SUSTAINABLE FINANCE PROGRAMME

SMITH SCHOOL OF ENTERPRISE AND THE ENVIRONMENT

UNIVERSITY OF OXFORD

Managing the political economy frictions of closing coal in China

Discussion Paper

February 2017

Authors: Ben Caldecott | Geraldine Bouveret | Gerard Dericks | Lucas Kruitwagen | Daniel J. Tulloch | Xiawei Liao

About the Sustainable Finance Programme

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.

We recognise that the production of high-quality research on environment-related factors is a necessary, though insufficient, condition for these factors to be successfully integrated into decision-making. Consequently, we develop the data, analytics, frameworks, and models required to enable the integration of this information into decision-making. We also research the barriers that might prevent integration, whether in financial institutions, companies, governments, or regulators, and develop responses to address them. Since 2012 we have also conducted pioneering research on stranded assets and remain the only academic institution conducting work in a significant and coordinated way on the topic.

The Programme is based in a world leading university with a global reach and reputation. We work with leading practitioners from across the investment chain (including actuaries, asset owners, asset managers, accountants, banks, data providers, investment consultants, lawyers, ratings agencies, stock exchanges), with firms and their management, and with experts from a wide range of related subject areas (including finance, economics, management, geography, anthropology, climate science, law, area studies, psychology) within the University of Oxford and beyond.

Global Advisory Council

The Sustainable Finance Programme is led by Ben Caldecott and its work is guided by the Global Sustainable Finance Advisory Council chaired by Professor Gordon L. Clark, Director of the Oxford Smith School. Members currently include:

Jane Ambachtsheer, Partner and Global Head of Responsible Investment, Mercer Investment
Rob Bailey, Research Director, Energy, Environment and Resources, Chatham House
Vicki Bakhshi, Head of Governance & Sustainable Investment, BMO Global Asset Management (EMEA)
Morgan Bazilian, Affiliate Professor, The Royal Institute of Technology of Sweden
David Blood, Co-Founder and Senior Partner, Generation IM
Yvo de Boer, President, Sustainability Challenge Foundation
Susan Burns, Founder and CEO, Global Footprint Network
James Cameron, Chairman, Overseas Development Institute
Diana Fox Carney, Pi Capital
Mike Clark, Institute and Faculty of Actuaries
Rowan Douglas, Head, Capital Science and Policy Practice, Willis Towers Watson
Professor Robert Eccles, Chairman of Arabesque Partners and Visiting Professor of Management Practice, Saïd Business School, University of Oxford
Emily Farnworth, Head of Climate Initiatives, World Economic Forum
Jessica Fries, Executive Chairman, The Prince of Wales's Accounting for Sustainability Project (A4S)
Ben Goldsmith, CEO, Menhaden Capital
Kristin Halvorsen, Director, Center for International Climate and Environmental Research (CICERO) and former Norwegian Minister of Finance
Connie Hedegaard, Chair, KR Foundation, and former European Commissioner for Climate Action
Thomas Heller, Chairman of the Board and Founder, Climate Policy Initiative
Anthony Hobley, CEO, Carbon Tracker Initiative
Christina Hood, Head of Unit, Environment and Climate Change, International Energy Agency
Andrew Howard, Head of Sustainable Research, Schroder Investment Management
Catherine Howarth, CEO, ShareAction
Zoe Knight, Head, Climate Change Centre of Excellence, HSBC
Bernice Lee, Executive Director, Hoffmann Centre for the Sustainable Resource Economy, Chatham House
Bob Litterman, Senior Partner and Chairman of Risk Committee, Kepos Capital
Mindy Lubber, President, Ceres
Nick Mabey, CEO, E3G
Richard Mattison, CEO, Trucost
Stephanie Pfeifer, CEO, Institutional Investors Group on Climate Change
Fiona Reynolds, Managing Director, UN Principles for Responsible Investment
Nick Robins, Co-Director, UNEP Inquiry into a Sustainable Financial System
Paul Simpson, CEO, Carbon Disclosure Project
Andrew Steer, President and CEO, World Resources Institute
James Thornton, CEO, ClientEarth
Simon Upton, Director, Environment Directorate, OECD
Steve Waygood, Chief Responsible Investment Officer, Aviva Investors
Peter Wheeler, Executive Vice President, The Nature Conservancy (TNC)
Michael Wilkins, Managing Director, Infrastructure Finance Ratings, Standard & Poor's
Baroness Bryony Worthington, Executive Director Europe, Environmental Defense Fund
Simon Zadek, Co-Director, UNEP Inquiry into a Sustainable Financial System
Dimitri Zenghelis, Principal Research Fellow, Grantham Institute, London School of Economics

About the Author

Ben Caldecott is Director of the Sustainable Finance Programme. He is concurrently an Adviser to The Prince of Wales's Accounting for Sustainability Project, an Academic Visitor at the Bank of England, and a Visiting Scholar at Stanford University.

Geraldine Bouveret is a Postdoctoral Research Associate in the Sustainable Finance Programme. Geraldine holds a PhD in Mathematics from Imperial College London. She also holds a Master Degree in Finance from ESSEC Business School, France and a Master Degree in Mathematics from Université Paris Dauphine and ENSAE ParisTech, France.

Gerard Dericks is a Postdoctoral Research Associate in the Sustainable Finance Programme. He was previously an analyst at Property Market Analysis LLP and research consultant for Policy Exchange in London. He holds a PhD and MSc from the London School of Economics and a BA from Ritsumeikan University.

Lucas Kruitwagen is a Research Assistant in the Sustainable Finance Programme and a DPhil student in the School of Geography and the Environment at the University of Oxford. He is also a Visiting Researcher at Imperial College London, and holds an MSc (with distinction) in Sustainable Energy Futures from Imperial College London, and a BEng from McGill University.

Daniel J. Tulloch is a Postdoctoral Research Associate in the Sustainable Finance Programme. Daniel holds a PhD in finance at the University of Otago, New Zealand. He also holds an MSc in International Accounting and Financial Management from the University of East Anglia, Norwich.

Xiawei Liao is a Research Assistant in the Sustainable Finance Programme and a DPhil candidate at the Environment Change Institute, University of Oxford. He holds a MSc (distinction) in Environmental Science from Peking University, China, and a MSc (distinction) in Environmental Policy from Waseda University, Japan. He is currently researching into the water-energy nexus in China's power sector.

Acknowledgements

We would like to thank the UK Foreign & Commonwealth Office and Growald Family Fund for providing grants to support this research.

We are particularly grateful to Simon Abele (University of Oxford) and Ted Nace (CoalSwarm) for their help and support throughout the research process.

Discussion Paper Series

This Discussion Paper is intended to stimulate discussion within the research community and among users of research. The views expressed in this paper represent those of the author(s) and do not necessarily represent those of the host institutions or funders.

University of Oxford Disclaimer

The Chancellor, Masters, and Scholars of the University of Oxford make no representations and provide no warranties in relation to any aspect of this publication, including regarding the advisability of investing in any particular company or investment fund or other vehicle. While we have obtained information believed to be reliable, neither the University, nor any of its employees, students, or appointees, shall be liable for any claims or losses of any nature in connection with information contained in this document, including but not limited to, lost profits or punitive or consequential damages.

Table of Contents

Executive Summary

China has pledged to invest around 70% of its 2014 GDP from 2020-2030 to achieve its Nationally Determined Contributions (NDCs),[1] and has set itself as a global leader in the low-carbon energy transition with a target of 20% non-fossil fuel sources by 2030 and investment in renewable energy 73% higher than that of the US.[2] For these reasons, as well as concerns about air pollution and water stress, the coal industry[3] is facing structural decline as China transitions away from fossil fuels.

This transition is necessary and desirable, but will likely result in stranded coal assets with associated economic, social, and political implications. These could impact foreign and domestic investors, companies, central and local governments, workers, and communities. Policymakers in China, as well as other stakeholders, therefore have a significant interest in seeking to manage the economic and political consequences of mine and power station closures in the transition to a low-carbon energy system. Failure to manage these political economy 'frictions' could destabilise the low-carbon transition, prevent the realisation of NDCs, and threaten the welfare of a broad range of groups in China.

This discussion paper undertakes an initial assessment of the political economy implications associated with the premature closure of coal assets in China. It discusses stranding facing the coal industry more broadly, before focusing on coal-fired generation specifically. The paper proceeds by briefly summarising China's political economy and its influence on shaping the deployment of the coal industry; surveying the different types of asset at risk of stranding and the likely economic, social, and political consequences; and then estimating the potential scale and geographical distribution of stranded coal-fired generation assets. Finally, we also set out avenues for future research in China and internationally.

Political economy of coal

China's coal industry plays a significant role in both national and provincial economies, accounting for 73% of China's energy production, 66% of energy consumed, and 93% of all thermal generation,[4] and remains one of China's largest employers[5]. The political economy of the coal industry has changed through communist (1949 to 1970s), reform (1970s to 1990s), and the current modern capitalist era.[6]

Coal mining and processing employs 5.8 million people,[7] with a large proportion of the 3 million working for power and heat utilities employed in coal-fired generation[8]. China has the world's third largest coal reserves behind Russia and the United States. However, exploiting coal reserves is more challenging in China than in other countries because of its relatively poor quality,[9] as well as the lack of accessibility of deposits and the distance from primary areas of coal-consumption along the southern coast[10]. In 2016, the China's coal fleet capacity was mainly located around the following populous and heavily industrialised areas: (1) central and yellow river plains,

---

[1] Valerie Volcovici and David Brunnstrom, "China Puts $6 Trillion Price Tag on Its Climate Plan," *Reuters*, 2015, http://www.reuters.com/article/us-usa-china-climatechange-idUSKBN0P32H020150623.
[2] The Climate Group - RE 100, "China's Fast Track to a Renewable Future," 2015, http://www.theclimategroup.org/_assets/files/Re100-China-briefing-ENGLISH-jv-final.pdf.
[3] Defined here as thermal coal mining, coal processing, and coal-fired generation
[4] China Statistical Yearbook, "9-1 Total Consumption of Energy and Its Composition 2014," 2015.
[5] Oxford University Smith School.
[6] Tim Wright, *The Political Economy of the Chinese Coal Industry: Black Gold and Blood-Stained Coal*, vol. 45 (Routledge, 2012).
[7] Hen Cheng and Per Ove Eikeland, "China's Political Economy of Coal," 2015, https://www.fni.no/getfile.php/132020/Filer/Publikasjoner/FNI-R1015.pdf.
[8] More recent data than 'China's Economic Census Yearbook 2008' (Zhongguo tongji nianjian 2008) does not appear to be available, http://www.stats.gov.cn/tjsj/pcsj/jjpc/2jp/indexce.htm.
[9] Wright, *The Political Economy of the Chinese Coal Industry: Black Gold and Blood-Stained Coal*. p.20.
[10] Oxford University Smith School.

(2) coastal areas, and (3) a cluster centred around Guizhou province exporting substantial amounts of power to neighbouring provinces. [11]

The implementation of NDCs will have an unequal impact across regions, provinces, and sub-provincial divisions depending on the concentration of coal activity. The number of coal industry employees is expected to fall to 1.6 million by 2050 because of technology and productivity advances, and to reduce by another 720,000 if coal cap policies were to be enforced,[12] but this decline in employment will be unevenly spread across the country.

On the other hand, implementing the NDCs will also generate new job opportunities. While coal can be replaced by a whole host other industries, it is worth highlighting the potential opportunities offered by the low carbon transition. The Chinese Academy of Social Sciences estimates that, by 2050, wind and solar power could generate 413,000 jobs related to power generation, power supply, and power-generating equipment manufacturing, as well as a further 3.5 million jobs in the broader economy.[13] The main challenge will be for policymakers to ensure that employment opportunities and skills are developed in alternative industries in regions suffering from the necessary closure of coal, and, more generally, that finite public funds are used in the most efficient and effective way for this purpose. Ensuring these alternative industries come online in step with coal closures may require policymakers to choreograph a range of different actions and interventions.

Scale and geographical distribution of asset stranding

It is not just physical assets (e.g. power stations, coal processing facilities, and coal mines) that will become stranded, but also financial assets (e.g. equities, debt, and derivatives), natural assets (e.g. water reserves), and labour assets connected to the coal industry. While the impact on these assets has not been quantified, considering that 14% of China's 2013 GDP (RMB 56.9 tn) came from 80 coal-based resource cities[14] (i.e., those with more than 40% of their economy dependent on coal)[15] the potential scale of the challenge is significant.

We attempt to quantify the scale and geographical distribution of stranding by focusing on coal-fired power stations – physical assets where the team at the Oxford Smith School have good asset-level data. A similar analysis could be conducted for other assets but are out of the scope of this short discussion paper and are contingent on the availability of good asset-level data tied to ownership.

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. In all four scenarios the start date is 2016 and the known installed capacity is 978 GW (including capacity planned for 2016).

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 or existing 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.

Assessing the likely scale of coal-power asset stranding is a complex question involving assumptions on discount rates, future electricity prices, fuel costs, salvage values, and non-market factors such as the timing and stringency

[11] Oxford University Smith School.
[12] "China's Coal Cap Policy Will Increase Country's Clean Energy Jobs," *Natural Resources and Defense Council*, 2015, http://www.nrdc.org/media/2015/150326.asp.
[13] Ibid.
[14] Oxford University Smith School.
[15] This is regularly quoted in academic journals, newspapers and dissertations, but is not written in government documents, see: "发展特色旅游 : **阜新**转型又一新思路 ," *Characteristic Tourism - A New Thought Of Economic Transformation in Fuxin* 8, no. 1 (2006): 9–12, doi:10.3969/j.issn.1673-2464.2006.01.003. "**技**术创新视角下的资源型城市经济转型——基于枣庄市经济转型的案例分析 Economic Transformation under High-Tech Innovation: Case Study of Zaozhuang, Shandong" (**山**东大学, 2007).

of regulation. We have made various assumptions in our analysis and these have been made transparently. Our objective is to illustrate the plausible upper bound of the scale of potential stranded assets over different time horizons.

Table 1 summarises estimates of stranded assets across China while Table 2 provides the results at the provincial level. Asset stranding is highest in the 2021 (5-year) scenario due to the large number of coal-fired plants planned in the near-term. Within the industry itself estimates of asset stranding could be as high as ¥3,086 – 7,201 billion ($449 – 1,047 billion), equivalent to 4.1 – 9.5% of China's 2015 GDP,[16] depending on the stranding timeframe and severity.

Table 1: Estimates of stranded coal-fired power station assets, CN¥ billion (US$ billion)

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)

Table 2: Upper bound 5, 10, 15, and 20-year asset stranding estimates by province and operational status in CN¥ million (US$ million)

		2021 (5 Years)		2026 (10 Years)		2031 (15 Years)		2036 (20 Years)	
Rank	*Province*	OPR	CON+PLN	OPR	CON+PLN	OPR	CON+PLN	OPR	CON+PLN
1	Inner Mongolia	¥220,146	¥600,825	¥166,248	¥500,626	¥113,094	¥400,427	¥62,259	¥300,228
		¥820,971 ($119,376)		¥666,875 ($96,969)		¥513,521 ($74,670)		¥362,487 ($52,708)	
2	Shaanxi	¥103,612	¥455,846	¥80,086	¥380,473	¥57,064	¥305,101	¥35,148	¥229,729
		¥559,458 ($81,349)		¥460,559 ($66,969)		¥362,165 ($52,662)		¥264,877 ($38,515)	
3	Xinjiang	¥185,048	¥368,368	¥148,281	¥305,808	¥111,903	¥243,247	¥75,904	¥181,658
		¥553,416 ($80,471)		¥454,089 ($66,028)		¥355,150 ($51,642)		¥257,562 ($37,451)	
4	Shanxi	¥154,231	¥368,313	¥116,347	¥306,738	¥80,450	¥245,164	¥46,223	¥183,590
		¥522,543 ($75,982)		¥423,086 ($61,520)		¥325,614 ($47,347)		¥229,813 ($33,417)	
5	Guizhou	¥92,004	¥385,298	¥71,032	¥320,860	¥50,156	¥256,422	¥29,839	¥192,331
		¥477,302 ($69,403)		¥391,892 ($56,984)		¥306,578 ($44,579)		¥22,2170 ($32,305)	
6	Jiangsu	¥231,978	¥232,773	¥175,682	¥193,748	¥121,687	¥154,723	¥70,769	¥115,699
		¥464,751 ($67,578)		¥369,430 ($53,718)		¥276,410 ($40,192)		¥186,467 ($27,114)	
7	Shandong	¥213,272	¥220,387	¥161,645	¥183,439	¥112,074	¥146,491	¥66,309	¥109,543
		¥433,659 ($63,057)		¥345,084 ($50,178)		¥258,565 ($37,597)		¥175,851 ($25,570)	
8	Henan	¥192,707	¥182,033	¥145,615	¥151,682	¥100,365	¥121,332	¥57,995	¥90,982
		¥374,739 ($54,490)		¥297,297 ($43,229)		¥221,697 ($32,236)		¥148,977 ($21,662)	
9	Guangdong	¥185,496	¥182,999	¥140,283	¥151,896	¥97,517	¥120,792	¥58,769	¥89,689
		¥368,495 ($53,582)		¥292,179 ($42,485)		¥218,309 ($31,744)		¥148,458 ($21,587)	
10	Anhui	¥139,402	¥163,953	¥107,499	¥136,269	¥76,630	¥108,584	¥47,591	¥80,900

[16] The World Bank, "World Bank National Accounts Data," 2016.

		¥303,355 ($44,110)		¥243,767 ($35,446)		¥185,215 ($26,932)		¥128,491 ($18,684)	
11	Gansu	¥68,951	¥227,568	¥52,904	¥189,996	¥37,370	¥152,424	¥22,574	¥114,852
		¥296,519 ($43,116)		¥242,900 ($35,320)		¥189,794 ($27,597)		¥137,426 ($19,983)	
12	Hubei	¥64,545	¥153,626	¥48,230	¥128,089	¥32,691	¥102,552	¥19,153	¥77,014
		¥218,171 ($31,724)		¥176,319 ($25,638)		¥135,243 ($19,665)		¥96,167 ($13,983)	
13	Hebei	¥102,100	¥108,274	¥75,350	¥90,132	¥50,358	¥71,990	¥27,845	¥53,849
		¥210,374 ($30,590)		¥165,482 ($24,062)		¥122,349 ($17,790)		¥81,694 ($11,879)	
14	Zhejiang	¥130,099	¥56,115	¥98,776	¥46,797	¥68,545	¥37,480	¥39,897	¥28,162
		¥186,214 ($27,077)		¥145,574 ($21,168)		¥106,025 ($15,417)		¥68,059 ($9,896)	
15	Ningxia	¥58,246	¥115,265	¥44,164	¥96,035	¥30,770	¥76,805	¥18,141	¥57,575
		¥173,511 ($25,230)		¥140,199 ($20,386)		¥107,576 ($15,642)		¥75,716 ($11,010)	
16	Fujian	¥63,583	¥109,000	¥47,723	¥90,682	¥32,061	¥72,363	¥17,789	¥54,044
		¥172,583 ($25,095)		¥138,404 ($20,125)		¥104,424 ($15,184)		¥71,833 ($10,445)	
17	Hunan	¥54,066	¥107,018	¥40,824	¥88,999	¥28,170	¥70,981	¥16,209	¥52,963
		¥161,083 ($23,423)		¥129,823 ($18,877)		¥99,151 ($14,417)		¥69,172 ($10,058)	
18	Jiangxi	¥57,005	¥95,513	¥43,910	¥79,622	¥31,150	¥63,730	¥19,232	¥47,838
		¥152,519 ($22,177)		¥123,532 ($17,962)		¥94,880 ($13,796)		¥67,070 ($9,752)	
19	Liaoning	¥74,151	¥60,280	¥54,212	¥50,264	¥35,868	¥40,249	¥20,109	¥30,233
		¥134,430 ($19,547)		¥104,476 ($15,192)		¥76,117 ($11,068)		¥50,342 ($7,320)	
20	Guangxi	¥49,077	¥77,547	¥37,670	¥64,418	¥26,409	¥51,288	¥15,456	¥38,159
		¥126,624 ($18,412)		¥102,088 ($14,844)		¥77,697 ($11,298)		¥53,615 ($7,796)	
21	Heilongjiang	¥34,590	¥51,693	¥25,156	¥43,166	¥16,728	¥34,640	¥9,525	¥26,113
		¥86,284 ($12,546)		¥68,323 ($9,935)		¥51,367 ($7,469)		¥35,637 ($5,182)	
22	Jilin	¥44,313	¥35,302	¥33,187	¥29,367	¥22,881	¥23,431	¥13,284	¥17,495
		¥79,615 ($11,577)		¥62,554 ($9,096)		¥46,312 ($6,734)		¥30,780 ($4,476)	
23	Chongqing	¥31,038	¥45,402	¥23,913	¥37,741	¥17,267	¥30,080	¥11,115	¥22,419
		¥76,440 ($11,115)		¥61,654 ($8,965)		¥47,347 ($6,885)		¥33,534 ($4,876)	
24	Sichuan	¥32,499	¥29,582	¥24,000	¥24,814	¥16,119	¥20,045	¥8,773	¥15,277
		¥62,081 ($9,027)		¥48,814 ($7,098)		¥36,164 ($5,259)		¥24,049 ($3,497)	
25	Tianjin	¥30,734	¥24,908	¥22,347	¥20,847	¥14,872	¥16,786	¥8,315	¥12,726
		¥55,642 ($8,091)		¥43,194 ($6,281)		¥31,659 ($4,603)		¥21,040 ($3,059)	
26	Yunnan	¥35,255	¥8,629	¥26,496	¥7,082	¥17,773	¥5,534	¥9,742	¥3,987
		¥43,884 ($6,381)		¥33,577 ($4,882)		¥23,307 ($3,389)		¥13,729 ($1,996)	
27	Shanghai	¥31,171	¥0	¥21,710	¥0	¥13,961	¥0	¥7,206	¥0
		¥31,171 ($4,533)		¥21,710 ($3,157)		¥13,961 ($2,030)		¥7,206 ($1,048)	
28	Qinghai	¥11,897	¥25,098	¥9,333	¥20,925	¥6,861	¥16,753	¥4,524	¥12,580
		¥36,995 ($5,379)		¥30,259 ($4,400)		¥23,613 ($3,434)		¥17,104 ($2,487)	

29	*Hainan*	¥10,384	¥6,372	¥7,911	¥5,310	¥5,506	¥4,248	¥3,407	¥3,186
		¥16,755 ($2,436)		¥13,221 ($1,922)		¥9,754 ($1,418)		¥6,592 ($959)	
30	*Hong Kong*	¥1,348	¥0	¥340	¥0	¥0	¥0	¥0	¥0
		¥1,348 ($196)		¥340 ($49)		¥0 ($0)		¥0 ($0)	
31	*Beijing*	¥316	¥0	¥49	¥0	¥0	¥0	¥0	¥0
		¥316 ($46)		¥49 ($7)		¥0 ($0)		¥0 ($0)	
32	*Tibet*	¥0	¥42	¥0	¥35	¥0	¥28	¥0	¥20
		¥42 ($6)		¥35 ($5)		¥28 ($4)		¥20 ($3)	
33	*Macau*	¥0	¥0	¥0	¥0	¥0	¥0	¥0	¥0
		¥0 ($0)		¥0 ($0)		¥0 ($0)		¥0 ($0)	
	Grand Total	**¥2,703,262**	**¥4,498,029**	**¥2,050,923**	**¥3,745,860**	**¥1,426,301**	**¥2,993,691**	**¥843,102**	**¥2,242,839**
		¥7,201,291 ($1,047,122)		**¥5,796,783 ($842,896)**		**¥4,419,991 ($642,700)**		**¥3,085,941 ($448,719)**	

Provinces are ranked by the maximum asset stranding assessed across the four scenarios.
OPR refers to operational plant asset stranding values, CON+PLN refers to plants under construction and planned.
Merged cells below each OPR and CON+PLN field are the total of OPR and CON+PLN asset stranding values.

As depicted in the 5-year scenario in Figure 1 below, the provinces with the highest amount of potential asset stranding are: Inner Mongolia, Shaanxi, Xinjiang, Shanxi, Guizhou, and Jiangsu. The so-called 'rust-belt' provinces of Heilongjiang, Jilin, and Liaoning have relatively moderate levels of estimated coal-fired asset stranding compared to the whole country. The 10-year, 15-year, and 20-year scenarios are depicted in Section 3.

Figure 1: Total coal-fired utility asset stranding in the 2021 (5-year) scenario

Our initial estimates highlight how potential stranded assets could be distributed across China's provinces. It should be noted that industries upstream and downstream of coal-fired generation would also be negatively affected; further expanding the scale of asset stranding and increasing the probability that such scenarios could significantly re-price associated financial assets.

In this discussion paper we have simply aggregated our asset-level results to show provincial and national-level impacts, but the bottom-up approach we employ enables much more granular assessments, looking at specific companies, communities, and sub-provincial units. Analysis at this resolution can be represented in a number of ways, including spatially, and can help policymakers manage the political economy frictions of NDC implementation in a very targeted and sophisticated way. This data driven approach to understanding at a high degree of granularity which specific stakeholders could be affected and when on the basis on different NDC implementation pathways is important area of future research. It is also relevant to wide range of sectors, not just coal.

Recommendations

China's transition away from coal is necessary and beneficial. But the transition will be complex and be distributed across China and within China's provinces in very different ways. There are strong social and political imperatives to ensure that the transition is managed smoothly and we now have the data, analytics, and methodologies to support this process in a sophisticated way. Policymakers should therefore consider the following:

- Policymakers need to be explicit about the fact that there are likely to be political economy frictions from NDC implementation that need to be proactively managed and that there is an important role for government in managing them. This is a necessary condition for acting.

- There needs to be forward looking analyses of specific regions where coal-fired power stations and coal mines are concentrated to see when assets will likely close given plausible scenarios. These analyses should also seek to understand the impacts upstream and downstream of asset closures. Scenarios can be determined by policymakers, but should include scenarios tied to China's NDCs and climate change. These analyses need not be limited to coal assets and could focus on other industries.

- The analyses proposed can also seek to determine local impacts on employment, tax revenues, and financial institutions. This would help policymakers better target interventions to smooth the transition, but can also help financial regulators to see where risks are building up within local and national financial institutions, and help them develop and run stress-tests to better respond.

- Good asset-level data tied to ownership is a necessary pre-requisite for this kind of very granular analysis and it might be prudent to develop a national platform or national set of data and IT infrastructures to support work in this area. This would be created to help national, provincial, and sub-provincial policymakers and regulators study the challenges and opportunities of the transition to the low carbon economy for the areas for which they have oversight and responsibility. This could be complemented by training and stress-tests to help policymakers and regulators understand the tools they have at their disposal to identify and then respond to political economy frictions. The creation of a national data platform would also help to open up new areas of academic research.

- Policymakers should develop a 'tool kit' of different policy responses to managing political economy frictions. This should be based on in-depth international case study analysis. These analyses should examine how some countries or regions have managed the closure of coal assets, assess in detail the instruments used to enable the transition away from coal, and investigate the extent to which such instruments could be applied to China to alleviate political economy frictions. Again, this research could extend beyond looking at coal assets and to other sectors, but should be focused on policy responses appropriate to a Chinese context.

1. Introduction

90% of China's carbon emissions come from the consumption of fossil fuels of which 68% are due to coal combustion.[17] With a target of 15% of non-fossil fuel sources by 2020 and 20% by 2030, combined with an investment in renewable energy 73% higher than the US,[18] China has set itself as a global leader in the low-carbon energy transition.

This transition is necessary and desirable, but will likely result in stranded coal assets with associated economic, social, and political implications. Navigating these issues could be challenging as they will affect a large range of stakeholders: the owners of assets potentially impacted, the businesses operating assets, communities hosting assets, and policymakers reliant on tax revenues generated from assets. Central and provincial-level government in China, as well as other stakeholders, therefore have a significant interest in seeking to manage the economic and political consequences of mine and power station closures in the transition to a low-carbon energy system.

Failure to manage these political economy 'frictions' could destabilise the low-carbon transition, prevent the realisation of Nationally Determined Contributions (NDCs), and threaten the welfare of a broad range of groups in China. Yet this remains an under researched area and little has been done to factor these issues into NDCs and low carbon development plans globally or in specific jurisdictions. This discussion paper attempts to correct this by undertaking an initial assessment of the political economy implications associated with the premature closure of coal assets in China. The paper discusses stranding facing the coal industry more broadly, before focusing on coal-fired generation specifically. It is an initial foray into these complex issues and one we hope spurs additional research on this topic in China and further afield. Not addressing these issues proactively could harm the chances of a successful low carbon transition in China, leading to prolonged lock-in of coal-fired generation that would almost certainly frustrate global efforts to tackle anthropogenic climate change.

The discussion paper proceeds as follows. Section 2 outlines China's political economy and its influence on shaping the deployment of the coal industry[19]. Section 3 briefly reviews the different types of asset at risk of stranding and the likely economic, social, and political consequences. We then estimate the potential scale and geographical distribution of stranded coal-fired generation assets. Finally, Section 4 discusses the results and provides recommendations, particularly in terms of avenues for future research.

[17] Zhu Liu, "China's Carbon Emissions Report 2015," 2015, https://www.belfercenter.org/sites/default/files/files/publication/carbon-emissions-report-2015-final.pdf.
[18] The Climate Group - RE 100, "China's Fast Track to a Renewable Future."
[19] Defined here as thermal coal mining, coal processing, and coal-fired generation

2. Political Economy of Coal in China

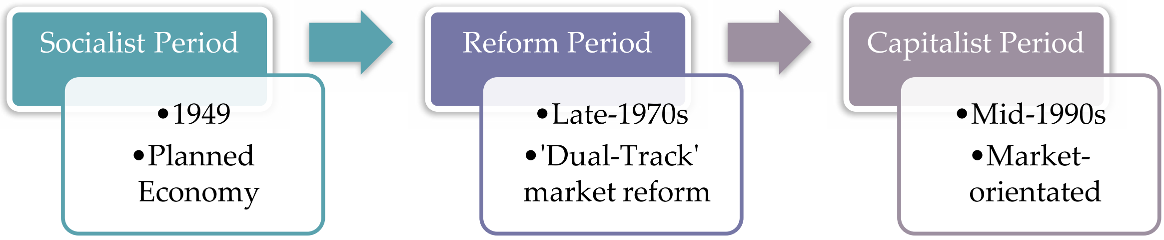
This section aims to provide a basic background on the political economy of coal in China. This preamble precedes the analysis, conducted in the forthcoming section, on the political economy frictions that could arise from a transition towards a low-carbon economy.

2.1. General Political Economy of China

2.1.1. *Three Economic Models*

To understand the shift in the coal-fired electricity industry in China, we must first outline the shift in the Chinese political economy over the past four decades. Since 1978, China has begun transitioning from a planned economy towards a market-based economy. This process can be divided into three periods, summarised in Figure 2: the socialist period (1949 to 1978), the reform period (late-1970s to mid-1990s), and the capitalist period (mid-1990s to present). The following paragraphs outline each period and their importance in China's economic history.[20]

Figure 2: An Overview of the three economic systems



Following decades of warfare, the People's Republic of China was founded in October 1949. The chief aim was to overcome the debilitating effects of civil war and to restore the economy to normal working order. The republic focused on a total overhaul of the land ownership system and planned extensive land reforms. The old system of landlord ownership was replaced with a distribution system, favouring landless peasants. The administration adopted the Soviet economic model, where any products produced were typically monopolised by the state, with collective enterprises (defined shortly) acting like state enterprises.[21] Government control was extended by applying financial pressures to induce private owners to sell their firms to the state or convert them to join public-private enterprises under state control. Rural areas were deindustrialised as much of the industrial activity became concentrated in urban State-Owned Enterprises (SOEs).[22]

In a typical capitalist system, the marginal cost of operation typically acts as a price signal to incentivise investment and development. However, a major challenge for investment in China was the great variety of geographic zones in China and the low levels of interaction between regions. China became a command economy, where investment decisions were determined politically and administratively, redistributing resources among regions and overcoming the lack of interaction. State ownership of industries, and central control over planning and financial systems, enabled the government to mobilise surplus capital to boost national economic output. Rents generated through state monopoly control of industries formed the basis of state revenue, which was redirected into social benefits for key groups who supported or were compliant with the state. This, in turn, fuelled further industrial investment.[23] The aim was to embark on an intensive programme of industrial growth and socialisation.

[20] Wright, *The Political Economy of the Chinese Coal Industry: Black Gold and Blood-Stained Coal*.
[21] Chris Bramall, *Chinese Economic Development* (Routledge, 2008).
[22] Linda Grove, *A Chinese Economic Revolution: Rural Entrepreneurship in the Twentieth Century* (Rowman & Littlefield, 2006); Barry Naughton, "The Chinese Economy: Transition and Growth" (Taylor & Francis, 2007).
[23] Wright, *The Political Economy of the Chinese Coal Industry: Black Gold and Blood-Stained Coal*.

The reform period began in 1978, when the *Third Plenum of the National Party Congress's 11th Central Committee* represented a major milestone at which party leaders decided to undertake a programme of gradual reform in China's economic system. The idea was not to abandon communism, but to improve the economic model by transitioning towards a more market-orientated economy. In doing so, government control and planning was reduced, but not completely eliminated. China introduced a 'dual-track' system which allowed government to control key sectors of the economy, while providing limited control to private enterprises in other sectors. A central component of the dual-track approach was the price reform strategy that enables commodities to circulate with both a market price and, within the command economy, an administrated one. New economic actors began to move into profitable niches,[24] which limited impact to the operating environment of SOEs and avoided threatening the interests of key beneficiaries in the command economy.[25] By 1987, the system created a new climate of dynamism and opportunity in the economy. The dual-track system encouraged new rural enterprises to develop alongside SOEs and enter niches of the economy which were previously neglected. The quasi market-based principles resulted in improvements in overall economic efficiency and economic performance, raising both output growth and living standards.[26]

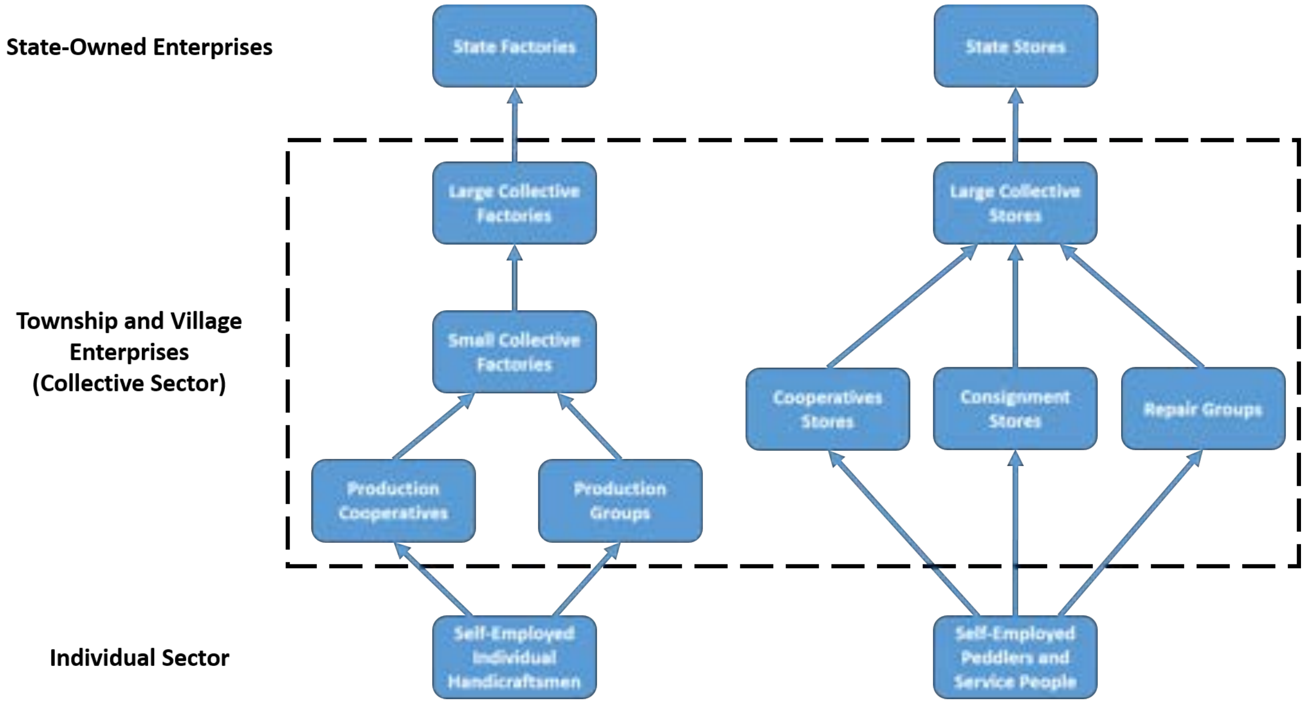
China brought an end to the dual-track system in the mid-1990s, with the key task of creating a socialist market economy. The capitalist period harmonised prices and marginal costs by allowing market forces to determine prices. Further, the period included extensive reforms of markets which affected both SOEs and rural enterprises. Loss-making SOEs were given less government support and thus forced to compete. The removal of state backing allowed some inefficient SOEs to become bankrupt and close. Further, the removal of niche markets forced rural enterprises to compete more directly with SOEs.[27] The shift in economic environment impacted the ownership of firms. The capitalist period was characterised by a large influx of foreign capital and a shift towards private enterprises. The following section elaborates on the various ownership structures observed in China today.

2.1.2. Three Tiers of Companies

In addition to the major reforms in economic models, China also reformed ownership structures at the industry-level. China's ownership structures can be divided into three tiers summarised in Figure 3. The nuances between each tier results in major differences in firm size, competition, investment and state support.

[24] Albert Park and Minggao Shen, "Joint Liability Lending and the Rise and Fall of China's Township and Village Enterprises," *Journal of Development Economics* 71, no. 2 (2003): 497–531.
[25] Naughton, "The Chinese Economy: Transition and Growth."
[26] Peter Nolan, "Economic Reform, Poverty and Migration in China," *Economic and Political Weekly* 28, no. 26 (1993): 1369–77.
[27] Wright, *The Political Economy of the Chinese Coal Industry: Black Gold and Blood-Stained Coal*.

Figure 3: Structural model of China's companies[28]



The first tier of firms consists of large SOEs and government controlled firms, which have some degree of natural monopoly or market power. This top tier of companies often represents legacy investments in state-owned firms which developed as part of the planned economy between 1949 and the late-1970s. The sectors that SOEs typically occupy are considered vital to national security and are primarily clustered in industries such as steel, coal, shipbuilding, and heavy machinery.

Such SOEs and government-controlled firms choose social above private benefits,[29] for example maintaining supply even when consumers are behind with payments, or expanding operations when faced with an economic slow-down.[30] In the planned economy, some state-owned coal companies were obliged to provide coal at below-market prices to the state-owned power and steel sectors, despite high wholesale electricity prices. Often, the market price of coal barely covered the marginal cost of production, assuming modern technology and safety standards.[31] The price differentials between cheap coal and power prices have historically led to large profits for SOE power utilities. SOEs also have a responsibility for the welfare of their workers beyond their role as production units. Historically, the Chinese authorities have rarely allowed lossmaking SOE groups go bankrupt, partly due to the mass unrest from the large number of employees. This has also led to a bloated workforce and social services as a legacy of their importance to the planned economy.[32] The latter implies that the operating costs of SOE utilities are likely higher than private utilities, while efficiency and performance may be lower. Thus, this tier of firms is the most likely to suffer when exposed to competitive market forces.

The second tier of industrial firms are Township and Village Enterprises (TVEs), representing the collective sector. TVEs are medium-sized firms, market-oriented, and exist in competitive markets. The TVE designation primarily refers to the location of the company, rather than the ownership structure. They are typically based within townships and villages and may originate from domestic start-ups, foreign investments, or from the state sector

---

[28] Jianzhong Tang and Laurence J C Ma, "Evolution of Urban Collective Enterprises in China," *The China Quarterly* 104 (1985): 614–40.
[29] Wright, *The Political Economy of the Chinese Coal Industry: Black Gold and Blood-Stained Coal*.
[30] Gabriel Wildau, "China's : The State-Owned Zombie Economy," *The Financial Times*, February 2016.
[31] Wright, *The Political Economy of the Chinese Coal Industry: Black Gold and Blood-Stained Coal*.
[32] Wildau, "China's : The State-Owned Zombie Economy."

or management buy-outs. Many TVEs are collectively-owned, either as the result of local government establishing a new TVE, or through a legacy of earlier sponsorship.

Most TVEs emerged during the dual-track reform period of 1978 to 1990. Originally, TVEs had a limited role as they were restricted to primary industries producing iron, steel, cement, and farm tools. Two factors led to the major uptake of TVEs: first, the political and institutional environments during the early years of reform which favoured public enterprises; second, the fiscal decentralisation in the early 1980s. Fiscal decentralisation provided a powerful incentive for local governments to develop economies under their jurisdiction. In addition, the emphasis on revenue targets and fiscal autonomy incentivised officials to maximise tax revenues and achieve key performance indicators as these metrics directly impacted career and fiscal interests.[33]

The third tier typically refers to individual ownership and self-employed craftsmen. These typically represent small-scale operations.

2.2. Political Economy of Coal

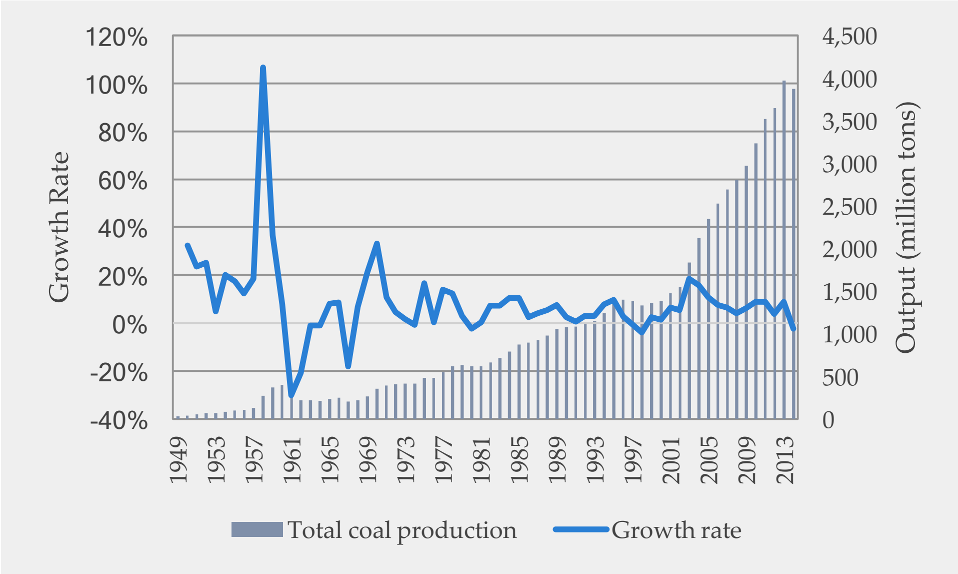
After having examined the Chinese political economy over the past four decades, we now outline the political economy of coal in China which will be critical in analysing the risks and opportunities implied by the achievement of NDCs.

2.2.1. China's Coal Industry

China is the world's largest producer of coal and coal-fired electricity, producing 3,874 Mt or 47% of global coal supply,[34,35] and operating 978 GW or 48% of global coal-fired generation capacity.[36] Coal represents the backbone of China's industrial economy, accounting for 73% of China's energy production, 66% of energy consumed,[37] and 93% of all thermal generation.[38] Over the past 40 years the rate of coal production growth has moved with economic cycles and has grown at an average rate of 5.7% per year, as shown in Figure 4.

[33] Hehui Jin and Yingyi Qian, "Public versus Private Ownership of Firms: Evidence from Rural China," *Quarterly Journal of Economics*, 1998, 773–808; Hongbin Li and Li-An Zhou, "Political Turnover and Economic Performance: The Incentive Role of Personnel Control in China," *Journal of Public Economics* 89, no. 9 (2005).
[34] China Statistical Yearbook, "13-12 Total Output of Industrial Products 2014," 2015.
[35] World Coal Association, "Coal Facts 2015," 2015.
[36] Oxford University Smith School.
[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] China Statistical Yearbook, "9-1 Total Consumption of Energy and Its Composition 2014."

Figure 4: China's coal production and growth rate (1949-2014)[39]



The main industries associated with coal in China are mining and electricity generation. According to the 2008 census (the most recently available data), total employment in power and heat utilities was estimated at 3.02 million,[40] while 2015 National Bureau of Statistics data registered 4.4 million coal mining employees. Coal mining has historically provided the opportunity for low-skill rural workers to earn wages many multiples of what they could have achieved in local agriculture. For this reason, in many regions coal mining is the most attractive employment option for many rural Chinese and is crucial for local economies. [41]

2.2.2. *Geographical Distribution of Coal*

China has the world's third largest coal reserves behind Russia and the United States. While the Chinese National Bureau of Statistics estimated ensured reserves in 2009 at 319 Bt[42] (sufficient for 100 years holding production at current levels), most Western estimates, using different definitions, assess recoverable reserves at only 114 Bt, or 13% of global reserves (sufficient for 29 years of current production).[43]

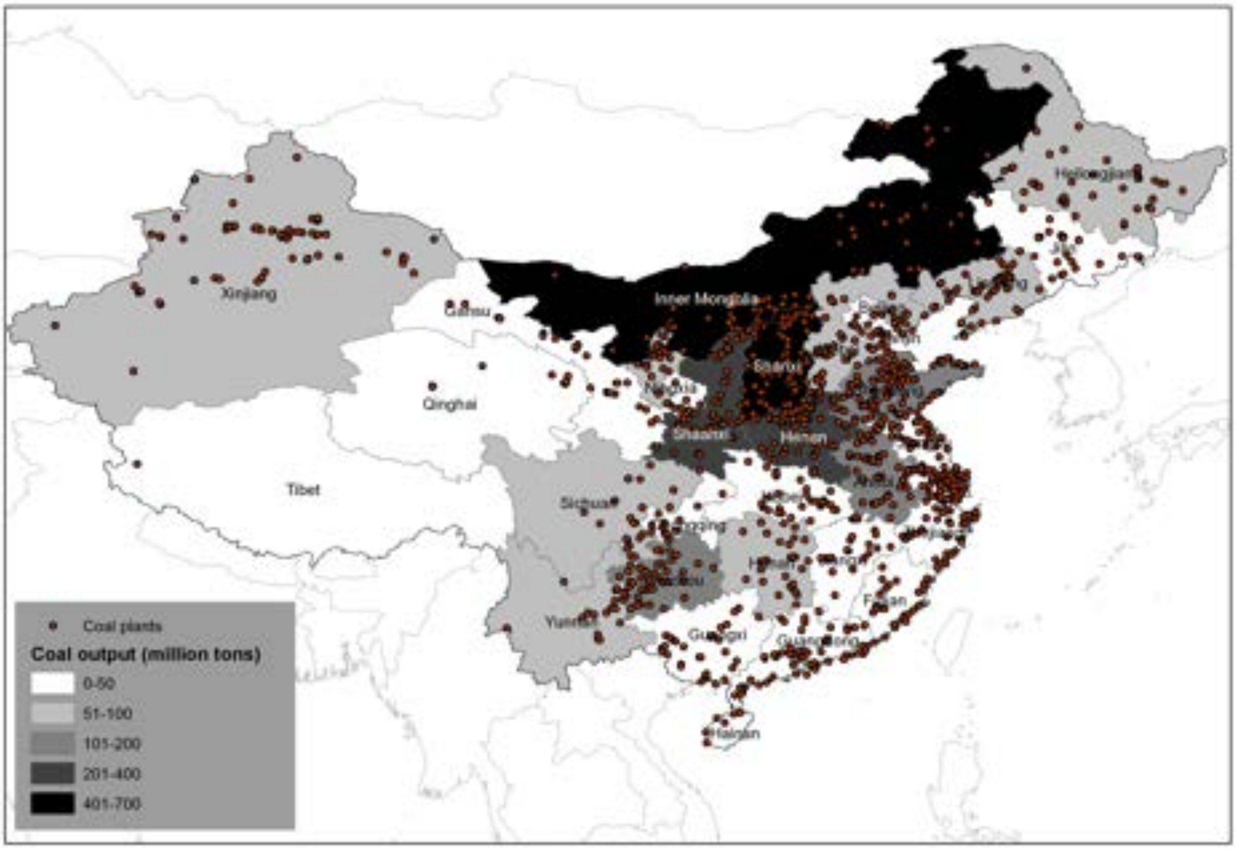
2.2.2.1. *Location of Coal Output*

Exploiting coal reserves in China is more challenging than in other countries. China's coal is of relatively poor quality,[44] its seams are generally thinner, and fewer deposits are located close to the surface increasing extraction costs. In 2009 (the most recent year for which data are available), coal was mined in almost all provinces (except Hainan and Tibet, and the metropolitan areas of Shanghai and Tianjin). The major coal producing regions were concentrated in the northcentral and central provinces of Inner Mongolia (20%), Shanxi (20%), and Shaanxi (10%), see Figure 5.[45] These major coal areas were located some distance from primary areas of coal-consumption along the southern coast.

---

[39] Zhongguo tongji nianjian 2008-2015, *SAWS, Zhongguo Meitan Gongye Fazhan Gaiyao* (Beijing: Meitan gongye chubanshe, 2010).
[40] More recent data than 'China's Economic Census Yearbook 2008' (Zhongguo tongji nianjian 2008) does not appear to be available, http://www.stats.gov.cn/tjsj/pcsj/jjpc/2jp/indexce.htm.
[41] Wright, *The Political Economy of the Chinese Coal Industry: Black Gold and Blood-Stained Coal*.
[42] Zhongguo tongji nianjian 2008-2015, *SAWS, Zhongguo Meitan Gongye Fazhan Gaiyao*.
[43] China Energy Group, "China Energy Databook," 2008.
[44] Wright, *The Political Economy of the Chinese Coal Industry: Black Gold and Blood-Stained Coal*. p.20.
[45] Zhongguo tongji nianjian 2008-2015, *SAWS, Zhongguo Meitan Gongye Fazhan Gaiyao*. 12-11.

Figure 5: Coal output by province and the location of coal-fired power plants (2009)



Coal mining techniques in China vary by mine.[46] However, mining is a classic labour-intensive industry. Although we were unable to source official statistics on coal mine employment levels by province, it is reasonable to assume that province-level coal-mining employment will be approximately proportionate to coal-production in that province, see Table 3.

[46] Coal Age, "Understanding the Chinese Coal Industry," n.d.

Table 3: Coal output by province (2009)[47]

Province	Output (million tons)	Share	Province	Output (million tons)	Share	Province	Output (million tons)	Share
Total	2,951	100%	Heilongjiang	87	3%	Gansu	39	1%
Inner Mongolia	601	20%	Hebei	85	3%	Jiangxi	30	1%
Shanxi	594	20%	Xinjiang	76	3%	Fujian	25	1%
Shaanxi	296	10%	Hunan	66	2%	Jiangsu	24	1%
Henan	230	8%	Liaoning	66	2%	Qinghai	13	0%
Shandong	144	5%	Yunnan	56	2%	Hubei	11	0%
Guizhou	137	5%	Ningxia	55	2%	Beijing	6	0%
Anhui	128	4%	Jilin	44	1%	Guangxi	5	0%
Sichuan	90	3%	Chongqing	43	1%	Others	0	0%

2.2.2.2. *Location of coal-fired assets*

In 2016, the Chinese coal fleet capacity was most heavily concentrated around the following populous and heavily industrialised areas: (1) central and yellow river plains, (2) coastal areas, and (3) a cluster centred around Guizhou province exporting substantial amounts of power to neighbouring provinces, see Figure 6. Other coal power agglomerations tended to be smaller and associated with a regionally important city. Large expansions to China's coal fleet were under construction in the central provinces of Shanxi, Shaanxi, and the western-most province of Xinjiang, see Figure 6. In particular, the latter had been targeted for economic development in order to calm local political tension. With regard to planned coal plants, the most notable province was coal-rich Inner Mongolia, which had a disproportionate 86,830 MW planned or 15% of total Chinese planned coal capacity, exceeding the 81,350 MW of coal-fired power operating at that time.

[47] Zhongguo tongji nianjian 2008-2015, *SAWS, Zhongguo Meitan Gongye Fazhan Gaiyao.*

Figure 6: Location of existing and planned coal-fired assets[48]

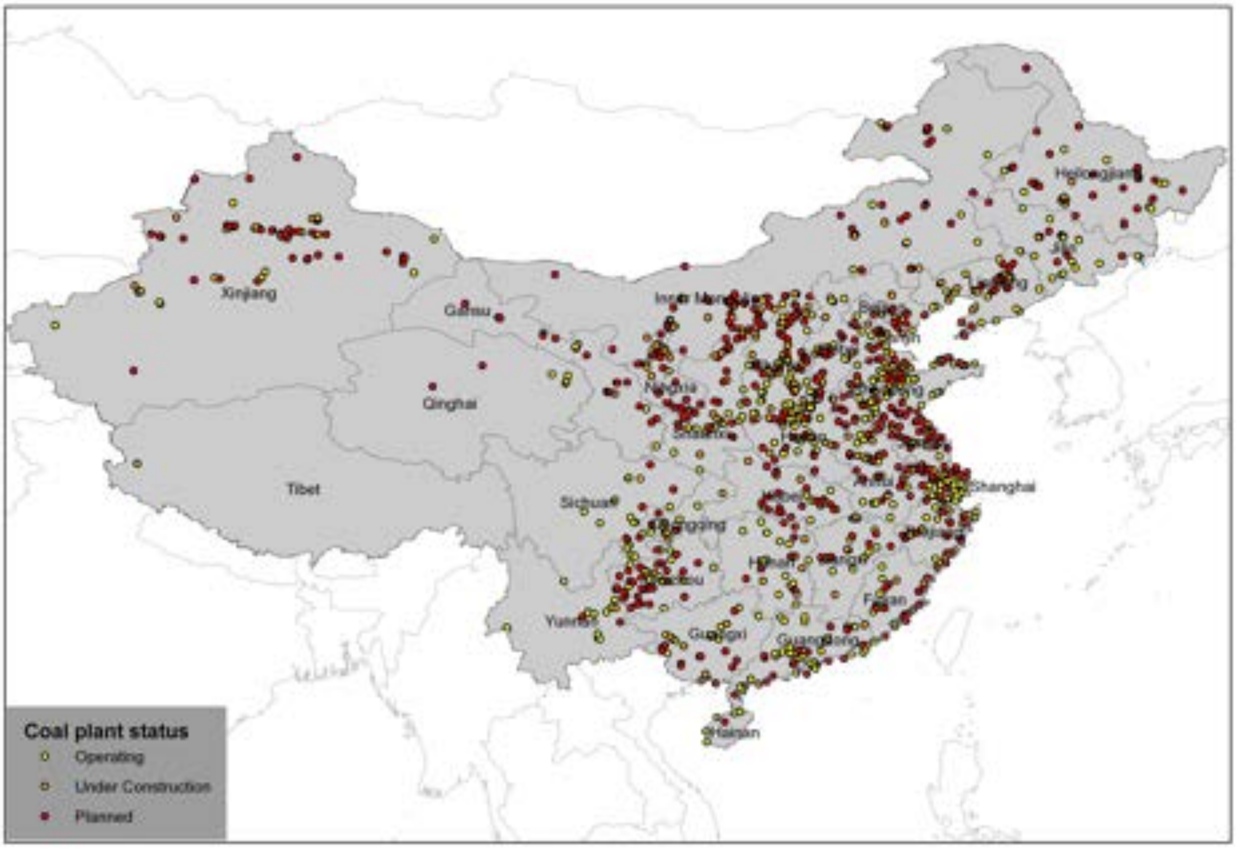


Table 4 below provides the operating, under construction and planned Chinese coal-fired generation capacity.

[48] Oxford University Smith School.

Table 4: Operating, under construction and planned Chinese coal-fired generation capacity[49]

	Operating		Under Construction		Planned	
	Capacity	*Share*	*Capacity*	*Share*	*Capacity*	*Share*
Inner Mongolia	81,350	8.32%	18,320	8.06%	81,710	14.50%
Jiangsu	78,579	8.03%	6,238	2.74%	33,042	5.86%
Shandong	77,804	7.95%	21,020	9.25%	21,961	3.90%
Henan	71,879	7.35%	11,575	5.09%	28,476	5.05%
Guangdong	65,048	6.65%	3,800	1.67%	33,280	5.91%
Shanxi	59,347	6.07%	31,697	13.94%	34,230	6.08%
Xinjiang	49,333	5.04%	20,380	8.97%	45,642	8.10%
Anhui	45,403	4.64%	8,678	3.82%	21,123	3.75%
Hebei	45,254	4.63%	7,400	3.26%	11,365	2.02%
Zhejiang	44,455	4.54%	242	0.11%	9,641	1.71%
Guizhou	33,045	3.38%	6,640	2.92%	50,845	9.02%
Shaanxi	32,918	3.37%	22,540	9.92%	45,360	8.05%
Liaoning	31,962	3.27%	5,570	2.45%	4,323	0.77%
Hubei	24,826	2.54%	6,340	2.79%	22,935	4.07%
Gansu	23,614	2.41%	6,700	2.95%	28,912	5.13%
Fujian	23,430	2.40%	6,640	2.92%	14,366	2.55%
Ningxia	20,289	2.07%	12,430	5.47%	7,942	1.41%
Hunan	18,716	1.91%	5,200	2.29%	14,144	2.51%
Jilin	18,627	1.90%	700	0.31%	7,770	1.38%
Jiangxi	17,960	1.84%	7,320	3.22%	12,725	2.26%
Heilongjiang	17,335	1.77%	2,612	1.15%	6,822	1.21%
Guangxi	16,747	1.71%	5,570	2.45%	8,764	1.56%
Shanghai	15,121	1.55%	0	0.00%		0.00%
Yunnan	14,047	1.44%	300	0.13%	1,800	0.32%
Sichuan	13,434	1.37%	2,000	0.88%	4,450	0.79%
Tianjin	12,148	1.24%	2,050	0.90%	1,850	0.33%
Chongqing	10,590	1.08%	4,640	2.04%	4,740	0.84%
Hong Kong	6,608	0.68%	0	0.00%		0.00%
Qinghai	3,785	0.39%	700	0.31%	4,500	0.80%
Hainan	3,724	0.38%	0	0.00%	700	0.12%
Beijing	800	0.08%	0	0.00%		0.00%
Tibet	0	0.00%	12	0.01%		0.00%
Grand Total	**978,177**	**100.00%**	**227,314**	**100.00%**	**563,418**	**100.00%**

[49] Oxford University Smith School.

2.2.3. *An Evolving Political Economy*

China's coal dependency raises profound governance challenges as the coal industry plays a significant role in both national and local economies.

After the reforms in the 1970s (as mentioned in the previous section), a 'revenue-sharing' system for SOE had been enforced between central and local governments. The central government's control over the coal industry had been reduced, creating opportunities for non-state rural enterprises and increasing the role played by local governments. A 'two-level' central and local administration had therefore been established. Local governments were, in particular, in charge of authorising and administering small-sized mines, encouraging coal production.[50]

Twenty years later, the revenue-sharing system had been replaced by a tax-sharing system. The central government became in charge of regulation and macroeconomic management, leaving the administration of coal mines to local authorities, with the Shenhua Group as an exception. One of the main consequences was a fragmented structure of the Chinese coal industry. This is supported by Figure 5, Figure 6, Table 3, and Table 4 above. The strategy adopted by local governments was driven by the willingness to maximise tax revenues and improve the local economy. Illegal mines with poor safety records grew significantly being responsible of around 70% of the world's mining deaths occurring in the country.[51] Corruption in SOEs and major coal-producing provinces has also been a serious issue.[52]

The central government had thus worked towards improving control of the industry, as exemplified by the dedicated State Administration of Coal Mine Safety which participated in the closure of 3,000 mines of under 90,000 tonne capacity. [53] The central and local governments had acted to take control of numerous small-sized mines. In particular, the local government in Shanxi province implemented, in late 2008, a policy introducing large state-owned coal enterprises that could potentially annex small private mines. This provoked the resistance of mine owners as well as non-local investors. It should however be underlined that, despite the stronger legal, technological, financial and human capacity of SOEs to operate responsibly, their large scale production combined with huge working force can often obstruct safety improvement.

The central and local governments profited from the 2008 market turmoil and the resulting low-cost restructuring opportunities, caused by a low coal price and a decreasing demand, to promote policies in favour of coal resource integration. In particular, the 12th Five-Year Plan of Coal Industry Development issued in March 2012 aimed at enhancing 'support from the national authorities for cross-region, cross-industry and cross-ownership merger and re-structuring of large-scale enterprises with advantages in capital, technology and management, as well as support for integrated, scaled-up and concentrated operations in coal exploration, power generation and transport'.[54] This plan contributed in increasing the market share of Shenhua Group, China Coal Energy Group and Datong Coal. [55]

In 2014, the coal demand decline had been associated with large losses in the coal industry. According to the China National Coal Association, in the first two months of 2015, over 80% of China's 90 major coal companies faced losses of altogether RMB 13.1 billion, while their profits over the same period a year before reached RMB 11.2 billion.[56] Since then, small and medium enterprises with weak financial capacity have had to decrease their market

---

[50] Wuyuan Peng, "Coal Sector Reform and Its Implications for the Power Sector in China," *Resources Policy* 36, no. 1 (2011): 60–71, http://www.sciencedirect.com/science/article/pii/S0301420710000267.
[51] Xiaozong Wang, "Over 97% of China's Mining Accidents Are Human Caused and Death Toll Counts about 70% of the World's Total," *People's Daily*, 2011, http://society.people.com.cn/GB/15020575.html.
[52] Cheng and Eikeland, "China's Political Economy of Coal."
[53] "Small-Sized Coalmines Make Severe Production Safety Issues," *China Daily*, 2012, http://www.chinadaily.com.cn/hqgj/jryw/2012-10-26/content_7343593.html.
[54] Cheng and Eikeland, "China's Political Economy of Coal."
[55] Ibid.
[56] "China National Coal Association: Over 80% of 90 Large-Sized Coal Companies in Loss in the First Two Months," *People's Daily*, 2015, http://politics.people.com.cn/n/2015/0410/c70731-26828211.html.

shares, leaving large-scale coal enterprises with strong financial capacities and secure financing channels with a huge opportunity to cheaply expand their businesses.

3. Political Economy Frictions

This section briefly examines the political economy frictions associated with a transition away from coal in China. Sections 3.1 – 3.3 summarise the different types of asset at risk of stranding and some potential downstream economic, social, and political consequences. Section 3.4 quantifies the potential scale of stranded coal-fired power station assets faced by China at the national and provincial levels, and the results are discussed in Section 3.5.

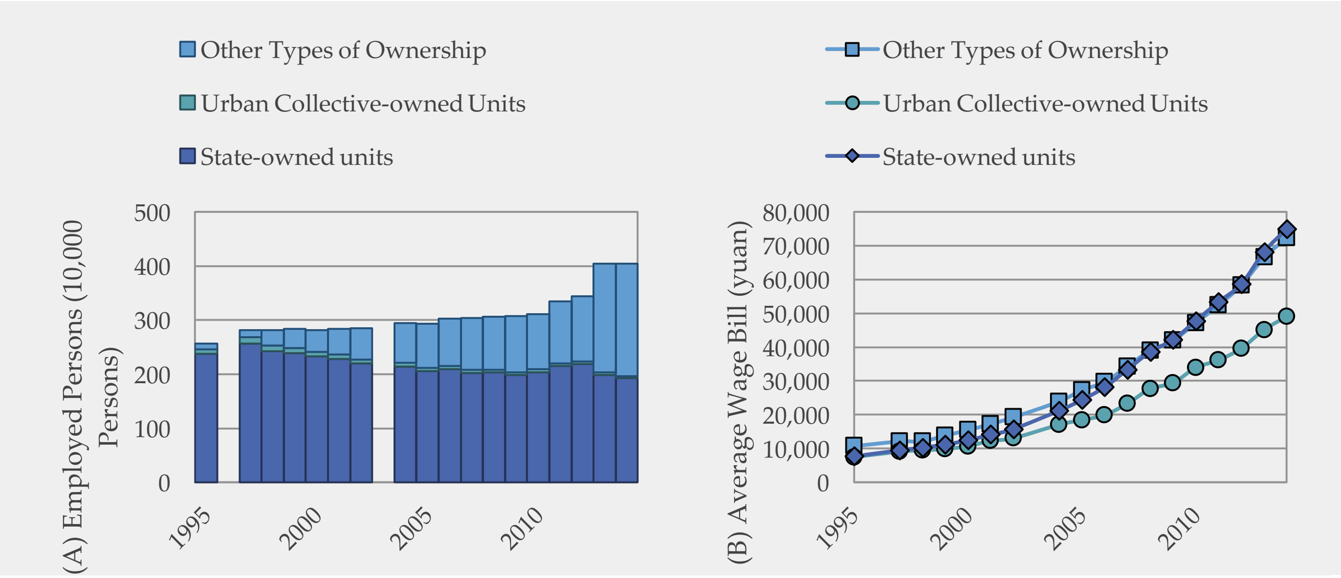
3.1. Economic and Socio-economic Stakeholders

Employment figures for the production and distribution of electricity, gas and water – collectively referred to as the utility industry – are reported in Figure 7 below.[57] Plot (A) illustrates that the utility industry has created significant employment opportunities since 1995. In total, the number of persons employed by the utility industry increased from 2.6 million in 1995 to over 4 million in 2014. However, the growth has been asymmetric across ownership types. State-owned utilities cut their workforce by 19%, from 2.4 million employees in 1995 to 1.9 million in 2014. Urban collective units never established themselves as major employers in the utility industry. In 1995, urban collectives only employed 92,000 workers, declining to only 40,000 workers in 2014. In contrast to the former three tiers, other ownership types (including private and foreign ownership) experienced a 20-fold increase in employment, from 100,000 employees in 1995 to around 2.1 million in 2014. The latter is of interest, as it also coincides with a massive influx of rural workers into private employment and the 'urbanisation' of rural areas.

Simultaneous to increasing the number of employees, Plot (B) shows that the average wage bill of employees in the utility industry increased substantially over the period too. At the absolute level, state-owned and other (private) employees receive the highest salaries, at around ¥72,000-75,000 per annum in 2014 – considerably above the national average of ¥56,360.[58] In contrast, urban collective employees typically receive around ¥50,000 per annum. While the number of state-owned employees decreased over time, this cohort typically experienced the greatest relative growth in wages, at 12.69% per annum. Urban collectives and other (private) ownerships only experienced wage increases of 10.42% and 10.56%, respectively. Clearly, employment in the utility industry provides above-average wages for the majority of its employees, and has generally kept pace with growth in the Chinese economy – especially for those employed by SOEs.

[57] Electricity-industry-only figures were not used due to data availability.
[58] National Bureau of Statistics of China, "National Bureau of Statistics of China >> Annual Data," 2016.

Figure 7: Employment and average wages for utility employees (1995-2014)[59]



China has little indigenous supply of natural gas and oil. Moreover, due to the importance of coal to various provinces, the trends in increased coal-related employment, and reliance of many SOEs on cheap coal suggests that China has little ability to wean itself off coal in the short-term, and that it will continue to play an important role over the coming years.

3.2. The struggle between electricity and coal

China's coal and electricity industries have a strong reliance on each other. The two industries are intrinsically linked as the electric power industry purchases over 50% of China's coal, while coal represents over 70% of the plants' operating costs.[60] However, excessive government interventions have made it difficult for the two industries to form a stable, reasonable, and transaction cost-saving relationship.[61] The significant inter-sectoral struggle between coal and electricity industries (*mei dian zhi zheng*) has been ongoing since the 1980s, with both attempting to garner preferential support from the state.[62]

The profit margins between the coal and electricity industries are inversely related: higher coal prices produce larger profits in coal mining but prices negatively impact the power industry. While this is intuitive, the underlying implications are that the Chinese coal-fired power industry will be particularly sensitive to their changing resource landscape in comparison to other countries with more diversified generation portfolios, which could potentially lead to significant amounts of asset stranding. However, the degree of asset stranding will vary at the province-level, where regulation and/or coal availability will represent major stranding factors.

[59] Ibid.
[60] Sylvie Cornot-Gandolphe, *China's Coal Market: Can Beijing Tame King Coal?*, 2014.
[61] Bing Wang, "An Imbalanced Development of Coal and Electricity Industries in China," *Energy Policy* 35, no. 10 (October 2007): 4959–68, doi:http://dx.doi.org/10.1016/j.enpol.2007.04.022.
[62] Wright, *The Political Economy of the Chinese Coal Industry: Black Gold and Blood-Stained Coal*.

3.3. The Stranding of Ancillary and Labour Assets

In addition to the direct asset-stranding of coal-fired power stations, the decarbonisation of the Chinese economy could potentially impair other assets closely linked to the coal sector such as, physical assets (e.g. infrastructure, coal processing technologies, and coal mines), natural assets (e.g. water reserves), financial assets (e.g. equities, debt, and derivatives), human assets (e.g. knowledge, management practices, and labour), and social assets (e.g. community networks). This gives rise to the so-called 'stranded nations' where a significant part of a nation's wealth may lastingly lose its value.[63]

3.3.1. Stranded Ancillary Assets

If Chinese coal-fired power plants are stranded, in addition to the plants themselves, coal mines and all the capital and machinery associated with them, which formerly supplied power plants, would incur stranding as well. Another potentially stranded asset is water, especially in the southern half of China where water is abundant. Water is heavily used in thermal power generation and coal mining, and decisions to close coal plants and mines could significantly decrease the value of water resources and capital dependent on these industries.

Other physical infrastructure built around serving coal industry employees such as housing, schools, and roads would also be affected by nationwide coal-power closures. A notable characteristic of Chinese cities is that many lack economic diversification. The Chinese government actually categorises 263 cities (comprising 48% of China's population) as 'resource-based'.[64] Resource-based cities are generally defined as cities which have greater than 40% of their economy dependent on non-renewable resources.[65] Among these 263 cities, 80 are classified as primarily coal-based resource cities. According to our own calculations, 14% of China's 2013 GDP (RMB 56.9 tn) came from these 80 coal-based resource cities. The real estate market in these cities represents a huge risk factor. Indeed many of the cities identified as resource-based have been overbuilt by local governments dependent on tax revenues linked to land sales.[66] The risk of non-performing loans associated with exuberant real estate development is increased by the departure of a significant fraction of workers due to poor employment prospects.[67]

Financial assets which derive their value from coal and related industries would also experience declines as a result of coal closures. This has potential implications for financial institutions assessing the risk of investing in coal assets and for financial regulators to ensure that such risks are being properly assessed and priced.

The extent to which such stranding events occur could be mitigated by China's ability to export its coal, thereby preserving its coal mining industry. At present, attempting to do so may prove difficult or impossible due to the scale involved (47% of global supply)[68] and the national and international initiatives to move away from coal-fired power. An additional factor which would obstruct coal exportation in China is, as mentioned in Section 2.2, the poor quality of its coal and the remote localisation of its mines, imparting heavy transportation costs. These factors would limit the viability of exporting coal overseas. This is evidenced by the fact that the lowest-quality form of coal (lignite) is almost always consumed at the point of extraction and no international market price exists for it. Given China's reliance on rail to transport coal from its interior to its urban and coastal areas, we could also see Chinese railways incur substantial stranding.

---

[63] David Manley, James Cust, and Giorgia Cecchinato, "Stranded Nations? The Climate Policy Implications for Fossil Fuel-Rich Developing Countries," 2016, http://www.oxcarre.ox.ac.uk/images/stories/papers/PolicyPapers/oxcarrepp201634.pdf.

[64] ***中国城市**统计年鉴 China City Statistical Yearbook*, 2014.

[65] This is regularly quoted in academic journals, newspapers and dissertations, but is not written in government documents, see: "发展特色旅游:**阜新**转型又一新思路." "**技**术创新视角下的资源型城市经济转型—基于枣庄市经济转型的案例分析 Economic Transformation under High-Tech Innovation: Case Study of Zaozhuang, Shandong."

[66] Jamil Anderlini, "The Chinese Chronicle of a Crash Foretold," *The Financial Times*, n.d.

[67] Lucy Hornby and Archie Zhang, "China's Rust Belt Faces Exodus of Young Talent," *The Financial Times*, n.d.

[68] World Coal Association, "Coal Facts 2015."

2.3.2 Stranded Labour

As intimated above, physical assets are not the only type of assets that can become stranded. The stranding of human capital (or 'stranded labour') is an unavoidable consequence of shifting environmental and energy landscapes. The specialisation of local economies could leave some particularly vulnerable.

For example, the adverse impact of transition in the UK coal sector has been evident in local communities and labour dynamics. The number of people employed in UK coal mines fell from 1.2 million in 1920 to below 3,000 in 2015.[69] The infamous UK miners' strike in the 1980s (known as the 'Great Strike for Jobs') is the kind of conflict that governments should seek to avoid if carbon-intensive sectors are phased out. This could be achieved by requiring better planning to ensure the future of communities likely to be affected by asset stranding.[70] This could be completed through voluntary relocation, education, training, and tax incentives to attract new industries to the region. However, this is likely to be even more complicated in the developing world, especially in communities lacking education and training in other skills, and where low-income jobs limit opportunities to relocate and find employment, as detailed below.

Although stranded labour is more difficult to quantify than those from physical assets, they are at least as relevant for determining the sustainability of any given policy direction. On the one hand, economic losses from unemployment consist of the loss of income and new job search costs borne by workers. On the other hand, economic losses from unemployment include the obsolescence of knowledge and skills related to a particular industry, location, corporate culture, and social environment.[71,72] Long-term unemployed workers may also experience a phenomenon known as 'scarring', whereby their skills, employability, and subsequent wages decline – especially for men of middle-age and older.[73,74] Finally, there are physical and psychic costs associated with the stresses of being unemployed.[75] Research also shows that the negative effects of unemployment can be substantial and long-lasting.[76]

Beginning in the late 1990s the Chinese government first allowed companies that were loss-making to declare bankruptcy, close, and lay-off their workers.[77] As in western countries, bankruptcy is now used in China as a way for companies to reduce workforces, increase efficiency, and reopen.[78] Historically these episodes have produced high levels of unemployment, such as in China's last major economic restructuring between the late 1990s and early 2000s. While official statistics universally reported much lower figures, it is believed that in many cities the real unemployment rate greatly exceeded 20% during this period.[79]Although we do not have data on utility worker lay-offs specifically, it is also thought that around a quarter of the 2.8 million total workers in state-owned coal mining companies were laid-off at the time.[80]

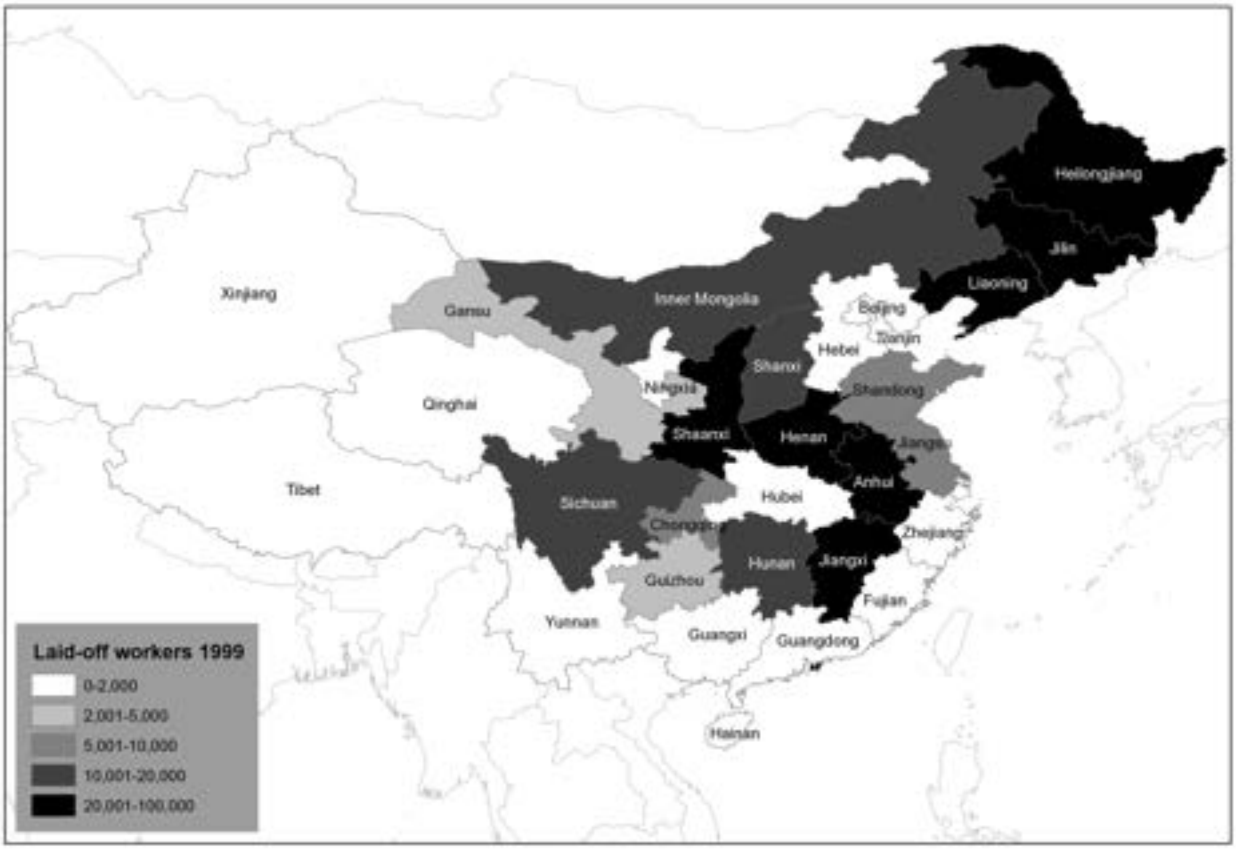
As depicted in Figure 8, the geographical distribution of laid-off coal mine workers was heavily concentrated in the 'rust-belt' of northeast China (Heilongjiang, Jilin, and Liaoning provinces). At the time, these lay-offs deprived many workers of what used to be secure and relatively well-paid jobs, and created a large new group of urban

---

[69] Ben Caldecott et al., "Stranded Assets and Thermal Coal: An Analysis of Environment-Related Risk Exposure," *Stranded Assets Programme, SSEE, University of Oxford*, 2016.
[70] Chris Cook and John Stevenson, *The Longman Handbook of Modern British History, 1714-1987* (Longman, 1988).
[71] Friedrich Hayek, "The Use of Knowledge in Society," *American Economic Review* 35, no. 4 (1945): 519–30.
[72] D Neal, "Industry-Specific Human Capital: Evidence from Displaced Workers," *Journal of Labor Economics* 13, no. 4 (1995): 653–77.
[73] M. Gregory and R. Jukes, "Unemployment and Subsequent Earnings: Estimating Scaring Among British Men 1984-94," *The Economic Journal* 111, no. 475 (2001): 607–25.
[74] W. Arulampalam, P. Gregg, and M. Gregory, "Unemployment Scarring," *The Economic Journal* 111 (n.d.): 577–84.
[75] F. McKee-Ryan et al., "Psychological and Physical Well-Being during Unemployment: A Meta-Analytic Study," *Journal of Applied Psychology* 90, no. 1 (2005): 53–76.
[76] R Topel, "Specific Capital and Unemployment: Measuring the Costs and Consequences of Job Loss," in *Carengie-Rochester Conference Series on Public Policy*, n.d., 181–214.
[77] Liu Chuangeng, "Guoyou Zhongdian Meikuang Zhigong Xiagang Xianzhuang Ji Qushi Fenxi," *Meikuang Xiandaihua* 1 (2001): 5–7.
[78] Wright, *The Political Economy of the Chinese Coal Industry: Black Gold and Blood-Stained Coal*.
[79] Lucy Hornby, "China Comes Full Circle with Talk of Mass Lay-Offs," *The Financial Times*, n.d.
[80] Wright, *The Political Economy of the Chinese Coal Industry: Black Gold and Blood-Stained Coal*. p.148.

poor.[81] It is believed that those laid-off workers were also the most vulnerable and least able to find re-employment.[82]

Figure 8: Coal mine lay-offs (1999) [83]



The preferred outcome from the point of view of the state and the enterprise is to re-employ laid-off workers. One of the ways that employers tried to organise this was by trying to diversify their activities into 'non-coal' production and to transfer workers to these units. For example, 40% of workers in key state-owned coal-mining enterprises in Jiangxi were transferred to non-coal production, which effectively eased the problem of redundancy.[84] However, such enterprises were often unproductive and alternative employment was not always possible to create.[85] This is especially true because many mines are located in remote regions where towns only exist on the basis of the mine.[86]

Some cities which have already experienced the closure of economically critical coal mines have subsequently seen their populations decline considerably, especially younger wage-earners. For instance, the population of

[81] Zhongguo meitan gongye Xiehui, *Zhongguo Hangye Fenxi Baogao* (Beijing: Zhongguo jingji chubanshe, 2005).; Carsten A Holz and Yi-min Lin, "Pitfalls of China's Industrial Statistics: Inconsistencies and Specification Problems," *China Review* 1.1 (2001): 29–71.
[82] Wright, *The Political Economy of the Chinese Coal Industry: Black Gold and Blood-Stained Coal*. p.148.
[83] Oxford University Smith School.
[84] Qian Linfang and Wang Shaozhou, "Shilun Dui Meikuang Xiagang Shiye Renyuan de Jiuye Yuanzhu," *MJY* 2 (2002): 57–58.
[85] Wright, *The Political Economy of the Chinese Coal Industry: Black Gold and Blood-Stained Coal*.
[86] Zhao Yanying and Zhang Shenli, "Dui Jilin Sheng Meitan Qiye Xiagang Zhigong Zaijiuyenandian Wenti de Diaocha Fenxi Yu Duice Jianyi," *Laodong Shijie* 7 (2000): 6–8.

some residential areas in Shuangyashan - a coal-mining town whose only mine is struggling financially - has fallen by a third in the past few years, as younger workers depart for better job prospects elsewhere.[87] This outpouring of workers is likely to result, at least temporarily, in the erosion of social capital in both the locations workers leave from and depart to.[88] The loss of social capital is likely to not only affect the subjective well-being of workers, but also their wage earning capacity. It is well known that a great deal of economic decision-making in China is based upon *guanxi* – or social relationships. By moving cities, workers may be deprived of many of these connections which may handicap their employability and attractiveness for pay-rises and promotion.

Many laid-off workers often lack education and training in other skills. As a result, they face limited opportunities, can hardly relocate to find better employment, and are locked into low-income trades. Such workers are also often reluctant to seek employment in new industries and locations because of cultural factors and a lack of transferable skills.[89] Moreover, Chinese workers who are unable to find re-employment in their original firm usually suffer steep declines in income.[90] For instance, a survey of 55 enterprises in 2001 showed that laid-off workers were only paid about 20-30% as much as workers who remained within their company. Furthermore, state provided aid for the unemployed is considered to be insufficient.[91]

3.3.2. Industrial Protests in China

Since the 1990s there has been a dramatic increase in industrial conflict in China as a result of a transformation in industrial relations. According to the All-China Federation of Trade Unions (ACFTU) roughly 1.3 million workers were annually involved in labour disputes between 1992-1997, but this figure nearly trebled to 3.6 million in 1998. Similarly, between 1994-2006 collective protests grew from 10,000 to 90,000.[92] This represents an annual growth rate of 20%, or twice the rate of GDP growth over the period. Most protests share in common the workers' collective discontent with rights abuses, poor working conditions, and deteriorating living standards.[93]

Most large-scale industrial protests are launched by workers in SOEs and generally stem from one of two root causes. The first one is a subsistence crisis – a situation where workers have drastically reduced or no incomes paid for a period of time, while the second one is the case of overt managerial corruption.[94] As worker discontent could boil over into wider protests against its authoritarian rule, the government is keen to avoid situations that incite demonstrations. It therefore imposes strict regulations on labour organisation,[95] regularly imprisons workers for leading protests,[96] and instructs local officials to take actions that prevent workers from taking their grievances to Beijing.[97]

---

[87] Christian Shepherd and Lucy Hornby, "Chinese Police Break up Coal Jobs Protest," *The Financial Times*, n.d.
[88] Christian A. L. Hilber, "New Housing Supply and the Dilution of Social Capital" (London, UK, 2007).
[89] See Jane Perlezand, "Mass Layoffs in China's Coal Country Threaten Unrest - The New York Times," n.d. 'Longmay Group, the biggest coal company in northeastern China, announced in September [2015] that it planned to lay off 100,000 workers'.
[90] Wright, *The Political Economy of the Chinese Coal Industry: Black Gold and Blood-Stained Coal*. p.150.
[91] Ibid.
[92] Hongyi Lai, "Uneven Opening of China's Society, Economy, and Politics: Pro-Growth Authoritarian Governance and Protests in China Title," *Journal of Contemporary China* 19, no. 67 (2010): 819–35.
[93] F Chen, "Industrial Restructuring and Workers' Resistance in China," *Modern China2* 29, no. 2 (2003): 237–62.
[94] F Chen, "Subsistence Crises, Managerial Corruption and Labour Protests in China," *The China Journal* 44, no. July (2000): 41–63.
[95] Eli Friedman and Ching Kwan Lee, "Remaking the World of Chinese Labour," *British Journal of Industrial Relations* 48, no. 3 (2010): 507–33.
[96] Lucy Hornby, "China Coal Protests Highlight Overcapacity Tensions," *The Financial Times*, n.d.
[97] Zhongguo meitan zhi bianzuan weiyuanhui, *Zhongguo Meitan Zhi: Guizhou Juan* (Beijing: Meitan gongye chubanshe, 1994). p. 151; Benxi shi dangshi difangzhi bagongshi, *Benxi Shi Zhi*, Vol.2 ed. (Dalian: Dalian chubanshe, 1998).

3.4. Analysis of Asset Stranding

This section seeks to quantify the scale of asset stranding potentially faced by China's coal power industry at the national and provincial levels. We use 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. In all four scenarios the start date is 2016 and the known installed capacity is 978 GW (including capacity planned for 2016).

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.

Assessing the likely scale of coal-power asset stranding is a complex question involving assumptions on discount rates, future electricity prices, fuel costs, salvage values, and non-market factors such as the timing and stringency of regulation. We have made various assumptions in our analysis and these have been made transparently. Our objective is to illustrate the plausible upper bound of the scale of potential stranded assets over different time horizons.

3.4.1. Methodology

To calculate potential asset stranding charges, we extract the capacities of all coal-fired generation assets by province in MW from Platt's WEPP database, Greenpeace, and CoalSwarm's coal database. We delineate the capacities into existing and planned (or currently under construction). We use IEA data[98] to estimate build cost (in 2012$) per kW, for all coal-fired technologies in our combined database.[99] For circulating fluidized bed (CFB) technologies, we estimate the build cost in 2015$ per kW based on the recently built CFB plant,[100] and discount to 2012$ build cost using World Bank inflation data.[101] We assume all sunk costs – such as fees and contingency, engineering, procurement and construction services, and any additional owner costs – [102] 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 Q3 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 9). 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 plot, 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 and permanently shut down.

---

[98] http://www.worldenergyoutlook.org/weomodel/investmentcosts/

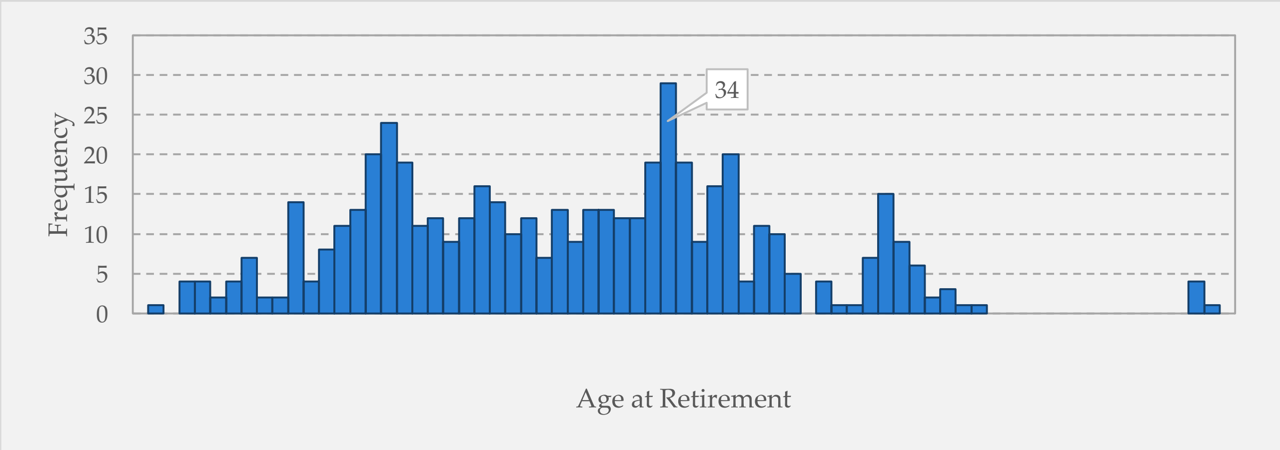
[99] Coal technologies include: Circulating fluidized bed (CFB), integrated gasification combined cycle (IGCC), IGCC with CCS, Subcritical, Supercritical, ultracritical, and coal with CCS.

[100] http://cornerstonemag.net/china-brings-online-the-worlds-first-600-mw-supercritical-cfb-boiler/

[101] 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.

[102] Fang Rong and David G. Victor, "What Does It Cost to Build a Power Plant?," *ILAR Working Paper*, vol. 17, 2012.

Figure 9: Plant age at retirement (Q3, 2016)[103]



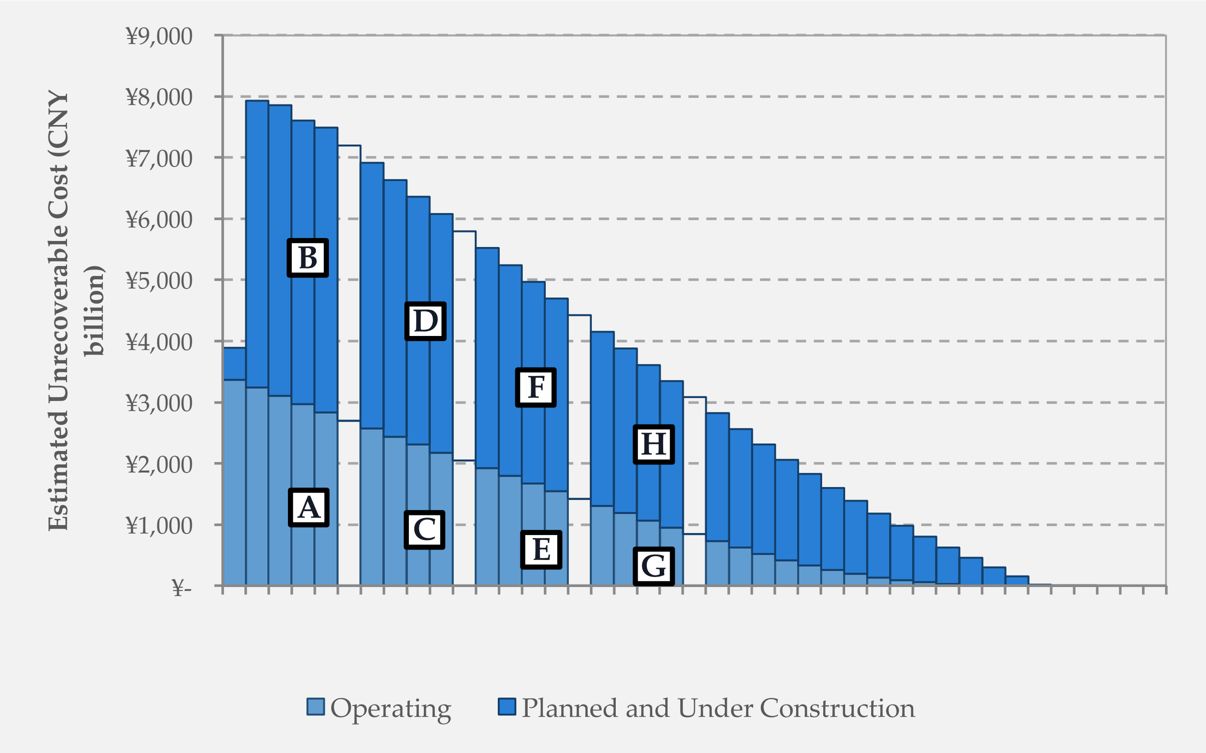
3.4.2. *Asset Stranding Results*

3.4.2.1. *National Level Results*

The results in Figure 10 show that at least some operating, planned and under construction capacity incur asset stranding regardless of the four scenarios. Noticeably, a large amount of coal-fired capacity is planned from 2017 onwards, suggesting much higher potential asset stranding for planned capacity. Figure 10 and Table 5 depict future asset stranding in nominal terms[104] for the four scenarios.

[103] Oxford University Smith School.
[104] 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 10: Estimated scale of asset stranding for existing and new build coal generators



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 5.

Table 5: Estimates of total asset stranding charges in CN¥ billion (US$ billion)

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 5, 10, 15, and 20-year scenarios, asset stranding for new-capacity is estimated using known planned 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, operating asset stranding charges are ¥2,703 billion ($393 billion). Almost two-thirds of the asset stranding charges arise from planned coal-fired projects. The total stranded charge (¥7,201 billion|$1,047 billion) is of a comparable level to immediately closing all coal-fired capacity in 2017. The implications are that stranded assets in China are potentially a costly risk faced by investors in the present and short-term. The 10-year scenario shows total asset stranding charges of ¥5,797 billion ($843 billion), of which about two-thirds (¥3,746 billion|$545 billion) is derived from planned coal-fired projects. As expected, estimates of stranded assets in the 15-year scenario are considerably lower, at only ¥4,420 billion ($643 billion), of which 68% (¥2,994 billion|$435 billion) comprises planned projects. Finally, the stranded asset charges in the 20-year scenario total ¥3,086 billion ($449 billion), of which 73% (¥2,243 billion|$326 billion) would fall on planned capacity.

These scenarios estimate that stranded coal assets could be as much as ¥3,086-7,201 billion ($449-1,047 billion), equivalent to 4.1-9.5% of China's 2015 GDP.[105] The substantial scale of these figures highlights the potential for systemic financial risk associated with the stranding and continued expansion of coal-fired power plants in China.

3.4.2.2. Provincial Level Results

This section disaggregates the national results of coal-fired asset stranding to each province. This exercise is depicted in Table 6 below.

Table 6: Upper bound 5, 10, 15, and 20-year asset stranding estimates by province and operational status in CN¥ million (US$ million)

		2021 (5 Years)		2026 (10 Years)		2031 (15 Years)		2036 (20 Years)	
Rank	*Province*	OPR	CON+PLN	OPR	CON+PLN	OPR	CON+PLN	OPR	CON+PLN
1	*Inner Mongolia*	¥220,146	¥600,825	¥166,248	¥500,626	¥113,094	¥400,427	¥62,259	¥300,228
		¥820,971 ($119,376)		¥666,875 ($96,969)		¥513,521 ($74,670)		¥362,487 ($52,708)	
2	*Shaanxi*	¥103,612	¥455,846	¥80,086	¥380,473	¥57,064	¥305,101	¥35,148	¥229,729
		¥559,458 ($81,349)		¥460,559 ($66,969)		¥362,165 ($52,662)		¥264,877 ($38,515)	
3	*Xinjiang*	¥185,048	¥368,368	¥148,281	¥305,808	¥111,903	¥243,247	¥75,904	¥181,658
		¥553,416 ($80,471)		¥454,089 ($66,028)		¥355,150 ($51,642)		¥257,562 ($37,451)	
4	*Shanxi*	¥154,231	¥368,313	¥116,347	¥306,738	¥80,450	¥245,164	¥46,223	¥183,590
		¥522,543 ($75,982)		¥423,086 ($61,520)		¥325,614 ($47,347)		¥229,813 ($33,417)	
5	*Guizhou*	¥92,004	¥385,298	¥71,032	¥320,860	¥50,156	¥256,422	¥29,839	¥192,331
		¥477,302 ($69,403)		¥391,892 ($56,984)		¥306,578 ($44,579)		¥22,2170 ($32,305)	
6	*Jiangsu*	¥231,978	¥232,773	¥175,682	¥193,748	¥121,687	¥154,723	¥70,769	¥115,699
		¥464,751 ($67,578)		¥369,430 ($53,718)		¥276,410 ($40,192)		¥186,467 ($27,114)	
7	*Shandong*	¥213,272	¥220,387	¥161,645	¥183,439	¥112,074	¥146,491	¥66,309	¥109,543
		¥433,659 ($63,057)		¥345,084 ($50,178)		¥258,565 ($37,597)		¥175,851 ($25,570)	
8	*Henan*	¥192,707	¥182,033	¥145,615	¥151,682	¥100,365	¥121,332	¥57,995	¥90,982
		¥374,739 ($54,490)		¥297,297 ($43,229)		¥221,697 ($32,236)		¥148,977 ($21,662)	
9	*Guangdong*	¥185,496	¥182,999	¥140,283	¥151,896	¥97,517	¥120,792	¥58,769	¥89,689
		¥368,495 ($53,582)		¥292,179 ($42,485)		¥218,309 ($31,744)		¥148,458 ($21,587)	
10	*Anhui*	¥139,402	¥163,953	¥107,499	¥136,269	¥76,630	¥108,584	¥47,591	¥80,900
		¥303,355 ($44,110)		¥243,767 ($35,446)		¥185,215 ($26,932)		¥128,491 ($18,684)	
11	*Gansu*	¥68,951	¥227,568	¥52,904	¥189,996	¥37,370	¥152,424	¥22,574	¥114,852
		¥296,519 ($43,116)		¥242,900 ($35,320)		¥189,794 ($27,597)		¥137,426 ($19,983)	
12	*Hubei*	¥64,545	¥153,626	¥48,230	¥128,089	¥32,691	¥102,552	¥19,153	¥77,014
		¥218,171 ($31,724)		¥176,319 ($25,638)		¥135,243 ($19,665)		¥96,167 ($13,983)	
13	*Hebei*	¥102,100	¥108,274	¥75,350	¥90,132	¥50,358	¥71,990	¥27,845	¥53,849
		¥210,374 ($30,590)		¥165,482 ($24,062)		¥122,349 ($17,790)		¥81,694 ($11,879)	

[105] The World Bank, "World Bank National Accounts Data."

14	***Zhejiang***	¥130,099	¥56,115	¥98,776	¥46,797	¥68,545	¥37,480	¥39,897	¥28,162
		¥186,214 ($27,077)		¥145,574 ($21,168)		¥106,025 ($15,417)		¥68,059 ($9,896)	
15	***Ningxia***	¥58,246	¥115,265	¥44,164	¥96,035	¥30,770	¥76,805	¥18,141	¥57,575
		¥173,511 ($25,230)		¥140,199 ($20,386)		¥107,576 ($15,642)		¥75,716 ($11,010)	
16	***Fujian***	¥63,583	¥109,000	¥47,723	¥90,682	¥32,061	¥72,363	¥17,789	¥54,044
		¥172,583 ($25,095)		¥138,404 ($20,125)		¥104,424 ($15,184)		¥71,833 ($10,445)	
17	***Hunan***	¥54,066	¥107,018	¥40,824	¥88,999	¥28,170	¥70,981	¥16,209	¥52,963
		¥161,083 ($23,423)		¥129,823 ($18,877)		¥99,151 ($14,417)		¥69,172 ($10,058)	
18	***Jiangxi***	¥57,005	¥95,513	¥43,910	¥79,622	¥31,150	¥63,730	¥19,232	¥47,838
		¥152,519 ($22,177)		¥123,532 ($17,962)		¥94,880 ($13,796)		¥67,070 ($9,752)	
19	***Liaoning***	¥74,151	¥60,280	¥54,212	¥50,264	¥35,868	¥40,249	¥20,109	¥30,233
		¥134,430 ($19,547)		¥104,476 ($15,192)		¥76,117 ($11,068)		¥50,342 ($7,320)	
20	***Guangxi***	¥49,077	¥77,547	¥37,670	¥64,418	¥26,409	¥51,288	¥15,456	¥38,159
		¥126,624 ($18,412)		¥102,088 ($14,844)		¥77,697 ($11,298)		¥53,615 ($7,796)	
21	***Heilongjiang***	¥34,590	¥51,693	¥25,156	¥43,166	¥16,728	¥34,640	¥9,525	¥26,113
		¥86,284 ($12,546)		¥68,323 ($9,935)		¥51,367 ($7,469)		¥35,637 ($5,182)	
22	***Jilin***	¥44,313	¥35,302	¥33,187	¥29,367	¥22,881	¥23,431	¥13,284	¥17,495
		¥79,615 ($11,577)		¥62,554 ($9,096)		¥46,312 ($6,734)		¥30,780 ($4,476)	
23	***Chongqing***	¥31,038	¥45,402	¥23,913	¥37,741	¥17,267	¥30,080	¥11,115	¥22,419
		¥76,440 ($11,115)		¥61,654 ($8,965)		¥47,347 ($6,885)		¥33,534 ($4,876)	
24	***Sichuan***	¥32,499	¥29,582	¥24,000	¥24,814	¥16,119	¥20,045	¥8,773	¥15,277
		¥62,081 ($9,027)		¥48,814 ($7,098)		¥36,164 ($5,259)		¥24,049 ($3,497)	
25	***Tianjin***	¥30,734	¥24,908	¥22,347	¥20,847	¥14,872	¥16,786	¥8,315	¥12,726
		¥55,642 ($8,091)		¥43,194 ($6,281)		¥31,659 ($4,603)		¥21,040 ($3,059)	
26	***Yunnan***	¥35,255	¥8,629	¥26,496	¥7,082	¥17,773	¥5,534	¥9,742	¥3,987
		¥43,884 ($6,381)		¥33,577 ($4,882)		¥23,307 ($3,389)		¥13,729 ($1,996)	
27	***Shanghai***	¥31,171	¥0	¥21,710	¥0	¥13,961	¥0	¥7,206	¥0
		¥31,171 ($4,533)		¥21,710 ($3,157)		¥13,961 ($2,030)		¥7,206 ($1,048)	
28	***Qinghai***	¥11,897	¥25,098	¥9,333	¥20,925	¥6,861	¥16,753	¥4,524	¥12,580
		¥36,995 ($5,379)		¥30,259 ($4,400)		¥23,613 ($3,434)		¥17,104 ($2,487)	
29	***Hainan***	¥10,384	¥6,372	¥7,911	¥5,310	¥5,506	¥4,248	¥3,407	¥3,186
		¥16,755 ($2,436)		¥13,221 ($1,922)		¥9,754 ($1,418)		¥6,592 ($959)	
30	***Hong Kong***	¥1,348	¥0	¥340	¥0	¥0	¥0	¥0	¥0
		¥1,348 ($196)		¥340 ($49)		¥0 ($0)		¥0 ($0)	
31	***Beijing***	¥316	¥0	¥49	¥0	¥0	¥0	¥0	¥0
		¥316 ($46)		¥49 ($7)		¥0 ($0)		¥0 ($0)	
32	***Tibet***	¥0	¥42	¥0	¥35	¥0	¥28	¥0	¥20

		¥42 ($6)		¥35 ($5)		¥28 ($4)		¥20 ($3)	
33	*Macau*	¥0	¥0	¥0	¥0	¥0	¥0	¥0	¥0
		¥0 ($0)		¥0 ($0)		¥0 ($0)		¥0 ($0)	
	Grand Total	**¥2,703,262**	**¥4,498,029**	**¥2,050,923**	**¥3,745,860**	**¥1,426,301**	**¥2,993,691**	**¥843,102**	**¥2,242,839**
		¥7,201,291 ($1,047,122)		**¥5,796,783 ($842,896)**		**¥4,419,991 ($642,700)**		**¥3,085,941 ($448,719)**	

Provinces are ranked by the maximum asset stranding assessed across the four scenarios.
OPR refers to operational plant asset stranding values, CON+PLN refers to plants under construction and planned.
Merged cells below each OPR and CON+PLN field are the total of OPR and CON+PLN asset stranding values.

As in the national case, the greatest potential asset stranding generally occurs for each province in second scenario, where all coal-fired utilities are shut down in 5 years (2021).

As depicted in Figure 11, the provinces with the greatest potential asset stranding are: Inner Mongolia, ¥820,972 (11.4% of total 5-year scenario stranding), Shaanxi, ¥559,458 (7.8%), Xinjiang, ¥553,416 (7.7%), Shanxi, ¥522,543 (7.3%), Guizhou, ¥477,302 (6.6%), and Jiangsu, ¥464,751 (6.5%). Perhaps surprising is the fact that the so-called 'rust-belt' provinces of Heilongjiang, Jilin, and Liaoning have relatively moderate levels of estimated coal-fired asset stranding compared to the country as a whole. While at a local level the asset stranding in these northeaster provinces may still be significant, at the national level these are comparatively minor concerns.

Figure 11: Total coal-fired utility asset stranding in the 2021 (5-year) scenario

In Figure 12, only Inner Mongolia retains the highest level asset stranding classification of >CN¥ 80,000m. Due to the high level of front loading of China's planned capacity, all provinces see a fall in asset stranding, and this is reflected in classification changes to a number of provinces.

Figure 12: Total coal-fired utility asset stranding in the 2026 (10-year) scenario

As it can be seen by comparing Figure 11 and Figure 12 to Figure 13 and Figure 14 below, no province falls more than a single classification level from one 5-year scenario to the next, and the initial relative levels of assets stranding depicted in Figure 11 are stable across the four scenarios.

Figure 13: Total coal-fired utility asset stranding in the 2031 (15-year) scenario

Figure 14: Total coal-fired utility asset stranding in the 2036 (20-year) scenario

3.5. Implications

This section has highlighted the demonstrably significant amount of resources potentially at stake in the event of asset stranding in China's coal-fired generation industry. Asset stranding is highest in the 2021 (5-year) scenario due to the large number of coal-fired plants planned in the near-term. Within the industry itself estimates of asset stranding could be as high as ¥3,086-7,201 billion ($449-1,047 billion), equivalent to 4.1-9.5% of China's 2015 GDP,[106] depending on the stranding timeframe and severity. Of course, downstream industries would also be negatively affected; further expanding this figure and increasing the likelihood that such an event could have significant implications for financial assets. The primary areas affected would be in China's north, central, and western provinces, but not necessarily its 'rust-belt' in the northeast.

We underline that the detailed preceding analysis of asset stranding under various scenarios uses asset-level data. The asset-level data is highly granular power station data linked with corporate ownership information. This data enables bottom-up analysis of the impact of energy transitions on companies and communities at a resolution unattainable with aggregate statistics.

The impact of asset stranding scenarios has been considered on a plant-by-plant basis. By using asset-level data, the projected date of closure for each power station was developed under different scenarios. This high resolution

[106] Ibid.

analysis provides much better visibility of company-, community-, and region-specific sensitivity to asset stranding. This sensitivity would otherwise be hidden by an aggregate top-down analytical approach.

The advantage of this form of analysis for policy development is apparent. By using high-resolution asset-level analysis policymakers can deliver their interventions directly to those who are most vulnerable. Policymakers can also better identify any potential conflicts between multiple policy interventions or communities which may suffer an unintended downside from a policy intervention. Political economy tensions and frictions (e.g. between governments and corporates, corporates and labour groups of different industries, or centralised and devolved governments) can be better identified and mitigated.

Analyses driven by asset-level data are just beginning to empower policy, investor, and company decision-makers, and the full scope of their potential is far from being realised. Asset-level data is crucial for understanding environmental risk more broadly.[107] The provision of asset-level data is a key priority for ongoing discussions concerning the disclosure of climate-related financial risk.[108,109] Its utility in this case for informing political economy sensitivities to energy transitions is apparent; asset-level data provides the information policymakers need to deliver a smooth energy transition.

We highlight, however, that, since not all power plants are equally likely to run-afoul of regulation and other constraints, analysis could be undertaken to flag the riskiest assets at the national and provincial level. This could be done along various metrics such as: carbon intensity, water stress, air pollution, and economic dependency on coal-fired power.[110] Such analysis could identify areas within provinces where power plants are particularly vulnerable to closure as well as the risks that have to be addressed there in order to prevent and mitigate future asset stranding.

[107] Ben Caldecott and Lucas Kruitwagen, "S&P Global Market Intelligence - Guest Opinion: How Asset Level Data Can Improve The Assessment Of Environmental Risk In Credit Analysis," 2016.
[108] Ben Caldecott, "The Future of Climate-Related Disclosure," *The Economist*, 2016, https://www.eiuperspectives.economist.com/sustainability/future-climate-related-disclosure.
[109] 2degrees-Investing, Environment, and Smith School of Enterprise and the, "Climate Disclosure: How to Make It Fly - from Annual Reporting to Physical Asset - Level Data," 2016, http://2degrees-investing.org/IMG/pdf/make_dislosure_fly_v0.pdf.
[110] For example see, Caldecott et al., "Stranded Assets and Thermal Coal: An Analysis of Environment-Related Risk Exposure."

4. Conclusion

In this discussion paper, we have highlighted how China's transition away from coal is necessary and beneficial, but that the transition will also be complex and be distributed across China and within China's provinces in very different ways. There are strong social and political imperatives to ensure that the transition is managed smoothly.

We argue that we now have the data, analytics, and methodologies to support this process in a sophisticated way. Identifying at a high degree of granularity which specific stakeholders could be affected and when, on the basis on different NDC implementation pathways, is critical. In this discussion paper we have simply aggregated our asset-level results to show provincial and national-level impacts, but the bottom-up approach we employ enables much more granular assessments, looking at specific companies, communities, and sub-provincial units. Analysis at this resolution can be represented in a number of ways, including spatially, and can help policymakers manage the political economy frictions of NDC implementation in a very targeted and sophisticated way.

We also make a number of high-level recommendations to help encourage and enable the use of these forms of analysis and to support the development of appropriate responses to managing the political economy frictions of stranded coal assets in China. These are as follows:

- Policymakers need to be explicit about the fact that there are likely to be political economy frictions from NDC implementation that need to be proactively managed and that there is an important role for government in managing them. This is a necessary condition for acting.

- There needs to be forward looking analysis of specific regions where coal-fired power stations and coal mines are concentrated to see when assets will likely close given plausible scenarios. These analyses should also seek to understand the impacts upstream and downstream of asset closures. Scenarios can be determined by policymakers, but should include scenarios tied to China's NDCs and climate change. These analyses need not be limited to coal assets and could focus on other industries.

- The analysis proposed can also seek to determine local impacts on employment, tax revenues, and financial institutions. This would help policymakers better target interventions to smooth the transition, but can also help financial regulators to see where risks are building up within the local and national financial institutions, and help them develop and run stress-tests to better respond.

- Good asset-level data tied to ownership is a necessary pre-requisite for this kind of very granular analysis and it might be prudent to develop a national platform or national set of data and IT infrastructures to support work in this area. This would be created to help national, provincial, and sub-provincial policymakers and regulators study the challenges and opportunities of the transition to the low carbon economy for the areas for which they have oversight and responsibility. This could be complemented by training and stress-tests to help policymakers and regulators understand the tools they have at their disposal to identify and then respond to political economy frictions. The creation of a national data platform would also help to open up new areas of academic research.

- Policymakers should develop a 'tool kit' of different policy responses to managing political economy frictions. This should be based on in-depth international case study analysis. These analyses should examine how some countries or regions have managed the closure of coal assets, assess in detail the instruments used to enable the transition away from coal, and investigate the extent to which such instruments could be applied to China to alleviate political economy frictions. Again, this research could extend beyond looking at coal assets and to other sectors, but should be focused on policy responses appropriate to a Chinese context.

References

2degrees-Investing, Environment, and Smith School of Enterprise and the. “Climate Disclosure: How to Make It Fly - from Annual Reporting to Physical Asset - Level Data,” 2016. http://2degrees-investing.org/IMG/pdf/make_dislosure_fly_v0.pdf.

Anderlini, Jamil. “The Chinese Chronicle of a Crash Foretold.” *The Financial Times*, n.d.

Arulampalam, W., P. Gregg, and M. Gregory. “Unemployment Scarring.” *The Economic Journal* 111 (n.d.): 577–84.

Benxi shi dangshi difangzhi bagongshi. *Benxi Shi Zhi*. Vol.2 ed. Dalian: Dalian chubanshe, 1998.

Bramall, Chris. *Chinese Economic Development*. Routledge, 2008.

Caldecott, Ben. “The Future of Climate-Related Disclosure.” *The Economist*, 2016. https://www.eiuperspectives.economist.com/sustainability/future-climate-related-disclosure.

Caldecott, Ben, and Lucas Kruitwagen. “S&P Global Market Intelligence - Guest Opinion: How Asset Level Data Can Improve The Assessment Of Environmental Risk In Credit Analysis,” 2016.

Caldecott, Ben, Lucas Kruitwagen, Gerard Dericks, Daniel J Tulloch, Irem Kok, and James Mitchell. “Stranded Assets and Thermal Coal: An Analysis of Environment-Related Risk Exposure.” *Stranded Assets Programme, SSEE, University of Oxford*, 2016.

Chen, F. “Industrial Restructuring and Workers’ Resistance in China.” *Modern China2* 29, no. 2 (2003): 237–62.

———. “Subsistence Crises, Managerial Corruption and Labour Protests in China.” *The China Journal* 44, no. July (2000): 41–63.

Cheng, Hen, and Per Ove Eikeland. “China’s Political Economy of Coal,” 2015. https://www.fni.no/getfile.php/132020/Filer/Publikasjoner/FNI-R1015.pdf.

China Energy Group. “China Energy Databook,” 2008.

“China National Coal Association: Over 80% of 90 Large-Sized Coal Companies in Loss in the First Two Months.” *People’s Daily*, 2015. http://politics.people.com.cn/n/2015/0410/c70731-26828211.html.

China Statistical Yearbook. “13-12 Total Output of Industrial Products 2014,” 2015.

———. “9-1 Total Consumption of Energy and Its Composition 2014,” 2015.

“China’s Coal Cap Policy Will Increase Country’s Clean Energy Jobs.” *Natural Resources and Defense Council*, 2015. http://www.nrdc.org/media/2015/150326.asp.

Chuangeng, Liu. “Guoyou Zhongdian Meikuang Zhigong Xiagang Xianzhuang Ji Qushi Fenxi.” *Meikuang Xiandaihua* 1 (2001): 5–7.

Coal Age. “Understanding the Chinese Coal Industry,” n.d.

Cook, Chris, and John Stevenson. *The Longman Handbook of Modern British History, 1714-1987*. Longman, 1988.

Cornot-Gandolphe, Sylvie. *China's Coal Market: Can Beijing Tame King Coal?*, 2014.

Friedman, Eli, and Ching Kwan Lee. "Remaking the World of Chinese Labour." *British Journal of Industrial Relations* 48, no. 3 (2010): 507–33.

Gregory, M., and R. Jukes. "Unemployment and Subsequent Earnings: Estimating Scaring Among British Men 1984-94." *The Economic Journal* 111, no. 475 (2001): 607–25.

Grove, Linda. *A Chinese Economic Revolution: Rural Entrepreneurship in the Twentieth Century*. Rowman & Littlefield, 2006.

Hayek, Friedrich. "The Use of Knowledge in Society." *American Economic Review* 35, no. 4 (1945): 519–30.

Hilber, Christian A. L. "New Housing Supply and the Dilution of Social Capital." London, UK, 2007.

Holz, Carsten A, and Yi-min Lin. "Pitfalls of China's Industrial Statistics: Inconsistencies and Specification Problems." *China Review* 1.1 (2001): 29–71.

Hornby, Lucy. "China Coal Protests Highlight Overcapacity Tensions." *The Financial Times*, n.d.

———. "China Comes Full Circle with Talk of Mass Lay-Offs." *The Financial Times*, n.d.

Hornby, Lucy, and Archie Zhang. "China's Rust Belt Faces Exodus of Young Talent." *The Financial Times*, n.d.

Jin, Hehui, and Yingyi Qian. "Public versus Private Ownership of Firms: Evidence from Rural China." *Quarterly Journal of Economics*, 1998, 773–808.

Lai, Hongyi. "Uneven Opening of China's Society, Economy, and Politics: Pro-Growth Authoritarian Governance and Protests in China Title." *Journal of Contemporary China* 19, no. 67 (2010): 819–35.

Li, Hongbin, and Li-An Zhou. "Political Turnover and Economic Performance: The Incentive Role of Personnel Control in China." *Journal of Public Economics* 89, no. 9 (2005).

Linfang, Qian, and Wang Shaozhou. "Shilun Dui Meikuang Xiagang Shiye Renyuan de Jiuye Yuanzhu." *MJY* 2 (2002): 57–58.

Liu, Zhu. "China's Carbon Emissions Report 2015," 2015. https://www.belfercenter.org/sites/default/files/files/publication/carbon-emissions-report-2015-final.pdf.

Manley, David, James Cust, and Giorgia Cecchinato. "Stranded Nations? The Climate Policy Implications for Fossil Fuel-Rich Developing Countries," 2016. http://www.oxcarre.ox.ac.uk/images/stories/papers/PolicyPapers/oxcarrepp201634.pdf.

McKee-Ryan, F., Z. Song, C. Wanberg, and A. Kinicki. "Psychological and Physical Well-Being during Unemployment: A Meta-Analytic Study." *Journal of Applied Psychology* 90, no. 1 (2005): 53–76.

National Bureau of Statistics of China. "National Bureau of Statistics of China >> Annual Data," 2016.

Naughton, Barry. “The Chinese Economy: Transition and Growth.” Taylor & Francis, 2007.

Neal, D. “Industry-Specific Human Capital: Evidence from Displaced Workers.” *Journal of Labor Economics* 13, no. 4 (1995): 653–77.

Nolan, Peter. “Economic Reform, Poverty and Migration in China.” *Economic and Political Weekly* 28, no. 26 (1993): 1369–77.

Park, Albert, and Minggao Shen. “Joint Liability Lending and the Rise and Fall of China’s Township and Village Enterprises.” *Journal of Development Economics* 71, no. 2 (2003): 497–531.

Peng, Wuyuan. “Coal Sector Reform and Its Implications for the Power Sector in China.” *Resources Policy* 36, no. 1 (2011): 60–71. http://www.sciencedirect.com/science/article/pii/S0301420710000267.

Perlezand, Jane. “Mass Layoffs in China’s Coal Country Threaten Unrest - The New York Times,” n.d.

Rong, Fang, and David G. Victor. “What Does It Cost to Build a Power Plant?” *ILAR Working Paper*. Vol. 17, 2012.

Shepherd, Christian, and Lucy Hornby. “Chinese Police Break up Coal Jobs Protest.” *The Financial Times*, n.d.

“Small-Sized Coalmines Make Severe Production Safety Issues.” *China Daily*, 2012. http://www.chinadaily.com.cn/hqgj/jryw/2012-10-26/content_7343593.html.

Tang, Jianzhong, and Laurence J C Ma. “Evolution of Urban Collective Enterprises in China.” *The China Quarterly* 104 (1985): 614–40.

The Climate Group - RE 100. “China’s Fast Track to a Renewable Future,” 2015. http://www.theclimategroup.org/_assets/files/Re100-China-briefing-ENGLISH-jv-final.pdf.

The World Bank. “World Bank National Accounts Data,” 2016.

Topel, R. “Specific Capital and Unemployment: Measuring the Costs and Consequences of Job Loss.” In *Carengie-Rochester Conference Series on Public Policy*, 181–214, n.d.

Volcovici, Valerie, and David Brunnstrom. “China Puts $6 Trillion Price Tag on Its Climate Plan.” *Reuters*, 2015. http://www.reuters.com/article/us-usa-china-climatechange-idUSKBN0P32H020150623.

Wang, Bing. “An Imbalanced Development of Coal and Electricity Industries in China.” *Energy Policy* 35, no. 10 (October 2007): 4959–68. doi:http://dx.doi.org/10.1016/j.enpol.2007.04.022.

Wang, Xiaozong. “Over 97% of China’s Mining Accidents Are Human Caused and Death Toll Counts about 70% of the World’s Total.” *People’s Daily*, 2011. http://society.people.com.cn/GB/15020575.html.

Wildau, Gabriel. “China’s : The State-Owned Zombie Economy.” *The Financial Times*, February 2016.

World Coal Association. “Coal Facts 2015,” 2015.

Wright, Tim. *The Political Economy of the Chinese Coal Industry: Black Gold and Blood-Stained Coal*. Vol. 45. Routledge, 2012.

Xiehui, Zhongguo meitan gongye. *Zhongguo Hangye Fenxi Baogao*. Beijing: Zhongguo jingji chubanshe, 2005.

Yanying, Zhao, and Zhang Shenli. "Dui Jilin Sheng Meitan Qiye Xiagang Zhigong Zaijiuyenandian Wenti de Diaocha Fenxi Yu Duice Jianyi." *Laodong Shijie* 7 (2000): 6–8.

Zhongguo meitan zhi bianzuan weiyuanhui. *Zhongguo Meitan Zhi: Guizhou Juan*. Beijing: Meitan gongye chubanshe, 1994.

Zhongguo tongji nianjian 2008-2015. *SAWS, Zhongguo Meitan Gongye Fazhan Gaiyao*. Beijing: Meitan gongye chubanshe, 2010.

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

***中国城市**统计年鉴 China City Statistical Yearbook*, 2014.

"发展特色旅游:**阜新**转型又一新思路." *Characteristic Tourism - A New Thought Of Economic Transformation in Fuxin* 8, no. 1 (2006): 9–12. doi:10.3969/j.issn.1673-2464.2006.01.003.

"**技**术创新视角下的资源型城市经济转型——**基于**枣庄市经济转型的案例分析 Economic Transformation under High-Tech Innovation: Case Study of Zaozhuang, Shandong." **山**东大学, 2007.

SUSTAINABLE
FINANCE

PROGRAMME

Smith School of Enterprise and the Environment
University of Oxford
South Parks Road
Oxford, OX1 3QY
United Kingdom

E enquiries@smithschool.ox.ac.uk
T +44 (0)1865 614942
F +44 (0)1865 614960
www.smithschool.ox.ac.uk/research/stranded-assets/

SMITH SCHOOL OF ENTERPRISE AND THE ENVIRONMENT

UNIVERSITY OF OXFORD