Harding, "Renewable Energy Poses Challenge for Tokyo."
239 International Energy Agency, "World Energy Outlook," 2015.
240 Reuters, "China Building 200 GW of Coal-Fired Power despite Capacity Glut: Greenpeace."
241 Greenpeace, "Study on Economics of Coal-Fired Power Generation Projects in China."
242 Johnson, "China Axes Part-Built Coal Power Plants."

Figure 34: China thermal power utilization rates



Source: China Electricity Council[243]

Following the methodology of *Stranded Assets and Thermal Coal,* in countries where historic utilisation rates have been decreasing, we find them to be 'at risk'. We combine this with research on future utilisation rates. If they are expected to decrease, this is also 'at risk'. If both are 'at risk' then we assign a 'high risk' opinion. If only one is, then we assign a 'medium risk' opinion.

China's historic utilisation rate has been decreasing, indicating high risk exposure. Moreover, we find the future utilisation rate of China's coal-fired power stations to be also 'at risk' of falling in the future. Combined, these two perspectives give a 'high risk' evaluation. Table 36 shows the risk hypotheses of China and the comparator countries from *Stranded Assets and Thermal Coal.*

Table 28: Utilisation rate risk hypothesis

	China	Australia	Japan	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
Utilisation rate - Historic	Yellow	Green	Green	Green	Yellow	Yellow	Green	Yellow	Green	Green
Utilisation rate - Outlook	Yellow	Yellow	Yellow	Green	Green	Yellow	Yellow	Yellow	Yellow	Yellow
RISK	Red	Yellow	Yellow	Green	Yellow	Red	Yellow	Red	Yellow	Yellow

NRH-10: Water Regulatory Risk

The hypothesis is that coal-fired power stations in countries that have strict water use requirements and an awareness of water issues are more likely to be affected by changes to water pricing or regulation.

Coal-fired power generation has a substantial water footprint.[244] This water footprint exposes coal-fired power utilities to regulatory risks, as policymakers may take action to restrict or price a utility's access to

[243] China Electricity Council, "Thermal Power Utilization Rates."
[244] See LRH-4: Water Risks in Section 2.2.1 above.

water. Public opinion on the water footprint of power generation may also put pressure on policymakers to restrict water use, exposing utilities to a reputational risk as well. Water risks are affected by policy in two primary ways. First, water-use hierarchies that give residential or agricultural water use precedence over industrial use might worsen impacts of physical scarcity on power generation. Second, areas with high water stress and low industrial water pricing are more vulnerable to price policy changes.

China faces severe water scarcity and quality challenges. China's massive coal bases are being built in areas of high water stress (see Section 2.2.1). A recent PNAS study founds that water is being exported from these areas both physically and virtually in the embedded water of products made in these areas[245]. Established seniority of water rights in China is as follows; (1) domestic, (2) agricultural, (3) industrial (including power generation), (4) the environment, and (5) shipping and navigation.[246] Therefore in the event of a shortage power users will be required to subordinate their needs to domestic and agricultural users. However, power plants in the dry northern regions may have dedicated water supplies via groundwater tapped from wells, although it has been forbidden to drill these since 2004.[247]

In 2010 the State Council issued a policy intention to establish 'three red lines'; standards for water use efficiency, minimum water quality, and total aggregate use[248]. After efficiency targets in consecutive FYPs, and the world's largest river diversion project[249], Chinese urban water prices were substantially reformed in 2014 – for execution by the end of 2015. In January 2014, the Ministry of Water Resources (MWR) issued a guidance for water reform which indicated that water pricing would move towards a market mechanism[250]. A month earlier, the MWR announced a plan which would not allow the development of large coal bases to threaten water resource availability.[251] China may face difficult policy decisions as mounting water stress threatens the productivity of thermal generation.

The World Resources Institute (WRI) maintains the Aqueduct Water Risk Indicator maps. The WRI's Water Regulatory & Reputational Risk indicator aggregates indicators from the World Health Organization (WHO) and the International Union for Conservation of Nature (IUCN) concerning water access, media coverage of water issues, and regulatory risk. With few exceptions, this indicator is provided at the national level. WRI provides an indicator in five groupings, with low risk in group 1 and very high risk in group 5. In this report, WRI groups 1 and 2 will be considered 'low risk' (green), group 3 will be considered 'medium risk' (yellow) and groups 4 and 5 'high risk' (red). Table 37 shows Water Regulatory Risk exposure of China and its comparator countries as defined by this metric.

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[245] Zhang et al., "Water-Carbon Trade-off in China's Coal Power Industry." And X Zhao, "Physical and Virtual Water Transfers for Regional Water Stress Alleviation in China," *Proceedings of the National Academy of Sciences* 112 (2015): 1031–35.
[246] 21st Clause of the 'Water Law of the P.R.C.'
[247] China Electricity Council, "National 600Mw Scale Thermal Power Unit Benchmarking and Competition Dataset (in Chinese)."
[248] S Moore, "Issue Brief: Water Resource Issues, Policy and Politics in China," *The Brookings Institute*, 2013.
[249] Christina Larson, "World's Largest River Diversion Project Now Pipes Water to Beijing," *Bloomber*, 2014, https://www.bloomberg.com/news/articles/2014-12-15/world-s-largest-river-diversion-project-now-pipes-water-to-beijing.
[250] Ministry of Water Resources (MWR), "Ministry of Water Resources on Deepening the Reform of Water Conservation," *China Water Resource News*, 2014.
[251] W Yongjing, "MWR of the General Office on Efforts to Develop Water Resources Planning" (Beijing, China, 2014).

Table 29: Water Regulatory Risk[252]

	China	Australia	Japan	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
Risk grouping	1	1	3	1	4	3	2	3	2	1
RISK	yellow	green	green	green	red	yellow	green	yellow	green	green

NRH-11: CCS Regulatory Environment

The hypothesis is that CCS could be a way for coal-fired power stations to keep running under stricter carbon constraints, but CCS will not happen without a supportive legal framework. Legal restrictions and regulatory uncertainties can present barriers to the development of CCS projects, which in turn present a risk to coal-fired utilities which could have CCS as an option for future GHG mitigation.

In China, carbon capture utilisation and storage has been mandated as an important measure to reduce emissions and to improve energy security. Nevertheless, to date China has very few CCS-specific laws applicable across the CCS project cycle, and ranks poorly on favourable CCS legislation and regulatory guidance compared with other major countries.[253] For instance, the lack of a regulatory framework for CO2 storage also means it is legally difficult to include CCS installations in Chinese emission trading schemes. As a result, emission reductions arising from CCS are currently not able to trade in China's seven pilot carbon markets.[254]

However, in recent years China has ramped up its efforts in CCS technology development. At the political level, China's National Development and Reform Commission (NDRC), the Ministry of Science and Techonology (MOST), and the Ministry of Environment (MOE) among other departments at different levels have established various funding schemes to promote the development of CCS technology. The National Development and Reform Commission (NDRC) has has however recently issued its own guidance on promoting CCS, which focuses on six areas: developing pilot and demonstration projects along the technology chain; developing integrated demonstration projects; exploring and establishing financial incentive mechanisms; strengthening strategy and planning for development; promoting standards and regulation; and strengthening capacity building and international collaboration.

Box 1: Opinion on CCS adapted from 'Stranded Assets and Thermal Coal'

Several factors may prevent the scale adoption of CCS as a mitigation technology. First, CCS is not currently developing at the pace necessary to meet the 2oC scenarios of the IEA and the IPCC. Second, other mitigation substitutes are becoming cost-competitive much more quickly than CCS. Third, a technology pathway which allows for enhanced oil recovery (EOR) is subject to additional economic and reputational risks. Fourth, current CCS technology still emits 100 kg of CO_2 per MWh, which precludes CCS from being a permanent climate solution.[255]

By 2040, in the IEA's 450S, CCS is deployed to store 4000 MtCO2 per year (Mtpa). The 15 currently

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[252] International Energy Agency, "World Energy Outlook," 2015.
[253] Global CCS Institute, "Global CCS Institute CCS Legal and Regulatory Indicator," 2015, http://hub.globalccsinstitute.com/sites/default/files/publications/196443/global-ccs-institute-ccs-legal-regulatory-indicator.pdf.
[254] Xi and Reiner, "How China Can Kick-Start Carbon Capture and Storage."
[255] Carbon Tracker Initiative, "Chasing the Dragon? China's Coal Overcapacity Crisis and What It Means for Investors."

operating projects are anticipated to store 28.4 Mtpa. The 30 additional projects planned to operate before 2025 will bring the total storage to 80 Mtpa, an annual growth rate of 11%. To reach 4000 Mtpa by 2040 will require a 48% growth rate from the 2025 planned fleet, or 22% growth from the operating fleet this year. This growth rate is unrealistic given the current state of deployment and technical progress.

The IEA foresees substantial deployment of CCS under the 450S only if policy supports CCS to become more affordable. As a mitigation technology for power generation, CCS will need to compete with falling prices of wind and solar power, and widespread efforts to improve grid flexibility. McKinsey estimates that by 2030, the abatement cost of solar and high-penetration wind power will be €18.0 and €21.0 per tCO2 respectively, while CCS coal retrofits, new builds, and gas new builds will be €41.3, €42.9, and €66.6 per tCO2 respectively. Bloomberg New Energy Finance (BNEF) estimates that the global average LCOE for onshore wind power is US$83/MWh, $122 for crystalline solar PV, and $174 for offshore wind , while the Global CCS Institute estimates the US levelised cost of electricity (LCOE) for coal with CCS is US$115/MWh to $160, and $82 to $93 for CCS-equipped gas-fired power . For markets and policymakers seeking abatement options in the context of finite public funds, CCS may remain a low priority for support.

The IEA suggests that the technology development pathway for power generation with CCS begins with co-locating the power station with EOR projects to enable commercial viability. The IEA admits that the public are already 'sceptical of end-of-pipe solutions apparently promoted by the same industries they hold responsible for the problem'. When co-located with EOR the stored carbon is used to extract additional hydrocarbons. Critics would argue any purported climate change merit of these projects is greenwashing – a reputational risk for the companies involved. Moreover, dependence on EOR also exposes power stations with CCS to oil price commodity risks. If the price of oil falls, then the profitability of EOR falls, and the profitability of the power station is reduced.

As a developing technology, there may also be unknown risks associated with large-scale and widespread CCS deployment. For example fracking, after a decade of exponential growth, has now been implicated in groundwater pollution and the causation of earthquakes.[256] Similar pollution outcomes and adverse geophysical events could possibly be attributed to CCS in the future.

In conclusion, CCS is unlikely to be significant in mitigating power sector emissions. Deployment of CCS has already been too slow to match IEA and IPCC scenarios. CCS compares unfavourably with other power sector mitigation options, especially considering that CCS also reduces plant efficiency, exacerbating existing merit-order challenges for conventional generators. CCS should remain an attractive option for industrial and process emitters that have few other mitigation options, and may be significant as a long-term option for delivering negative emissions with Bio-Energy with CCS (BECCS).

The development of a robust hypothesis of risk exposure requires a repeatable, testable measure. Certain countries have been proactive in developing policy and law specifically for CCS. The Global CCS Institute periodically evaluates their progress and publishes an indexed indicator. The institute groups countries into three performance bands, which are used here as an indicator for CCS liability risk. Band A, the most CCS-ready, is considered 'low risk', Band B 'medium risk', and Band C 'high risk'. China, in Band C, has among the lowest CCS regulatory scores of the 55 countries examined.

[256] F Walsh and M. Zoback, "Probabilistic Assessment of Potential Fault Slip Related to Injection-Induced Earthquakes: Application to North-Central Oklahoma, USA," *Geology* G38275.1 (n.d.).

Table 30: CCS legal environment indicator[257]

	China	Australia	Japan	Germany	Indonesia	India	Poland	South Africa	United Kingdom	United States
Band	C	A	B	B	C	C	B	C	A	A
RISK	🔴	🟢	🟡	🟡	🔴	🔴	🟡	🔴	🟢	🟢

NRH-12 Investor Sentiment

The hypothesis is that investor sentiment drives asset valuations and impacts the cost of capital, and therefore can influence asset stranding. At the national level investor sentiment in coal-fired power will incorporate concerns related to expanding international and national climate targets and the growth of coal divestment campaigns.

While direct asset investment in China seems not to have been driven by concerns of profitability even in the intermediate term, there are indications that utility investors may begin demanding closer accountability around financial performance and climate change. This, combined with the Chinese government's recent push to curtail access to capital for investment in coal-fired power generation may have an impact on the cost of capital for utilities, particularly those that do not excel in operational efficiency and decarbonisation.

As is discussed fully in NRH-3, provincial benchmark power prices have been slow to react to low coal prices. Due to this, return on investment in coal-fired generators has been unduly high. This has driven significant investment in coal fired power generation, with installed capacity increasing from 48GW in 2014 to 72GW in 2015. Significant investment in Chinese coal-fired power generation continued throughout 2016. While the Chinese National Energy Administration attempted to stop the permitting of building new coal-fired capacity in March 2016, analysis suggests that this has failed, as there is still 227 GW of coal-fired power generation under construction (Greenpeace, 2016).

Though direct investment by state-owned banks in coal-fired power generation is thought to have been phased out, it is likely that such continued investment may be driven by group access to capital through these institutions.[258] However, institutional investment groups, including the Asia Investor Group on Climate Change, representing $20 trillion have set out what they expect from utilities. These include stress testing to understand how implementation of the Paris Agreement will affect companies, operational efficiency, and decarbonisation.[259]

Investor sentiment could also be affected by a rising incidence of social protests directed at air pollution and the perceived threat of carbon emissions. According to Yang Chaofei, former chief of engineering in China's Ministry of Environmental Protection, in the last 15 years environmental disputes and incidents of social unrest have grown in number in China at a rate of around 30% per year.[260] As this trend progresses, public perception could become a major barrier to continued coal-fired investment, potentially leading to calls for targeted asset divestment and increased government regulation.

[257] Global CCS Institute "CCS Legal and Regulatory Indicator", 2015.
[258] International Institute for Sustainable Development, "Global Subsidies Initiative."
[259] IIGCC, "Investor Expectations of Electric Utilities Companies Looking down the Line at Carbon Asset Risk," 2016.
[260] Xi and Reiner, "How China Can Kick-Start Carbon Capture and Storage."

Table 31: Investor Sentiment Assessment

Risk Level	Description	Evaluation
High	Severe impacts on cost of capital and asset valuation in short term	○
Medium	Some impacts on cost of capital and asset valuation foreseeable	●
Low	No impacts expected	○

1.4 Summary of Companies Owning Operating, Under Construction, and Planned Coal Plants

Table 33 below aggregates data on the operating, under construction, and planned capacities of all coal generationacross the 50 companies Analysed. This table is ordered according to total coal generation capacity. Table 32 outlines the units used for each LRH.

As can be seen in Table 33 below, there is little variation in average coal generation CO2 intensity across major Chinese utilities, which are generally just within the threshold for supercritical efficiency (880 kg CO2/MWh). China's MW-weighted average coal-fired power CO_2 intensity is 873 kg.CO_2/MWh, which compares favourably with the United States and Europe, whose plants are on average considerably older and less efficient.

On a MW-weighted basis there is also little variation among the top 50 utilities with respect to average coal plant age - which on average were built in 2007. China's coal generation fleet is among the world's youngest.

Air pollution, measured as atmospheric particulate matter of less than 2.5 µm (PM 2.5), is extremely high. Only 16 out of the 50 companies (32%) comply on a MW-weighted basis with China's national annual average limit of $\mu g_{PM2.5}/m^3$, and only two comply with the WHO's annual limit of 10 $\mu g/m^3$.

Water Risk (LRH-4) incorporating Water Stress, Frequency of Flooding, and the Severity of Drought is displayed above as a rank among the 50 companies in order to aggregate these variables into a single metric: 1 = [highest risk, 50 = lowest risk].

As can been seen from Figure 21: CCS geological suitability, China has excellent CCS potential along its heavily populated coasts, as well as certain areas in the northeast, central China, and Xinjiang (western-most province). The potential CCS suitability of Chinese utilities reflects this pattern, however many potential reservoirs are near population centres which could object to local CCS adoption.

Figure 20: Chinese coal deposits by type shows that China's major lignite deposits are primarily located in central and southern China. However, lignite only comprises a significant portion of the generation portfolios of a handful of Chinese power companies.

Projected increases in heat stress by 2035 is shown in Figure 22 and follows a slow increase as one travels north. Therefore, levels of future heat stress increases show little variation, all averaging around $1^{o}C$.

Table 32: Units of measurement for companies

	Hypothesis	Unit
LRH-1	Carbon intensity of generated electricity	[kg.CO_2/MWh]
LRH-2	Plant age, year constructed	[year]
LRH-3	Local air pollution exposure with $PM_{2.5}$ as a proxy	[$\mu g_{PM2.5}/m^3$]
LRH-4	Water risk	[Rank (1=lowest,50=highest]
LRH-5	Quality of coal	[Per cent burning lignite]
LRH-6	CCS Retrofitability described by criteria in Section 2.2.1	[Per cent retrofitable]
LRH-7	Average temperature change in 2035 above preindustrial levels	[Δ^oC by 2035]

Table 33: Summary of financial and environment-related risk exposure

SUMMARY OF RISK EXPOSURE	COAL-FIRED CAPACITY			DEBT / EQUITY	CURRENT RATIO	(EBITDA-CAPEX) / INTEREST	LRH-1: CARBON INTENSITY	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLLUTION	LRH-4: WATER RISK	LRH-5: QUALITY OF COAL	LRH-6: CCS RETROFITABILITY	LRH-7: FUTURE HEAT STRESS
	OPR [MW]	CON [MW]	PLN [MW]				Local Risk Hypothesis						
China Huaneng Group	124,928	22,720	49,180	0.59	0.34	3.79	878	2005	40	22	9%	39%	1.02
China Guodian Corporation	103,512	11,140	60,550	1.19	0.21	3.40	867	2006	42	18	4%	35%	1.02
China Datang Corporation	102,035	16,200	58,243	1.36	0.30	3.76	880	2005	44	10	4%	37%	1.03
China Huadian Corporation	90,525	18,150	49,218	0.66	0.36	3.50	878	2006	42	12	3%	36%	1.01
State Power Investment Corporation	76,416	13,310	46,239	0.06	0.42	3.11	888	2006	41	19	26%	35%	1.03
China Shenhua Energy Co. Ltd.	69,475	20,880	60,590	8.38	1.19	0.29	868	2009	38	26	3%	43%	1.04
China Resources Power Holdings Co. Ltd.	39,358	5,300	21,430	5.56	0.43	1.06	865	2008	56	12	0%	44%	0.94
Guangdong Yudean Group Co., Ltd.	33,336	3,200	14,860	4.53	0.93	0.75	882	2006	28	42	0%	51%	0.85
Zhejiang Provincial Energy Group Company Ltd.	22,410	900	5,320	2.58	1.04	0.57	846	2007	37	23	0%	0%	0.88
State Development & Investment Corporation	14,636	9,660	8,885	0.50	1.00	1.73	863	2008	42	34	0%	48%	0.99
Beijing Energy Investment Holding Co., Ltd.	13,720	10,860	6,890	-	0.74	1.08	880	2007	35	23	0%	32%	1.12
Shandong Weiqiao Pioneering Group Co., Ltd.	13,100	10,080	0	1.53	1.76	0.58	870	2013	72	2	0%	0%	0.92
HeBei Construction & Investment Group CO., Ltd.	9,722	1,400	2,000	-	1.14	1.16	860	2002	66	11	0%	19%	1.04
Jiangsu Guoxin Investment Group Limited	9,365	1,000	8,393	-	-	-	863	2009	60	15	0%	73%	0.92
Wenergy	8,880	2,440	3,980	6.09	0.57	0.41	849	2007	54	19	0%	45%	0.96
CLP Holdings Ltd.	8,352	1,320	0	4.14	0.58	0.55	874	1999	42	30	0%	40%	0.90
State Grid Corporation of China	8,145	0	7,020	-	0.30	0.54	868	1999	45	6	0%	26%	1.00
Shanxi International Energy Group Co., Ltd.	7,290	7,170	3,900	-	-	-	881	2008	36	28	0%	17%	1.07
CITIC Group Corporation	7,010	0	375	-	-	-	860	2002	68	46	0%	18%	0.95
China Coal Energy Company Limited	6,660	5,550	1,960	-	0.92	1.13	869	2010	34	23	0%	13%	1.12
Henan Investment Group	5,870	3,180	2,000	-	-	-	848	2007	77	3	0%	71%	1.00
Shenzhen Energy Group Co., Ltd.	5,628	1,140	5,300	-	0.88	1.01	850	2002	26	39	0%	55%	0.84
Shenergy (Group) Company Limited	5,184	0	0	-	0.89	0.13	842	2005	57	44	0%	76%	0.90
China Petroleum & Chemical Corp.	5,099	300	0	6.77	0.72	0.33	869	2000	53	5	0%	34%	0.97
Shandong Xinfa Aluminum & Electricity Group	4,815	350	2,200	-	-	-	886	2012	25	28	46%	7%	1.22
Cheung Kong Infrastructure Holdings Ltd.	4,610	0	0	4.46	2.52	0.25	874	1994	30	48	4%	9%	0.74
Xinjiang Tianfu Energy Co., Ltd.	4,500	2,160	2,640	-	0.53	1.40	872	2012	12	17	0%	0%	1.27
East Hope Group Company Limited	4,300	0	1,050	-	-	-	873	2014	9	47	0%	100%	1.32
Aluminum Corporation Of China Limited	4,195	2,370	1,360	-	0.79	2.15	900	2008	41	16	0%	69%	1.09
Formosa Plastics Corporation	4,050	0	0	9.77	2.50	0.30	845	2002	22	49	0%	89%	0.76
Xingfa	4,040	1,320	750	2.82	0.85	1.41	832	2014	85	4	0%	0%	0.92
Gansu Province Electric Power Investment Group Co., Ltd	3,940	2,700	660	0.55	1.52	1.16	869	2009	10	19	0%	33%	1.17
Huainan Mining Group Power Generation Co., Ltd.	3,540	0	0	-	-	-	868	2011	64	27	0%	0%	0.90
Hangzhou Jinjiang Group Co., Ltd.	3,020	1,332	3,690	-	-	-	935	2013	16	8	79%	9%	1.22
Xishan Coal & Electricity (Group) Co., Limited	3,000	1,320	2,000	-	-	-	908	2008	61	32	0%	0%	1.04
Jiuquan Iron & Steel (Group) Co., Ltd.	2,950	0	1,632	-	0.33	1.80	858	2011	7	34	0%	0%	1.19
GCL-Poly Energy Holdings Ltd.	2,648	0	1,000	-	0.81	2.54	865	2006	60	37	0%	13%	0.90
Inner Mongolia Guodian Energy Investment Co., Ltd.	2,400	680	4,560	-	-	-	911	2007	15	32	50%	25%	1.23
Fujian Energy Group Co., Ltd.	2,012	0	1,758	0.79	1.00	1.35	855	2013	21	39	0%	15%	0.83
Chongqing Energy Investment Group Co. Ltd.	1,920	2,680	4,300	-	0.69	1.89	882	2011	53	34	0%	100%	0.90
Sichuan Qiya Aluminium Industry Group Co., Ltd.	1,800	1,800	0	-	-	-	841	2014	9	45	0%	100%	1.32
Power Construction Corporation of China	1,610	0	6,000	-	-	-	851	2010	25	37	0%	100%	1.12
Qinghai Province Investment Group Limited	1,595	0	1,920	-	-	-	868	2007	9	9	0%	0%	1.14
Guangdong Baolihua New Energy Stock Co., Ltd.	1,470	0	3,800	2.30	1.02	0.84	953	2009	30	6	0%	41%	0.91
Guangdong Pearl River Investment Co., Ltd.	1,320	0	0	-	-	-	834	2013	30	50	0%	0%	0.76
Wanji Holding Group Graphite Product Co., Ltd.	1,140	0	1,200	-	-	-	868	2008	61	1	0%	0%	1.05
Shaanxi Coal and Chemical Industry Group Co., Ltd.	950	2,600	3,653	-	0.66	2.79	881	2012	29	30	0%	32%	1.16
Datong Coal Mine Group Co.,Ltd.	500	2,100	2,000	-	1.19	4.19	863	2009	38	12	0%	0%	1.13
Shaanxi Provincial Investment (Group) Co., Ltd.	300	2,320	11,000	-	-	-	868	2008	20	43	0%	100%	1.20
Inner Mongolia Asset Management Bureau	0	700	4,020	-	-	-	849	2017	15	41	0%	0%	1.20

For LRH-4, companies are ranked by exposure, with '1' being the most exposed
For more details, see tables in Appendix C.

3 Potential scale of coal-fired power station asset stranding in China

Stranded assets are assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities, and can be caused by a variety of risks. Risk factors related to the environment are stranding assets and this trend is accelerating, potentially representing a discontinuity able to profoundly alter asset values across a wide range of sectors.[261] The following section examines the potential scale of asset stranding faced by Chinese coal-fired utilities.

To calculate potential asset stranding charges in China's utility industry, we extract the capacities of all coal-fired generation assets in MW. To avoid double-counting jointly-owned capacity, we divide capacity among joint-owners. We delineate the capacities into existing and planned (or currently under construction). We use IEA data[262] to estimate build cost (in 2012$) per kW, for all coal-fired technologies in the WEPP database.[263] For circulating fluidized bed (CFB) technologies, we estimate the build cost in 2015$ per kW based on the recently built CFB plant,[264] and discount to 2012$ build cost using World Bank inflation data.[265] We assume all sunk costs – such as fees and contingency, engineering, procurement and construction services, and any additional owner costs[266] - as these represent losses in the case of asset stranding. For each asset, we depreciate the asset using the straight-line method over an assumed useful life of 35 years since the date (or planned date) of build. The assumption of 35 years stems from analysis of the Q4 2016 WEPP dataset, which shows a bimodal distribution of plant age at retirement. Coal-fired plants are typically retired at either 16 or 34 years old, with the latter being the most common retirement age (see Figure 35). We assume a salvage value of zero. As the last planned coal-fired generating asset is scheduled for 2020, our total time series covers 2016 to 2056 to include all depreciation. The series plots, for each year, the total estimated asset stranding charge if the value of all the coal generating assets were to decline to zero. Therefore, these estimates should be interpreted as an upper bound of possible asset stranding in the case where all coal-fired power plants are prematurely shut.

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[261] Atif Ansar, Ben Caldecott, and James Tibury, "Stranded Assets and the Fossil Fuel Divestment Campaign: What Does Divestment Mean for the Valuation of Fossil Fuel Assets?," *Stranded Assets Programme, SSEE, University of Oxford*, no. October (2013): 1–81, doi:10.1177/0149206309337896.
[262] http://www.worldenergyoutlook.org/weomodel/investmentcosts/
[263] Coal technologies include: Circulating fluidized bed (CFB), integrated gasification combined cycle (IGCC), IGCC with CCS, Subcritical, Supercritical, ultracritical, and coal with CCS.
[264] http://cornerstonemag.net/china-brings-online-the-worlds-first-600-mw-supercritical-cfb-boiler/
[265] Note, we estimate the CFB cost at ~832 2012$/kW, which is marginally higher than the cost of (expensive) ultracritical technologies at 800 2012$/kW. We find the estimated CFB cost to be a reasonable assumption.
[266] Rong and Victor, "What Does It Cost to Build a Power Plant?"

Figure 35: Plant Age at Retirement. Source: Q4 2016 WEPP dataset

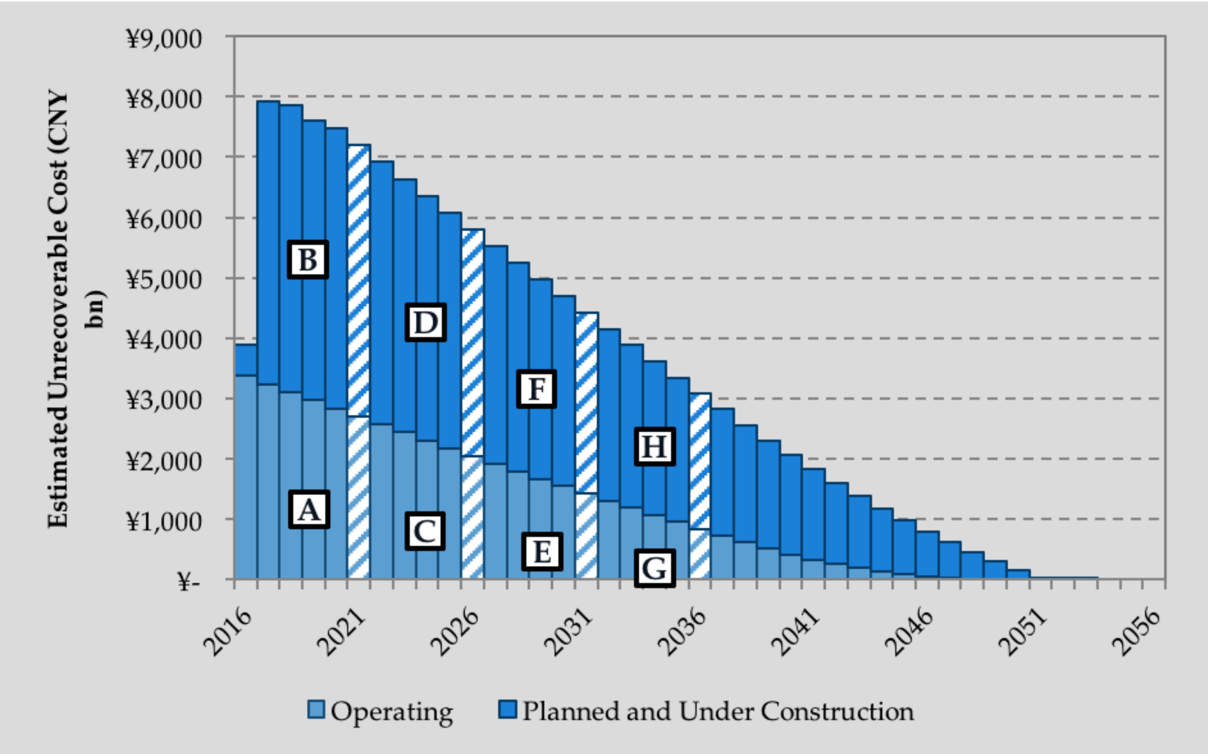
In addition to the estimated asset stranding charges, we present four highly illustrative scenarios to completely remove coal-fired generation from the energy system: five years, ten years, 15 years, and 20 years. In all four scenarios the start date is 2016 and the known installed capacity is 978 GW (including capacity planned for 2016). Note that unlike other recent research into China's power generation, this methodology applies expected plant start-up and closure timelines on an individual asset basis, allowing for greater accuracy and the examination years outside our four 5-year scenarios.[267]

The results in Figure 36 show that regardless of the four scenarios operating and planned and under construction capacity incur at least some asset stranding. Noticeably, a large amount of coal-fired capacity is planned from 2017 onwards, suggesting much higher potential asset stranding for planned capacity. The following paragraphs estimate future asset stranding in nominal terms[268] for a variety of future scenarios.

[267] For instance in their several scenarios, Carbon Tracker Initiative (2016) assumes all under construction plant complete within 5 years and all planned plants complete within ten.

[268] We estimate stranded assets in 2012$ costs and present the nominal values. Over the 1987 to 2015 period, China's inflation rate varied between 24% to -1.4%. As such, presenting nominal costs refrains from making assumptions regarding appropriate discount rates, and allows the reader to discount future values to present value.

Figure 36: Estimated scale of asset stranding for existing and new build coal plants



NB: The difference between the value on the y-axis and zero represents estimated stranded assets charge.
Letters in the chart correspond to the labels in Table 34.

Table 34: Estimates of total asset stranding charges in CN¥bn (US$bn)

Coal Offline in:	Operating Assets	Planned and Under Construction	Total
2021 (5 Years)	**[A]** ¥2,703 ($393)	**[B]** ¥4,498 ($654)	**[A+B]** ¥7,201 ($1,047)
2026 (10 years)	**[C]** ¥2,051 ($298)	**[D]** ¥3,746 ($545)	**[C+D]** ¥5,797 ($843)
2031 (15 Years)	**[E]** ¥1,426 ($207)	**[F]** ¥2,994 ($435)	**[E+F]** ¥4,420 ($643)
2036 (20 Years)	**[G]** ¥843 ($123)	**[H]** ¥2,243 ($326)	**[G+H]** ¥3,086 ($449)

For the five, ten, 15, and 20-year scenarios, asset stranding for new-capacity is estimated using capacity either planned or currently under construction. Therefore, this number could change due to currently planned projects becoming cancelled and additional planned capacity being added over upcoming years. In the 5-year scenario, operating asset stranding charges are ¥2,703bn ($393bn), but almost two-thirds (¥7,01bn|$1,047bn) of the asset stranding charges arise from coal-fired projects in the pipeline (ie under construction or planned). The ten-year scenario shows total asset stranding charges of ¥5,797bn ($843bn), of which ¥3,746bn ($545bn) - or again about two-thirds - is derived from pipelined coal-fired projects. As expected, estimates of stranded assets in the 15-year scenario are considerably lower, at only ¥4,420bn ($643bn), of which 2,994 ($435bn) or 68% comprises new projects. Finally, the stranded asset charges in the 20-year scenario total ¥3,086bn ($449bn), of which 73% (¥2,243bn|$326bn) would fall on pipelined capacity.

These scenarios estimate that stranded coal assets could be as much as ¥3,086-7,201bn ($449-1,047bn), equivalent to 4.1-9.5% of China's 2015 GDP[269]. This compares with a recent Carbon Tracker Initiative (2016) report which found that China does not need to build any more coal plants, and that it risked misallocating half a trillion US dollars in capital if it did.[270]

Our conclusion from the preceding analysis is that asset stranding has the potential to fall heavily on both existing and planned generating capacity, with planned capacity comprising an increasing proportion of stranded assets in later closure scenarios. Importantly, all four scenarios highlight the risk of operating coal-fired capacity incurring some stranded costs by 2049, due to the large number of coal-fired assets built in the 2000s and 2010s. For existing capacity, the impact is highest in the short-term – within five years – and declines continuously thereafter. For planned capacity, the impact is highest after five years. Although total potential impairment charges in our analysis decline beyond five years, if additional capacity is planned and constructed within this time-period, then future stranded assets would continue to rise.

It will be increasingly difficult to convince investors to commit capital to coal power projects if there is a high likelihood that assets will become stranded. Figure 35 shows that many coal-fired assets in China are retired in as little as 16 years, suggesting a relatively rapid removal of coal from the electricity system. Thus, recognizing the magnitude of potential stranded planned coal-fired capacity, China is in a position to cancel much of this planned capacity before construction begins or also to pull this capacity off the grid early.

1.5 Utility Case Studies

At the company-level, we prepared case studies of five utilities selected because they comprised the former national State Power Corporation and currently dominate coal generation in China, controlling over half of all coal-fired generation assets. These company case studies are for: 1) Huaneng 2) Datang; 3) Guodian; 4) Huadian; and 5) State Power Investment Corp. In these case studies we examine the sensitivity of these companies to the risks outlined in this report, and estimate potential scale of asset stranding specifically attributable to them following the national methodology used earlier in this section.

Table 35: Breakdown of the five utilities' operating, under construction, and planned coal capacity

Rank	Company	Coal Generating Capacity* [MW] (per cent of total capacity)			
		OPR	CON	PLN	Total
1	HUANENG	124,928 (63%)	22,720 (12%)	49,180 (25%)	196,828 (100%)
2	DATANG	102,035 (58%)	16,200 (9%)	58,243 (33%)	176,478 (100%)
3	GUODIAN	103,512 (59%)	11,140 (6%)	60,550 (35%)	175,202 (100%)
4	HUADIAN	90,525 (57%)	18,150 (11%)	49,218 (31%)	157,893 (100%)
5	STATE POWER INVESTMENT CORP	76,416 (56%)	13,310 (10%)	46,239 (34%)	135,965 (100%)

Table 36: Units of measurement of LRHs for power plants

	Hypothesis	Unit
LRH-1	Carbon intensity of generated electricity	[kg.CO_2/MWh]
LRH-2	Plant age, year constructed	[year]
LRH-3	Local air pollution exposure with $PM_{2.5}$ as a proxy	[$\mu g_{PM2.5}/m^3$]
LRH-4	Water stress	[% Renewable resource]
LRH-5	Quality of coal	[Per cent burning lignite]
LRH-6	CCS Retrofitability described by criteria in Section 2.2.1	[Per cent retrofitable]
LRH-7	Average temperature change in 2035 above preindustrial levels	[Δ°C by 2035]

[269] The World Bank, "World Bank National Accounts Data."
[270] Carbon Tracker Initiative, "Chasing the Dragon? China's Coal Overcapacity Crisis and What It Means for Investors," 2016.

Table 37: Financial Ratios, Local Risk Hypotheses (LRH) 1-7 for operating and planned plants, and Estimates of total asset stranding (¥bn)

	Ratio Analysis[i]				Env.-Related Risks[i]							Stranded Assets[ii]			
	DEBT / EQUITY	CURRENT RATIO	(EBITDA - CAPEX) / INTEREST	OPR / PLN[iii]	LRH-1	LRH-2	LRH-3	LRH-4	LRH-5	LRH-6	LRH-7	2021 (5 year)	2026 (10 year)	2031 (15 year)	2036 (20 year)
HUANENG	3.79x	.34x	0.6x	**OPR**	878	2005	40	28%	9%	39%	1.02	¥322 ($47)	¥239 ($35)	¥161 ($23)	¥91 ($13)
				PLN	861	2017	26	48%	3%	47%	1.13	¥406 ($59)	¥337 ($49)	¥268 ($39)	¥200 ($29)
DATANG	3.76x	.30x	1.4x	**OPR**	867	2006	42	30%	4%	35%	1.02	¥253 ($37)	¥187 ($27)	¥125 ($18)	¥67 ($10)
				PLN	856	2017	37	47%	0%	38%	1.02	¥471 ($68)	¥392 ($57)	¥313 ($46)	¥234 ($34)
GUODIAN	3.40x	.21x	1.2x	**OPR**	880	2005	44	42%	4%	37%	1.03	¥282 ($41)	¥214 ($31)	¥149 ($22)	¥88 ($13)
				PLN	848	2017	41	47%	0%	31%	1.03	¥368 ($54)	¥306 ($45)	¥244 ($36)	¥182 ($26)
HUADIAN	3.50x	.36x	0.7x	**OPR**	878	2006	42	37%	3%	36%	1.01	¥239 ($35)	¥180 ($26)	¥123 ($18)	¥71 ($10)
				PLN	847	2017	42	27%	0%	27%	1.04	¥365 ($53)	¥305 ($44)	¥244 ($36)	¥184 ($27)
STATE POWER	3.11x	.42x	0.1x	**OPR**	888	2006	41	47%	26%	35%	1.03	¥204 ($30)	¥155 ($23)	¥110 ($16)	¥66 ($10)
				PLN	858	2017	30	54%	14%	38%	1.05	¥315 ($46)	¥262 ($38)	¥209 ($30)	¥156 ($23)

i) Ratio risk presented as follows: $N_{D/E}$, $N_{Current\ Ratio} = 45$; $N_{(EBITDA\text{-}CAPEX)/INT} = 35$; $N_{OPR} = 40$; $N_{PLN} = 34$
ii) Environment-related risk is presented according to Table 36
iii) Stranded Assets expressed in bn¥ and as a fraction of total utility assets
iv) OPR: Operating plants; PLN: Planned and under construction plants

Table 37 above shows the existing and pipelined capacities potentially at risk of asset stranding in the baseline (now), five, ten, 15, and 20-year caol phase-outscenarios. All five companies will be subject to stranded assets in each of the four scenarios. As we can also note in Table 37, the five major Chinese utilities have broadly similar risk exposures to all LRHs. These characteristics are on average; (LRH-1) comparatively low CO_2 intensity of coal generation (at or slightly superior to supercritical efficiency), (LRH-2) young coal plant fleets around a decade in age, (LRH-3) $PM_{2.5}$ pollution levels close to the national annual limit of 35 µg/m^3, (LRH-4) plants located in areas of relatively low levels of water stress (water usage to availability ratios of around 35%), (LRH-5) low levels of lignite use, (LRH-6) moderate levels of CCS retrofitability (around 40%), and (LRH-7) uniform projected temperature changes of about 1^{o}C by 2035.

There are however some interesting trends that can be noted between existing and planned capacities. For example, each of the planned coal generation fleets of all five companies have the same or lower air pollution levels than those currently operating, suggesting a deliberate move across the five companies to mitigate or at least contain local air pollution levels. All five companies are also pursuing less carbon intensive generation in their planned fleets, which will all exceed supercritical efficiency thresholds on average. Like the nation as a whole, in all five companies the greatest potential asset stranding occurs in the first 5-year scenario, decreasing steadily thereafter. This result is caused by the heavy front-loading of expected completion dates of the coal plants in the generation pipeline. Estimates of potential asset stranding correspond closely with total generating capacity. The only time that this pattern is broken is for Huadian in the 20-year scenario, where due to high levels of under construction plants its potential asset stranding in this scenario exceeds Guodian.

We briefly evaluate each company below on the basis of 1) their existing coal-fired power station portfolio, 2) the coal-fired generation capacity they are constructing or planning to construct and 3) their financial condition with regard to DEBT/EQUITY, CURRENT RATIO, and EBITDA-CAPEX/INTEREST ratios, and 4) the extent their existing and planned portfolios are exposed to local environment-related risks. Table 36 provides guidance on the interpretation of LRH exposure.

1.5.1 Huaneng

Huaneng has the most coal generation (124,928 MW) of all utilities in China. It also has the greatest capacity under construction at 22,720 MW. Its planned capacity is nearly double this at 49,180 MW, however Guodian Datang, and Huadian have planned coal generation capacities that exceed this. Given its high combined operating, under construction, and planned capacities, it is not surprising that Huaneng generally has the greatest potential asset stranding losses in all stranding scenarios.

With regard to local risk hypotheses, it is notable that Huaneng's planned capacity is markedly more CCS compatible (LRH-6) than its existing capacity (39% operating versus 47% planned), and that Huaneng's planned plants are also located in areas with significantly lower $PM_{2.5}$ air pollution (LRH-3): 40 µg/m^3 for existing versus 26 µg/m^3 for planned plants. Lignite use (LRH-5) is also expected to fall from 9% in existing plants to just 3% of planned capacity. CO_2 intensity (LRH-1) is additionally expected to fall marginally from 878 to 861 kg CO_2/MWh. On the other hand water stress (LRH-4) and heat stress is expected to rise in planned plants, from 28% to 48% and 1.02 to 1.13^{o}C, respectively.

Figure 37: Estimated scale of asset stranding for Huaneng's existing and new build coal plants

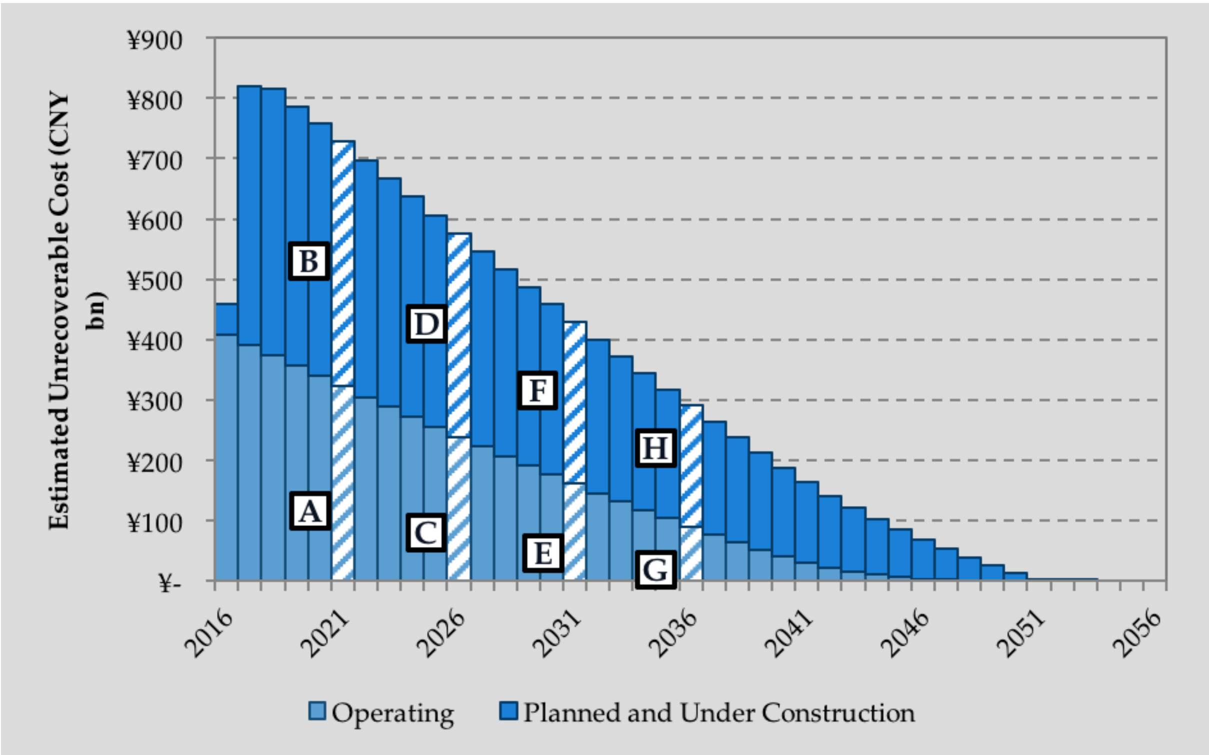


Table 38: Environment-related risk exposure of Huaneng's operating plants

PLANT	CAPACITY[ii] [MW]	LRH-1: CARBON INTENSITY [kg CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLLUTION [µgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: QUALITY OF COAL [1 = LIGNITE]	LRH-6: CCS RETROFITABILITY [1 = RETROFITABLE][iii]	LRH-7: FUTRE HEAT STRESS [Δ°C]
Huaneng Shangdu power station	5,040	953	2009	13	0%	1	0%	1.21
Huaneng Qinbei power station	4,400	844	2009	69	100%	0	100%	1.04
Huaneng Yuhuan power station	4,200	828	2007	24	40%	0	0%	0.86
Huaneng Haimen power station	4,144	828	2011	20	58%	0	0%	0.81
Shidongkou power station	3,820	846	1997	57	72%	0	0%	0.90
Huaneng Yimin power station	3,400	949	2006	5	34%	1	100%	1.22
Dalate power station	3,180	868	2002	15	0%	0	0%	1.19
Huaneng Fuzhou power station	2,720	848	2002	27	10%	0	74%	0.85
Huaneng Luohuang power station	2,640	965	2000	55	2%	0	73%	0.90
Huaneng Dezhou power station	2,570	965	1997	84	100%	0	0%	0.92
Huaneng Shang'an power station	2,540	904	2001	73	100%	0	0%	1.09
Huaneng Yueyang power station	2,524	943	2005	54	1%	0	71%	0.95
Jiangsu Nantong power station	2,404	857	2002	59	72%	0	0%	0.90
Diandong power station	2,400	965	2007	25	15%	0	100%	0.92
Huaneng Yangluo power station	2,400	950	2001	55	1%	0	0%	0.97
Huaneng Pingliang power station	2,400	854	2006	24	100%	0	100%	1.12
Linyi power station	2,100	850	2008	62	100%	0	0%	0.91
Rizhao power station	2,060	856	2006	55	100%	0	0%	0.91
Huaneng Jinling power station	2,060	828	2010	64	4%	0	100%	0.97
Huaneng Qinling power station	2,000	852	2001	50	34%	0	0%	1.05
Weihai power station	1,960	841	2006	31	100%	0	100%	0.99
Huaneng Jinggangshan power station	1,920	840	2006	40	5%	0	0%	0.85
Huaneng Taicang power station	1,900	850	2004	58	72%	0	0%	0.90
Huaneng Yingkou power station	1,840	832	2003	36	91%	0	0%	1.13
Huaneng Hainan East power station	1,400	847	2011	13	7%	0	100%	0.70
Huaneng Dalian power station	1,400	868	1994	38	100%	0	50%	0.99
Huangtai power station	1,360	949	2000	79	100%	0	51%	0.92
Huaneng Jiutai power station	1,340	938	2009	32	76%	1	100%	1.24
Huaneng Changxing power station	1,320	835	2015	56	69%	0	100%	0.97
Daba-1 power station	1,320	868	1994	17	100%	0	50%	1.18
Hanfeng power station	1,320	965	2001	83	100%	0	0%	1.04
Huaneng Huaiyin power station	1,320	868	2006	61	100%	0	0%	0.91
Huaneng Anyuan power station	1,320	828	2015	41	16%	0	0%	0.95
Huaneng Yangliuqing power station	1,300	868	2002	73	100%	0	0%	0.98
Huaneng Zuoquan power station	1,262	834	2012	64	100%	0	100%	1.04
Huaneng Chaohu power station	1,200	841	2008	43	4%	0	100%	0.93
LIULIN HUAGUANG	1,200	867	2008	28	0%	0	0%	1.08
Huaneng Hegang power station	1,200	854	2003	15	10%	0	0%	1.19
HUANENG TURPAN	1,200	842	2012	11	0%	0	0%	1.32
PINGLIANG	1,200	842	2010	24	100%	0	100%	1.12
Diandong Yuwang power station	1,200	965	2010	14	6%	0	100%	0.91
HUANENG CHANGXING	1,200	871	2004	57	69%	0	100%	0.90
Huaneng Tongchuan power station	1,200	868	2007	61	0%	0	100%	1.08
Huaneng Shantou power station	1,200	854	2001	20	58%	0	0%	0.81
Yunhe power station	1,180	868	2004	79	100%	0	100%	0.92
Huaneng Hohhot power station	1,100	851	2006	16	64%	0	0%	1.21
Huaneng Haikou power station	1,074	868	2002	18	15%	0	61%	0.73

Huaneng Wuhai Haibowan power station	1,060	874	2011	14	100%	0	100%	1.18
Huaneng Baotou-2 power station	1,000	868	2006	14	71%	0	0%	1.19
Huaneng Luoyang power station	970	854	2012	67	100%	0	100%	1.05
Huaneng Jining power station	970	868	2008	79	100%	0	100%	0.92
Huaneng Liaocheng power station	940	965	2003	85	100%	0	0%	0.92
Baiyanghe power station	890	965	2007	67	100%	0	100%	0.91
Huaneng Fengzhen power station	800	868	1994	20	0%	0	0%	1.20
Huaneng Luntai power station	700	841	2016	13	0%	0	0%	1.18
Hohhot power station	700	841	2011	16	0%	0	0%	1.21
Huaneng Ruijin power station	700	935	2008	40	14%	0	100%	0.93
Huaneng Yingkou Coastal power station	700	868	2009	36	91%	0	0%	1.13
Dandong Kaite power station	700	874	1998	23	10%	0	0%	1.14
Huaneng Daqing power station	700	847	2013	22	31%	0	100%	1.22
Huaneng Dandong power station	700	868	1998	23	10%	0	0%	1.14
Huaneng Changchun power station	700	938	2010	33	76%	1	0%	1.24
Huaneng Yichun power station	700	847	2015	12	10%	0	100%	1.19
Huaneng Linhe power station	700	841	2011	11	100%	0	0%	1.25
Huaneng Jingmen power station	700	847	2014	55	8%	0	0%	1.01
Huaneng Yingcheng power station	700	841	2015	60	39%	0	0%	0.97
Yantai power station	700	868	2002	35	100%	0	0%	0.99
Huaneng Baishan power station	660	889	2011	16	0%	0	100%	1.15
Huaneng Jiaxiang power station	660	874	2007	80	100%	0	100%	0.92
Wuhai Hainan power station	660	868	2006	14	0%	0	100%	1.18
Huaneng Laiwu power station	660	868	2009	67	100%	0	100%	0.91
Huaneng Nanjing power station	640	847	1994	62	4%	0	0%	0.97
Wulashan power station	600	868	2006	12	0%	0	0%	1.19
North United Power Mengxi power station	600	889	2008	14	0%	0	100%	1.18
Huaneng Baotou-3 power station	600	868	2007	14	71%	0	0%	1.21
Xindian power station	600	868	2006	74	100%	0	0%	0.98
包头第一热电厂	600	867	2004	14	71%	0	0%	1.19
华能北方联合蒙西发电厂	600	867	2004	16	39%	0	0%	1.16
包头第三热电厂	600	867	2004	14	71%	0	0%	1.19
Hohhot Jinqiao power station	600	868	2007	15	100%	0	0%	1.21
Hohhot Jinshan power station	600	881	2015	16	100%	0	0%	1.21
Huaneng Yushe power station	600	965	2004	43	0%	0	0%	1.04
Huaneng Xinhua Daqing power station	530	868	1995	24	82%	0	62%	1.21
Huaneng Qufu power station	450	874	2006	74	100%	0	0%	0.92
Huaneng Manzhouli Guangming power station	424	969	2009	4	8%	1	94%	1.22
TASHDIAN	325	868	2008	14	100%	0	0%	1.24
Huaneng Zhanhua power station	300	868	2005	70	100%	0	100%	0.98
Shandong Zhongtai power station	300	889	2007	64	100%	0	100%	0.91
Huaneng Baotou-1 power station	270	868	2007	14	71%	0	0%	1.19
Changji Fukang power station	270	874	2011	9	39%	0	100%	1.32
Tashdian power station	250	874	2012	15	100%	0	0%	1.24
LIAONING-2	200	868	1991	34	100%	0	0%	1.14
HUANENG CHANGSHAN	200	868	1988	16	76%	0	0%	1.15
Huaneng Manzhouli Dalaihu power station	200	860	2012	4	19%	0	100%	1.22
Ulanhot Xing'an-2 power station	136	969	2008	13	0%	1	0%	1.25
GreenGen power station	125	752	2012	74	100%	0	0%	0.98
HUANENG YUDAI	100	868	2015	63	4%	0	0%	0.97
Huaneng Yakeshi Huiliuhe power station	100	874	2000	5	0%	0	0%	1.18
XILINHOT-2	86	868	1998	9	67%	0	0%	1.34
LINGQUAN	62	868	2006	4	19%	0	0%	1.22
EAST HAILAR	50	868	2006	5	34%	0	0%	1.22
ZHALANTUN	30	868	2006	10	100%	0	0%	1.19
DONGWUQI	30	868	2008	6	72%	0	0%	1.38
HAILAR	24	968	2006	5	34%	1	0%	1.22
YAKESHI	18	868	1975	5	34%	0	0%	1.18
TOTAL[i]	**124,928**	**878**	**2005**	**40**	**53%**	**9%**	**39%**	**1.02**

i. MW-weighted averages; ii. Capacity only for owned portion; iii. Retrofitability is expressed as a percentage of the total powerplant unit MW capacity that is retrofitable.

Table 39: Environment-related risk exposure of Huaneng's planned plants

PLANT	CAPACITY[ii] [MW]	LRH-1: CARBON INTENSITY [kg CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLLUTION [μgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: QUALITY OF COAL [1 = LIGNITE]	LRH-6: CCS RETROFITABILITY [1 = RETROFITABLE][iii]	LRH-7: FUTRE HEAT STRESS [Δ°C]
Huaneng Yan'an power station	2,640	844	2017	25	12%	0	0%	1.15
Huaneng Zhanhua power station	2,000	841	2017	70	100%	0	100%	0.98
Huaneng Shanyin power station	2,000	834	2018	25	0%	0	0%	1.09
Huaneng Hami Sha'erhu power station	2,000	860	1998	15	10%	0	0%	1.19
Huaneng Yueyang power station	2,000	920	2017	54	1%	0	100%	0.95
Huaneng Pingliangzhuang Langhandian power station	2,000	860	2017	24	100%	0	100%	1.12
Huaneng Zhengning power station	2,000	834	2017	29	0%	0	0%	1.15
Huaneng Shanghaimiao power station	2,000	834	2017	17	15%	0	0%	1.18
Dalate power station	2,000	855	2011	15	0%	0	0%	1.19
Huaneng Gulei power station	1,520	837	2017	20	20%	0	87%	0.75
Huaneng Ili Qingshui River power station	1,400	860	2017	7	100%	0	100%	1.25
Huaneng Jiaxiang power station	1,360	847	2017	80	100%	0	100%	0.92
Huaneng Hami Heavy Industrial Park power station	1,320	847	2012	6	0%	0	0%	1.38
Huaneng Zhunger Weijiamao power station	1,320	860	2017	20	0%	0	0%	1.20
HUANENG JIMUSAER	1,320	829	2018	10	0%	0	0%	1.32
Huaneng Bayanbaolige power station	1,320	860	2017	8	67%	0	100%	1.34
Huaneng Jiutai power station	1,320	938	2017	32	76%	1	100%	1.24
Huaneng Usu power station	1,320	860	2017	9	100%	0	0%	1.31
华电龙口发电股份有限公司四期扩建项目	1,320	867	2017	39	100%	0	0%	0.99
Yuka power station	1,320	834	2017	5	100%	0	0%	1.15
Huaneng Xilinhot power station	1,320	860	2017	9	67%	0	100%	1.34
Huaneng Qinling power station	1,320	860	2017	50	34%	0	0%	1.05
Diandong Yuwang power station	1,200	965	2014	14	6%	0	100%	0.91
HUANENG HUAZHONG	1,200	868	2017	76	100%	0	0%	1.04
Huaneng Yimin power station	1,200	860	2017	5	34%	0	100%	1.22
Huaneng Yangqu power station	700	847	2017	36	100%	0	0%	1.09
华能洋浦热电联产工程	700	867	2017	16	15%	0	100%	0.70
华能大连第二热电厂	700	867	2017	38	100%	0	100%	0.99
Huaneng East Hailar power station	700	860	2017	5	34%	0	0%	1.22
Huaneng Anyang power station	700	847	2017	84	100%	0	100%	1.04
Fukang Second Power Plant	700	847	2017	10	100%	0	100%	1.32
山丹县汇泽节能电力有限责任公司低热值煤发电项目	700	867	2017	9	100%	0	100%	1.17
Jimsar Wucaiwan Beisan power station	660	834	2017	9	39%	0	100%	1.32
Huaneng Wuhai Haibowan power station	600	860	2017	15	100%	0	100%	1.18
Wuhai Haibowan Power Station	600	860	2017	15	100%	0	100%	1.18
Huaneng Xifeng power station	600	874	2017	25	100%	0	0%	1.15
Huaneng Manzhouli Zhalainuor power station	600	860	2017	4	8%	0	100%	1.22
Huaneng Minhe power station	600	860	2017	14	100%	0	100%	1.14
GreenGen power station	400	980	2020	74	100%	0	0%	0.98
HAILAR	400	968	2017	5	34%	1	0%	1.22
Huaneng Nanjing power station	100	860	2017	62	4%	0	0%	0.97

TOTAL[i]	**49,180**	**861**	**2016**	**26**	**48%**	**0**	**47%**	**1.13**

i. MW-weighted averages; ii. Capacity only for owned portion; iii. Retrofitability is expressed as a percentage of the total powerplant unit MW capacity that is retrofitable.

1.5.2 Datang

Datang has the third highest coal generation capacity (102,035MW) of all utilities in China, but the second greatest capacity planned at 58,243 MW. Its coal capacity under construction represents the second smallest fraction of total capacity of all the five companies studied, at 9% (16,200 MW).

As is evident from Table 37 above, Datang's existing and planned fleets only vary significantly with respect to water stress (LRH-4), with planned water stress averaging 47% compared to 30% for existing plants, indicating an substantial increase in vulnerability to water shortages. Datang's LRHs are otherwise similar to the other five companies, and there are only marginal expected decreases in CO_2 intensity (LRH-1, from 867 to 856 kg CO_2/MWh) and air pollution (LRH-3, from 42 to 37 μg/m^3), and marginal increases in CCS retrofitability (LRH-6, from 35 to 38%) and hard coal use (LRH-5, lignite falling from 4% to 0%).

Figure 38: Estimated scale of asset stranding for Datang's existing and new build coal plants

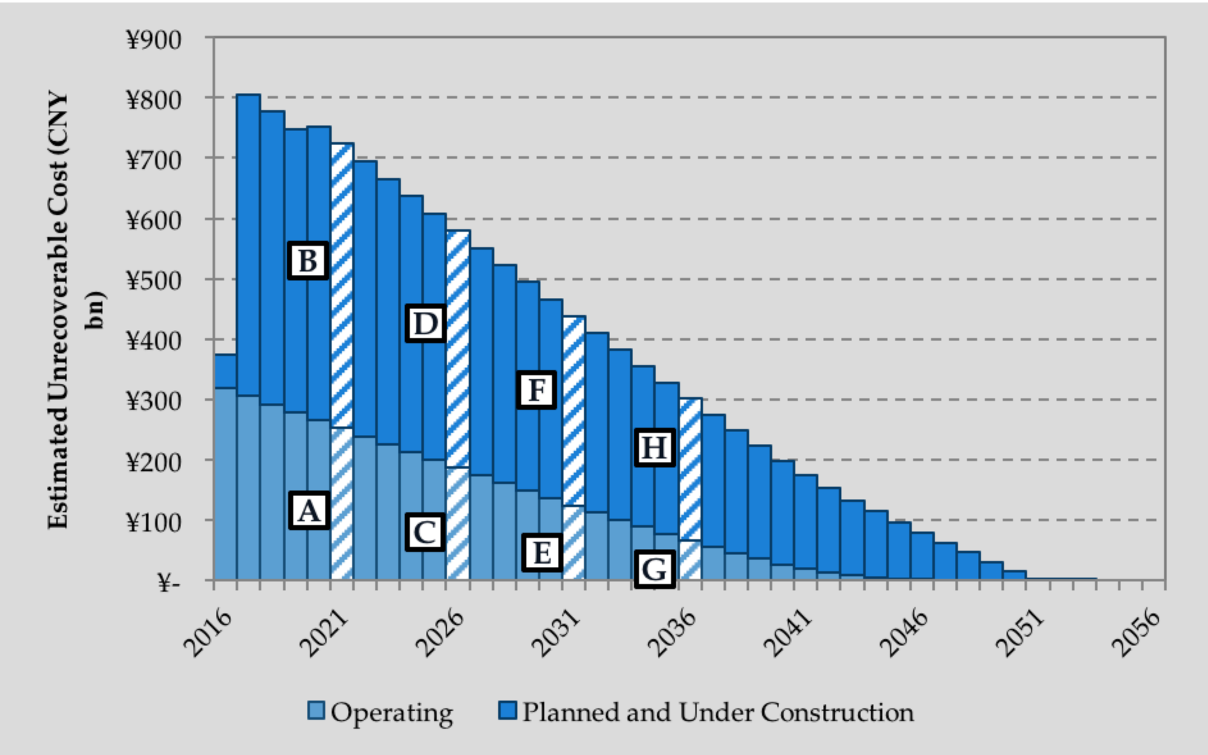


Table 40: Environment-related risk exposure of Datang's operating plants

PLANT	CAPACITY[ii] [MW]	LRH-1: CARBON INTENSITY [kg CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLLUTION [µgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: QUALITY OF COAL [1 = LIGNITE]	LRH-6: CCS RETROFITABILITY [1 = RETROFITABLE][iii]	LRH-7: FUTRE HEAT STRESS [Δ°C]
Datang Tuoketuo power station	5,400	868	2005	19	17%	0	0%	1.21
Yangcheng power station	3,300	965	2004	62	0%	0	100%	1.04
Chaozhou Sanbaimen power station	3,200	833	2009	20	17%	0	0%	0.81
Lusigang power station	2,640	828	2010	62	72%	0	0%	0.90
Zhangjiakou power station	2,560	868	1996	22	100%	0	0%	1.20
Datang Ningde power station	2,520	841	2007	18	6%	0	100%	0.83
Huainan Luohe power station	2,500	854	1999	64	21%	0	0%	0.90
Wushashan power station	2,400	841	2006	30	83%	0	0%	0.86
Hancheng-2 power station	2,400	868	2007	51	13%	0	100%	1.08
Xuchang Yulong power station	2,020	936	2006	82	100%	0	0%	0.95
Datang Shentou power station	2,000	868	1999	25	100%	0	0%	1.09
Datang Xinyang power station	1,920	840	2007	86	100%	0	100%	0.95
Datang Qitaihe power station	1,900	868	2006	16	60%	0	100%	1.19
Taiyuan-2 power station	1,860	868	2006	35	100%	0	78%	1.09
Huayin Zhuzhou power station	1,820	945	2007	46	16%	0	0%	0.95
Xiangtan power station	1,800	945	2004	48	16%	0	0%	0.95
Datang Sanmenxia power station	1,800	850	2003	53	100%	0	67%	1.05
Huangdao power station	1,770	942	2002	50	91%	0	75%	0.92
Datang Fuzhou power station	1,500	834	2015	39	14%	0	0%	0.93
Datang Heshan power station	1,330	950	2007	40	4%	0	0%	0.88
Datang Nanjing Xiaguan-3 power station	1,320	828	2010	62	4%	0	100%	0.97
Datang Jingtai power station	1,320	847	2009	21	0%	0	0%	1.14
Huaibei Hushan power station	1,320	841	2013	69	100%	0	100%	0.90
Datang Ma'anshan Dangtu power station	1,320	841	2008	59	4%	0	0%	0.97
Douhe power station	1,300	868	1982	63	100%	0	0%	0.98
HESHAN	1,260	951	2008	40	4%	0	0%	0.88
Datang Binchang power station	1,260	847	2009	30	0%	0	0%	1.15
TANGSHAN	1,250	868	2007	62	100%	0	96%	0.98
Datang Anyang-2 power station	1,240	868	2003	82	100%	0	0%	1.04
Tangshan Wangtan power station	1,200	868	2005	63	100%	0	0%	0.98
DATANG PANSHAN	1,200	867	2002	60	100%	0	100%	0.98
Datang Tangshan power station	1,200	864	2008	63	100%	0	100%	0.98
DABA	1,200	868	1994	17	100%	0	50%	1.18
Changchun-2 power station	1,200	868	2001	32	76%	0	0%	1.24
Daba-2 power station	1,200	935	2009	17	100%	0	100%	1.18
Yuncheng power station	1,200	868	2007	51	26%	0	100%	1.05
Jiayuguan Hongsheng power station	1,200	868	2007	7	100%	0	0%	1.19
Jinzhushan power station	1,200	965	2008	47	19%	0	0%	0.92
Datang Xutang power station	1,200	868	2003	65	100%	0	0%	0.91
Datang Yungang power station	1,040	868	2006	23	0%	0	0%	1.20
Datang Luoyang Shouyangshan power station	1,040	868	1991	78	100%	0	0%	0.95
DATANG LUOYANG	1,040	868	2002	69	100%	0	100%	1.05
Datang Matou power station	1,020	965	2001	83	100%	0	0%	1.04
Leiyang power station	1,020	965	1998	44	16%	0	0%	0.85
Datang Luoyang power station	1,005	874	2003	69	100%	0	93%	1.05
DATANG HUICHUN	860	968	2002	12	20%	1	0%	1.21

Baqiao power station	850	868	2007	46	100%	0	100%	1.05
Jixi power station	850	868	2008	15	17%	0	100%	1.19
Chongqing Shizhu power station	700	847	2014	42	1%	0	0%	0.98
Changchun-3 power station	700	868	2009	33	76%	0	0%	1.24
Datang Linzhou power station	700	841	2011	75	100%	0	0%	1.04
Datang Binzhou power station	700	847	2015	71	100%	0	100%	0.91
Datang Lueyang power station	660	860	2011	33	22%	0	100%	1.06
GUIGUAN HESHAN	660	868	2004	40	4%	0	0%	0.88
Taiyuan Second Gangue power station	660	889	2014	36	100%	0	100%	1.09
Datang Hunchun power station	660	969	2006	12	20%	1	0%	1.21
Datang Baoji power station	660	874	2009	35	100%	0	100%	1.09
Liaoyuan Datang power station	660	969	2009	29	100%	1	100%	1.24
LUEYANG	660	868	2011	38	17%	0	100%	1.06
Datang Changshan power station	660	938	2013	29	22%	1	100%	1.21
Datang Gangu power station	660	874	2007	17	0%	0	0%	1.12
Datang Baoding power station	650	874	2006	71	100%	0	0%	0.98
Datang Anhui Huainan Tianjia'an power station	640	868	2001	64	21%	0	0%	0.90
Datang Weihe power station	600	868	2009	38	12%	0	0%	1.08
Kaiyuan-2 power station	600	965	2007	14	15%	0	0%	0.88
TANGWEIHE	600	868	2009	46	100%	0	0%	1.05
Datang Wu'an power station	600	889	2012	74	100%	0	0%	1.04
Datang Xigu power station	600	868	2009	18	39%	0	100%	1.14
Linfen power station	600	868	2011	47	0%	0	0%	1.08
Datang Hutubi power station	600	874	2013	10	0%	0	0%	1.30
Fengrun power station	600	874	2009	60	100%	0	100%	0.98
Datang Liancheng-2 power station	600	868	2005	18	39%	0	100%	1.14
TIANJIAAN-2	600	868	2001	64	21%	0	0%	0.90
Datang Harbin power station	600	969	2009	29	31%	1	0%	1.22
Datang Qingyuan power station	600	874	2012	72	100%	0	0%	0.98
ZHANGJIAKOU	600	868	2011	22	100%	0	0%	1.20
HUXIAN-2	600	868	2010	46	100%	0	100%	1.05
Huxian-2 power station	600	868	2005	46	100%	0	100%	1.05
Jinzhou Datang power station	600	969	2009	38	100%	1	100%	1.13
Duolun Coal Chemical power station	500	874	2010	13	0%	0	0%	1.21
Xinyu power station	440	965	1996	43	5%	0	0%	0.95
Datang Shuangyashan power station	400	874	2006	16	64%	0	100%	1.19
LANZHOU XIGU	330	868	1999	18	39%	0	100%	1.14
Lanzhou Xigu power station	330	868	1999	18	39%	0	100%	1.14
Xuchang Longgang power station	270	874	1995	82	100%	0	0%	0.95
HUAIBEI	220	868	1993	69	100%	0	0%	0.90
Huaibei power station	220	868	1993	69	100%	0	0%	0.90
Datang Qian'an power station	220	874	2007	49	100%	0	0%	1.21
Xiahuayuan power station	200	910	1988	20	100%	0	0%	1.20
MATOU	200	964	1978	83	100%	0	0%	1.04
DATONG MINE	50	868	2007	24	0%	0	0%	1.20
Datang 803 power station	50	874	2005	18	39%	0	0%	1.14
HENGYANG	20	868	2006	50	16%	0	0%	0.85
TOTAL[i]	**102,035**	**880**	**2005**	**44**	**54%**	**0**	**37%**	**1.03**

i. MW-weighted averages; ii. Capacity only for owned portion; iii. Retrofitability is expressed as a percentage of the total powerplant unit MW capacity that is retrofitable.

Table 41: Environment-related risk exposure of Datang's planned plants

PLANT	CAPACITY[ii] [MW]	LRH-1: CARBON INTENSITY [kg CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLLUTION [µgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: QUALITY OF COAL [1 = LIGNITE]	LRH-6: CCS RETROFITABILITY [1 = RETROFITABLE][iii]	LRH-7: FUTRE HEAT STRESS [Δ°C]
Datang Xingren power station	2,640	860	2019	30	8%	0	0%	0.88
Lusigang power station	2,520	834	2017	55	54%	0	100%	0.90
DATANG PANNAN	2,400	867	2017	20	8%	0	100%	0.92
Datang Zhunge'er Dalu power station	2,000	860	2017	20	39%	0	0%	1.20
Datang Wushashan power station	2,000	834	2017	30	83%	0	0%	0.86
大唐彬长发电有限责任公司（二期）	2,000	867	2017	30	100%	0	0%	1.15
Datang Fugu Integration Project power station	2,000	860	2017	20	39%	0	100%	1.20
Datang Xutang power station	2,000	828	2017	65	100%	0	0%	0.91
Datang Guangyuan power station	2,000	834	2017	37	22%	0	100%	0.98
Datang Binchang power station	2,000	834	2017	32	100%	0	0%	1.15
Datang Jingtai power station	2,000	847	2017	21	0%	0	0%	1.14
Datang Anhui Huainan Tianjia'an power station	2,000	860	2017	64	21%	0	0%	0.90
Datang Junan power station	2,000	834	2017	61	100%	0	0%	0.91
Datang Xinyu power station	2,000	935	2017	43	5%	0	0%	0.95
Datang Leizhou power station	2,000	834	2015	24	19%	0	0%	0.76
Datang Yuncheng power station	2,000	860	2008	57	0%	0	100%	1.08
DATANG LUOYANG	2,000	829	2017	69	100%	0	100%	1.05
Datang Ma'anshan Dangtu power station	2,000	834	2017	59	4%	0	0%	0.97
Datang Ningde power station	2,000	841	2017	18	6%	0	100%	0.83
Datang Tangshan Beijiao power station	1,400	860	2017	61	100%	0	100%	0.98
Datang Hami Dananhu power station	1,400	860	2017	6	100%	0	0%	1.38
Huan County power station	1,320	834	2017	19	100%	0	0%	1.12
Datang Hutubi power station	1,320	860	2017	10	0%	0	0%	1.30
DATANG TAIER	1,320	842	2017	33	100%	0	0%	1.09
Datang Shuicheng power station	1,320	860	2017	23	8%	0	100%	0.92
大唐滁州发电厂	1,320	867	2017	60	4%	0	100%	0.97
Datang Sanmenxia power station	1,000	828	2017	53	100%	0	100%	1.05
Datang Baoji Cogen power station	700	860	2017	33	100%	0	0%	1.06
Datang Ordos Aluminum power station	700	860	2017	20	39%	0	0%	1.20
Datang Daqing CCS power station	700	1169	2020	22	31%	0	100%	1.21
Datang Jimsar power station	700	847	2017	10	100%	0	0%	1.32
Datang Yichun power station	700	874	2017	40	5%	0	0%	0.95
Datang Xiangyang power station	700	847	2017	53	3%	0	0%	1.01
Datang Sha County power station	700	860	2017	24	10%	0	100%	0.83
Datang Golmud power station	660	834	2017	7	15%	0	0%	1.14
大同煤矿集团山西漳电大唐热电有限公司三期	660	867	2017	23	100%	0	0%	1.20
辽宁调兵山煤矸石发电有限责任公司	600	867	2017	37	100%	0	0%	1.14
ZHANGJIAKOU ZTP	600	868	2017	73	100%	0	0%	1.09
Dawan Waste Coal power station	600	876	2017	23	8%	0	100%	0.92
Datang Huayin Dongguan Sanlian power station	233	860	2017	35	3%	0	0%	0.85
如皋市开源热电投资有限公司如皋经济技术开发区热电联产项目	24	868	2017	60	54%	0	0%	0.90
大庆龙唐供热有限公司	6	868	2017	22	31%	0	0%	1.22

TOTAL[i]	58,243	856	2017	37	47%	0	38%	1.02

i. MW-weighted averages; ii. Capacity only for owned portion; iii. Retrofitability is expressed as a percentage of the total powerplant unit MW capacity that is retrofitable.

1.5.3 Guodian

Guodian has the second highest coal generation capacity (103,512 MW) of all utilities in China, but the greatest capacity planned at 60,550 MW. It also has the greatest proportion of plants planned at 35%, however its coal capacity under construction represents the smallest fraction of operating capacity of all the five companies studied, at only 6% (11,140 MW).

Guodian's LRHs are similar to the other five companies, and there are little appreciable change between currently operating and planned capacities, with $PM_{2.5}$ levels (LRH-3) only falling marginally from 44 to 41 µg/m^3 within a 100km radius of planned plants, and water stress (LRH-4) increasingly slightly from 42% to 47% usage rates. On the other hand they do expect CO_2 intensity (LRH-1) to fall from 880 to 848 kg CO_2/MWh, which is the second lowest level among the five companies.

Figure 39: Estimated scale of asset stranding for Guodian's existing and new build coal plants

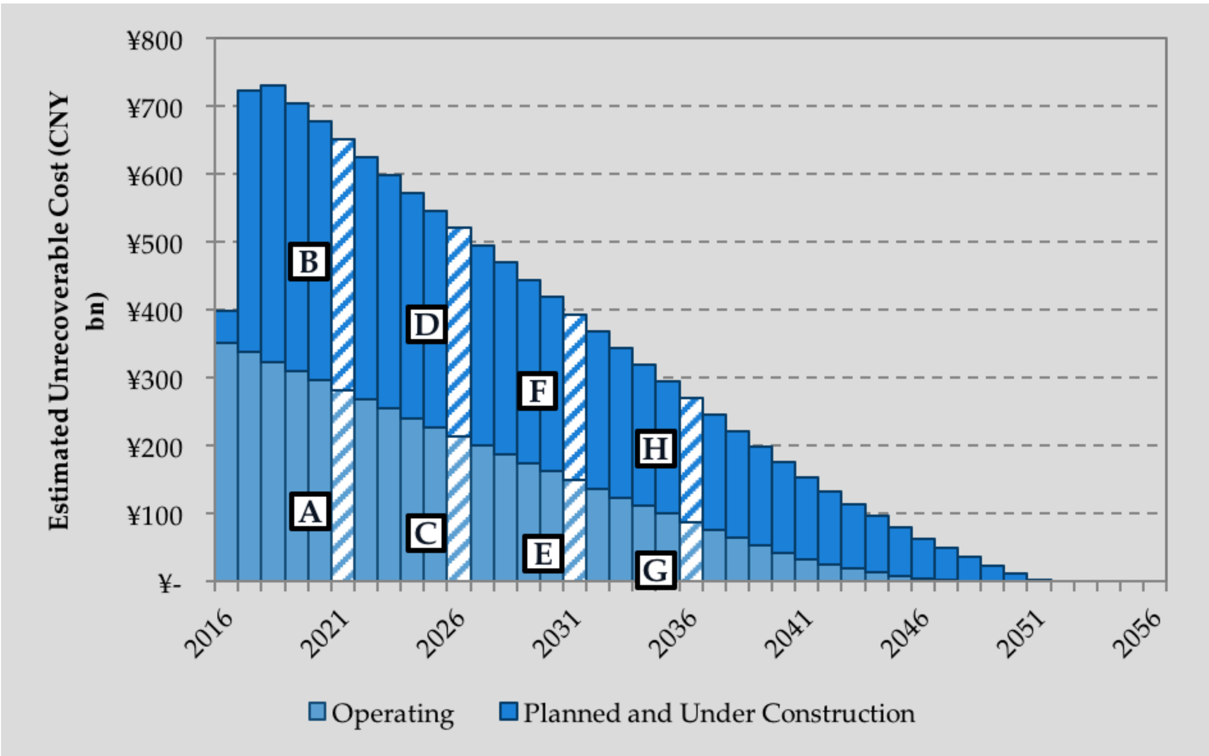


Table 42: Environment-related risk exposure of Guodian's operating plants

PLANT	CAPACITY[ii] [MW]	LRH-1: CARBON INTENSITY [kg CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLLUTION [µgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: QUALITY OF COAL [1 = LIGNITE]	LRH-6: CCS RETROFITABILITY [1 = RETROFITABLE][iii]	LRH-7: FUTRE HEAT STRESS [Δ°C]
Guodian Taizhou power station	4,000	828	2012	65	4%	0	0%	0.97
Jianbi power station	3,980	848	2002	65	4%	0	67%	0.97
Datong-2 power station	3,720	858	2000	24	0%	0	0%	1.20
Beilun power station	3,200	843	2003	31	83%	0	0%	0.86
Fengcheng power station	2,520	854	2002	45	5%	0	0%	0.93
Guodian Baoji-2 power station	2,520	857	2006	32	0%	0	0%	1.06
Guodian Jiujiang power station	2,420	876	2006	44	1%	0	83%	0.93
Hanchuan power station	2,260	856	2002	82	100%	0	0%	0.98
Shuangliao West power station	2,060	959	2003	17	76%	1	66%	1.24
Shuangyashan power station	2,040	852	2000	16	64%	0	0%	1.19
Shizuishan-2 power station	1,980	868	2004	15	100%	0	100%	1.18
Nanpu Quanzhou power station	1,940	849	2009	19	23%	0	100%	0.75
Xuanwei power station	1,800	868	2003	16	8%	0	100%	0.92
Yiyang power station	1,800	945	2005	52	19%	0	100%	0.92
Guodian Jingmen power station	1,600	848	2000	55	8%	0	0%	1.01
Heze power station	1,510	965	2002	84	100%	0	0%	0.92
Guodian Guangdong Zhaoqing Dawang power station	1,400	854	2013	36	7%	0	100%	0.85
Guodian Dananhu power station	1,320	834	2016	6	100%	0	0%	1.38
Bulian power station	1,320	828	2013	18	0%	0	0%	1.16
Guodian Baoqing power station	1,320	841	2012	49	19%	0	0%	0.89
Guodian Nanning power station	1,320	935	2012	37	8%	0	0%	0.88
Guodian Zhijin power station	1,320	847	2016	29	11%	0	0%	0.88
Guodian Huangjinbu power station	1,300	847	2007	43	14%	0	100%	0.93
Guodian Feixian power station	1,300	841	2007	64	100%	0	0%	0.91
Guodian Shangqiu Minquan power station	1,260	841	2008	79	100%	0	0%	0.90
Guodian Changzhou power station	1,260	847	2006	61	69%	0	100%	0.90
Xingyang Integration power station	1,260	935	2010	88	100%	0	100%	0.95
Taiyuan-1 power station	1,225	868	1996	36	100%	0	49%	1.20
Jiangyin Sulong power station	1,214	868	2002	63	72%	0	0%	0.90
Guodian Duyun power station	1,200	841	2013	35	7%	0	0%	0.89
SHANGQIU	1,200	842	2008	79	100%	0	0%	0.90
Huozhou power station	1,200	841	2012	42	0%	0	0%	1.08
Kangping power station	1,200	841	2009	36	78%	0	100%	1.19
Hebei Longshan power station	1,200	868	2007	23	0%	0	100%	1.21
Tongling Guodian power station	1,200	841	2008	47	4%	0	100%	0.97
Anhui Bengbu power station	1,200	841	2009	63	21%	0	0%	0.90
Chengdu Jintang power station	1,200	841	2007	57	38%	0	0%	0.97
Guodian Zhuanghe power station	1,200	841	2007	29	38%	0	100%	0.97
Guodian Jiangyin power station	1,200	841	2007	19	10%	0	100%	0.83
Qingshan power station	1,030	965	2007	56	1%	0	0%	0.97
Yangzonghai-2 power station	1,000	969	2004	14	15%	1	100%	0.88
Jiangsu Nantong power station	1,000	834	2014	59	72%	0	0%	0.90
Luanhe power station	990	874	2010	28	100%	0	0%	1.21
NANTONG LONGYUAN	910	868	2002	60	54%	0	0%	0.90
Guodian Kuqa power station	870	868	2010	13	100%	0	0%	1.21
Jingyuan-1 power station	800	868	1991	21	39%	0	0%	1.14

SHASHI	800	868	2004	63	52%	0	0%	1.01
JILIN LONGTAN	750	868	1986	26	76%	0	0%	1.24
Guodian Pingnan power station	700	847	2014	30	31%	0	0%	1.22
ZHAOQING	700	842	2013	38	2%	0	100%	0.90
Hainan Southwest power station	700	847	2015	12	7%	0	100%	0.70
Guodian Dongsheng power station	660	874	2008	16	0%	0	0%	1.16
Lanzhou Fanjiaping power station	660	874	2011	18	39%	0	0%	1.14
Tianjin Northeast power station	660	868	2009	74	100%	0	0%	0.98
Guodian Jiuquan power station	660	874	2011	20	0%	0	0%	1.12
Huai'an power station	660	874	2008	20	0%	0	0%	1.20
Guodian Jiangnan power station	660	868	2011	13	76%	0	100%	1.19
Guodian Shenyang power station	660	874	2012	40	100%	0	100%	1.14
Changzhi power station	660	874	2012	53	100%	0	0%	1.04
Yuci power station	660	868	2010	38	100%	0	0%	1.09
Guodian Dawukou power station	660	874	2010	15	0%	0	100%	1.18
Hongyanchi-1 power station	660	868	2011	10	100%	0	0%	1.32
Zhumadian-3 power station	660	874	2011	69	63%	0	0%	0.95
Ningdong Younglight power station	660	874	2013	16	100%	0	100%	1.18
Guodian Jilin power station	650	939	1993	18	100%	1	38%	1.21
Liaocheng Zhonghua power station	630	860	2006	87	100%	0	0%	0.92
Handan power station	600	871	2001	83	0%	0	0%	1.04
Wansheng power station	600	874	2007	44	2%	0	100%	0.90
Xiaolongtan power station	600	969	2007	14	15%	1	0%	0.88
Guodian Changchun power station	600	847	2012	33	76%	0	0%	1.24
Huayingshan power station	600	868	2006	37	17%	0	100%	0.98
Guodian Alashan Left Qi Wusitai power station	600	860	2010	15	100%	0	100%	1.18
Guodian Anshun power station	600	965	1998	30	11%	0	0%	0.88
ORDOS DONGSHENG	600	868	2008	16	0%	0	0%	1.16
Wanyuan power station	600	868	2007	47	19%	0	100%	0.98
Hengfeng-2 power station	600	874	2005	86	100%	0	100%	0.98
Guodian Yongfu power station	600	965	2007	37	7%	0	100%	0.89
Guodian Penglai power station	600	868	2006	38	100%	0	0%	0.99
SHIZUISHAN-2	600	868	2006	15	100%	0	100%	1.18
Guodian Changyuan Jingzhou power station	600	874	2009	63	52%	0	0%	1.01
Shiheng-2 power station	473	868	1998	63	100%	0	0%	0.91
Puyang Pangking power station	420	874	2006	87	100%	0	0%	1.04
Longhua Yanji power station	400	874	2010	12	20%	0	100%	1.19
Longhua Baicheng power station	400	874	2011	20	22%	0	0%	1.21
Karamay power station	350	847	2014	9	100%	0	0%	1.44
Suzhou Huiyuan power station	350	874	2006	66	100%	0	0%	0.90
Tianjin Guodian Beitang power station	350	860	2014	74	100%	0	0%	0.98
Guodian Yuyuan power station	300	874	2005	70	100%	0	100%	1.04
Shengli Dongying power station	300	868	2015	67	100%	0	100%	0.91
Sujiawan power station	300	874	2006	56	1%	0	0%	0.97
Zhangze Linfen power station	300	860	2012	47	100%	0	0%	1.08
LUANHE	300	868	2012	28	100%	0	0%	1.21
JIYUAN	300	868	2007	69	100%	0	100%	1.04
Guodian Suqian power station	270	868	2005	62	100%	0	0%	0.91
Minjiang power station	270	965	2006	33	15%	0	100%	1.14
Guodian Yuzhong power station	220	874	1990	19	39%	0	0%	1.14
Wangping power station	220	868	2011	24	0%	0	0%	1.09
LANZHOU DONGCHENG	220	868	1990	18	39%	0	0%	1.14
Neijiang Baima power station	200	965	1996	67	54%	0	0%	0.90
SUZHOU HUIYUAN	175	868	2006	60	69%	0	100%	0.90
Shenyang CHP power station	150	965	2003	38	100%	0	0%	1.14
Dalian ETDC power station	144	874	2004	38	100%	0	0%	0.99
LONGHUA CHANGCHUN	140	868	2002	33	76%	0	0%	1.24
Bei'an power station	100	868	1997	13	100%	0	0%	1.17
Yiwuling power station	100	874	1974	63	0%	0	0%	1.04
Jiaohe New power station	24	874	2000	19	76%	0	0%	1.24
JIAOHE NEW	24	868	2000	19	76%	0	0%	1.24
TIECHANGGOU	24	868	1988	6	100%	0	0%	1.44
GUODIAN LONGJING	9	868	1995	26	76%	0	0%	1.24

TOTAL[i]	103,512	867	2006	42	43%	0	35%	1.02

i. MW-weighted averages; ii. Capacity only for owned portion; iii. Retrofitability is expressed as a percentage of the total powerplant unit MW capacity that is retrofitable.

Table 43: Environment-related risk exposure of Guodian's planned plants

PLANT	CAPACITY[ii] [MW]	LRH-1: CARBON INTENSITY [kg.CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLLUTION [µgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: QUALITY OF COAL [1 = LIGNITE]	LRH-6: CCS RETROFITABILITY [1 = RETROFITABLE][iii]	LRH-7: FUTRE HEAT STRESS [Δ°C]
Jianbi power station	2,400	834	2012	65	4%	0	100%	0.97
Guodian Nanning power station	2,000	847	2017	37	8%	0	0%	0.88
Guodian Xilinguole Wulagai power station	2,000	860	2017	6	72%	0	0%	1.38
FENGCHENG	2,000	829	2017	46	5%	0	0%	0.93
Tongling Guodian power station	2,000	828	2011	47	4%	0	100%	0.97
Guodian Baoqing power station	2,000	834	2017	49	19%	0	0%	0.89
Guodian Shangqiu Minquan power station	2,000	841	2017	82	100%	0	0%	0.90
Guodian Feixian power station	2,000	841	2017	64	100%	0	0%	0.91
Guodian Xinyu power station	2,000	834	2017	43	5%	0	0%	0.95
Guodian Huangjinbu power station	2,000	834	2018	43	14%	0	100%	0.93
SHANGQIU	2,000	842	2017	79	100%	0	0%	0.90
Guodian Jingyuan power station	2,000	860	2017	21	16%	0	0%	1.14
Guodian Miluo power station	2,000	834	2017	49	1%	0	100%	0.95
Bulian power station	2,000	828	2017	18	39%	0	0%	1.16
Guodian Jilin power station	1,400	841	2017	18	100%	0	100%	1.21
Guodian Penglai power station	1,340	828	2017	38	100%	0	0%	0.99
Guodian Jingmen power station	1,320	834	2017	55	8%	0	0%	1.01
Guodian Anlu power station	1,320	834	2018	56	39%	0	100%	0.97
Guodian Tacheng power station	1,320	860	2017	6	100%	0	0%	1.44
Guodian Turpan power station	1,320	834	2017	11	100%	0	0%	1.32
Xixia Wanxi power station	1,320	847	2017	46	25%	0	100%	1.05
Guodian Nilka Power Plant	1,320	847	2017	7	100%	0	0%	1.25
Guodian Zhunger Changtan power station	1,320	860	2017	20	39%	0	0%	1.20
Guodian Anshun power station	1,320	951	2017	30	11%	0	0%	0.88
Guodian Changzhou power station	1,320	847	2017	63	4%	0	0%	0.90
Guodian Suqian power station	1,320	834	2017	63	100%	0	0%	0.91
Guodian Jiangyin power station	1,320	860	2017	19	27%	0	0%	0.83
Guodian Chongzuo power station	1,200	847	2017	34	8%	0	100%	0.86
Guodian Liaocheng power station	1,200	847	2017	85	100%	0	0%	0.92
Jinsha Hubei power station	1,200	860	2017	63	52%	0	0%	1.01
Guodian Shuangwei Shanghaimiao power station	1,000	834	2018	17	15%	0	0%	1.18
Guodian Zunhua-2 power station	700	841	2017	51	100%	0	0%	1.21
Guodian Dawukou power station	700	847	2017	15	0%	0	100%	1.18
Guodian Yuyuan power station	700	874	2017	70	100%	0	100%	1.04
Tianjin Northeast power station	700	868	2017	74	100%	0	0%	0.98
Guodian Yongfu power station	700	965	2015	37	7%	0	100%	0.89
XI'AN WEIYANG	700	842	2017	46	100%	0	100%	1.05
JIYUAN	700	868	2017	69	100%	0	100%	1.04
Pulandian Cogen Power Station	700	874	2017	35	100%	0	0%	0.99
Guodian Shanghaimiao Waste power station	700	847	2017	17	15%	0	0%	1.18
Guodian Alashan Left Qi Wusitai power station	660	860	2017	15	100%	0	100%	1.18
Jimsar Wucaiwan Beisan power station	660	834	2017	9	39%	0	100%	1.32

Guodian Dongsheng power station	600	874	2017	16	0%	0	0%	1.16
Wangping power station	600	841	2017	24	100%	0	0%	1.09
Longhua Yanji power station	600	874	2017	12	20%	0	100%	1.19
Guodian Qingzhou power station	600	874	2017	63	100%	0	0%	0.91
Guodian Beitun power station	270	874	2012	6	100%	0	0%	1.37
TOTAL[i]	**60,550**	**848**	**2017**	**41**	**47%**	**0**	**31%**	**1.03**

i. MW-weighted averages; ii. Capacity only for owned portion; iii. Retrofitability is expressed as a percentage of the total powerplant unit MW capacity that is retrofitable.

1.5.4 Huadian

Huadian has the fourth highest coal generation capacity at 90,525 MW, and among the five major companies has the second highest percentage of its total capacity under construction at 11% (18,150 MW). Although Huadian ranks fourth in total potential asset stranding in the five, 10, and 15 years scenarios, because of its high level of plants under construction, it surpasses Guodian and ranks third in asset stranding in the 20 year scenario.

Across the five companies Huadian's planned capacity expects to achieve notable reductions in water stress (LRH-4, from 37% to 27%), and its planned plants are the most efficient at 847 kg CO2/MWh (LRH-1). On the negative side it also expects stagnant air quality improvements (LRH-3, holding at 42 μg/m³), and declining CCS retrofitability (LRH-6, from 36% to 27%).

Figure 40: Estimated scale of asset stranding for Huadian's existing and new build coal plants

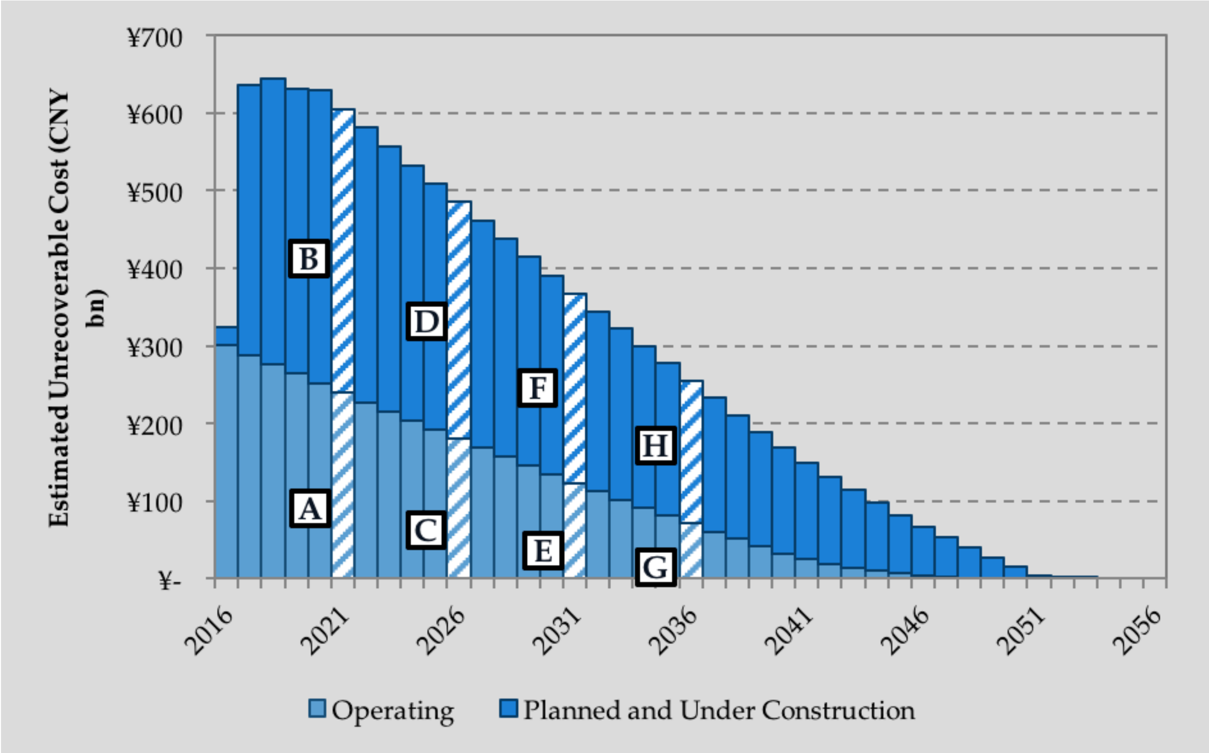


Table 44: Environment-related risk exposure of Huadian's operating plants

PLANT	CAPACITY[ii] [MW]	LRH-1: CARBON INTENSITY [kg CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLLUTION [µgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: QUALITY OF COAL [1 = LIGNITE]	LRH-6: CCS RETROFITABILITY [1 = RETROFITABLE] [iii]	LRH-7: FUTRE HEAT STRESS [Δ°C]
Zouxian power station	4,540	850	1998	73	100%	0	70%	0.92
Huadian Ningxia Lingwu power station	3,320	842	2009	17	0%	0	100%	1.18
Pucheng power station	2,580	951	2004	50	100%	0	0%	1.05
Tieling power station	2,520	847	2002	35	100%	0	64%	1.14
Xiangfan power station	2,400	854	2002	53	8%	0	0%	1.01
Guang'an power station	2,400	937	2004	54	26%	1	0%	0.98
Fuzhou Kemen power station	2,400	841	2007	19	10%	0	100%	0.83
Huadian Laizhou power station	2,078	828	2012	44	100%	0	0%	0.92
Huadian Xisaishan power station	2,020	872	2009	48	1%	0	0%	0.98
Huadian Gourong power station	2,000	828	2013	65	4%	0	100%	0.97
Huadian Weifang power station	2,000	850	2002	58	100%	0	0%	0.91
Huadian Wangting power station	1,920	840	2004	62	69%	0	69%	0.90
Huadian Harbin-3 power station	1,640	868	1995	29	31%	0	0%	1.22
Huadian Lu'an power station	1,590	835	2013	50	21%	0	0%	0.98

Junliangcheng power station	1,540	868	1999	74	100%	0	0%	0.98
Huadian Wuhu power station	1,320	828	2008	53	4%	0	100%	0.97
Huadian Baotou Tuyou power station	1,320	847	2016	14	0%	0	0%	1.19
Huadian Changde power station	1,320	860	2015	53	2%	0	0%	0.92
Xinxiang Baoshan power station	1,320	841	2007	80	100%	0	0%	1.04
Huadian Suzhou power station	1,260	841	2007	34	22%	0	100%	0.91
Yangzhou-2 power station	1,230	855	2002	65	4%	0	100%	0.97
Mudanjiang-2 power station	1,230	868	2001	15	60%	0	49%	1.19
Huadian Guigang power station	1,200	847	2006	37	8%	0	0%	0.88
Tongzi power station	1,200	935	2013	38	2%	0	100%	0.90
Tangzhai power station	1,200	935	2013	32	11%	0	0%	0.88
HUADIAN BAOTOU	1,200	867	2007	14	71%	0	0%	1.19
Huadian Fulaerji-2 power station	1,200	969	1986	18	6%	1	0%	1.21
HUADIAN YUHENG	1,200	829	2013	22	0%	0	0%	1.16
Qingdao power station	1,200	868	2001	49	100%	0	50%	0.92
Huadian Zhenxiong power station	1,200	935	2012	31	2%	0	0%	0.92
Huadian Changsha power station	1,200	841	2007	49	16%	0	100%	0.95
Dafang power station	1,200	965	2007	30	11%	0	0%	0.88
Zhangping power station	1,200	965	2012	22	10%	0	100%	0.83
Laicheng power station	1,200	868	2001	67	100%	0	100%	0.91
Bayanhua Jinshan power station	1,200	874	2010	7	62%	0	0%	1.27
Huadian Gongxian power station	1,200	935	2011	53	1%	0	100%	0.88
Baotou Hexi power station	1,200	868	2006	14	71%	0	0%	1.19
Huadian Shimen power station	1,200	965	2001	51	15%	0	50%	0.92
Huadian Shijiazhuang power station	1,100	965	2006	73	100%	0	0%	1.09
Huangshi power station	1,100	874	2004	49	1%	0	0%	0.98
Huadian Zibo power station	1,072	868	2008	68	100%	0	0%	0.91
Tengzhou Xinyuan power station	930	868	2005	64	100%	0	100%	0.91
Huadian Changji power station	910	868	2010	10	100%	0	0%	1.30
Huadian Kashi power station	900	853	2012	15	81%	0	0%	1.19
Zhangqiu power station	890	965	2005	73	100%	0	0%	0.92
Huadian Longkou power station	880	965	1992	39	100%	0	0%	0.99
Huadian Zhuozi power station	800	874	2005	15	100%	0	0%	1.20
Hongyanchi-2 power station	800	868	2002	10	100%	0	0%	1.32
Xunjiansi power station	735	874	2006	14	15%	0	0%	0.88
Huadian Shiliquan power station	725	868	1994	68	100%	0	41%	0.91
Pingshi power station	725	965	2008	33	7%	0	100%	0.85
Huadian Yangling Cogen power station	700	847	2016	41	0%	0	0%	1.05
Huadian Luhua power station	660	965	2011	68	0%	0	0%	1.09
Huadian Luohe power station	660	874	2010	76	100%	0	0%	0.95
Huadian Urumqi power station	660	874	2009	10	100%	0	0%	1.32
Qudong power station	600	874	2013	85	100%	0	100%	1.04
GUIZHOU DALONG	600	868	2006	43	7%	0	0%	0.89
Huadian Harbin-1 power station	600	868	2007	29	31%	0	0%	1.22
Jiamusi-2 power station	600	868	2008	16	10%	0	100%	1.19
Baotou Donghua power station	600	868	2005	15	71%	0	0%	1.21
Guizhou Dalong power station	600	868	2006	43	7%	0	0%	0.89
Dandong Jinshan power station	600	874	2012	23	10%	0	0%	1.14
Kunming power station	600	868	2005	13	6%	0	100%	0.92
Yong'an power station	600	965	2011	23	10%	0	100%	0.85
Luzhou Chuannan power station	600	965	2008	63	1%	0	100%	0.90
Heilongjiang Qiqihar power station	600	868	2007	18	6%	0	100%	1.21
Qinghai Datong power station	600	874	2006	9	100%	0	0%	1.14
Huangjiaozhuang power station	400	965	1993	63	6%	0	0%	0.88
Huadian Yaochi Power station	400	876	2010	34	100%	0	0%	1.15
Qingzhen power station	400	874	1989	31	11%	0	0%	0.88
Huadian Shuozhou power station	350	860	2015	25	100%	0	0%	1.20
Yangzhou-1 power station	330	868	2005	65	54%	0	100%	0.97
NINGDONG MALIANTAI	330	868	2009	16	100%	0	100%	1.18
Jingxi Guangxi power station	315	874	1986	38	8%	0	0%	0.88
Bijie power station	300	874	2009	31	11%	0	0%	0.88
Panzhihua power station	300	889	2005	15	4%	0	100%	0.93
Huadian Wuda power station	300	874	2005	15	100%	0	100%	1.18

BIJIE DONGHUA	300	965	2009	30	11%	0	0%	0.88
Huadian Hami power station	295	860	2002	6	100%	0	0%	1.38
Huadian Turpan power station	270	868	2006	11	100%	0	0%	1.32
Huadian Datong-1 power station	270	868	2006	9	100%	0	0%	1.14
Hami Tianguang power station	250	868	2003	36	5%	0	100%	0.85
Huadian Shaowu power station	250	965	1998	29	10%	0	100%	0.85
HUADIAN WEIHULIANG	250	868	1999	10	100%	0	0%	1.32
Neijiang Baima power station	200	965	1989	67	54%	0	0%	0.90
Huadian Xinzhou Guangyu power station	135	860	2007	32	100%	0	0%	1.09
Neijiang Gaoba power station	100	965	1996	67	54%	0	0%	0.90
Xiamen Xinglin power station	92	874	2010	20	20%	0	0%	0.75
YINCHUAN	63	868	2006	16	0%	0	100%	1.18
Yinchuan power station	30	874	2006	16	100%	0	0%	1.18
TOTAL[i]	**90,525**	**878**	**2006**	**42**	**47%**	**0**	**36%**	**1.01**

i. MW-weighted averages; ii. Capacity only for owned portion; iii. Retrofitability is expressed as a percentage of the total powerplant unit MW capacity that is retrofitable.

Table 45: Environment-related risk exposure of Huadian's planned plants

PLANT	CAPACITY[ii] [MW]	LRH-1: CARBON INTENSITY [kg CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLLUTION [µgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: QUALITY OF COAL [1 = LIGNITE]	LRH-6: CCS RETROFITABILITY [1 = RETROFITABLE][iii]	LRH-7: FUTRE HEAT STRESS [Δ°C]
JINGZHOU	3,320	829	2017	64	0%	0	100%	1.01
Huadian Shenqiu power station	2,000	834	2017	70	100%	0	0%	0.90
Huadian Xiangyang power station	2,000	828	2017	53	3%	0	0%	1.01
Fuzhou Kemen power station	2,000	828	2018	19	10%	0	100%	0.83
Huadian Pianguan power station	2,000	834	2017	21	39%	0	0%	1.20
Huadian Dingtao power station	2,000	834	2019	83	100%	0	0%	0.92
Huadian Tongzhou Bay power station	2,000	860	2017	58	54%	0	0%	0.90
Huadian Hunyuan power station	2,000	834	2017	23	100%	0	0%	1.20
HUADIAN YUHENG	2,000	829	2017	22	0%	0	0%	1.16
Huadian Jiangling power station	2,000	834	2017	64	0%	0	100%	1.01
Huadian Lu'an power station	2,000	828	2020	50	21%	0	0%	0.98
Huadian Taiqian power station	2,000	834	2017	85	100%	0	0%	0.92
Baotou Donghua power station	1,320	834	2017	15	71%	0	0%	1.21
Baotou Hexi power station	1,320	860	2017	14	71%	0	0%	1.19
Huadian Toksun power station	1,320	847	2017	11	100%	0	0%	1.32
Huadian Anshun Caiguan power station	1,320	860	2017	30	8%	0	0%	0.88
SHI'ER LIANCHENG	1,320	829	2018	18	0%	0	0%	1.21
Huadian Duolun power station	1,320	834	2017	13	100%	0	0%	1.21
Huadian Guigang power station	1,320	847	2017	37	8%	0	0%	0.88
ORDOS SHUANGXIN	1,200	867	2017	15	100%	0	100%	1.18
HUANGJIAOZHUANG	1,200	964	2017	63	6%	0	100%	0.88
Quwo power station	1,200	834	2017	23	100%	0	0%	1.20
Huadian Longkou power station	1,200	958	2017	37	100%	0	0%	0.99
Bayanhua Jinshan power station	1,200	834	2017	7	62%	0	0%	1.27
Huadian Wuhu power station	1,000	828	2017	53	4%	0	100%	0.97
Yuling Longtan power station	700	860	2017	31	18%	0	100%	0.81
河北华电石家庄鹿华热电有限公司(二期)	700	867	2017	67	100%	0	0%	1.09
河北华电石家庄裕华热电有限公司(二期)	700	867	2017	79	100%	0	0%	1.09
Huadian Luhua power station	700	847	2017	68	0%	0	0%	1.09

Huadian Tianshui Cogen power staion	700	874	2017	23	100%	0	0%	1.06
Bijie power station	700	860	2017	31	11%	0	0%	0.88
Huadian Zhunger Shierliancheng power station	660	834	2017	18	71%	0	0%	1.21
Huadian Shiliquan power station	660	828	2017	68	100%	0	100%	0.91
NINGDONG MALIANTAI	600	842	2017	16	100%	0	100%	1.18
Luzhou Chuannan power station	600	965	2017	63	1%	0	100%	0.90
Huadian Zhunger Dalu Waste Coal power station	600	874	2017	20	39%	0	0%	1.20
Huadian Harbin-1 power station	300	868	2017	29	31%	0	0%	1.22
江苏华电如皋热电联产项目	38	868	2017	60	54%	0	0%	0.90
TOTAL[i]	**49,218**	**847**	**2017**	**42**	**49%**	**0**	**27%**	**1.04**

i. MW-weighted averages; ii. Capacity only for owned portion; iii. Retrofitability is expressed as a percentage of the total powerplant unit MW capacity that is retrofitable.

1.5.5 State Power Investment Corp

State Power Investment Corp (SPIC) has the fifth highest coal generation capacity in China at 76,416 MW. Notably, among the five major companies SPIC has the highest percentage of total capacity that is under construction or planned at 44% (13,310 MW under construction and 46,239 MW plaanned). Because of its smaller size, total potential asset stranding in the five, 10, 15, and 20 year scenarios is also the lowest of the five companies.

The most notable characteristic of SPIC's LRHs is its abnormally high percentage of operating capacity that uses lignite fuel (LRH-5, 26%). However this is expected to decline to only 14% in planned plants. Still, the CO_2 intensity (LRH-3) of its planned plants is expected to decrease slightly overall from 888 to 858 kg CO_2/MWh. Across the five companies SPIC is also noteworthy for having the highest water stress (LRH-4) for operating plants (47%), and planned plants are expected to have even greater water stress (54%). Local air pollution (LRH-3) is expected decline however, from 41 to 30 μg/m^3 in planned plants.

Figure 41: Estimated scale of asset stranding for State Power Investment Corp's existing and new build coal plants

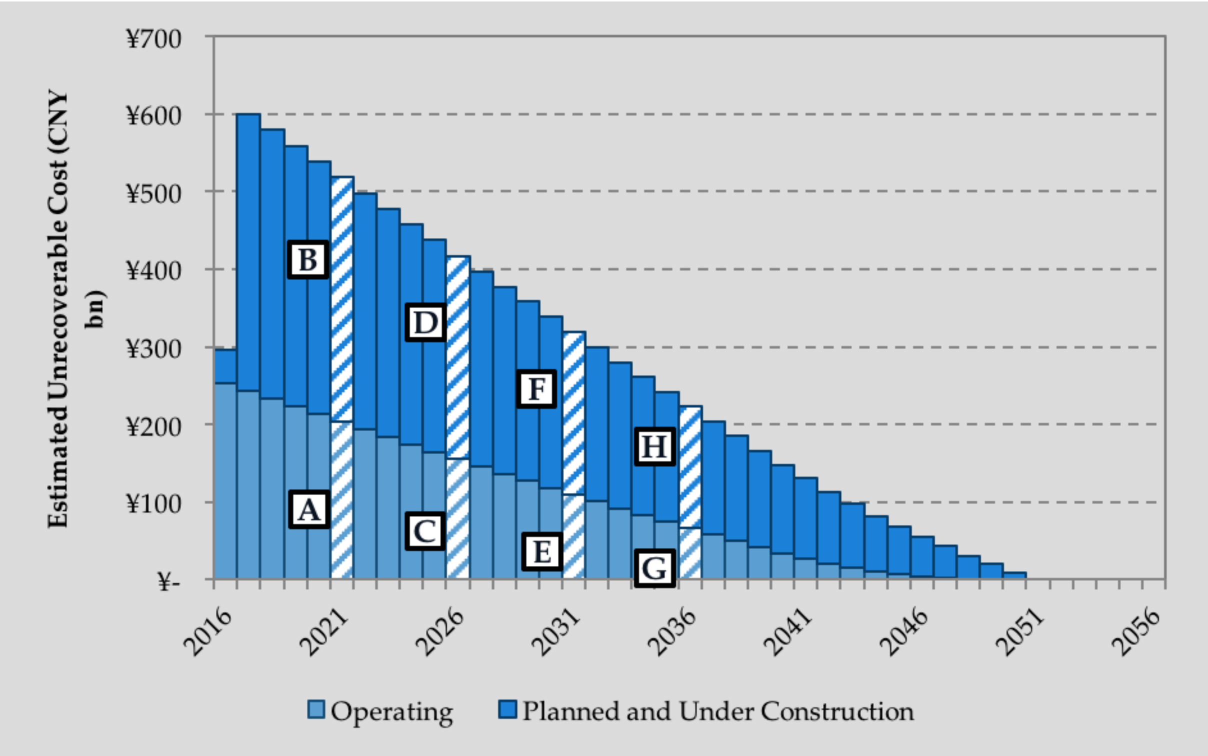


Table 46: Environment-related risk exposure of State Power Investment Corp's operating plants

PLANT	CAPACITY[ii] [MW]	LRH-1: CARBON INTENSITY [kg.CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLLUTION [μgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: QUALITY OF COAL [1 = LIGNITE]	LRH-6: CCS RETROFITABILITY [1 = RETROFITABLE][iii]	LRH-7: FUTRE HEAT STRESS [Δ°C]
CPI Pingwei power station	4,480	842	2006	64	21%	0	0%	0.90
CPI Changshu-1 power station	3,320	844	2005	59	72%	0	0%	0.90
Yaomeng power station	2,400	854	1994	72	100%	0	0%	0.95
YUANBAOSHAN	2,194	967	1994	19	100%	1	0%	1.21
Chifeng Yuanbaoshan power station	2,100	969	1994	19	100%	1	0%	1.21
Tongliao power station	2,070	969	1997	27	0%	1	0%	1.21
Shanghai Caojing power station	2,000	834	2010	57	69%	0	0%	0.90
Pingdingshan Luyang power station	2,000	828	2010	71	100%	0	0%	0.95
Hongjun Aluminum power station	1,900	952	2011	7	0%	1	0%	1.29
Guixi power station	1,880	850	2010	39	14%	0	100%	0.93
Qianbei power station	1,700	868	2002	36	11%	0	100%	0.88
CPI Qinghe power station	1,600	940	2004	35	100%	1	75%	1.14
CPI Xinchang power station	1,400	828	2010	45	1%	0	100%	0.93
Jingdezhen power station	1,320	834	2011	40	14%	0	100%	0.93

Wuhu Zhongdian power station	1,320	828	2011	53	4%	0	100%	0.97
Jinsha Chayuan power station	1,320	847	2016	36	11%	0	100%	0.88
CPI Shentou power station	1,320	841	2013	26	100%	0	0%	1.09
Xishui Erlang power station	1,320	860	2015	41	2%	0	100%	0.90
CPI Baicheng power station	1,320	938	2010	20	0%	1	0%	1.21
CPI Xining power station	1,320	834	2015	10	0%	0	0%	1.14
DABIESHAN	1,280	842	2008	59	80%	0	100%	0.97
Waigaoqiao power station	1,280	868	1996	57	91%	0	25%	0.90
Huainan Tianji power station	1,260	847	2007	64	21%	0	0%	0.90
Nayong-2 power station	1,200	965	2006	31	11%	0	0%	0.88
DABAN	1,200	967	2010	12	100%	1	0%	1.27
WEISHANHU YANSHANHU	1,200	939	2012	23	0%	1	100%	1.14
Fuxi power station	1,200	841	2012	62	1%	0	100%	0.88
Nayong-1 power station	1,200	965	2004	31	11%	0	0%	0.88
CPI Huolinhe power station	1,200	969	2008	7	0%	1	0%	1.29
Qianxi power station	1,200	965	2006	32	11%	0	0%	0.88
BAIYINHUA JINSHAN	1,200	867	2010	7	62%	0	0%	1.27
Chaoyang Yanshanhu power station	1,200	938	2012	30	100%	1	100%	1.13
Huanggang Dabieshan power station	1,200	841	2008	47	1%	0	0%	0.97
CPI Chifeng Daban power station	1,200	969	2013	12	100%	1	0%	1.27
Yaxi power station	1,200	965	2005	38	11%	0	0%	0.90
Kaifeng-2 power station	1,200	841	2009	88	100%	0	100%	0.95
Fuxin power station	1,100	868	2004	36	100%	0	82%	1.13
Xinxiang Huayu power station	1,000	868	1999	83	100%	0	60%	1.04
Hunjiang power station	1,000	885	2002	16	10%	0	80%	1.15
Chongqing Shuanghuai power station	960	840	2011	60	32%	0	100%	0.90
Zhangze Changzhi power station	840	874	1990	51	0%	0	0%	1.04
Songhuajiang power station	730	969	2009	27	76%	1	82%	1.24
CPI Linhe power station	700	847	2011	11	100%	0	0%	1.25
Hejin power station	700	868	2000	52	12%	0	100%	1.08
Chongqing Baihe power station	700	965	2004	55	1%	0	86%	0.90
Liaoning-3 power station（Liaoning Dongfang Power Station）	700	868	2005	39	100%	0	100%	1.14
CPI Shanxi Houma power station	700	882	2012	54	100%	0	0%	1.08
Wujing-2 cogen power station	600	868	2009	56	69%	0	0%	0.90
GUANGZHOU XINTANG	600	868	2012	33	15%	0	0%	0.85
Dalian Ganjingzi power station	600	969	2010	38	100%	1	100%	0.99
Shijiazhuang Liangcun power station	600	868	2011	73	100%	0	0%	1.09
Wujing-1 power station	600	868	1992	56	69%	0	0%	0.90
Shunde Desheng power station	600	868	2008	36	3%	0	100%	0.85
Fushun CPI power station	600	969	2008	33	100%	1	0%	0.99
CPI Wusu power station	600	874	2011	9	0%	0	0%	1.31
Erdaojiang power station	600	910	2003	17	10%	0	67%	1.15
Guangzhou Lixin power station	600	874	2012	33	15%	0	0%	0.85
Fenyi power station	540	868	2008	42	5%	0	0%	0.95
Pingdingshan power station	420	868	2006	73	100%	0	0%	0.95
CPI Nanyang power station	420	874	2008	61	78%	0	100%	0.95
CHONGQING WEST	400	868	2001	55	1%	0	50%	0.90
SONGHUAJIANG	350	967	2012	26	76%	1	100%	1.24
Siping power station	350	969	2013	33	100%	1	0%	1.19
Yongchuan-3 power station	270	868	2008	60	2%	0	100%	0.90
Chifeng Meiganshi power station	270	874	2007	18	100%	0	0%	1.21
Dalian Taishan power station	270	874	2006	38	100%	0	100%	0.99
Wuhu Zhaoda power station	250	868	1997	53	4%	0	50%	0.97
ZHONGDIAN HONGZE	30	868	2006	61	54%	0	0%	0.91
QINGPU	12	868	2006	58	69%	0	0%	0.90
TOTAL[i]	**76,416**	**888**	**2006**	**41**	**47%**	**0**	**35%**	**1.03**

i. MW-weighted averages; ii. Capacity only for owned portion; iii. Retrofitability is expressed as a percentage of the total powerplant unit MW capacity that is retrofitable.

Table 47: Environment-related risk exposure of State Power Investment Corp's planned plants

PLANT	CAPACITY[ii] [MW]	LRH-1: CARBON INTENSITY [kg CO2/MWh]	LRH-2: PLANT AGE	LRH-3: LOCAL AIR POLLUTION [μgPM2.5/m3]	LRH-4: WATER STRESS [% RENEWABLE RESOURCE]	LRH-5: QUALITY OF COAL [1 = LIGNITE]	LRH-6: CCS RETROFITABILITY [1 = RETROFITABLE][iii]	LRH-7: FUTRE HEAT STRESS [Δ°C]
CPI Guangdong Jieyang Qianzhan power station	4,000	834	2017	21	58%	0	0%	0.81
QINGYANG COMPLEX	4,000	829	2017	25	100%	0	0%	1.15
Qingtongxia Aluminum Works power station	2,100	828	2017	17	100%	0	100%	1.18
CPI Wuwei Liangzhou power station	2,000	860	2017	12	100%	0	100%	1.19
BAICHENG CPI	2,000	939	2017	20	0%	1	0%	1.21
中电投蒙西能源有限责任公司（一期）	2,000	867	2017	16	100%	0	0%	1.21
Pingdingshan Luyang power station	2,000	828	2017	71	100%	0	0%	0.95
CPI Baicheng power station	2,000	938	2017	20	0%	1	0%	1.21
CPI Dengzhou power station	2,000	834	2017	56	78%	0	0%	1.05
CPI Shangrao power station	2,000	834	2017	34	14%	0	100%	0.91
CPI Tianshui Qingshui power station	2,000	834	2017	24	100%	0	0%	1.06
CPI Xinchang power station	2,000	828	2017	45	1%	0	100%	0.93
CPI Weining power station	1,320	854	2017	18	6%	0	100%	0.92
Shanxi Aluminum power station	1,320	860	2017	29	100%	0	0%	1.09
CPI Dabieshan power station	1,320	841	2017	59	80%	0	100%	0.97
Jinsha Chayuan power station	1,320	847	2017	36	11%	0	100%	0.88
Xishui Erlang power station	1,320	860	2016	42	2%	0	100%	0.90
BAIYINHUA JINSHAN	1,320	842	2017	7	62%	0	0%	1.27
Pu'an power station	1,320	860	2017	32	11%	0	0%	0.88
SHUANGHUAI	1,000	829	2017	60	32%	0	100%	0.90
CPI Binhai power station	1,000	834	2017	57	54%	0	100%	0.91
Tanggangzi power station	700	860	2017	38	100%	0	0%	1.14
HUOLINHE CIRCULAR	700	968	2017	15	0%	1	0%	1.21
CPI Wusu power station	700	874	2017	9	0%	0	0%	1.31
Hongjun Aluminum power station	700	969	2015	7	0%	1	0%	1.29
Lanzhou New District power station	700	860	2016	19	39%	0	100%	1.14
Panxian-2 power station	660	841	2017	20	8%	0	100%	0.92
CPI Guizhou Qianxi power station	660	956	2017	32	11%	0	0%	0.88
XINCHENG COGEN	600	868	2017	18	0%	0	0%	1.21
QINGHE	600	939	2017	35	100%	1	100%	1.14
Siping power station	350	969	2012	33	100%	1	0%	1.19
大兴安岭能源开发有限公司(加格达奇)	240	868	2017	3	2%	0	100%	1.25
CPI Suiyang power station	150	860	2016	39	11%	0	100%	0.90
石家庄良村热电有限公司（二期）	50	868	2017	81	100%	0	0%	1.09
NINGJIN COGEN	50	868	2017	79	100%	0	0%	0.98
盐城热电有限责任公司（二期）	24	868	2017	61	54%	0	0%	0.90
中电（洪泽）热电有限公司（扩建）	15	868	2017	61	54%	0	0%	0.91
TOTAL[i]	**46,239**	**858**	**2017**	**30**	**54%**	**0**	**38%**	**1.05**

i. MW-weighted averages; ii. Capacity only for owned portion; iii. Retrofitability is expressed as a percentage of the total powerplant unit MW capacity that is retrofitable.

4 Conclusion

- We examined the environment-related risks facing current and planned coal-fired power stations owned by the top 50 coal-fired power utilities in China (which together comprise 89% of China's coal-fired capacity). We measured each power station's exposure to seven local risk hypotheses and 12 national risk hypotheses. This asset-level analysis, which was then aggregated to the parent company level, can help to inform specific investor actions related to risk management, screening, voting, engagement, and disinvestment. We also prepared in-depth case studies of exposure to environment-related risks and potential stranding for the five largest coal-fired utilities in China: 1) Huaneng; 2) Datang; 3) Guodian; 4) Huadian; and 5) State Power Investment Corp.

- We examined the financial structure and market value of Chinese utilities over time. This was done to help to determine the performance, stability, and health of our sample companies. This also provides insight into the ability to finance future generating capacity, as investors also seek this information to determine expected rates of return. Utilities in good financial health may also be better able to adapt to stranded assets created by the risks we identify and analyse in this report. If the sample is found to be under considerable financial stress, investors may consider the sector non-investment grade and be hesitant to commit capital, or demand higher rates of return on their investment. Access to capital is also crucial to facilitate investment in China's low carbon transition.

- We found that the financial position of the top 50 coal-fired power utilities in China is generally getting worse. First, between 2008 and 2015, the industry has impaired CN¥13.8 billion of assets. Second, Chinese utilities have a large reliance on short-term debt (current liabilities), which may introduce additional financial risk and risk of bankruptcy if market conditions were to rapidly deteriorate. Third, profit margins have been declining over time, from 23% in 1995 to 9% in 2015. Fourth, the companies in our sample have made efforts to increase their financial leverage, inducing higher financial risk to operations. Fifth, China's coal-fired utilities have typically held low levels of cash reserves, which diminishes their ability to satisfy debt commitments using cash or near-cash equivalents. Sixth, the proportion of debt to earnings is growing, increasing the time taken to repay debt.

- To examine the upper bound and potential scale of stranded coal assets in China, we used four illustrative scenarios where all existing and planned coal-fired power stations are completely stranded over 5-year, 10-year, 15-year, and 20-year periods. These scenarios are suitable time horizons to consider given the pace of change in the global energy system. Disruption appears to be accelerating as tipping points are reached and the idea that the power sector will remain relatively static and 'safe' for new thermal coal assets is counter to the evidence we see internationally across the G20.

- The four scenarios reflect the different speeds and scales at which the environment-related risk factors identified in this report could realistically materialize. While highly illustrative, these scenarios highlight the maximum potential impact of stranded coal assets on the utility sector in China. These scenarios estimate that stranded coal assets could be as much as CN¥3,086–7,201bn (US$449-1,047bn), equivalent to 4.1–9.5% of China's 2015 GDP. Given the scale of this potential stranding, it might be prudent for financial regulators to examine which parts of China's financial system are more or less exposed to these risks and to consider taking steps to mitigate this exposure.

- Given growing overcapacity, competition from renewables, carbon emissions curtailment, and falling demand growth; a failure to examine the exposure of China's existing and proposed coal-fired power plants to the risk of asset stranding may have significant consequences. Stranded coal assets would affect utility returns for coal-fired utilities investors; impair the ability of utilities to service outstanding debt obligations; and create stranded assets that have to be absorbed by taxpayers and ratepayers.

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Appendix: Dataset Preparation

This report uses a number of data sources to provide analysis of coal-fired power utilities, thermal coal mining companies, and coal processing technologies. Table 56 summarises the main sources of data. Where the data was not available for all plants and mines, the remainder was either estimated from available data or completed by the Oxford Smith School as noted.

Table 56: Data sources and completeness

Data	Data Source (in order of seniority)	Completion %	Notes
Number of Coal-Fired Generating Assets (N = 1721 coal-fired power stations)			
Location	CoalSwarm Global Coal Plant Tracker (CoalSwarm, Q4 2016) Enipedia Carbon Monitoring for Action Database (CARMA, v3.0 released Jul 2012) Platts' World Electric Power Plant Database (WEPP, Q4 2016) Greenpeace coal plant database (Q3 2016) National China Electric Power University coal plant database (Q3 2016)	100%	
Capacity [MW]	CoalSwarm, WEPP, Enipedia, CARMA	100%	
Plant Age	CoalSwarm, WEPP, Enipedia, CARMA, Oxford Smith School	100%	19% estimated
CO_2 Intensity	CoalSwarm, Enidpedia, CARMA, Greenpeace, Oxford Smith School	100%	22% estimated
Market Analysis			
General Information	S&P CapitalIQ, Trucost	-	
Bond Issuances	S&P CapitalIQ	-	
Local Risk Hypotheses			
$PM_{2.5}$ Emissions 2012-2014 Average	Atmospheric Composition Analysis Group, Dalhousie University	Global	
NO_2 Emissions 2015	NASA GES DISC OMNO2	Global	
Mercury Emissions 2010	AMAP/UNEP 2010	Global	
Water Stress 2015	WRI Aqueduct	Global	
Quality of Coal	CoalSwarm, WEPP, Oxford Smith School	Global	
CCS Geologic Suitability	CARMA, CoalSwarm, WEPP, Geogreen	Global	
Heat Stress Change 2016-2035	IPCC AR5 WGII	Global	
National Risk Hypotheses			
Renewables Resource	EY Renewable Energy Country Attractiveness Index	See NRHs for details	
Renewables Policy Support	REN21 Global Status Report	See NRHs for details	
Water Regulatory Risk	WRI Aqueduct 2015	See NRHs for details	
CCS Legal Environment	Global CCS Institute Legal and Regulatory Indicator	See NRHs for details	

Individual power station information is taken from the most recent versions of; CoalSwarm's Global Coal Plant Tracker, Enipedia, the Carbon Monitoring for Action (CARMA) database, Greenpeace's China Coal Power Plant Database, and North China Electric Power University's (NCEPU) Coal Power Plant Database. These databases are merged, and when power station matches occur, we preferentially use fields from CoalSwarm, then Greenpeace, NCEPU, Enipedia, and finally CARMA. The Platts World Electric Power Plants Database (WEPP) is used to exclude power stations that have been closed, but not reported as such in CARMA, Enipedia, or CoalSwarm. We also use WEPP to identify non-coal-fired power stations that are operational, but not included in CARMA.

CoalSwarm has data on all global coal-fired power plants (we use the August 2016 update). Enipedia is continuously updated on an individual power plant basis. CARMA contains data on existing and planned plants and was last systematically updated to the end of 2009. Greenpeace and NCEPU have data on all planned coal-fired power plants in China. And WEPP is updated quarterly (we currently use data from the Q4 2016 release). The merger between these datasets has produced a database that effectively defines the locations of all the world's power plants, their ownership, the annual megawatt hours of electricity produced, plant age, fuel type, capacity, and carbon intensity. It is particularly current and comprehensive for coal-fired power stations.

Information on the accuracy of data in the CoalSwarm, Enipedia, and WEPP databases is not available, but CARMA data has a number of caveats that are thoroughly enumerated on its website (carma.org), two of which are particularly relevant to this database. The first is that CARMA estimates electricity generation and CO2 emissions using statistical models that have been fitted from detailed US plant data. CARMA reports that fitted CO2 emissions values are within 20% of the true value 60% of the time, and that electricity generation is within 20% of the true value 40% of the time. Second, CARMA geographical location data varies in its degree of precision. For almost all power plants the state/province location is known, for 80% of power plants at least the city location is known, for 40% county/district data is known, and for 16% of power stations a unique postal code is assigned. Comparisons of approximate and precise coordinates suggest that the average spatial error is about 7 km, which is well within the bounds of all our geographical analyses (scales of 40km and 100km used).

Where possible, International Securities Identification Numbers (ISINs) which uniquely identify securities have been matched to the equities of the top-50 Chinese coal-fired utilities. Equity ISINs are not available for state-owned and private companies. ISINs were acquired directly from the public database[271] and through internet research.

[271] Accessible at http://www.isin.org.

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