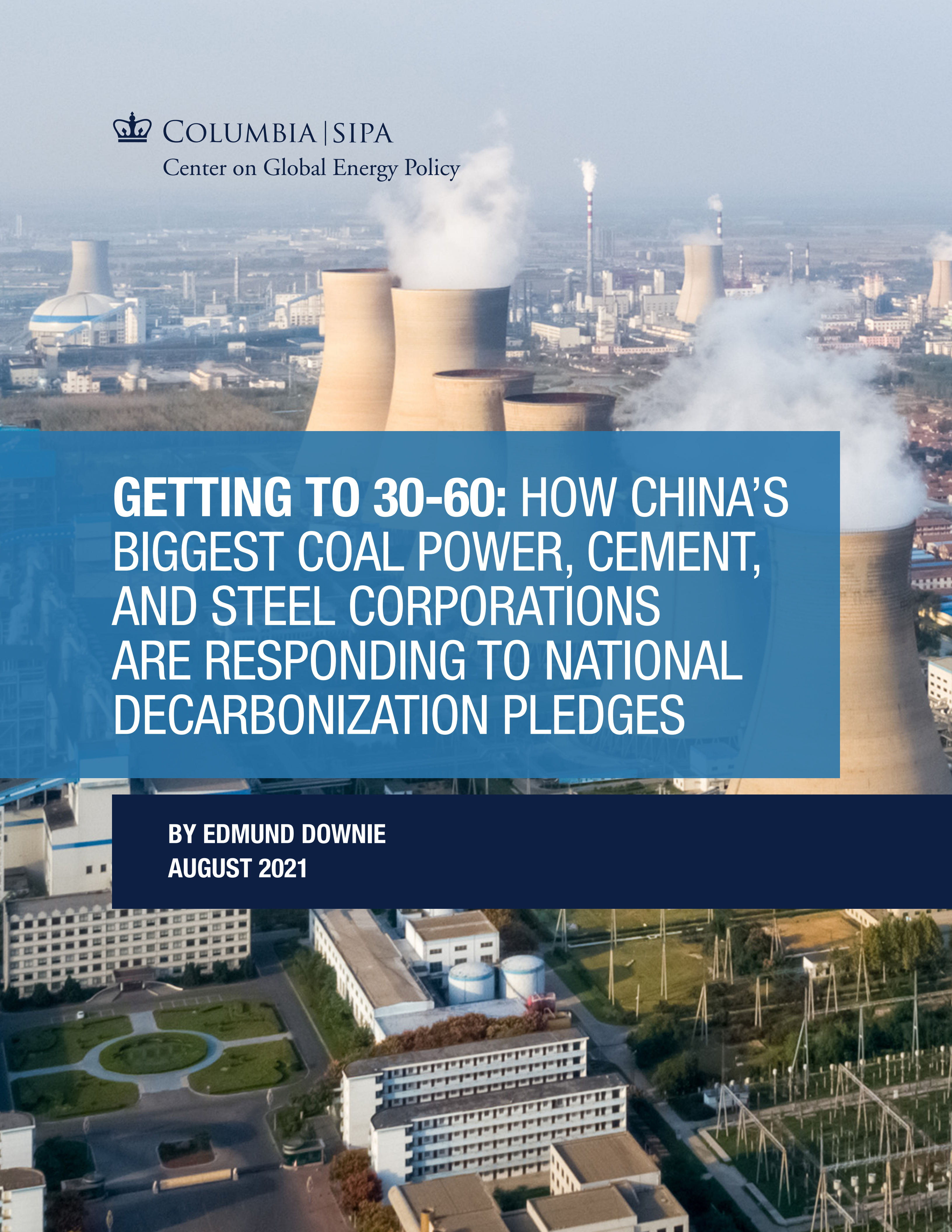

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GETTING TO 30-60: HOW CHINA'S BIGGEST COAL POWER, CEMENT, AND STEEL CORPORATIONS ARE RESPONDING TO NATIONAL DECARBONIZATION PLEDGES

BY EDMUND DOWNIE

AUGUST 2021

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

In September 2020, China announced its intentions to peak carbon emissions by 2030 and achieve carbon neutrality by 2060. The neutrality goal in particular was a breakthrough for global climate ambitions: a net-zero target from the world's largest emitter, responsible for around one-quarter of global greenhouse gas (GHG) emissions.

The two new goals—referred to in Chinese policy discourse as the "30-60" goals—are not China's first public targets on GHG reduction. They are, however, the centerpieces of a new Chinese climate policy in which GHG cuts are a standalone goal rather than an ancillary benefit of more immediate priorities like energy efficiency and industrial upgrading. Prior approaches had required little engagement from firms in carbon management. Indeed, none of the largest Chinese firms in the coal power, cement, and steel sectors had publicized quantitative targets for reducing or controlling carbon emissions before the government announced the 30-60 goals. They faced little pressure to do so; authorities pressed firms in climate-adjacent areas like reducing air pollution rather than carbon management. The 30-60 announcement appears to mark a break from this era, forcing firms to adjust accordingly.

This report, part of the China Energy and Climate Program at Columbia University's Center on Global Energy Policy, assesses how China's high-emitting industries have responded to the 30-60 targets and the accompanying elevation of climate within national policy priorities. It focuses on corporate and sectoral emissions reduction targets through June 2021 among 30 major firms in three of China's largest sources of direct emissions: coal power generation, cement, and steel. Based on this study, the author finds the following:

- Nine months after the 30-60 announcement, target-setting efforts by major firms and industry associations have been modest: a handful of near-term peaking pledges and just four net-zero pledges among the 30 firms reviewed. Many firms may be still addressing gaps in carbon management expertise and waiting for further policies and pronouncements that can clarify government expectations or establish official frameworks for target-setting.

- Targets from sector-leading firms in electricity generation suggest a push to complete their ongoing shift from coal to renewables as their main source of capacity additions. At least four of China's six biggest coal power generators are aiming to peak emissions by 2025, and targets on expansions of non-coal capacity could collectively require sector leaders to add hundreds of gigawatts of renewable capacity to their portfolios. These additions will require an embrace of solar, a technology that China's biggest power producers have historically eschewed. They will also require institutional reforms to enable the transition from a coal-heavy power system with rigid dispatch protocols to a low-carbon grid with flexible market designs.

- Cement firms have proposed a 2023 peaking target, while authorities are reportedly targeting a 2025 peaking date for steel. These targets are deceptively cautious. China's infrastructure-heavy COVID stimulus has delayed long-expected output declines in each sector; the peaking dates proposed give each sector time to absorb excess demand.

- Chinese steel sector firms have offered more medium-term and long-term targets than their coal generation or cement counterparts, including 2050 neutrality targets from steel-sector giants Baowu and Hebei Iron and Steel. Policy pressures related to reducing air pollution and lessening dependence on imports for raw materials, as well as an anticipated decline in steel demand, may be incentivizing steel firms to issue such targets.
- Decarbonization targets issued or proposed thus far by the three high-emitting sectors and their leading firms evaluated in this report may align with China's 2030 peaking target—the most immediate focus of emissions action planning and a fairly straightforward goal to meet. But achieving neutrality by 2060 will require far greater ambition—and policy signals that reward such ambition.

Observers should watch for the release of key policy documents over the coming months, particularly national sectoral five-year plans and emissions peaking action plans, to see whether Chinese officials are sending the signals needed for firms to start ratcheting up their long-term ambitions.

INTRODUCTION

On September 22, 2020, at the general debate of the 75th session of the United Nations General Assembly, Chinese president Xi Jinping announced that China would "aim to have CO_2 emissions peak before 2030 and achieve carbon neutrality before 2060."[1] The peaking goal was a modest update on China's prior target of peaking "around 2030."[2] But the neutrality goal was a breakthrough for Chinese and global climate ambitions: a net-zero target from a country responsible for around one-quarter of global greenhouse gas (GHG) emissions, more than any other country.[3]

The new peaking and neutrality targets—often identified in Chinese policy discussions as the "30-60" targets—have become centerpieces of Chinese climate policy. They serve as key reference points for both government and corporate actors in defining the scope and ambition of their climate actions. They also marked a break from China's prior approach to climate policy, which had demanded little direct engagement from firms in carbon management. In the past, carbon intensity declines came as an ancillary benefit of more immediate priorities like energy efficiency and industrial upgrading that determined the actual landscape of mandates and incentives guiding firm strategic decisions. The 30-60 targets have turned carbon emissions cuts into a stand-alone priority and forced firms' policy expectations to shift accordingly.

This report examines corporate and sectoral emissions reduction targets through the first half of 2021 from three of China's largest sources of direct emissions: coal electricity generation, cement, and steel. Such targets can work as greenwashing if unaccompanied by deeper corporate commitments to carbon management. But they can also be powerful tools for firms to develop and implement these kinds of deeper commitments, by scoping emissions reductions strategies and setting clear benchmarks to coordinate firm-wide efforts. They are like yeast in making bread: invaluable in the right environment.

The report finds that none of the largest Chinese firms in the coal generation, cement, and steel sectors had publicized quantitative targets for reducing or controlling carbon emissions before the 30-60 pledges were announced. Corporate inaction reflected Chinese authorities' policy priorities, which emphasized meeting national carbon goals through progress in climate-adjacent areas like energy efficiency rather than carbon management itself. The limited array of corporate targets released since September suggests that many sector majors are still filling gaps in carbon management expertise and waiting for further policies and pronouncements that can clarify government expectations or establish official frameworks for target setting, as has been done for energy efficiency from the late 2000s.

Nonetheless, the targets released thus far do give useful insights into how firms are adapting to the 30-60 reality. In coal generation, China's biggest firms have been slowly shifting their growth strategy over the past decade from adding coal plants to adding renewables. Pledges from sector leaders to peak emissions by 2025 and ramp up renewable capacity installations suggest a push to complete that shift over the coming five years. Their success in this work will require an embrace of solar, which they have historically eschewed in favor of large-scale wind projects that fit with their traditional expertise in enormous thermal and hydropower plants. It will also require further progress in tackling institutional challenges—affecting wind as well as solar—impeding China's transition from a coal-heavy power system with rigid dispatch protocols to a low-carbon grid with flexible market designs to guarantee energy security.

In cement and steel, meanwhile, targets to peak sectoral emissions in 2023 and 2025 reflect long-expected output declines that are likely to come once spending wraps up from China's infrastructure-heavy COVID stimulus. (The steel sector's target has been reported but not officially confirmed.) But the steel sector has also led the way in introducing neutrality commitments to the Chinese corporate world with 2050 net-zero targets from its two biggest companies, Baowu and Hebei Iron and Steel. More widespread long-term target setting within the steel sector reflects a pair of drivers. In comparison with electricity, steel demand is declining, and disruptions in steel supplies do not have the immediate economic impacts of power outages; these circumstances may give steel firms more flexibility in their long-term goal setting than their electricity peers. More generally, steel firms benefit from an array of nonclimate policy priorities in the sector that overlap neatly with key actions for decarbonization like boosting scrap steel use and expanding electric arc furnace deployment.

The report relies for its analyses upon a combination of quantitative data analysis and document review, as well as 22 expert interviews.[4] It is structured as follows:

- Section 1 describes China's emissions profile and identifies major high-emitting sectors as well as leading firms in those sectors.
- Section 2 discusses the state of carbon management in Chinese high-emitting sectors before the 30-60 pledges, introducing the policy approaches by which China pursued its earlier climate targets and their significance for Chinese firms.
- Section 3 reviews emissions peaking, reduction, and neutrality targets as of July 1, 2021, from Chinese firms since the announcement of the 30-60 pledges. It further analyzes signals from these targets for how high-emitting industries and their largest firms intend to integrate the peaking and neutrality priorities within their own business plans.

BACKGROUND: CHINA'S EMISSIONS PROFILE

The global drive to net-zero demands decarbonization efforts across a host of sectors, from electricity generation and transportation to industrial processes and agriculture. But varying economic structures across countries create varying GHG emissions profiles that affect the contribution of each sector to national emissions reduction efforts. This report covers three crucial sectors: coal electricity generation, cement, and steel. In each, state-owned enterprises play leading roles.

China's Emissions by Sector

China has not published official data on its total GHG or carbon emissions since 2014. However, a comparison of Chinese and global GHG emissions per data in the World Resources Institute's Climate Analysis Indicators Tool (CAIT) illustrates unique features of China's emissions profile that reflect its coal-heavy power system and its dominance in energy-intensive manufacturing. CAIT data, presented in Table 1, reports around half of global emissions from energy use in electricity and heat generation and manufacturing and construction, as well as industrial processes. In China, however, these sources comprise almost three-quarters of its emissions. China alone is responsible for 36.7 percent of global emissions from these sources, compared to just 12.9 percent of agricultural and transportation emissions. (These shares, it should be noted, exclude emissions from bunker fuels as well as land use, land-use change, and forestry.)

Table 1: GHG emissions in 2018: China vs. world (million tons of CO_2e)

Source	World		China	
	Total	Share	Total	Share
Energy: electricity and heat	15,591	32.8%	5,214	42.2%
Energy: manufacturing and construction	6,158	13.0%	2,667	21.6%
Industrial processes	2,903	6.1%	1,166	9.4%
Transportation	8,258	17.4%	917	7.4%
Agriculture	5,818	12.2%	673	5.4%
Energy: fugitive emissions	2,883	6.1%	694	5.6%
Energy: buildings	2,883	6.1%	542	4.4%
Energy: other fuel combustion	1,452	3.1%	284	2.3%
Waste	1,607	3.4%	198	1.6%
Total GHG emissions (excluding land use, land-use changes, and forestry and bunker fuels)	*47,552*	*100.0%*	*12,355*	*100.0%*
Electricity and heat + manufacturing and construction + industrial processes	*24,652*	*51.8%*	*9,048*	*73.2%*
China share of world emissions				
Energy and industrial processes	*36.7%*			
Transportation	*11.1%*			
Agriculture	*11.6%*			

Note: China has not reported official estimates of national GHG or carbon dioxide emissions totals or sectoral breakdowns since 2014.

Source: See Appendix, Section A, part i.

In electricity and heat generation, emissions come primarily from coal power combustion, both the largest and most polluting source of thermal electricity and heat in China. In electricity generation, coal plants comprise around 50 percent of all generation capacity and 85 percent of thermal generation capacity.[5] A Greenpeace analysis of 2016 government data found that coal covered 83 percent of heating energy in China, though this figure is likely to be lower today given China's recent coal-to-gas heating conversion campaigns in northern China.[6] Electricity generators are themselves major players in the heating sector; combined heat-and-power plants, for instance, provide half of all space heating in northern urban China.[7]

Among sources of GHG emissions from energy use in manufacturing and construction and from industrial processes, the most significant—in China and around the world—are steelmaking and cement. Globally, these sectors are estimated to each account for around 25 percent of direct industrial carbon dioxide (CO_2) emissions.[8] In China, industry participants suggest that each sector is responsible for around 15 percent or more of national CO_2 emissions.[9] These figures broadly align with those of the China Emissions Accounts and Datasets project, the most detailed scholarly breakdown of sectoral CO_2 footprints in China. It estimates that around 30 percent of national CO_2 emissions from fuel combustion and cement manufacturing are attributable to the "smelting and pressing of ferrous metals" (primarily steelmaking) and "nonmetal mineral products" (primarily cement).[10]

How Making Steel and Cement Produces Emissions

Steel is an alloy of iron and carbon, produced by removing impurities from iron ore and combining it with other carbon and small amounts of other elements.[11] Production takes place broadly through one of two routes. The first route is known as the blast furnace/basic oxygen furnace route (BF-BoF). The blast furnace (BF) reduces iron ore into a purer form of metallic iron. Iron ore usually contains iron bonded with oxygen in iron oxide compounds, and the blast furnace strips the oxygen atoms in a process is known as "reduction." The basic oxygen furnace (BoF) takes the molten iron ("hot metal") produced by the BF and refines it into steel. Iron inputs for BoFs can be supplemented by modest shares of recycled steel (scrap steel).

The second route is the electric arc furnace (EAF) route. EAFs occupy a similar position in the production process to BoFs as facilities for refining iron into steel, but they can take up to 100 percent shares of scrap steel as their source of iron. Most EAF production globally relies primarily upon scrap steel, with some supplementation from various types of virgin iron—"pig iron" produced by allowing BF hot metal to cool, for instance, or direct reduced iron (DRI) produced outside of a BF.

The BF-BoF and EAF routes can have significantly different emissions profiles. Hasanbeigi and Springer (2019), for instance, estimate national averages across 16 coverages from 1.5 to 2.5 or more tons of carbon dioxide (tCO_2) per ton for the BF-BoF route versus 0.3–1.6 tCO_2/ton for EAF production.[12] The largest emissions driver in the BF-BoF route is the reduction process in the blast furnace, which involves the combustion of fossil fuels: usually a coal product called coke, though some producers use less carbon-intensive natural gas.[13] The EAF route allows producers to use much higher scrap shares. As a result, EAF production relying fully upon scrap can achieve emissions factors of less than 0.5tCO_2/ton.[14] But higher shares of DRI or pig iron in EAF production can raise emissions factors dramatically.[15]

Cement is the primary binding material in concrete, made by combining calcium-rich materials like limestone with a host of other materials, such as clay or fly ash. Direct CO_2 emissions come almost entirely from the production of an intermediate output known as clinker, which results from heating the raw mixture of limestone and other materials, such as clays or shale, in a rotating kiln.[16] Sixty to 70 percent of these direct emissions come from chemical reactions in clinker formation that release CO_2, and 30–40 percent from fuel combustion for heating.[17] There are modest additional indirect emissions from the consumption of electricity for raw materials preparation and other stages of the cement-making process.[18]

Carbon emissions from steel and cement, in comparison to electricity generation, are generally considered hard to displace. In steel, scrap-EAF production can substantially reduce emissions profiles but is limited by several factors, most importantly scrap supply constraints.[19] Substitutes for fossil fuels, like low-carbon hydrogen for BF-BoF production, still require significant advances to become cost competitive and still need to be supplemented with carbon capture equipment to approach net-zero emissions.[20] In cement, CO_2 is a chemical by-product of clinker production, and steep reductions in emissions footprints will require carbon capture as well as major R&D breakthroughs around low-clinker cement.[21]

The Chinese steel industry is, by global standards, particularly carbon intensive. Worldwide, steel production takes place largely through one of two processes: the blast furnace-basic oxygen furnace (BF-BoF) route or the electric arc furnace (EAF). The former, which has much higher average emissions, is far and away the dominant mode of steel production in China; it comprises around 90 percent of the country's crude steel output, with EAFs accounting for the remaining 10 percent. By contrast, more than 45 percent of world steel production in 2019 (around 400 million tons, or mt) outside of China came from EAFs. China's tilt toward BF-BoF production reflects limited scrap supply and high electricity prices, as well as the prevalence of newer, more efficient BF-BoF facilities. Even Chinese EAFs themselves are relatively high emitting. Hasanbeigi and Springer (2019) estimate national average EAF carbon intensity of 0.3–1.6 tCO_2/ton across 16 countries; they put China's EAFs on the high end of that range, at 1.4 tCO_2/ton.[22] Drivers of these higher emissions include the use of elevated shares of pig iron in place of scrap steel in Chinese EAF feedstocks as well as high emissions factors for grid power in China.

In coal-fired generation, steelmaking, and cement, China produces an enormous share of global output. In 2020, the China Electricity Council (CEC) reported 1.08 terawatts of installed coal capacity nationwide, comprising 49.1 percent of national installed capacity and supplying 60.8 percent of national electric power.[23] China's 2018 coal generation of 4,772 terawatt-hours (TWh) equaled more than 45 percent of global coal generation.[24] As for cement and steel, Chinese industrial associations report 2.38 billion tons (bt) of cement production and 1.05 bt of crude steel production in 2020, indicating year-on-year production growth for each commodity despite the pandemic.[25] China's share of global production in each commodity in 2018 exceeded 50 percent.[26]

Major Firms in Coal Generation, Steelmaking, and Cement

The prominence of coal generation, steelmaking, and cement within Chinese CO_2 emissions makes it particularly important to track decarbonization efforts from their leading firms. Chinese majors in these sectors are global majors. They include the world's 5 largest owners of coal capacity by megawatts; 6 of the world's 10 largest steel firms by production tonnage; and 6 of the world's 10 largest cement firms by integrated production capacity.[27]

This report focuses on top-10 companies in each sector, defined as follows:

- **Coal generation:** the 10 Chinese companies with the greatest installed coal capacity in January 2021 per the Global Coal Plant Tracker (GCPT), a unit-level open-source database developed by Global Energy Monitor. This database does not include plants under 30 MW. It recorded around 1,040 gigawatts (GW) of total coal capacity in China as of January 2021, just shy of official totals of 1,080 GW.
- **Steelmaking:** the 10 Chinese companies with the greatest crude steel output in 2019, as reported by global industry association worldsteel.
- **Cement:** the 10 companies with the greatest installed clinker[28] capacity in China in 2020, as reported by the China Cement Association.

The companies are listed in Table 2. The author was able to identify official coal capacity counts for several top-10 coal generation firms from company documents and includes this information as well, as the differences are nontrivial.[29]

Of the 30 firms reviewed, 27 are Chinese firms: all 20 coal generation firms and steelmakers as well as seven cement firms. The remaining three cement firms include Huaxin, a joint venture between a foreign firm and a local state-owned enterprise (SOE); Taiwan Cement, a Taiwanese company listed in Taiwan; and Asia Cement (China), a Hong Kong–listed subsidiary of the Taiwanese company Asia Cement Corporation. Note also that Shandong Weiqiao, the 10th-largest owner of coal generation in China per GCPT, is one of China's biggest aluminum smelters; its coal capacity consists primarily (if not entirely) of captive generators that power its industrial facilities.

Table 2: Top 10 Chinese companies in thermal generation, steelmaking, and cement

Electricity

Company	Controlling owner type (SOE/private/foreign)	January 2021 installed coal capacity (GWs)	National share
China Energy Investment Corp. 国家能源投资集团有限责任公司	Central SOE	140.7 (GCPT) 188.4 (official)	13.5% (GCPT) 17.4% (official)
China Huaneng Group 中国华能集团有限公司	Central SOE	109.3 (GCPT)	10.5% (GCPT)
China Datang Group 中国大唐集团有限公司	Central SOE	86.1 (GCPT)	8.3% (GCPT)
China Huadian Group 中国华电集团有限公司	Central SOE	82.5 (GCPT)	7.9% (GCPT)
State Power Investment Corp. 国家电力投资集团	Central SOE	65.0 (GCPT) 77.4 (official)	6.2% (GCPT) 7.2% (official)
China Resources Power 华润电力控股有限公司	Central SOE	36.1 (GCPT) 31.9 (official)	3.5% (GCPT) 3.0% (official)
Zhejiang Energy Group 浙江省能源集团	Provincial SOE (Zhejiang)	25.3 (GCPT)	2.4% (GCPT)
Guangdong Energy Group 广东省能源集团有限公司	Provincial SOE (Guangdong)	20.5 (GCPT)	2.0% (GCPT)
Beijing Energy Group 北京能源集团有限责任公司	Provincial SOE (Beijing)	17.7 (GCPT)	1.7% (GCPT)
Shandong Weiqiao 山东魏桥	Private	17.5 (GCPT)	1.7% (GCPT)

Steelmaking

Company	Controlling owner type (SOE/private/foreign)	2019 crude steel output (mt)	National share
China Baowu Iron and Steel Group 中国宝武钢铁集团有限公司	Central SOE	95.5	9.6%
Hebei Iron and Steel Group 河钢集团有限公司	Provincial SOE (Hebei)	46.6	4.7%
Jiangsu Shagang Group 江苏沙钢集团有限公司	Private	41.1	4.1%
Ansteel Group 鞍钢集团有限公司	Central SOE	39.2	3.9%
Beijing Jianlong Heavy Industry Group 北京建龙重工集团有限公司	Private	31.2	3.1%
Shougang Group 首钢集团有限公司	Provincial SOE (Beijing)	29.3	2.9%

continued on next page

Company	Controlling owner type (SOE/private/foreign)	2019 crude steel output (mt)	National share
Shandong Iron and Steel Group 山东钢铁集团有限公司	Provincial SOE (Shandong)	27.6	2.8%
Hunan Valin Iron and Steel Group 湖南华菱钢铁集团有限责任公司	Provincial SOE (Hunan)	24.3	2.4%
Bengang Group 本钢集团有限公司	Provincial SOE (Liaoning)	16.2	1.6%
Liaoning Fangda Group 辽宁方大集团实业有限公司	Private	15.7	1.6%

Cement

Company	Controlling owner type (SOE/private/foreign)	2020 installed clinker capacity (mtpa)	National share
China National Building Materials Group 中国建材集团有限公司	Central SOE	391.2	21.4%
Anhui Conch Cement 安徽海螺水泥股份有限公司	Provincial SOE (Anhui)	215.5	11.8%
Tangshan Jidong Cement 唐山冀东水泥股份有限公司	Provincial SOE (Beijing)	105.3	5.8%
China Resources Cement 华润水泥控股有限公司	Central SOE	66.9	3.7%
Huaxin Cement 华新水泥股份有限公司	Foreign with local SOE as minority shareholder (Huangshi City, Hubei)	63.0	3.4%
Hongshi Holdings Group 红狮控股集团有限公司	Private	57.2	3.1%
Shandong Shanshui Cement Group 山东山水水泥集团有限公司	Private	54.6	3.0%
Taiwan Cement 台湾水泥股份有限公司	Foreign	40.8	2.2%
Tianrui Cement Group 天瑞水泥集团有限公司	Private	35.2	1.9%
Asia Cement 亚洲水泥（中国）控股公司	Foreign	22.4	1.2%

Note: Information from Global Energy Monitor (GEM) and its GCPT database is insufficient to identify a single corporation corresponding to Shandong Weiqiao. Based upon review of GEM staff statements as well as corporate records databases, the author infers this listing refers to a set of companies owned by the Zhang family including China Hongqiao, one of China's largest aluminum producers. The GEM database is based upon open-source document review and only includes plants of at least 30MW in size. Installed capacity shares of coal units reflect GCPT national recorded coal capacity for GCPT data (1043.0GW) and official national coal capacity for firm-reported data (1080.0GW).

Source: See Appendix, Section B, part ii and Section C, parts ii and iii.

As suggested by Table 2, state-owned enterprises have a significant presence in each of these industries. All of the top four cement enterprises (40 percent of national clinker capacity) and 7 of the top 10 steel enterprises are SOEs owned either by central or provincial governments. In these sectors, at least, there is significant private participation across the sector as a whole. The China Chamber of Commerce for Metallurgical Enterprises, comprised primarily of private iron and steel firms, reported that private firms accounted for more than 60 percent of crude steel output in 2020.[30] But coal electricity generation is almost entirely in the hands of state-owned enterprises. A 2015 analysis from the Climate Policy Initiative, using data from 2013, found 94 percent of installed coal power capacity to be owned by SOEs.[31]

Five centrally owned SOEs—the "Big 5" (五大发电集团)—are particularly powerful in thermal generation:

- China Energy Investment Corporation (CEIC), which is also China's largest coal producer[32]
- China Huaneng Group
- China Huadian Group
- China Datang Group
- State Power Investment Corporation (SPIC)

Official reported capacity by source from these companies, shown in Table 3 below, indicates that they had thermal holdings equivalent to half of national thermal capacity as of 2019.[33] (Thermal includes coal, gas, oil, and biomass and is not generally broken out in firms' reporting.[34]) These assets comprise the bulk of their holdings at 69 percent of collective installed capacity; the balance comes mostly from hydropower and wind (13–14 percent each). The one firm with a thermal share below two-thirds was SPIC, which is both the only member of the Big 5 with substantial solar holdings (13 percent) and the only active nuclear developer.

Table 3: "Big 5" electricity companies: installed generation capacity mix in 2019

Company	Thermal		Hydro		Wind		Solar		Nuclear		Total
	GWs	Share	GWs	Share	GWs	Share	GWs	Share	GWs	Share	
China Energy Investment Corporation 国家能源投资集团有限责任公司	184.7	75.1%	18.6	7.6%	41.2	16.7%	1.3	0.5%	0.0	0.0%	245.8
China Huaneng Group 中国华能集团有限公司	131.9	72.1%	27.0	14.8%	20.0	10.9%	4.0	2.2%	0.0	0.0%	182.8
China Huadian Group 中国华电集团有限公司	108.3	70.8%	27.3	17.8%	14.2	9.3%	3.2	2.1%	0.0	0.0%	153.1
China Datang Group 中国大唐集团有限公司	97.3	67.5%	27.0	18.7%	18.4	12.8%	1.5	1.0%	0.0	0.0%	144.2
State Power Investment Corporation 国家电力投资集团	81.6	54.0%	24.0	15.9%	19.3	12.8%	19.3	12.8%	7.0	4.6%	151.1
All China	1189.6	59.2%	358.4	17.8%	209.2	10.4%	204.2	10.2%	48.7	2.4%	2010.1
Big 5 only	603.7	68.8%	123.9	14.1%	113.1	12.9%	29.3	3.3%	7.0	0.8%	876.9
Big 5 share of all China	**50.8%**		**34.6%**		**54.1%**		**14.3%**		**14.3%**		**43.6%**

Source: See Appendix, Section B, parts i and ii.

SOEs' ownership status means that policy signals around state priorities—central priorities for SOEs owned by the central government, provincial priorities for provincial SOEs—are particularly important for defining their agenda. These firms are charged with advancing a mixture of corporate, state, and party interests; Leutert (2020), writing on central SOEs, describes their leadership as "simultaneously company executives, government bureaucrats, and Party officials."[35] In some cases, the leaders themselves are taken directly from government positions. Chen Derong of Baowu Steel, China's biggest steel producer, served his whole career as an official in Zhejiang Province, becoming one of its top leaders as a member of the Provincial Politburo Standing Committee. He only entered the steel industry in 2014 as a director and general manager at Baowu in 2014, before becoming chairman in 2018.[36] Wang Xiangxi of CEIC, China's biggest energy generator and coal producer, began his career in Hubei-based state-owned coal enterprises but spent the past two decades rising to senior positions in the Hubei provincial government before being appointed CEIC chairman in 2019.[37]

SOEs' mixed priorities can hurt their financial performance; the state-owned economy saw a 3.9 percent return on assets as of the end of 2017, as opposed to 9.9 percent among private firms.[38] But the party-state seeks a broader return from SOEs as providers of stable employment as well as tools for pursuing its strategic priorities—as in, for instance, carbon policy.[39] Chen Derong's political background might be expected to make him particularly savvy on this front, and, indeed, a Baowu meeting readout reports him giving a vivid distillation of these obligations for central SOEs at a company meeting in April 2021:

> Chen Derong noted: General Secretary Xi Jinping has made a promise to the world of carbon peaking and carbon neutrality in China. This is a major strategic decision made per the responsibility of building a community of common destiny for mankind and the intrinsic requirements of realizing sustainable development. … *For China Baowu, carbon peaking and carbon neutrality are not just technical matters; they are economic matters, and, even more so, they are political matters. The steel industry is traditionally a high source of carbon emissions. As a leading firm, China Baowu must apply pressure upon itself and willingly take action. Taking the lead in raising carbon peaking and carbon neutrality goals is the responsibility that industry leaders should shoulder.* It is not just for the development needs of the firm and the industry; it is also the development needs of the nation, and bears upon the shared interests of humanity.[40] (emphasis added)

The domestic political and regulatory environment—in addition, of course, to core economic and competitiveness concerns—determines much of the context in which state-owned and private Chinese coal generators, steelmakers, and cement firms consider decarbonizing their domestic operations. Tight political controls make civil society a nonissue beyond highly localized demands around environmental quality, as in antinuclear protests that grounded a proposed project in 2016.[41] Channels for international pressure are limited. Coal generators and cement producers almost exclusively serve Chinese customers; Chinese cement exports have hovered around 0.5 percent of domestic production throughout the past decade, and electricity exports take place only through a handful of modest connections to China's neighbors.[42] Steel sector exports are larger but still comprised only 5–10 percent of steel production over the past decade.[43] In equity markets, international exposure is largest in the cement sector, with one foreign-domestic joint venture, a Taiwan-listed firm, and five firms listed in Hong Kong. Most of China's largest coal generators are SOEs whose Hong Kong-listed subsidiaries only hold minority shares of their assets, and just 2 of the largest 10 steel producers have any Hong Kong–listed subsidiaries. Firms' other public listings are on mainland markets, where international investors are a growing but still minor presence; UBS in September 2019 estimated that foreign holdings comprised 7.3 percent of free-floating market capitalization in these markets.[44] Data on other financing channels is harder to access, but researchers from the German nongovernmental organization Urgewald report a 10 percent foreign share in Chinese coal sector financing. (Their database relies upon public disclosures and is thus incomplete.[45])

CARBON MANAGEMENT PRE-30-60: NATIONAL POLICY AND COMPANY ACTIONS

Through 2020, Chinese firms in high-emitting industries had fairly limited experience in carbon management. This lack of experience reflected China's approach to climate policy over the past two decades, under which China has met its climate targets as a by-product of more immediate policy priorities like economic upgrading, energy security, and air pollution control.

China has had public, long-term carbon emissions reduction targets for more than a decade.[46] Its first such target was announced at the 2009 Copenhagen Summit, a goal of cutting carbon intensity (that is, carbon emissions per unit of GDP) 40–45 percent by 2020 against 2005. Similar carbon intensity reduction targets were incorporated into the country's subsequent Five-Year Plans (FYPs), which set the country's overarching economic development priorities for the forthcoming five-year period. Authorities sought a 17 percent decline for the 12th FYP (2011–15) and an 18 percent decline for the 13th FYP (2016–20).[47] In 2015, China also announced a goal of peaking emissions "around 2030" as part of its Nationally Determined Contributions to the Paris Agreement.[48]

Chinese authorities have reported success in meeting their emissions intensity reduction targets over the past 15 years. They claim a 48.1 percent carbon emissions intensity reduction from 2005 to 2019,[49] including a 20 percent reduction during the 12th FYP[50] and an 18.2 percent reduction between 2015 and 2019.[51] But the policy tools that have helped China achieve these targets have not made formal demands of firms to monitor carbon emissions and reduce their carbon footprints. The gains have rather accompanied policy initiatives to improve energy efficiency, address air pollution, and foster a domestic renewables industry.[52] These initiatives addressed a mix of policy aims that include reducing energy security vulnerabilities in a high fossil-fuel economy, responding to public dissatisfaction over air pollution, and positioning China to lead global supply chains in a green-growth era.[53] Key metrics for these efforts—energy intensity, for instance, or emissions rates for air pollutants like nitrogen oxides (NO_X) and particulate matter—make no explicit demands around CO_2 reduction. But they drive avoided emissions by forcing fuel efficiency upgrades or encouraging reduced economic reliance on high-emitting industries.

The secondary standing of emissions reduction in Chinese environmental and economic policy is evident from a review of China's previous FYP "outlines" (纲要), the headline documents that present overall aims for each five-year period. Quantitative targets on energy intensity reduction and local air pollution control both appeared in FYPs well before carbon intensity. The 9th FYP (1996–2000), for instance, targeted reducing energy intensity by 22 percent between 1995 and 2000; the 10th FYP (2001–5) sought to reduce major air pollutants by 10 percent from 2000; and targets for both appeared in the 11th FYP (2006–10).[54] Greenhouse gas (GHG) emissions, by contrast, do not feature until the 11th FYP outline, which calls for "achieving success in controlling greenhouse gas emissions" but includes no quantitative targets or further elaboration. The mention of GHGs takes place within the chapter on "building a resource-saving and environmentally friendly society," underscoring the leading role of energy conservation in environmental policy at the time.[55]

The 12th FYP introduced carbon emissions intensity reduction targets as well as a new section in the outline on "actively confronting climate change." But it continued to rely upon energy consumption control for meeting these targets. For one, climate discussion took place again in the section on "building a resource-saving and environmentally-friendly society."[56] More significantly, in the 12th FYP outline's discussion of "controlling greenhouse gas emissions," energy consumption control measures were the only direct tools mentioned for reducing short-term emissions.[57] Williams (2014), in her report on Chinese climate policy drivers, notes that "many of those interviewed for this paper said the 12th Five Year Plan carbon intensity target was directly derived from the energy intensity target."[58]

One of the 12FYP's other carbon action items was the "the construction and consolidation of a GHG emissions statistical calculation and verification system"—a goal that underscores just how new the issue of carbon management was within China as of 2011. China first introduced standards on GHG emissions reporting methodologies in 2013 and issued its first requirements on corporate reporting of GHG emissions to authorities in 2014.[59] By comparison, the EU introduced mandatory emissions reporting across a variety of high-emitting sectors in the mid-2000s as part of its emissions trading system (ETS) launch.[60] The United States only mandated national GHG reporting from 2010–11 onward, but participants in state-based cap-and-trade systems have faced reporting requirements since the mid-2000s.[61]

The 13th FYP (2016–20) indicated the beginnings of a greater focus in Chinese policy around carbon emissions management as a stand-alone action area. The section on "effectively controlling greenhouse gas emissions," which had formerly focused upon energy consumption, instead emphasized key sectors for emissions reduction work ("energy, steel, building materials, and petrochemicals") and called for China to "advance low-carbon development in key spheres including industry, energy, construction, and transit."[62] (The 12th FYP had only included a call to "control GHG emissions in spheres including industry, construction, transit, and agriculture.")[63] The section also said that China would "support well-developed regions in achieving carbon emissions peaks early."

Nonetheless, policy priorities during this period continued to center around air pollution control and energy efficiency.[64] Efforts around the former had stepped up from 2013 with the release of the Air Pollution Prevention and Control Action Plan, which backed up particulate pollution reduction targets of 10–25 percent for specific cities with a host of measures—increased priority for pollution reduction in bureaucratic performance evaluations, for instance, and prohibitions on new coal-fired power plants in three high-pollution regions.[65] Li Keqiang underscored the central leadership's emphasis on air pollution control in his work report at the annual "Two Sessions" convocation of the Chinese legislature in March of 2014 by comparing it to the core national task of poverty alleviation: "we will resolutely declare war upon pollution in the same way that we have declared on poverty."[66] Xi Jinping extended this framing in his report to the 19th Party Congress in 2017, declaring pollution prevention and control as one of three national "tough battles" (攻坚战 *gongjianzhan*) alongside reducing risk in the financial system and implementing targeted antipoverty measures.[67] China's air quality efforts drove 39 percent declines in average particulate pollution exposure nationwide from 2013 to 2018, comprising almost three-quarters of such declines worldwide.[68] Authorities have expanded these efforts across the country as part of the Three-Year Action Plan for Winning the Blue-Sky War (2018–20).[69]

Meanwhile, in energy efficiency, Chinese policy during the 13th FYP persisted with the 12th FYP's "double control" system of paired targets for energy intensity and total energy consumption, defined nationally and (from 2014 onward) broken down into individual targets for subnational governments.[70] The political heft of these targets was underscored by extreme measures taken to meet them in Yiwu, a major commercial hub in Zhejiang Province, which began rationing power in December 2020 to help meet the province's energy consumption targets.[71] Similar extremes were seen on the air pollution front around coal-to-gas heating conversions in rural northern China, developed as part of China's pollution control efforts for the Beijing-Tianjin-Hebei region. A rushed rollout during the early 13th FYP period contributed to millions of homes without heat for parts of the 2017–18 winter amid natural gas shortages.[72]

A 2016 International Energy Agency (IEA) report stated that China's efficiency policies had been "one of the most important factors in limiting the growth of energy-related CO_2 emissions anywhere in the world over the past decade," driving 1.2 gigatons (gt) of avoided CO_2 emissions annually by 2014 as compared to business-as-usual projections from 2000.[73] Coal generation, steelmaking, and cement have all contributed to these gains. The cement sector saw a comprehensive fleet upgrading from small-scale shaft kiln production lines to larger and more efficient precalciner kilns. Data collected by Liu et al. (2021) indicates the precalciner kilns saw their production shares increase from 13 percent in 2000 to 44 percent by 2005 and 99.8 percent by 2015.[74] This shift helps explains why the cement industry's coal consumption increased by 46 percent from 2005–14 even as production volumes increased 133 percent.[75] Steel production energy intensity had by 2015 fallen to 572 kg/ton from above 800 kg/ton in 2000, and Hasanbeigi and Springer's 2019 benchmarking study of BF-BoF energy intensity worldwide found China as one of the world's most efficient producers by this route.[76] China's coal power fleet today is also "one of the world's most efficient" per the IEA, with average plant efficiency up from 30 percent in 2000 to 39 percent in 2018.[77] Meanwhile, outside of energy efficiency, further avoided emissions have come from the growth of wind and solar installations. Generation sources other than thermal and hydropower provided just 2.9 percent of Chinese electricity in 2010; by 2020, they provided 14.4 percent, with 9.5 percent from wind and solar alone.[78]

Progress in energy efficiency and renewables expansion have secured noteworthy avoided emissions over the past two decades, but these gains are of modest significance set against the dramatic expansion in China's emissions during the same period. Per CAIT data, total national emissions (excluding bunker fuels as well as land use, land-use changes, and forestry) more than doubled, from around 4.8 gt in 2000 to 11.9 gt in 2014, an increase of more than 7 gt. This increase represented around 60 percent of total growth in world emissions during those years.[79]

Nonetheless, Chinese authorities have not imposed any comparable policy campaigns or detailed sets of mandates directly around carbon emissions reduction work during the past decade. Beyond reporting requirements, Chinese firms' main exposure to carbon management has come through China's regional ETS pilots, launched across eight provinces and cities between 2013 and 2016. These requirements gave participating firms initial expertise in monitoring, reporting, and verification as well as the basics of carbon allowance trading. But prevailing price levels in most pilots of 40 RMB/ton or less (around $6–$7 or less) since 2013 are well below the range required for Paris-compatible temperature reductions.[80] Academic literature on the pilots suggests some positive spillover impacts in areas like low-carbon innovation,[81] but representatives of China's carbon trading exchanges have publicly acknowledged minimal impacts from the pilot ETSs on carbon emissions. Officials at Guangdong's carbon trading and power dispatch exchanges, for instance, have estimated current coal unit carbon allowance costs in the province, China's largest carbon trading pilot by value and volume in 2019–20, at around just 0.5 percent of operating costs, which "basically will not have an effect upon the operating costs of coal units today."[82]

Several interviewees also noted that basic issues in monitoring, reporting, and verification remain areas for continued capacity building in the steel sector.[83] A December 2020 report from respected Chinese business outlet *Caixin*, for instance, indicated that, though steel firms had reported emissions to authorities for 2013–19, "government verification of these figures is being still awaited."[84] Even the emissions reporting is not necessarily comprehensive. The provincially owned steelmaker Shandong Iron and Steel, the seventh-largest steelmaker in China, says that it began conducting emissions inventories in 2013 for its largest subsidiary and is now extending these efforts to the rest of the group.[85]

Limited policy expectations help explain why few major emitting Chinese firms had issued formal decarbonization targets before the neutrality pledge. The only such pledges among the 30 firms reviewed for this report came from Taiwan Cement—the eighth-largest cement firm in China by clinker capacity and, notably, a Taiwanese company listed in Taiwan.[86]

In fact, many high-emitting firms in coal generation, steelmaking, and cement did not release public emissions data, particularly if they were not listed on Hong Kong equity markets. Table 4 lists greenhouse gas emissions from the Chinese companies reviewed in this report who reported data on this front in 2019. For companies who do not report emissions, it also includes emissions volumes from their largest listed subsidiary (by total assets) involved in the relevant sector, if available. Only one nonlisted major emitter in coal generation, steelmaking, or cement—China National Building Materials Group (CNBM), the country's largest clinker capacity owner—reported emissions data for 2019. All five other major emitters reporting emissions were Hong Kong–listed companies, and four of the five major emitter subsidiaries reporting emissions were also listed in Hong Kong or internationally. Companies that did not report, meanwhile, were generally either nonlisted or listed on the Shenzhen or Shanghai exchanges. By contrast, the firms reviewed generally disclosed information on energy consumption and pollutant discharge—the government's main energy and environment priorities. The contrast here with carbon disclosures underscores the influence of policy priorities in guiding firm decision-making.

Table 4: 2019 GHG emissions disclosures from top Chinese firms in thermal generation, steelmaking, and cement

Sector	Company	Listing locations	Disclosed GHG emissions		Chinese industry parent (if applicable)	Total assets as % of industry parent total assets	Emissions notes
			Total	Scope			
Cement	China National Buiding Materials Group 中国建材集团有限公司	None	277.8mt CO_2	Not specified	--	--	Covers group-wide emissions across a range of building materials sectors, including cement and glass. Driven primarily by cement emissions.
Cement	Anhui Conch Cement 安徽海螺水泥股份有限公司	Hong Kong, Shenzhen	199.7mt CO_2eq	Not specified	--	--	
Thermal power	China Resources Power 华润电力控股有限公司	Hong Kong	134.0mt CO_2	Scope 1+2 (fuel combustion, desulfurization, purchased electricity)	--	--	
Cement	China Resources Cement 华润水泥控股有限公司	Hong Kong	58.7mt CO_2eq	Scope 1 ("major discharge outlets from cement production plants")	--	--	
Cement	China Shanshui Cement 中国山水水泥集团有限公司	Hong Kong	34.5mt CO_2	Not specified ("emissions of all clinker-producing enterprises")	--	--	Attributable almost entirely (if not entirely) to its subsidiary, **Shandong Shanshui**, China's sixth-largest clinker producer by capacity.
Cement	China Tianrui Group Cement 中国天瑞集团水泥有限公司	Hong Kong	22.8mt CO_2eq 1.0mt CO_2eq	Scope 1 Scope 2	--	--	Attributable entirely to its subsidiary, **Tianrui Cement**, China's ninth-largest clinker producer by capacity.
Cement	Asia Cement 亚洲水泥（中国）控股公司	Hong Kong	21.7mt CO_2	Not specified	--	--	

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Sector	Company	Listing locations	Disclosed GHG emissions		Chinese industry parent (if applicable)	Total assets as % of industry parent total assets	Emissions notes
			Total	Scope			
Thermal power	Datang International Power 大唐国际发电股份有限公司	London, Hong Kong, Shanghai	198.5mt CO_2 0.1mt CO_2	"Direct" (Scope 1) "Indirect" (unspecified; Scope 2 or Scope 2+3	China Datang Group 中国大唐集团有限公司	37.2%	
Thermal power	China Shenhua Energy 中国神华能源股份有限公司	Hong Kong, Shanghai	151.5mt CO_2eq 5.9mt CO_2eq	Scope 1 Scope 2	China Energy Investment Corporation 国家能源投资集团有限责任公司	32.2%	
Thermal power	Huadian Power International 华电国际电力股份有限公司	Hong Kong, Shanghai	167.9mt CO_2 0.1mt CO_2	"Direct" (Scope 1) "Indirect" (unspecified; Scope 2 or Scope 2 + 3)	China Huadian Group 中国华电集团有限公司	28.2%	
Thermal power	China Hongqiao 中国宏桥集团有限公司	Hong Kong	55.0mt CO_2eq 13.3mt CO_2eq	Scope 1 Scope 2	--	--	Member of the Shandong Weiqiao group of companies
Thermal power	China Power International Development 中国电力国际发展有限公司	Hong Kong	48.9mt CO_2	Scope 1+2 (fuel combustion, desulfurization, purchased electricity)	State Power Investment Corporation 国家电力投资集团	10.6%	
Steel	Hunan Valin Iron and Steel 湖南华菱钢铁股份有限公司	Shenzhen	34.2mt CO_2	Not specified	Hunan Valin Iron and Steel Group 湖南华菱钢铁集团有限责任公司	78.3%	

Note: Only the largest listed subsidiaries of each major as measured by total assets are considered. (China Hongqiao is the largest listed company among a group of aluminum and textile companies owned by the Zhang family and collectively referred to in this report as Shandong Weiqiao, but the lack of a formal subsidiary relationship between these companies prevents the attribution of a single industry parent or corresponding asset share.) Companies from Table 2 whose controlling shareholders are foreign are excluded. China Resources Power and China Power International Development state that their emissions are reported based upon thermal emissions reported per national standard GB32151.1-2015, which specifies thermal emissions reporting from fuel combustion, desulfurization, and purchased electricity. Huadian Power International does not specify whether its indirect emissions include Scope 3 emissions or not.

Source: See Appendix, Part A, section ii; National Carbon Emissions Managment Standardization Technical Committee, "Requirements of the greenhouse gas emission accounting and reporting—Part 1: Power generation enterprise" ("温室气体排放核算与报告要求 第1部分：发电企业"), GB/T 32151.1-2015, effective January 1, 2016, accessed May 13, 2021, http://www.cqjnw.org/article.php?id=11833.

RAISING AMBITION: CORPORATE CARBON COMMITMENTS SINCE THE PLEDGES

Limited engagement from Chinese firms with carbon management reflected its secondary status within Chinese economic and environmental policy. The 30-60 announcement was a powerful signal from Xi Jinping himself for elevating official attention to carbon emissions and forcing firms to start engaging more directly with these issues. Peaking "before 2030" instead of "around 2030" does not require a dramatic shift in behavior. Analyses of China's emissions trajectory suggest that meeting this goal will be relatively straightforward but will not put China on a pathway consistent with a 1.5-degree temperature increase.[87] The 2060 net-zero target is better aligned with this pathway.[88] But it will demand a dramatic transformation in China's economy, with firms in energy generation and heavy industry shifting from their current production models to carbon-neutral modes of operating.

One early signal of firm engagement around this transition is the introduction of corporate emissions control and reduction targets. These targets are not on their own a measure of climate commitment. Firms can use targets as greenwashing; they can publish targets narrowly defined to exclude their main emissions drivers, or targets that brand preexisting energy efficiency or product diversification plans as carbon reduction efforts.[89] Indeed, the scholarly literature on corporate climate target setting confirms the limits of using emissions reductions targets alone as measures of firms' engagement with the climate transition. Dahlmann et al. (2019), analyzing corporate emissions targets recorded worldwide between 2010 and 2013 in the Carbon Disclosure Project (CDP) database, model firms' propensity to set emissions reduction targets and find no evidence to suggest that the types of firms setting reduction targets for themselves reduce emissions more than firms that do not.[90] Callery and Kim (2020), reviewing CDP data from 2011 to 2019, find widespread evidence of firms lagging the linear emissions reduction rates required to meet their targets and claiming target attainment in CDP records even when their public GHG inventories indicate otherwise.[91] Studies like Dahlmann et al. and Ioannou et al. (2016) find a relationship between more ambitious targets and greater reported emissions reductions, but Callery and Kim's detailed scrutiny of GHG inventories turns up no such link.[92]

If public relations-driven targets are shown on *average* not to drive emissions reductions, that does not mean targets never matter. Process-focused studies of corporate sustainability strategy, like Kiron et al. (2017) and Sroufe (2017), emphasize the value of measurable targets, incorporated into KPIs, as tools for making high-level sustainability commitments implementable.[93] Freiberg et al. (2021), in discussing why firms choose to establish GHG reduction targets verified by the UN-backed Science-Based Targets Initiative (SBTi), noted comments from interviewees about how the SBTi process prompted deeper internal collaboration in their firms on finding ways to cut emissions.[94] These studies suggest that targets can be powerful tools if deployed as part of deeper corporate commitment to carbon management. This assessment is reflected in the methodologies of the Transition Pathways Initiative (TPI) and the World Benchmaking Alliance (WBA), which publish assessments of listed companies' preparedness for decarbonization. Both projects include the presence and character of corporate decarbonization targets alongside a host of other indicators in their assessments.[95]

A comprehensive assessment of these many factors that determine the corporate environment for target implementation is beyond the scope of this report; TPI and WBA assessments incorporate reviews of public disclosures on a much wider array of issues like climate risk management, board composition, and trade association stances. But targets are worth tracking on their own—because of their value in the right environment, described above, but also because of their special significance in the Chinese context. Chinese authorities rely heavily upon plan-based target setting for high-level policy goals. Many of the largest emitters in coal generation, cement, and steel are state-owned groups expected to align their own corporate planning with government targets, and large private firms must contend with these targets as well as part of engagements with local authorities. These circumstances create additional pressures for firms to use targets to ensure compliance with government mandates.

Review of Firm and Industry Target Setting Post-30-60

Table 5 lists commitments as of July 1, 2021 from the 30 firms reviewed in this report as well as industry-wide commitments announced by industry associations or reported from official sectoral peaking plans under development. All of these targets have been released since the neutrality and peaking goals were announced last September except for that of Taiwan Cement. Taiwan Cement is also the only firm with an SBTi-approved goal covering Chinese facilities.[96] (Seeking SBTi approval is voluntary.) The targets do not specify the emissions scope covered. National reporting requirements cover scope 1 and scope 2 emissions.[97] The analyses in this paper thus assume that pledges cover these categories, though the lack of clarity from firms and associations is a reason for scrutiny.[98]

Table 5: Emissions reduction targets from top 10 firms in Chinese high-emitting sectors as of July 1, 2021

Electricity

Industry-wide targets: none announced

Company	Controlling owner type (SOE/ private/foreign)	January 2021 installed coal capacity (GWs)	National share	Emissions reduction targets
China Energy Investment Corporation. 国家能源投资集团有限责任公司	Central SOE	140.7 (GCPT) 188.4 (official)	13.6% (GCPT) 17.4% (official)	**Peak** by 2025 (in "coal-based industries") **Neutral** by 2055 (in "coal-based industries") *Scope not specified*
China Huaneng Group 中国华能集团有限公司	Central SOE	109.3 (GCPT)	10.5% (GCPT)	*None announced*
China Datang Group 中国大唐集团有限公司	Central SOE	86.1 (GCPT)	8.3% (GCPT)	"Guarantee **peaking** before 2030 and strive to peak early"
China Huadian Group 中国华电集团有限公司	Central SOE	82.5 (GCPT)	7.9% (GCPT)	Peak by 2025
State Power Investment Corpporation 国家电力投资集团	Central SOE	65.0 (GCPT) 77.4 (official)	6.3% (GCPT) 7.1% (official)	**Peak** by 2023 *Scope not specified*
China Resources Power 华润电力控股有限公司	Central SOE	36.1 (GCPT) 31.9 (official)	3.5% (GCPT) 3.0% (official)	**Peak** by 2025 *Scope not specified*
Zhejiang Energy Group 浙江省能源集团	Provincial SOE (Zhejiang)	25.3 (GCPT)	2.4% (GCPT)	*None announced*
Guangdong Energy Group 广东省能源集团有限公司	Provincial SOE (Guangdong)	20.5 (GCPT)	2.0% (GCPT)	*None announced*
Beijing Energy Group 北京能源集团有限责任公司	Provincial SOE (Beijing)	17.7 (GCPT)	1.7% (GCPT)	*None announced*
Shandong Weiqiao 山东魏桥	Private	17.5 (GCPT)	1.7% (GCPT)	*None announced*

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Steelmaking

Industry-wide targets: peak by 2025 and cut emissions by 30 percent by 2030 (draft, reported but not yet officially announced)

Company	Controlling owner type (SOE/ private/foreign)	2019 crude steel output (mt)	National share	Emissions reduction targets
China Baowu Iron and Steel Group 中国宝武钢铁集团有限公司	Central SOE	95.5	9.6%	**Peak** by 2023 Cut emissions by 30% by 2035 **Neutral** by 2050 *Scope not specified*
Hebei Iron and Steel Group 河钢集团有限公司	Provincial SOE (Hebei)	46.6	4.7%	**Peak** by 2022 **Cut emissions by 10%+** by 2025 **Cut emissions by 30%+** by 2030 **Neutral** by 2050 *Scope not specified*
Jiangsu Shagang Group 江苏沙钢集团有限公司	Private	41.1	4.1%	*None announced*
Ansteel Group 鞍钢集团有限公司	Central SOE	39.2	3.9%	**Peak** by 2025 **Cut emissions by 30%** by 2035 *Scope not specified*
Beijing Jianlong Heavy Industry Group 北京建龙重工集团有限公司	Private	31.2	3.1%	*None announced*
Shougang Group 首钢集团有限公司	Provincial SOE (Beijing)	29.3	2.9%	*None announced*
Shandong Iron and Steel Group 山东钢铁集团有限公司	Provincial SOE (Shandong)	27.6	2.8%	*None announced*
Hunan Valin Iron and Steel Group 湖南华菱钢铁集团有限责任公司	Provincial SOE (Hunan)	24.3	2.4%	*None announced*
Bengang Group 本钢集团有限公司	Provincial SOE (Liaoning)	16.2	1.6%	*None announced*
Liaoning Fangda Group 辽宁方大集团实业有限公司	Private	15.7	1.6%	*None announced*

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Cement

Industry-wide target: peak by 2023

Company	Controlling owner type (SOE/ private/foreign)	2020 installed clinker capacity (mtpa)	National share	Emissions reduction targets
China National Building Materials Group 中国建材集团有限公司	Central SOE	391.2	21.4%	*None announced*
Anhui Conch Cement 安徽海螺水泥股份有限公司	Provincial SOE (Anhui)	215.5	11.8%	*None announced*
Tangshan Jidong Cement 唐山冀东水泥股份有限公司	Provincial SOE (Beijing)	105.3	5.8%	*None announced*
China Resources Cement 华润水泥控股有限公司	Central SOE	66.9	3.7%	*None announced*
Huaxin Cement 华新水泥股份有限公司	Foreign with local SOE as minority shareholder (Huangshi City, Hubei)	63.0	3.4%	*None announced*
Hongshi Holdings Group 红狮控股集团有限公司	Private	57.2	3.1%	*None announced*
Shandong Shanshui Cement Group 山东山水水泥集团有限公司	Private	54.6	3.0%	*None announced*
Taiwan Cement 台湾水泥股份有限公司	Foreign	40.8	2.2%	**2025: cut Scope 1 emissions intensity by 11%, Scope 2 by 32%** [Taiwan + China; SBTi-approved] **2030: cut emissions intensity by 20%** vs. 2016 [China only; scope not specified] **2050:** "carbon neutrality for concrete products"

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Cement (cont)
Industry-wide target: peak by 2023

Company	Controlling owner type (SOE/ private/foreign)	2020 installed clinker capacity (mtpa)	National share	Emissions reduction targets
Tianrui Cement Group 天瑞水泥集团有限公司	Private	35.2	1.9%	*None announced*
Asia Cement 亚洲水泥（中国）控股公司	Foreign	22.4	1.2%	*None announced*

Note: Information from Global Energy Monitor (GEM) and its GCPT database is insufficient to identify a single corporation corresponding to Shandong Weiqiao. Based upon review of GEM staff statements as well as corporate records databases, the author infers this listing refers to a set of companies owned by the Zhang family including China Hongqiao, one of China's largest aluminum producers. The GEM database is based upon open-source document review and only includes plants of at least 30MW in size. Installed capacity shares of coal units reflect GCPT national recorded coal capacity for GCPT data (1043.0GW) and official national coal capacity for firm-reported data (1080.0GW).

Source: For firms, see Appendix, Section B, part ii, Section C, parts ii and iii, and Section D. For industry, see China Building Materials Federation, "Action Declaration for Advancing Carbon Peaking and Carbon Neutrality in Building Materials" ("推进建筑材料行业碳达峰、碳中和行动倡议书"*), January 16, 2021, accessed April 28, 2021, http://www.cnggg.cn/news/shownews.php?lang=cn&id=229; Liang Qing, "Steel Industry Carbon Emissions Peaking and Reduction Action Plan Takes Shape" (*"钢铁行业碳达峰及降碳行动方案成型"*), Economic Information Daily (*经济参考报*), March 30, 2021, accessed April 28, 2021, http://www.jjckb.cn/2021-03/30/c_139845634.htm.*

Seven of the 27 Chinese firms reviewed in this report have issued targets for peaking emissions by 2025 or earlier. All seven of these firms have elevated profiles as sector leaders. Six are central SOEs, firms charged with serving as public example setters in carbon neutrality by virtue of their ownership status. The remaining firm, the provincial SOE Hebei Iron & Steel (HBIS), is China's second-largest steel producer. It has served as a global standard-bearer for the Chinese steel industry as one of China's two representatives (alongside Baowu) on the executive committee of worldsteel, the global steel industry association, since 2016–17.[99] HBIS chairman Yu Yong is currently the association's chair.[100]

In terms of sectoral breakdown, the bulk of peaking commitments for 2025 or earlier thus far have come from electricity generators: three of the Big 5, as well as China Resources, the sixth-largest coal power operator.[101] These firms together accounted for 34.1 percent of national installed thermal capacity in 2019. Only four firms have publicized neutrality targets: top energy generator and coal giant CEIC; Taiwan Cement; and Baowu and HBIS, the world's number two and number four steel producers in 2019.[102] (Baowu became the world's largest producer in 2020.[103]) CEIC's pledge covers only its coal-based industries, but these should represent the vast majority of its carbon emissions.[104]

Firm-level emissions reduction targets in cement and steel have come only from Baowu, HBIS, Taiwan Cement, and Anshan Steel. But there has been activity at the industry level. In mid-January 2021, the China Building Materials Federation announced a 2023 peaking target for the cement sector as part of a general 2025 peaking target for the whole building materials sector.[105] In steel, media reports on a national emissions peaking action plan for the sector suggest an expected 2025 target date for steel emissions peaking followed by a 30 percent reduction from peak levels by 2030.

Chinese firms' commitments as of the first half of 2021 were broadly more conservative than sector leaders globally, most of whom come from the developed world. In electricity generation, reports by S&P Global Market Intelligence indicate that 70 percent of the 30 largest US utilities had net-zero targets as of December 2020, mostly introduced since 2019, and all but 3 of the largest 22 European utilities had net-zero targets as of April 2021.[106] Commitments from peers outside of these regions are much less common, with long-term deep decarbonization targets from only a handful of large thermal power owners outside the West: India's Tata Power and JSW Energy, for instance, and Japan's J-POWER.[107]

Global cement and steel peers are as a whole less aggressive in setting net-zero targets—unsurprisingly, given the abatement challenges in both sectors. Still, as of December 2020, Transition Pathways Initiative (TPI) assessments of 33 cement producers included 5 companies—CRH and HeidelbergCement from Europe as well as Mexico's Cemex, India's Dalmia Bharat, and Japan's Taiheiyo Cement—with deep decarbonization targets, seeking to achieve net zero by at least 2050 or to lower carbon intensity levels to those consistent with a below 2-degrees pathway.[108] Notably, there are four top-10 global cement producers by integrated production capacity that are not Chinese: Cemex, HeidelbergCement, Lafarge Holcim (Switzerland), and UltraTech Cement (India). Each of these companies has more substantial decarbonization targets than their Chinese counterparts: LafargeHolcim (Switzerland) and UltraTech (India) hold carbon intensity reduction targets for 2030 and

2032, respectively.[109] Some national industry associations—such as the United States' Portland Cement Association, which represents more than 90 percent of American cement production capacity—have also set a 2050 net-zero target.[110]

In steel at least, the neutrality pledges from Baowu and HBIS put China's two biggest producers toward the front of an emerging net-zero trend in the industry. This trend was initially confined to firms with significant European production bases; European majors like ThyssenKrupp as well as Tata Steel's European operations announced 2050 neutrality targets in 2018–19.[111] Its expansion to other geographies has only begun in the past year. ArcelorMittal, the largest producer in 2019 in Europe, the Americas, and worldwide, announced a 2050 neutrality target in September 2020. Korea and Japan's national 2050 net-zero targets, released in fall 2020, have occasioned similar targets from Nippon Steel (Japan) and POSCO (Korea), the number three and number five global producers in 2019.[112] Beyond Baowu and HBIS, though, the absence of targets from other Chinese producers contrasts with 2030 interim reduction targets that feature among several additional firms reviewed by the TPI, including JFE (Japan), Kobe Steel (Japan), JSW Steel (India), and Bluescope Steel (Australia).[113]

Drivers of Firm and Industry Targets

Realizing the 2060 neutrality target will demand much more aggressive emissions reductions from Chinese high-emitting firms than those reflected in the targets that most sector majors had laid out through June 2021. (And that is to say nothing of firms not reviewed in this report that comprise the remaining 40–60 percent of production and capacity in each of these sectors.) This gap, of course, in part reflects the challenges of deep decarbonization. If Chinese cement and electricity generation firms are by no means global leaders in their target setting, they are not alone in their caution, particularly outside of Western markets. This caution reflects expertise gaps in carbon management and the importance of policy guidance in determining firms' decarbonization approaches.

Chinese firms generally remain in the early stages of building carbon management expertise that can inform their decarbonization efforts. Several consultancies with climate-related practices in China discussed in interviews how the neutrality pledge has driven a major expansion of client interest in carbon emissions management and planning services.[114] A former Chinese government official interviewed described a surge of inquiries to government think tanks from companies and industrial associations since Xi's announcement seeking their help around carbon planning and management.[115] Reporters with the Chinese state media outlet Global Times wrote in January 2021 that "many state-owned enterprises are still 'watching'—some of them are still learning how to set their goals, where to start and how to implement them."[116]

But authorities are also still early in the process of turning the neutrality and peaking targets into concrete guidance for firms. Before the pledge, China's policy environment gave firms little reason to invest in carbon management. The pledge itself signaled a forthcoming change but gave no details about how it would take place. Indeed, there were no details yet to give. The pledge's formulation took place through a highly centralized process, limited to senior leadership and a core research team led by Tsinghua University scholars; for firms, and for most of the bureaucracy, the announcement was a surprise.[117] Moreover, the announcement took place at an international forum rather than as part of a key agenda-setting event in the Communist Party of China's policy calendar like the annual Two Sessions meeting. Making the pledge before an international audience reflected the value of climate diplomacy as a tool for strengthening China's global image, but it did not immediately place the pledge in the context of other national policy priorities with which it must compete for state attention.

The neutrality pledge was, in Michal Meidan's words, "the beginning of a policy planning process rather than the culmination of one."[118] The first major signal about the direction of that policy process came in mid-December, at the Central Economic Work Conference (CEWC), an annual mid-December meeting at which China sets its economic policy priorities for the coming year.[119] The December 2020 CEWC's readout listed "carrying out carbon peaking and carbon neutrality work" as the last of its eight "key tasks" for Chinese economic policy in 2021 and stated that China "must seize the establishment of action plans to peak carbon emissions before 2030."[120] This pronouncement confirmed that these pledges had a place within China's immediate policy agenda; official readouts from the prior year's CEWC, by contrast, had not mentioned carbon emissions at all.[121]

Reinforcing signals for central SOEs came at the late December annual meeting of central SOE representatives held by the national State-Owned Assets Supervision and Administration Commission, in charge of central SOE oversight. As with the CEWC, carbon emissions had been absent from the 2020 "major tasks" set out for SOEs in the prior year's meeting.[122] This time, though, officials called upon firms to "actively participate in 'carbon peaking' and 'carbon neutrality' actions" as part of the last of their eight "major tasks" for 2021: "actively serving and supporting major national strategies."[123]

Among the firms reviewed in this report, the only firm with a public emissions reduction target before the CEWC was SPIC, the most ambitious low-carbon energy developer among the Big 5 energy generation firms.[124] Days after the CEWC, China's largest energy generator and coal producer, CEIC, held its standard annual leadership meeting on the conference and announced that it was working on a plan to peak emissions by 2025.[125] January would see a further batch of announcements as firms defined their work plans for 2021: targets for carbon peaking by 2025 from Big 5 member Huadian, as well as Baowu's 2050 neutrality target.[126] (Around this time, Datang announced that it "sought to have non-fossil installed energy capacity exceeding 50 percent by 2025 and achieve 'carbon peaking' five years early." But their emissions peaking plan, released in late June, did not mention a 2025 emissions peaking target.) HBIS announced its neutrality target on the same day as the 14th FYP outline was published in full.[127]

The first months of 2021 have seen ministries, firms, and industrial associations starting to translate high-level political signals into policy plans that clarify just how authorities seek to balance peaking and neutrality with other nonclimate priorities. China's 14th FYP outline established status quo headline targets for 2025 around emissions intensity (18 percent decline over the five years) and energy intensity (13.5 percent decline), though it also contained stronger language around curtailing coal capacity growth and accelerating growth of zero-carbon alternatives.[128] The neutrality target was also followed by issuance of regulations to launch China's national emissions trading system for power generators in 2021, four years after the initial road map release for the sector in 2017; officials plan to add seven other sectors in the coming years, including cement and steel, though there is no official expansion timetable.[129] (The ETS's emissions impact is highly uncertain for several reasons, including, for instance, its use of allowances based upon relative carbon-intensity benchmarks instead of absolute emissions levels. Interviewees suggested that whatever impacts it may have over the coming decade or so are likely to be more pronounced for small firms than many of the large firms reviewed in this report, which tend to operate more efficient capacity than their smaller peers.[130])

But a number of crucial policy plans and regulations for corporate emissions reductions remain forthcoming. Sectoral FYPs in energy and high-emitting heavy industry sectors like cement and steel will not be released until late 2021 or early 2022. The emissions peaking road maps identified as a piece of China's 2021 carbon peaking and neutrality work at the CEWC are also not yet released, though media reports have already publicized a proposed peaking timeline for the steel sector, as noted above.

These forthcoming plans involve answers to crucial questions about the pace of China's decarbonization transition in this key period. They are likely to set specific timing for national and sectoral emissions peaking, for instance, and to give more clarity about potential total emissions targets during the 14FYP, which the plan outline had identified as a "supplement" to carbon intensity targets.[131] They may also sketch out regulatory tactics by which policy makers intend to achieve their targets—for instance, the introduction of mandates for large emitters like the Top-1,000 and Top-10,000 programs. These programs, introduced in the late 2000s, assigned annual energy consumption quotas to large energy consumers and are seen by Chinese policy makers as major drivers of efficiency gains.[132]

In this way, policy and regulatory pronouncement in the coming months will prove important guides for peaking and emissions reduction plans from high-emitting firms, particularly beyond sector leaders expected to set examples for their peers. But their significance for long-term target setting around carbon neutrality is less certain. The modest ambition of the peaking target allows firms to discharge their political obligations around contributing to China's carbon goals without many of the expensive or painful decisions required by neutrality—major retirements of coal assets, for instance, or widespread deployment of carbon capture, utilization, and storage (CCUS).

Signals from Early Commitments on Emissions Peaking and Reduction

Even as many firms have not announced their own targets, commitments made thus far offer several useful clues for how major firms in coal generation, steelmaking, and cement intend to start controlling their emissions in the next decade and beyond.

Coal Generation

At the US-convened Leaders Summit on Climate in April 2021, Xi Jinping stated that China would "strictly limit the increase in coal consumption over the 14th FYP period and phase it down [*zhubu jianshao* 逐步减少, literally "reduce progressively/step-by-step"] in the 15th FYP period."[133] His statement reinforced expectations of a likely peaking target for Chinese coal consumption around 2025 or shortly thereafter. Before his statement, though, China already had commitments from four of its six largest coal generators to peak emissions by 2025 or earlier.

Their commitments suggest that these firms view the 14th Five-Year Plan period (which ends in 2025) as the final window for coal capacity additions. This shift has been a long time coming. China has more than tripled its installed thermal capacity over the past 15 years, from 391 GW in 2005 to 1,245 GW in 2020.[134] These additions have strained thermal plants' revenues by cutting their average annual utilization hours more than 25 percent since the mid-2000s.[135] Still, the Big 5's additions in the coming several years will not be trivial, as shown in Table 6. GCPT data records 50 GW of coal either permitted or under construction from these five firms and 150 GW of such projects total by Chinese firms. The completion of these five firms' projects will increase installed coal capacity by the equivalent of 5 percent of existing Chinese capacity, per GCPT data. Indeed, simply finishing all coal projects under construction by Chinese firms will add another 94 GW of coal capacity, an increase of around 9 percent.

Table 6: Coal capacity under construction or permitted as of January 2021 by firms pledging to peak emissions by 2025 or earlier

Company	Under construction	Permitted	Total under construction and permitted	Operating	Under construction % of operating	Total % of operating
CEIC	12.2	9.7	21.9	140.7	8.7%	15.5%
Huadian	5.4	1.1	6.5	82.5	6.5%	7.9%
SPIC	4.5	2.0	6.5	65.0	6.9%	10.0%
China Resources	2.0	3.3	5.3	36.1	5.5%	14.7%
All-China total	93.7	53.2	146.9	1,037.8	9.0%	14.2%
2025 peakers' total	24.0	16.1	40.2	324.2	7.4%	12.4%
2025 peakers' share	*25.6%*	*30.3%*	*27.3%*	*31.2%*	--	--

Note: SPIC targets emissions peaking by 2023; the other three firms target peaking by 2025. Figures are based on the GCPT database and so do not include projects under 30MW..

Source: See Appendix, Section B, part iii.

To be clear, large firms' expected coal additions will be accompanied by a much larger renewables expansion. China has pledged to reach 1,200 GW of installed wind and solar capacity by 2030, up from 535 GW in 2020.[136] Since the 30-60 announcement, the 10 electricity generation majors reviewed in this report have announced plans to add hundreds of GWs of "renewable," "nonfossil," "clean energy," or "new energy" capacity during the 14FYP (Table 7). The energy sources implied by these installation targets vary. "Renewable," "nonfossil," and "clean" energy have official definitions in China's draft Energy Law, published in April 2020.[137] From among China's major generation sources, renewables cover solar, wind, and hydropower. Nonfossil includes these three as well as nuclear.[138] "Clean energy" is defined not in terms of sources but in terms of having zero or low emissions of CO_2 and other "environmental pollutants." "New energy" does not have a formal policy definition, but it is often used to refer to recently developed generation technologies like wind and solar as opposed to traditional fossil or hydro generation technologies.[139]

Table 7: Selected 14FYP generation capacity targets

Company	2019 capacity mix	2025 target
CEIC	75.1% thermal (184.7GW) 17.3% wind/solar (42.5GW) 7.6% hydro (18.6GW)	70–80GW of renewables added 25–30GW of solar added *(vs. 1.3GW online in 2019)* 40% installed capacity as "new energy"
Huaneng	72.1% thermal (131.9GW) 14.8% hydro (27.0GW) 13.1% wind/solar (24.0GW)	80GW of "new energy" capacity added 50% of installed capacity as "low-carbon clean energy" *(officially reported at 33.7% in 2019)*
Huadian	70.8% thermal (108.3GW) 17.8% hydro (27.3GW) 11.4% wind/solar (17.4GW)	50% of installed capacity as non-fossil 60% of installed capacity as non-coal
Datang	67.5% thermal (97.3GW) 18.7% hydro (27.0GW) 13.8% wind/solar (19.9GW)	50% of installed capacity as non-fossil
SPIC	54.0% thermal (81.6GW) 15.9% hydro (24.0GW) 25.6% wind/solar (38.6GW) 4.6% nuclear (7.0GW)	c. 70% of installed capacity as "clean energy" *(officially reported at 51% in 2019, 56% in 2020)*
China Resources	76.7% thermal (31.0GW) 0.7% hydro (0.3GW) 22.6% wind/solar (9.1GW)	40GW of renewables added 50%+ of installed capacity as renewables
Zhejiang Energy	35+GW total capacity c. 2–3% hydro (0.8GW) c. 6–7% non-hydro renewables (2.3GW)	"Renewable installed capacity will double; we will strive to add 20GW of renewables; and renewable installed capacity share will reach 28.8%" *[see notes]*
Beijing Energy	N/A	50%+ "clean energy"

Note: Targets from Zhejiang Energy are puzzlingly inconsistent. Adding 20GW of renewables, for instance, would take the company well above its goal of 28.8 percent renewable installed capacity unless accompanied by an improbable 40+GW of additions in non-renewable capacity. As for doubling installed renewable capacity, Zhejiang Energy reports that its total renewable installed capacity exceeded 3.5GW by the end of the 13FYP period, in 2020. Adding another 3.5GW of renewables, assuming 35GW total capacity today (likely a slight underestimate), would take Zhejiang Energy's share to 20 percent.

Source: See Appendix, Section A, part i and Section D, part ii.

The definitions above do not support a definitive gap analysis for "new energy" and "clean energy" targets. The lack of firm-reported data on coal capacity poses the same issue for analyzing noncoal capacity targets.[140] But even just the renewable and nonfossil targets imply several hundred GWs of new zero-carbon additions through 2025. CEIC and China Resources together plan to add 110–120 GW of new renewables. Huadian and Datang's targets of 50 percent installed nonfossil capacity by 2025 imply a minimum of 63 GW and 51 GW, respectively, of nonfossil capacity additions from their 2019 portfolios, not accounting for net coal capacity additions in 2020 and beyond.[141] (Net coal capacity declines would lower this minimum, but they are unlikely—Huadian intends to shut just 3 GW of coal by 2025, less than the 5.4 GW of additions reported by GCPT as under construction as of January 2021.[142]) S&P Global Platts, in a report on the Big 5 companies' targets, states that "the companies define clean fuels as wind, solar, hydro, nuclear, biomass, geothermal and natural gas."[143] Based on this definition, SPIC's target of 70 percent clean energy by 2025 would entail a minimum of 81 GW of additions of "clean" capacity. (Natural gas is unlikely to be more than a supporting player in this; SPIC's combined gas and biomass installed capacity in 2020 were around an eighth of its total solar and wind capacity.[144])

These targets will require China's biggest energy generators to enter the solar market in earnest. These firms have been marginal players in solar development; beyond SPIC, the other four Big 5 firms all have total solar holdings of 1–4 GW, comprising 3 percent or less of their overall portfolios (Table 3). Interviewees suggested that big SOEs' traditional focus on large-scale thermal and hydropower projects has fit more neatly into the development of large centralized wind projects than solar, whose growth has been more concentrated in smaller-size projects, including distributed solar.[145] Though installed capacity in both solar and wind will grow more in absolute terms than either nuclear or hydropower in the coming five years, solar is particularly promising. Analysts with CITIC Securities, for instance, project 73 GW of new solar and 34 GW of new wind capacity annually on average nationwide from 2021 to 2025, implying compound annual growth rates (CAGRs) of 19.5 percent for solar and 9.9 percent for wind, while reporters at the respected Chinese financial magazine *Caijing* cite industry projections of 70–90 GW of solar and 50–60 GW of wind.[146] (Some forecasters foresee smaller gaps between the two; the Global Energy Interconnection Development and Cooperation Organization, a think tank affiliated with China's biggest grid operator, projects 60 GW in annual solar additions and 50 GW in wind.[147]) By contrast, the 14th FYP outline's target of 70 GW of installed nuclear implies an additional 20 GW over the next five years (a 7 percent CAGR); nuclear unit development and operational control is highly concentrated among approved participants, of which only SPIC is a top-10 thermal firm.[148] As for hydropower, its growth has declined steadily over the past decade. Between 2010 and 2015, 103.5 GW in new capacity came online (a 8.1 percent CAGR); between 2015 and 2020, it was only 38.1 GW (a 3 percent CAGR).[149]

Given these trends, major generation firms will struggle to meet their targets without participating in solar's surging growth. Several have already begun doing so amid solar's plummeting costs, as noted by energy sector analyst Yuki Yu.[150] CEIC, with just 1.3 GW of solar in operation as of 2019, is planning 25–30 GW of additional solar growth in 2021–25, and Huaneng is in the midst of acquiring the solar assets of major developer and manufacturer GCL Poly. But interviewees suggested that the dive into solar will challenge firms in balancing effective site selection and project development with rapid capacity additions or, alternatively, in integrating mergers and acquisitions (M&A) targets with existing solar portfolios.[151]

These challenges are intertwined with a broader set of institutional challenges for China—affecting wind as well as solar growth—around building a power grid that can manage large volumes of low-carbon power. Analysts have discussed many of these challenges at length.[152] For instance, ongoing reforms in China are seeking to transition dispatch and compensation systems in China from administrative allocation to more flexible forms of market contracting.

But they have yet to appropriately incentivize the coal flexibility investments needed to accompany greater renewables penetration and guarantee energy security amid rising demand. The central role of provinces as grid operators balkanizes grid systems by constraining interprovincial trade, a drawback for renewables hubs in interior China that rely upon access to coastal load centers. Hopes around coal retirements to open up market share for renewables also must contend with energy security pressures from rising power demand in China as well as political economy incentives around coal as a value driver in local economies. These challenges are not necessarily firm-level challenges. But they affect wind and solar project economics as well as the political pressures to which SOEs must respond. In this way, they shape the environment in which firms attempt to ramp up their installed renewable capacity.

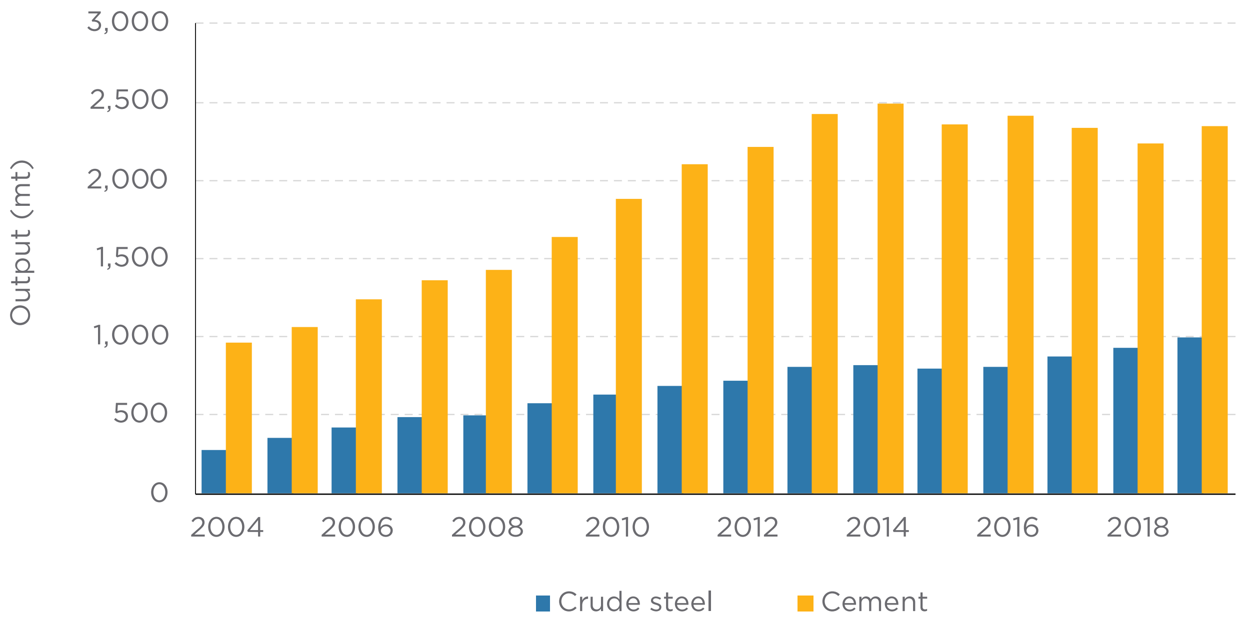
Steel and Cement

Efforts to reduce steel and cement emissions rely in the short term upon long-awaited output peaks that will easily deliver peaking in each sector. Progress beyond this stage will demand technologies that are not yet commercial. Efforts on this front around steel, more so than cement, will benefit from convenient overlaps between the steps the sector must take to decarbonize and the steps it must take to fulfill several key policy priorities unrelated to climate.

Both steel and cement demand are expected to fall this decade amid China's fitful shift away from infrastructure-driven growth. Morgan Stanley and CITIC, for instance, project a 5–10 percent decline in Chinese steel production between 2020 and 2030, while CITIC foresees around a 25 percent drop in Chinese cement production over the same period.[153] These conditions mean that peaking emissions in these sectors is closely tied to peaking output. China Cement Association Vice Chair Li Shen told reporters in January 2021 that "clinker production volume is the biggest factor influencing the cement industry's carbon emissions" and projected that the production peak expected during the 14th FYP would secure an emissions peak.[154] Several interviewees echoed Li's comments and suggested that this peaking target required little proactive work by firms beyond following market demand; one interviewee noted sardonically that the sector had long been in a "peaking period."[155] In steel, authorities at the Ministry of Industry and Information Technology (MIIT) have pledged since the start of 2021 to reduce national steel output this year and, from the very beginning, have cited the peaking and neutrality pledges as part of their rationale.[156]

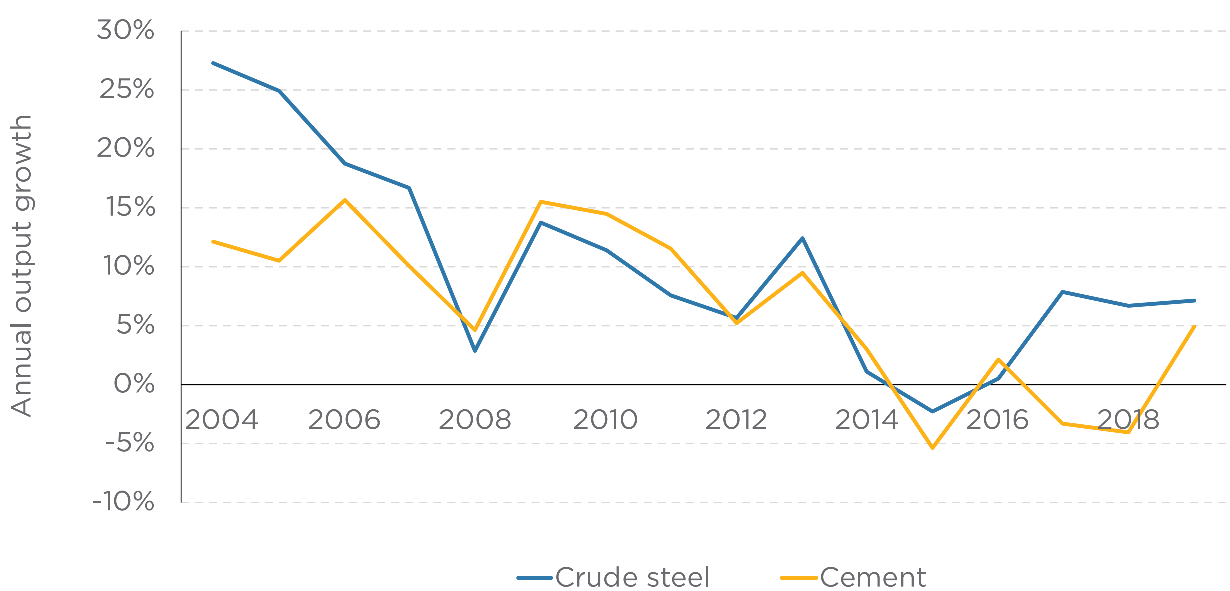
Output peaks have been long awaited. After decades of runaway expansion, a mid-2010s dip in steel and cement output reflected the onset of China's "new normal" era of lower economic growth. But production has since held steady in cement and possibly even grown in steel, as shown in Figures 1 and 2. (Note that official data on growing steel production over the past several years likely overstates actual production growth, reflecting shifts in production from unrecorded induction furnaces—formally illegal since 2000 but only pushed out of the market during the 13th FYP period—to new mills whose production registers in official statistics.[157]) These trends reflect Chinese policy makers' continued reliance upon infrastructure as a growth driver during the late 2010s to counter an economic slowdown exacerbated by US-China tensions.[158]

Figure 1: Chinese crude steel and cement output, 2004–2019



Source: See Appendix, Section C, part i.

Figure 2: Growth in Chinese crude steel and cement output, 2004–2019



Source: See Appendix, Section C, part i.

Steel and cement production has remained high over the past five years despite high-profile campaigns to reduce severe overcapacity in both sectors.[159] These campaigns' measures have proven challenging to enforce, with firms finding a variety of ways to maintain or even expand capacity in line with continued strong market demand—for instance, swapping idle or inefficient capacity for new, more efficient production lines.[160] The steel sector's 13th FYP sought to reduce raw steel production capacity from 1.13 bt to less than 1 bt, but after outpacing that target through 2018, a new wave of installations brought estimated capacity to 1.2–1.3 bt in 2019.[161]

As noted in Table 5, the cement industry seeks to peak emissions in 2023, whereas steel's reported target gives until 2025. Cement's earlier date aligns with its more stable production trends over the past several years, but both sectors are preserving several years of headroom when they can grow output to meet surging demand from China's infrastructure-heavy COVID stimulus.[162] Cement production was up 10.7 percent in January–May 2021 compared to the same period in 2019, and crude steel up 16.9 percent, even as high-profile antipollution output limitations curbed production from the major North China steelmaking hub of Tangshan starting in March.[163] For steel, in particular, production increases have exposed tensions among policy participants about output peaking timelines. Li Xinchuan, who heads the Metallurgical Planning Institute, an influential state-run think tank, publicly questioned in March the MIIT's plan to reduce 2021 production, saying that it would be "difficult for raw steel production to decline" amid growing demand as well as a surge in sectoral investment during 2020. He called for authorities to instead "gradually research and establish production restrictions based upon carbon emissions, pollution, and total energy consumption."[164]

Of course, even as the steel sector seeks greater breathing room on peaking production, its leading firms were some of the first high emitters in China to set net-zero targets: Baowu in late January, and HBIS in March.[165] The depth of Baowu and HBIS's commitment to these targets will be properly tested in the years to come, but both firms' announcements did include interim milestones. Baowu aims to peak by 2023 and achieve a 30 percent reduction by 2035; HBIS targets a 2022 peak and a 30 percent reduction by 2030.[166] (Baowu is expected to pursue significant M&A growth in steelmaking capacity in the coming five years, with targets including provincially owned steelmaker Shandong Iron and Steel, the seventh-largest steel producer in China.[167] Such additions will likely increase the firm's total emissions, so observers should watch for how the firm claims to peak amid such growth—perhaps, for instance, by adjusting its baseline to reflect M&A additions' historical emissions.) HBIS also provided valuable detail on near-term actions that will contribute to their goals; they announced quantitative 2025 targets for EAF capacity shares, scrap shares, and hydrogen-based iron production as well as specific large-scale investments in their scrap supply chain.[168] Baowu has not issued comparable details, though it plans to announce its "low-carbon metallurgy roadmap" this year.[169] Anshan Steel's goal of a 30 percent emissions decline from peak levels by 2035 also represents a longer-term goal than any firm-wide aims from the power-sector majors. The 11th-largest steel producer as of 2019, Baotou Iron and Steel, has also announced a goal of peaking by 2023 and hitting net zero by 2050.[170]

Absent insider knowledge, firm-specific motivations for releasing early climate pledges can be difficult to nail down. Baowu was formed as a merger of two major steelmakers in 2016 and had 58 mt of crude steel production capacity that year. It has since tripled in size and became in 2020 the world's biggest steel producer.[171] A neutrality pledge may be one further way for the company to consolidate its claim to sector leadership, as suggested by interviewee Li Hongmei of the steel trade publication Mysteel Global. In addition, chairman Chen Derong's pre-Baowu career as a provincial bureaucrat may encourage an approach that is even more politically motivated than his counterparts at other firms. As for HBIS and Anshan, they may have felt pressure to follow Baowu's example with pledges of their own.

Interviews with sector specialists, as well as a review of firm statements about their road to neutrality, also highlight several features of the steel sector that may make it both easier and more appealing for firms to announce long-term commitments to emissions reductions. Some of these features are structural aspects of the demand for Chinese steel products. For instance, one senior Chinese energy-sector expert interviewed suggested that continued debates within China about securing reliability and meeting growing demand in a decarbonized electricity system complicate the issuance of net-zero pledges by electricity generators at this stage.[172] Steel and cement sector transitions, like electricity generation, involve tricky decisions around worker employment, asset management, and community economic transitions. But there are no consumer-side pressures comparable to grid reliability, or even demand growth, that firms must weigh in their production choices.

Chinese steel firms also have a (moderately) more international demand footprint than either electricity generators or cement firms, exposing them more directly to the decarbonization goals of developed markets like the European Union. The EU is not a major source of demand; it takes only around 5 percent of Chinese steel exports, rising toward 10 percent for high-value stainless steel.[173] Surprisingly, though, firms profess to be taking note of the EU's growing ambition. *China Environment News*, citing Baowu representatives, claimed that that the company's pledge was motivated not just by the domestic neutrality target but also by international trends:

> Many foreign iron and steel firms are saying that they wish to achieve carbon neutrality in 2050. Many European Union clients have requested to Baowu that products have life-cycle assessment reports, and that firms want sustainable development reports and carbon emissions reduction roadmaps; otherwise, they will refuse to purchase.[174]

The EU's proposed carbon border adjustment tariff has also attracted the attention of Chinese steelmakers. Baowu, HBIS, and the China Iron and Steel Association (CISA), one of two major industry associations for the sector, have all mentioned this measure in public statements as a competitiveness challenge for which firms must prepare.[175]

Steel decarbonization may also benefit from a broader set of policy priorities unrelated to climate that incentivize greater scrap usage and electric arc furnace (EAF) deployment, changes that should lower the sector's emissions intensity. As explained earlier in the text box on steel emissions, the most carbon-efficient steel production today involves recycling scrap steel into new products through EAFs, and higher scrap shares in basic oxygen furnaces (BoFs) can reduce hot metal production demands from blast furnaces (BFs). The Chinese steel industry relies disproportionately upon the BF-BoF route, which enjoys a 90 percent share in production; expanding scrap use in BoFs and, more importantly, encouraging the displacement of BF-BoF facilities by EAFs using scrap will be a crucial tool for reducing steel's carbon emissions intensity. HBIS includes both of these approaches as part of its public plans for meeting its emissions reduction targets. It targets a 25 percent EAF capacity share and a 20 percent share of scrap steel in its BoFs by 2030. (They do not state current levels for either metric, so the gains implied may or may not be significant.) It also intends to develop a scrap automotive recycling hub with 5 million tons per annum (mtpa) capacity by 2025 and 10 mtpa by 2030 near their new EAF production hub in Shijiazhuang, developed in place of older BF-BoF facilities.[176]

Chinese steelmakers have two reasons to expand their use of scrap steel and EAFs. First, analysts foresee a surge in domestic scrap supply that should cut scrap prices, as buildings from China's late 20th century construction boom reach the end of their useful lives. A November 2020 Morgan Stanley report projected that China's annual end-of-life steel availability would double over the coming decade, driving scrap's share of Chinese iron supply from 20 percent to 30 percent and cutting total steel emissions by 8 percent.[177]

Second, expanded EAF usage aligns with national policy concerns around air quality and import reliance in strategic inputs. Scrap-heavy EAF production produces much less local air pollution than the BF-BoF route, particularly where EAFs do not rely upon electricity supply from local or captive coal power. As of 2017, the widespread adoption of ultra-low-emissions (ULE) retrofits within China's coal fleet had left steel (and specifically blast furnaces) as the largest industrial source of major air pollutants.[178] The steelmaking hubs of Hebei Province—the province surrounding Beijing, where HBIS is based—have been a particular focus for enforcement activities. Central pressures around air pollution forced Tangshan to introduce production curbs in 2019 and again this spring, and interviewee Li of Mysteel Global noted that HBIS's location intensifies the pressure it faces around air pollution mitigation.[179]

The CISA reports that around half of national steel capacity (620 mt) is undergoing its own ULE retrofits right now.[180] But China's capacity replacement regulations also incentivize EAF adoption by allowing new EAF projects of equal size to the BoFs they displace, as opposed to the net reductions (officially) required for new BoFs.[181] The MIIT's five-year road map for the industry, released in December 2020, targets increasing China's EAF share from 10 percent in 2019 to 15–20 percent in 2025, though some early signs are discouraging.[182] Global Energy Monitor's Global Steel Plant Tracker, an open-source database of steel plants around the world, identifies 39 mtpa of BF-BoF crude steel production capacity currently under construction in China, as opposed to just 3 mtpa of EAFs.[183] (The tracker only covers plants with 1mtpa of capacity.)

As for input self-sufficiency, Chinese steelmaking relies heavily upon iron ore imports, which comprise around 80 percent of national supply.[184] More than 80 percent of these imports come from a single country, Australia.[185] Such import reliance exposes Chinese steel producers to global iron ore price volatility but also to geopolitical risks from souring China-Australia relations.[186] The MIIT's industry road map calls for China to achieve 45-plus percent self-sufficiency in iron supply for steelmaking by 2025 through expanding its equity holdings in overseas iron ore mines and increasing domestic scrap steel production to 300 mtpa, up around 25 percent from 2019 levels. It further specifies a 30 percent target share for scrap steel in China's iron supply for steelmaking in 2025, a target that would entail faster emissions intensity declines than those projected by the Morgan Stanley report cited above.[187] These efforts all fit neatly into China's larger "dual circulation" development strategy that emphasizes strengthening domestic economic networks and reducing vulnerability to international economic coercion.[188]

Beyond scrap, deep decarbonization efforts in steel also intersect with the hydrogen economy, a high-buzz sector that a number of Chinese steel majors are examining.[189] The past three years have seen a surge of interest from Chinese authorities in hydrogen infrastructure development. Chinese energy-sector expert (and CGEP nonresident fellow) Kevin Tu has counted 37 hydrogen-related policies issued by central and local governments in the first six months of 2020 alone.[190] Hebei Province is one of a number of provinces who have participated in this wave,[191] and so it is perhaps no surprise that HBIS, owned by Hebei authorities, is planning projects for hydrogen steelmaking. The Hebei Province Development and Reform Commission's 2020 list of hydrogen projects included an HBIS project to be completed in 2021 that intends to produce 3,000 kg/day of hydrogen from coke oven gas, a by-product of coke production.[192] More recently, HBIS's neutrality pledge announcement included plans to develop 3.6 mtpa of "hydrogen metallurgy" capacity by 2025.[193] One-sixth of that capacity is specified as coming from a DRI facility under construction that uses hydrogen-rich coke oven gas and, per its Italian developer Tenova, will have a final carbon footprint of less than 0.3 tCO_2/ton.[194] HBIS expects to obtain the balance (3 mtpa) from facilities using hydrogen produced via renewable electricity, though they do not specify whether those facilities will be DRI plants or blast furnaces.

HBIS is not the only Chinese net-zero pledger with a strong interest in hydrogen. It is also prominent in Sinopec's pledge. The company is already a major hydrogen producer, accounting for 15 percent (3.5 mt) of China's production.[195] In its net-zero announcement, it reported that it would build 1,000 hydrogen or combined hydrogen-gasoline refueling stations by 2025, up from the 10 it currently has built today, and "build 'China's biggest hydrogen company.'"[196]

Deep decarbonization in steelmaking involves boosting scrap and EAF shares and establishing a supply chain of low-carbon hydrogen. Policy maker pressure and shifting market conditions give Chinese steel majors reasons beyond carbon management to signal interest today in all of these steps—regardless of how much progress they have made in building carbon management capacity and outlining a feasible pathway to net zero. HBIS's neutrality plan was released the day after a central government inspection team visited Tangshan and found an HBIS subsidiary among four firms violating restrictions around production in high-pollution periods.[197] Baotou is a provincial SOE in Inner Mongolia, and its net-zero pledge comes against the backdrop of enormous central pressure on the province to end its economic reliance on energy-intensive, high-pollution heavy industry.[198]

The net-zero pathways that do emerge will require more than just EAFs using scrap steel and DRI from low-carbon hydrogen. (Not that we should assume that China's hydrogen supply will be low carbon anytime soon: conventional hydrogen production is carbon intensive, and Sinopec's net-zero announcement, for example, contained little detail on its timeline for decarbonizing its hydrogen production.)[199] IEA data indicates that China's enormous blast furnace fleet has an average age of just 12 years, in comparison to these facilities' typical lifetime of 40 years.[200] Decarbonizing the portions of this fleet that adapt to China's future demand declines will require significant deployment of CCUS. This set of technologies, like green hydrogen, has yet to prove commercial viability outside of niche applications like oil and gas extraction.[201] Unlike green hydrogen, however, CCUS has remained stuck at this stage for at least a decade, and it does not enjoy the intense enthusiasm from local Chinese authorities that hydrogen has experienced in recent years.[202] Baowu is conducting pilot work at its Xinjiang subsidiary around capturing and reusing by-product blast furnace gas, but targeted emissions cuts at its current stage of development are modest.[203]

CCUS will also be crucial for decarbonization in cement. So, too, will accelerating development and deployment of new cement compositions that can reduce clinker-to-cement ratios or sequester carbon as part of their curing process. Many of these proposed compositions either have niche applications or remain at demonstration or R&D stages. Low-clinker formulations using limestone and calcined clay have demonstrated commercial viability elsewhere, but raw materials availability for these types of cement within China remains under debate.[204]

Cement as a whole has a somewhat more limited array of areas where short-term policy priorities in China intersect neatly with the needs of deep decarbonization. The expansion of "alternative fuels" (AFs)—process-heating replacements for coal like waste materials and biomass—stands out as one exception here. Existing Chinese cement-sector policy already encourages the expansion of AF coprocessing capabilities in cement, citing its circular-economy merits for waste management.[205] A sector participant interviewed noted that cement majors have also investigated alternative fuels as a way to reduce exposure to coal price fluctuation.[206] But China's alternative fuel shares in cement thermal energy input are generally estimated at around 2–3 percent, in contrast to the EU's 2014 average of around 40 percent.[207]

The China Building Materials Federation's 2020 sector emissions report's list of "key peaking actions" includes improving technology R&D and government support for waste coprocessing in cement as part of broader "energy structure adjustment" across the sector.[208] Achieving 50 percent AF shares, with the optimistic assumption of net-zero biomass use, would position firms to reduce their carbon intensity somewhere around 15 percent.[209]

CONCLUSION

The 30-60 targets have significantly elevated the standing of carbon management in Chinese policy priorities. The country has adopted national targets for carbon emissions intensity reduction since the late 2000s but has achieved those targets as an adjunct to more immediate policy priorities: energy efficiency, infant-industry promotion, and air quality improvement. The new targets have turned carbon management itself into a stand-alone policy focus area of real significance to the central leadership. Peaking and neutrality work feature among China's eight "key tasks" for economic policy in 2021, and Xi himself stated in mid-March 2021 that the realization of these targets would be "a great test of our party's ability to govern the nation."[210]

Limited engagement with carbon management in Chinese policy before the 30-60 targets was mirrored among Chinese firms in high-emitting sectors. Among China's biggest firms in coal generation, cement, and steelmaking, no domestic firm had issued any formal targets for reducing their carbon emissions footprints. The new national targets have forced firms and industry associations to examine emissions footprints and levers for decarbonization more closely. Formal target setting thus far remains limited to peaking pledges from a handful of sector-leading firms as well as steel and cement industry associations and regulators. Only three of the Chinese majors reviewed—top steel producers Baowu and HBIS as well as coal giant CEIC—had issued long-term net-zero targets as of the start of July 2021. This cautious response reflects in part the capacity building required around carbon management for firms that have never engaged with these issues beyond reporting requirements and carbon trading compliance. But key policies that will inform firms' own emissions reduction trajectories—around national peaking timelines, for instance, and provincial development plans—remain in formation, to be published later this year or next. Sector-leading central SOEs may face expectations to set examples; their smaller colleagues have more space to wait or allow authorities to set out more detailed frameworks for target setting, akin to the annual energy consumption mandates of the Top-1000 and Top-10,000 programs.

Nonetheless, targets announced thus far do offer clues about the import of the 30-60 targets for the country's biggest emitting sectors. In coal generation, targets from China's biggest coal power companies suggest that they view the coming five years as a final window for coal capacity additions and as a major period for investment in new low-carbon capacity. Meeting firms' targets for hundreds of new gigawatts of renewable or low-carbon energy will require these SOEs to diversify their zero-carbon generation portfolios and finally enter the solar market. It will also require continued progress in institutional reforms in China to build a grid better suited to the renewables age.

In cement and steel, meanwhile, proposed peaking targets for 2023 and 2025, respectively, give several years to absorb additional demand from China's post-COVID stimulus, and production volumes will be key to determining emissions trajectories in both sectors over the coming decade. Meanwhile, greater ambition from central SOEs in the steel sector highlights forces unrelated to carbon management itself—policy maker demands around strategic input independence, for instance, and structural aspects of the steel market like its shrinking demand footprint—that make long-term decarbonization pledges of particular interest.

This report serves as an initial assessment of firms' responses to the 30-60 targets, formed as many firms make their first substantive forays into carbon management and as officials continue to hash out a host of key policies for China's near-term climate ambitions. The targets announced thus far may be in line with China's aim of peaking emissions by 2030. But delivering neutrality by 2060 is a far more demanding task and will require much greater ambition.

More targets may be announced as these policies emerge. But it is crucial to remember throughout that targets are not emissions reductions. They can help firms attain reductions, but they can also greenwash inaction. Officials, investors, and stakeholders in China and elsewhere must hold firms to the goals they set and push firms to raise their ambition to leave the world any hope of success against the climate crisis.

APPENDIX: SOURCES

Tables in this report draw upon a series of major sources, listed below in sections A–D. (National-level data excludes Hong Kong and Macau.) Section E lists interviews conducted.

A. Emissions

Chinese and World GHG Emissions (Table 1)

The World Resources Institute's Climate Indicators Analysis Tool (CAIT) uses estimates from a variety of sources, including national reports to the UN Framework Convention on Climate Change, International Energy Agency (fuel combustion), and the Carbon Dioxide Information Analysis Center (cement).

- World Resources Institute, Climate Analysis Indicators data set, Climate Watch platform, 2021, available at https://www.climatewatchdata.org/ghg-emissions.
  - For the detailed methodology, see World Resources Institute, "CAIT Country Greenhouse Gas Emissions: Sources & Methods," June 2015, accessed May 11, 2021, available at http://cait.wri.org/docs/CAIT2.0_CountryGHG_Methods.pdf.
  - Data sources include the IEA's fuel combustion emissions data set: CO_2 Emissions from Fuel Combustion, OECD/IEA, 2021.

Firm Emissions (Table 4)

Firm emissions were identified from 2019 corporate annual reports and (where available) ESG reports. For firms that did not report emissions at a group level and had public subsidiaries active in the relevant sector (electricity, steelmaking, or cement), annual and ESG reports from the largest relevant public subsidiary (by total assets) were also reviewed.

Annual reports were sourced from S&P Global NetAdvantage. ESG reports examined are cited below; they were taken from company websites and, for listed companies, stock exchange disclosure records.

Reported Emissions

- China National Building Material Group Co. Ltd., *2019 Sustainability Report*, accessed May 11, 2021, 40, https://www.cnbm.com.cn/skin/model/202012031153537290.pdf.
- Anhui Conch Cement Company Limited, *2019 Social Responsibility Report*, accessed May 11, 2021, 61, http://www.conch.cn/cn/web/viewer.html?file=../../ uploadfiles/2020/03/2019%E5%B9%B4%E5%BA%A6%E7%A4%BE%E4%BC%9A%E8%B4%A3%E4%BB%BB%E6%8A%A5%E5%91%8A.pdf.
- China Resources Cement Holdings Limited, *2019 Annual Report*, 88.

- China Shanshui Cement Group Limited, *2019 Environmental, Social, and Governance Report* (環境、社會及管治報告), accessed May 11, 2021, 11, http://www.sdshanshuigroup.com/Static/attachment/2020-07-01/5efbdae00712d.pdf.
- China Tianrui Group Cement Company Limited, *Environmental, Social, and Governance Report 2019*, accessed May 11, 2021, 7, http://www.trcement.com/release/ESG%20Report%202019%20Tianrui%20Eng%20D6_clear.pdf.
- Asia Cement (China) Holdings Corporation, *Corporation Social Report*, 2019, accessed May 11, 2021, 22, https://csr.acc.com.tw/en/files/2019--Asia%20Cement%20China%20CSR%20report.pdf.

Reported Emissions (Firm Subsidiaries)

- China Hongqiao Group Limited, Environmental, Social, and Governance Report 2019, accessed May 11, 2021, 46, http://en.hongqiaochina.com/Uploads/File/2020/07/06/E1378-ESG.20200706180057.pdf.
  - The relationship between China Hongqiao Group and the Shandong Weiqiao group of companies was assessed through a review of China Hongqiao's 2019 annual report (China Hongqiao Group Limited, *Annual Report 2019*, 14, 18–21, 80, and passim); listings of Chinese companies held by Hongqiao chairman Zhang Bo 张波 and his late father Zhang Shiping 张士平 on corporate records database Aiqicha 爱企查; and media coverage of the company citing GEM staff (Ben Heubl, "Investigation: Can China Clean Up after the Aluminium King?," *Engineering & Technology*, February 11, 2021, accessed May 20, 2021, https://eandt.theiet.org/content/articles/2021/02/can-china-clean-up-after-the-aluminium-king/). China Hongqiao Group Limited's parent is China Hongqiao Holdings Limited, a BVI-listed company for which the author was not able to obtain corporate records. Aiqicha records indicate that Zhang Bo and Zhang Shiping are likely also the largest shareholders in Shandong Weiqiao Pioneering, identified as a related company in Hongqiao's 2019 annual report (14).
- China Shenhua Energy, *2020 Environmental, Social Responsibility, and Firm Governance Report*, accessed May 12, 2021, 94, http://www.csec.com/zgshwwEn/csrrpt2020/202103/72e4f8a7bfa94686b23cacbdf7c2ca87/files/ba0dc29d97e04253afc4e850db3d15ea.pdf.
  - **Asset shares:** China Shenhua Energy Company Limited, *2019 Annual Report*, 189; China Energy Investment Group Company Limited, *Corporate Securities Annual Report (2019)* (公司债券年度报告（2019年）), 22.
- Datang International Power Generation Co. Ltd, *2019 Social Responsibility Report*, accessed May 12, 2021, 46, https://photos.prnasia.com/prnk/20200330/2763952-1.
  - **Asset shares:** Datang International Power Generation Co. Ltd, *2019 Annual Report*, p. 97; China Datang Corporation Ltd., *Corporate Securities Annual Report (2019)* (公司债券年度报告（2019年）), 37.

- Huadian Power International Corporation Limited, *2019 Social Responsibility Report (ESG Report)* (2019年社会责任报告（ESG报告）), accessed May 11, 2021, 42, http://www.hdpi.com.cn/webfront/fileDownLoad.do?fileId=88640.
  - **Asset shares:** Huadian Power International Corporation Limited, *2019 Annual Report*, 51; China Huadian Corporation Ltd., *Corporate Securities Annual Report (2019)* (公司债券年度报告（2019年）), 26.
- China Power International Development Limited, *2019 Sustainable Development Report* (2019年可持续发展报告), accessed May 11, 2021, 30, https://doc.irasia.com/listco/hk/chinapower/annual/2019/scesr.pdf.
  - **Asset shares:** China Power International Development Limited, *2019 Annual Report*, p. 97; State Power Investment Corporation Limited, *Corporate Securities Annual Report (2020)* (公司债券年度报告（2020年）), 65.
- Hunan Valin Steel Co. Ltd., *2019 Annual Report* (2019年年度报告), 41.
  - **Asset shares:** Hunan Valin Steel Co. Ltd., *2019 Annual Report* (2019年年度报告), 79; REANDA International, *Hunan Valin Iron and Steel Group Audit Report: 2019* (湖南华菱刚体集团有限责任公司：审计报告：2019年度) p. 5.

ESG Reports Reviewed with No Reported Emissions

- **Electricity**
  - China Energy Investment Corporation, *2019 Social Responsibility Report*（2019年社会责任报告), accessed May 11, 2021, https://www.ceic.com/gjnyjtww/chnzrbg/202006/45bf3dcf0c0e4f6b8dd0c8a7150008c2/files/7ab50447caf64115a67130ddd8bdb542.pdf.
  - China Huaneng Group Co. Ltd., *2019 Sustainable Development Report* (2019年可持续发展报告), accessed May 11, 2021, https://www.chng.com.cn/documents/20181/0/2bb9c201-64ce-46cf-8601-5ab8f3cc0978.pdf.
  - China Huadian Corporation Ltd., *Sustainability Report 2019* (2019年度可持续发展（社会责任）报告), accessed May 11, 2021, http://www.chd.com.cn/webfront/doFileDownload.do?serviceId=articleAttach_20201127142511.
  - China Datang Corporation Ltd., *2019 Social Responsibility Report* (2019年社会责任报告), accessed May 11, 2021, https://news.bjx.com.cn/html/20200727/1092345.shtml.
  - State Power Investment Corporation Ltd., Green Development: *2019 Corporate Social Responsibility Report* (卢瑟发展：企业社会责任报告・ 2019), accessed May 11, 2021, http://sp.spic.com.cn/shzrbg.zip.
  - China Resources Power Holdings Company Ltd., *2019 Sustainable Development Report* (可持续发展报告2019), accessed May 11, 2021, https://www.cr-power.com/duty/kcxfzbg/202005/P020200720559605593328.pdf.

- Zhejiang Provincial Energy Group Company Ltd., *2019 Corporate Social Responsibility Report* (2019社会责任报告), accessed May 11, 2021, http://www.zjenergy.com.cn/ZNWW/upload/files/2020/11/6c221dac285c2402.pdf.

- Guangdong Energy Group, *2019 Social Responsibility Report*, accessed May 11, 2021, http://www.geg.com.cn/ydqk/YdqkWS/book/shzr_2019/index.html.

- Beijing Jingneng Power Co. Ltd., *2019 Corporate Social Responsibility Report* (2019年社会责任报告), accessed May 11, 2021, http://www.sse.com.cn/assortment/stock/list/info/announcement/index.shtml?productId=600578.

- **Steelmaking**

  - Baoshan Iron & Steel Co., Ltd., *2019 Sustainable Development Report* (2019可持续发展报告), accessed May 11, 2021, http://res.baowugroup.com/attach/2020/07/23/ab36d2add8f34eda8ffbfec4f4c0c3b8.pdf (the largest public subsidiary of Baowu).

  - HBIS Company Ltd., *2019 Social Responsibility Report* (2019年度社会责任报告), accessed May 11, 2021, http://www.hebgtgf.com/download.do?fileid=559a7f47-546d-4359-9870-0dc819917b58 (the largest public subsidiary of HBIS).

  - Ansteel Group Corporation Limited, *2019 Sustainability Report*, accessed May 11, 2021, http://en.ansteel.cn/upload/pdf/2019.pdf.

  - Beijing Jianlong Heavy Industry Group Co, *Sustainable Development Report 2019* (2019年可持续发展报告), accessed May 11, 2021, http://www.ejianlong.com/social/report. (The author did not identify any public subsidiaries of this company.)

  - Beijing Shougang Co. Ltd., *2019 Environmental Responsibility Report* (2019年度环境责任报告书), accessed May 11, 2021, http://www.sggf.com.cn/downdoc.jspx?cid=3152 (the largest public subsidiary of Shougang Group).

  - Shandong Iron & Steel Co. Ltd., *2019 Social Responsibility Report* (2019年社会责任报告), accessed May 11, 2021, http://www.sse.com.cn/disclosure/listedinfo/announcement/c/2020-03-20/600022_20200320_25.pdf (the largest public subsidiary of Shandong Iron and Steel Group).

  - Fangda Specialty Steel Co. Ltd., *2019 Social Responsibility Report* (2019年度社会责任报告), accessed May 11, 2021, http://www.sse.com.cn/assortment/stock/list/info/announcement/index.shtml?productId=600507 (the largest public steelmaking subsidiary of Liaoning Fangda Group).

- **Cement**

  - Tangshan Jidong Cement Co. Ltd., *2019 Social Responsibility Report* (2019年度社会责任报告), accessed May 11, 2021, http://www.szse.cn/disclosure/listed/bulletinDetail/index.html?2ff3281e-402f-4eb1-834c-e7a05ba4909d.

  - Huaxin Cement Co. Ltd., *2019 CSR Report* (2019企业社会责任报告),

accessed May 11, 2021, http://static.sse.com.cn/disclosure/listedinfo/announcement/c/2020-04-29/600801_20200429_13.pdf.

Firms with No Emissions Reports in Annual Reports and for Which No ESG Reports Could Be Identified

No ESG reports from 2019 could be found on either company websites or (where applicable) stock exchange disclosure records for the following firms:

- **Electricity**
  - Zhejiang Zheneng Electric Power Co. Ltd., the largest public subsidiary of Zhejiang Provincial Energy Group
  - Guangdong Electric Power Development Co. Ltd., the largest public subsidiary of Guangdgong Energy Group[211]
  - Beijing Energy Group
- **Steelmaking**
  - Jiangsu Shagang Co. Ltd., the largest public subsidiary of Jiangsu Shagang Group
  - Shougang Group
  - Shandong Iron and Steel Group
  - Hunan Valin Iron and Steel Group[212]
  - Bengang Group or its largest public subsidiary, Benxi Steel Plates Co. Ltd.
  - Liaoning Fangda Group
- **Cement**
  - Hongshi Holdings Group

B. Electricity

National Data (Tables 2–3, 5–6)

National data on installed capacity composition was taken from the CEC, China's national electricity industry association.

- *2017 and earlier:* China Electricity Council, "Data Report Table of Basic Electricity Statistics for 2017" (2017年电力统计基本数据一览表), October 9, 2018, accessed May 11, 2021, https://cec.org.cn/detail/index.html?3-126875.
- *2019 and 2020:* China Electricity Council, "Data Report Table of National Electricity Industry Statistics for 2020" (2020年全国电力工业统计快报数据一览表), January 22, 2021, accessed April 23, 2021, https://www.cec.org.cn/detail/index.html?3-292820.

- *2020 coal:* China Electricity Council, "Report on 2020–2021 National Electricity Supply and Demand Situation, Analysis, and Forecast") (2020 - 2021年度全国电力供需形势分析预测报告), February 2, 2021, accessed April 22, 2021, https://www.cec.org.cn/detail/index.html?3-293198.

Official Firm Data (Tables 2–3, 5–7)

Official firm data on 2019 installed capacity composition was taken from corporate environmental, social, and governance (ESG) reports. (Reports on 2020 were not uniformly available as of the preparation of this report.) Firms generally break out capacity by thermal, hydropower, solar, wind, and, where appropriate, nuclear; details on thermal resource composition across coal, gas, oil, and biomass are not uniformly available.

Among firms that had published their 2020 ESG reports as of the preparation of this report, several did state 2020 coal installed capacity. Their 2020 ESG reports are also listed below.

- China Energy Investment Corporation, *2019 Social Responsibility Report* (2019年社会责任报告), accessed May 11, 2021, 43, https://www.ceic.com/gjnyjtww/chnzrbg/202006/45bf3dcf0c0e4f6b8dd0c8a7150008c2/files/7ab50447caf64115a67130ddd8bdb542.pdf; China Energy Investment Corporation, *2020 Social Responsibility Report* (2020年社会责任报告), accessed June 28, 2021, 9, 40, https://www.ceic.com/gjnyjtww/chnzrbg/202105/0cd2c68c8f0a4e94b594643557eeb0c6/files/fb06d2c1fb2e44239cff2f9d5f0e8100.pdf.
- China Huaneng Group Co. Ltd, *2019 Sustainable Development Report* (2019年可持续发展报告), accessed May 11, 2021, 84–85, https://www.chng.com.cn/documents/20181/0/2bb9c201-64ce-46cf-8601-5ab8f3cc0978.pdf.
- China Huadian Corporation Ltd., *Sustainability Report 2019* (2019年度可持续发展（社会责任）报告), accessed May 11, 2021, 44, http://www.chd.com.cn/webfront/doFileDownload.do?serviceId=articleAttach_20201127142511.
- China Datang Corporation Ltd., *2019 Social Responsibility Report* (2019年社会责任报告), accessed May 11, 2021, 7, https://news.bjx.com.cn/html/20200727/1092345.shtml.
- State Power Investment Corporation Ltd., *Green Development: 2019 Corporate Social Responsibility Report* (卢瑟发展：企业社会责任报告・ 2019), accessed May 11, 2021, 7–18, http://sp.spic.com.cn/shzrbg.zip; *2020 Corporate Social Responsibility Report* (企业社会责任报告), accessed May 21, 2021, 12–13, http://sp.spic.com.cn/shzr/2020/%E4%B8%AD%E6%96%87%E5%AE%A3%E4%BC%A0%E5%86%8C.pdf.
- China Resources Power Holdings Company Ltd., *2019 Sustainable Development Report* (可持续发展报告2019), accessed May 11, 2021, 33, https://www.cr-power.com/duty/kcxfzbg/202005/P020200720559605593328.pdf; China Resources Power Holdings Company Ltd., *2020 Sustainable Development Report* (可持续发展报告2020), accessed June 28, 2021, 20, https://www.cr-power.com/duty/kcxfzbg/202104/P020210429759401739293.pdf.

- Zhejiang Provincial Energy Group Company Ltd., *2019 Corporate Social Responsibility Report* (2019社会责任报告), accessed May 11, 2021, 25, 29, http://www.zjenergy.com.cn/ZNWW/upload/files/2020/11/6c221dac285c2402.pdf.

Breakouts were not available for Beijing Energy Group. The author was unable to identify a single corporate parent as a source of centralized reporting for capacity across the Shandong Weiqiao group of companies, controlled by the late entrepreneur Zhang Shiping and his family. The author reviewed annual reports and websites from two major members, China Hongqiao Group and Shandong Weiqiao Pioneering Group, and was unable to identify breakouts.

Firm Coal Capacity Data (Unofficial) (Tables 2 and 6)

Global Energy Monitor's Global Coal Plant Tracker (GCPT) reports global ownership of coal plants greater than 30 MW based upon open-source research and is the best public, nonsubscription plant-level database of corporate coal capacity in China. They report 1,043 GW of coal capacity as of January 2021 in China. The China Electricity Council, China's national electricity industry association, reported 1,080 GW of coal capacity in China as of the end of 2020. The database records firm-level investment shares (as well as parent total investment shares, where subsidiaries are the direct investors).

The author was unable to identify from GCPT's website the specific criteria by which it determines ownership.

- Global Energy Monitor, Global Coal Plant Tracker, Global Ownership of Coal Plants (MW), January 2021, accessed April 21, 2021, https://docs.google.com/spreadsheets/d/1bcWh2stWSwRdxAP-ot78sbMkXUcPwfS7HMJhFZ9jECw/edit?usp=sharing.

C. Steelmaking and Cement

National Output and Export Shares (Charts 1 and 2 and passim)

Data on steel and cement output and exports are sourced from the National Bureau of Statistics.

- National Bureau of Statistics, Annual Data, Industry: Industrial Product Output Volume (工业：工业产品产量), items "Cement Production Volume (10,000 Tons)" (水泥产量 （万吨））and "Crude Steel Production Volume (10,000 Tons)" (粗钢产量（万吨）), years 2004–19, accessed June 28, 2021, https://data.stats.gov.cn/easyquery.htm?cn=C01&zb=A0E0H&sj=2020.

- National Bureau of Statistics, "Annual Data, International Economic Trade: Exports Volumes and Values for Main Goods: Export Volumes for Main Goods" (对外经济贸易：出口主要货物数量和金额：主要货物出口数量), items "Cement and Cement Clinker Export Volumes (10,000 Tons)" (水泥及水泥熟料出口数量（万吨））and "Steel Materials Export Volumes (10,000 Tons)" (钢材出口数量（万吨）), years 2004–19, accessed May 11, 2021, https://data.stats.gov.cn/easyquery.htm?cn=C01&zb=A0E0H&sj=2020.

Firm-Level Crude Steel Output and Firm-Level & National Installed Clinker Capacity (Table 3)

Data on firm-level crude steel output in 2019 is taken from worldsteel. (Data on 2020 was not available as of the preparation of this report.) Data on installed clinker capacity in 2020 is taken from the China Cement Association.

- **Firm-Level Steel Output:** worldsteel, "World Steel in Figures 2020," accessed April 21, 2021, https://www.worldsteel.org/en/dam/jcr:f7982217-cfde-4fdc-8ba0-795ed807f513/World%2520Steel%2520in%2520Figures%25202020i.pdfw.

- **Firm-Level Clinker Capacity:** CCA, "China Cement Association Announces the Top-50 Firms by Clinker Capacity in 2021" (中国水泥协会公布2021年水泥熟料产能50强名单), March 25, 2021, accessed June 25, 2021, http://www.dcement.cn/Item/171108.aspx.

- **National Clinker Capacity:** Chen Bolin, "Chinese Cement Industry 2020 Economic Performance and 2021 Forecast" (2020年中国水泥行业经济运行及2021年展望), Digital Cement (数字水泥网), February 2, 2021, accessed April 22, 2021, http://www.dcement.com/Item/169754.aspx. (Digital Cement is an industry news and information portal operated by the CCA, and Chen Bolin was CCA vice secretary at the time of this document's publication.)

D. Corporate Targets

Emissions Reduction Targets (Table 5)

The following documents contain information on emissions reductions set by the Chinese firms examined in this report. In each case except for Taiwan Cement, they have been identified as the first public announcements of these targets on corporate WeChat channels.

- **Electricity**
  - **CEIC:** "China Energy Investment Corporation Party Committee Transmits, Studies, and Implements the Spirit of the Central Economic Work Conference" (国家能源集团党组传达学习贯彻中央经济工作会议精神), CEIC WeChat channel (国家能源之声), December 20, 2020, accessed May 11, 2021, https://mp.weixin.qq.com/s?__biz=MjM5MTE2MDk0OA==&mid=2650356983&idx=1&sn=0b8b0e9cc455d5a319860 1711d2c 2361&chksm=beb453ec89%20c3dafa2 70e609d529ce0da13012eac350487d3aaed25563f10e44f442509c8b21f#rd.
  - **Huadian:** "Part 2 of the Report Series The Unchanging Foundation Is Struggle, on Development: Steady Helm, Striving Oar, and Moving Forward in High Spirits" (【"不变的底色是奋斗" 系列报道之二 · 发展篇】稳舵奋楫势昂扬), Huadian WeChat channel (中国华电), January 28, 2021, accessed April 28, 2021, https://mp.weixin.qq.com/s?__biz=MzA5Mjk3MDg2MQ==&mid=2652663697&idx=1&sn=a84 1d24e4ac7c5d6b3a2ecb0ef23391f&chksm=8b8dc593bcfa 4c854ac6612854e417a07aac018c1f91e52f3776f392377679d3c65a14960a17#rd.

- **Datang:** "Launching a Second New Innovation Journey | China Datang Holds Its 2021 Work Meeting" (开启二次创业新征程｜中国大唐集团召开2021年工作会议), China Datang WeChat channel (中国大唐集团公司), accessed April 28, 2021, https://mp.weixin.qq.com/s/Exvyq8gCoUfPkjVjitVOLA; "Understand in One Image | China Datang Carbon Peaking and Carbon Neutrality Action Plan Outline" (一图读懂｜中国大唐碳达峰碳中和行动纲要), China Datang WeChat channel (中国大唐集团公司), accessed July 2, 2021, https://mp.weixin.qq.com/s?__biz=MzA4NDY4MzkyNA==&mid=2654066687&idx=2&sn=611b10b54df4a746f87fed3359f70999&chksm=84260a04b351831293a3f7dd644e5ef44a61acccac829ebb45d681e5e34ef36b7213054d8fc8#rd.
- **SPIC:** "Qian Zhimin: The Era of the Major Green, Smart Energy Brand Has Arrived" (钱志民：绿色智慧能源大品牌时代来了), SPIC WeChat channel (国家电力投资集团有限公司), December 8, 2020, accessed April 28, 2021, https://mp.weixin.qq.com/s/t01uPxjsKGAa7838v7rq2Q.
- **China Resources:** "Net Profits Surge 43.8% in New Energy Business, China Resources Electric Power's Net Earnings Were HKD 7.583 bn Last Year" (新能源业务净利润劲增43.8%，华润电力去年净赚75.83亿港元), China Resources WeChat channel (华润), March 18, 2021, accessed May 11, 2021, linked here.

- **Cement**
  - **Taiwan Cement:** Taiwan Cement Corporation, "TCC Commitment to Carbon Neutrality in 2050," accessed May 11, 2021, https://www.taiwancement.com/en/esgGhgCarbonEmissions.html; Taiwan Cement Corporation, 2020 Corporate Sustainability Report, accessed July 2, 2021, https://www.taiwancement.com/en/csrReportRead.html?ch=all.

- **Steelmaking**
  - **Baowu:** "Major News | A Carbon Emissions Declaration from the World's Biggest Steel Firm, China Baowu: Aiming for 'Carbon Peaking' in 2023 and for Achieving 'Carbon Neutrality' in 2050" (重磅 | 全球最大钢企中国宝武碳减排宣言：力争2023年"碳达峰"2050年实现"碳中和"), Baowu WeChat channel (中国宝武), January 20, 2021, accessed April 28, 2021, https://mp.weixin.qq.com/s?__biz=MjM5MDEzNzA5Ng==&mid=2654852246&idx=1&sn=d479656526315c56691b0101482a16af&chksm=bd801af18af793e733b0f5cdd0d7d101eef0150feb831bddf9d705673f715b6128e57e0619d0#rd.
  - **HBIS:** "HBIS Announces Low-Carbon Green Development Action Plan" (河钢集团发布低碳绿色发展行动计划), HBIS WeChat channel (河钢集团), March 12, 2021, accessed May 11, 2021, https://mp.weixin.qq.com/s__biz=MzA5MjA2Mjk3MA==&mid=2653109712&idx=1&sn=9539988bd1af53094e892177fc7752db&chksm=8ba54845bcd2c1533f04fc3a53789adb1e68c0dc5c3674a4007aea087b970cbaa2de89d27e83#rd.

Other Targets (Table 7)

Electricity: Many of the sources in section D, part 1 above describe targets for "renewable," "nonfossil," "low-carbon," or "clean" energy capacity expansion during the coming 5–10 years. The following sources describe targets not already in those sources:

- **CEIC:** "CEIC Will Add 70–80 GW of Renewable Energy during the '14th Five-Year Plan'" (国家能源集团"十四五"新增7000 - 8000万千瓦可再生能源), CEIC WeChat channel (国家能源之声), December 18, 2020, accessed May 11, 2021, https://mp.weixin.qq.com/s?__biz=MjM5MTE2MDk0OA==&mid=2650356978&idx=1&sn=3599b8b1fe550e567430802f3cab0bb9&chksm=beb453e989c3daff5236d3df19968e73057df6fabd3a95e16c3e4159f9ead76708ff2f2d51b0#rd; "CEIC Holds Ecological and Environmental Protection Leading Small Group Meeting" (国家能源集团召开生态环境保护领导小组会议), CEIC WeChat channel (国家能源之声), January 6, 2021, accessed May 11, 2021, https://mp.weixin.qq.com/s?__biz=MjM5MTE2MDk0OA==&mid=2650357352&idx=2&sn=bb9c739a4aa3d6d0fac8d399d8c04c14&chksm=beb4517389c3d865de12898b7fe063542239086a39b33bcf5d44162919210a77531239961e37#rd.
- **Huaneng:** Huaneng, "Huaneng Holds 2021 Work Meeting: Aims at 6 Big 'New Leaderships,' Launches a Second New Innovation Journey" (华能召开2021年工作会议；锚定六大"新领先" 开启二次创业新征程), January 18, 2021, accessed May 11, 2021, http://www.chng.com.cn/detail_jtyw/-/article/ccgb60va5Gwc/v/905993.html.
- **Huadian:** Muyu Xu and Shivani Singh, "Exclusive: China Huadian to Shut 3 GW of Coal-Fired Power Capacity by 2025—chairman," March 8, 2021, accessed May 11, 2021, https://www.reuters.com/article/us-china-parliament-huadian-exclusive/exclusive-china-huadian-to-shut-3-gw-of-coal-fired-power-capacity-by-2025-chairman-idUSKBN2B00V1.
- **SPIC:** "Transcript of Carbon Neutrality Countdown" (《碳中和倒计时》文字实录), SPIC WeChat channel (国家电力投资集团有限公司), April 11, 2021, accessed June 27, 2021, available at https://mp.weixin.qq.com/s/DDPT-htTaKopToDCOS3rBg.
- **Zhejiang Energy:** "Zhejiang Energy Group Strives to Be a Pace-Setter in 'Carbon Peaking and Carbon Neutrality' Green Development" (浙能集团致力于打造"碳达峰碳中和"绿色发展"排头兵"), Zhejiang Energy WeChat channel (浙江能源), March 30, 2021, accessed May 11, 2021, https://mp.weixin.qq.com/s?__biz=MzA5OTg2MzIwOA==&mid=2658689626&idx=1&sn=672fb72e65c50b992c2465d3027bd5e6&chksm=8b771d9dbc00948b1328b2724b1f4ec3b520fb888c96d51398550407a90943d814b0763eba93#rd.
- **Beijing Energy:** Party Committee Propaganda Department, "Tender Won! A 400 MW Wind Base Project" (中标！400MW风电大基地项目), Beijing Energy WeChat channel (京能集团), December 12, 2020, accessed May 11, 2021, https://mp.weixin.qq.com/s/xFHsl9zLneB-QAWpGz9f3Q.

Steelmaking: HBIS supplemented its pledge announcement with additional details about related targets for 2025 as well as specific projects it seeks to pursue during the 2021–25 period.

- "Achieving Carbon Peaking in 2022: This Is How HBIS Will Do It" (2022年实现碳达峰 河钢集团这样"干"), World Metals Report WeChat channel (世界金属导报), March 14, 2021, accessed April 29, 2021, https://mp.weixin.qq.com/s?__biz=MzA5ODEzMjgwNA==&mid=2656702107&idx=2&sn=3c51e422b51f0cadcaf9abde2a802736&chksm=8b3898b0bc4f11a6cb6bc5dd965cdf302f974be42fc56fa184d1a6f8c8adaa65187267a6c86b#rd.

E. List of Interviewees

All interviews were conducted via video or cell phone calls. Interviewees are listed anonymously except for those who gave permission to be named.

1. Carbon market consultant at multinational firm, January 2021
2. Professor at Chinese university studying carbon markets, January 2021
3. Former Chinese government official, March 2021
4. Power sector consultant at multinational firm, March 2021
5. Former Chinese cement-sector executive, March 2021
6. Carbon market consultant #1 at Chinese firm, March 2021
7. Lucas Liutong Zhang, director, WaterRock Energy Economics, March 2021
8. Carbon market consultant #2 at Chinese firm, March 2021
9. Former Chinese energy-sector executive, March 2021
10. Metals and mining analyst at American financial research provider, March 2021
11. Researcher #1 at American university working on Chinese energy and heavy industry, March 2021
12. Researcher #2 at American university working on Chinese energy and heavy industry, March 2021
13. Researcher #3 at American university working on Chinese energy and heavy industry, March 2021
14. Head of cement-sector multinational firm's China office, March 2021
15. Karen Scrivener, full professor, Construction Materials Laboratory, École polytechnique fédérale de Lausanne, March 2021
16. Cement technology researcher at Chinese firm, March 2021

17. Partner at multinational consulting firm, April 2021
18. Partner at multinational consulting firm, April 2021
19. Li Hongmei, head of English Editorial, Mysteel Global, April 2021
20. Steel-sector editor at multinational trade publication, April 2021
21. Energy-sector researcher at Chinese think tank, April 2021
22. Financial analyst at American investment firm, May 2021

NOTES

1. "Statement by H. E. Xi Jinping President of the People's Republic of China at the General Debate of the 75th Session of the United Nations General Assembly," Ministry of Foreign Affairs of the People's Republic of China, September 22, 2020, accessed April 21, 2021, https://www.fmprc.gov.cn/mfa_eng/zxxx_662805/t1817098.shtml.

2. NRDC (National Development and Reform Commission of the People's Republic of China), "Enhanced Actions on Climate Change: China's Intended Nationally Determined Contribution," June 30, 2015, accessed April 21, 2021, https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/China%20First/China%27s%20First%20NDC%20Submission.pdf. The targets were formally submitted as Intended Nationally Determined Contributions and converted to Nationally Determined Contributions upon China's ratification of the Paris Agreement in September 2016. *Paris Agreement*, Paris, December 12, 2015, *United Nations Treaty Collection*, chap. 27, sec. 7.d, accessed April 21, 2021, https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27&clang=_en; Mengpin Ge and Kelly Levin, "INSIDER: What's Changing as Countries Turn INDCs into NDCs? 5 Early Insights," World Resources Institute, April 18, 2018, accessed April 21, 2021, https://www.wri.org/insights/insider-whats-changing-countries-turn-indcs-ndcs-5-early-insights.

3. Climate Analysis Indicators Tool (CAIT) data for 2018, accessed April 21, 2021, https://www.climatewatchdata.org/ghg-emissions. In 2018, GHG Chinese emissions comprised 26.9 percent of total global GHG emissions excluding land use, land-use change, and forestry (LULUCF).

4. Quantitative data came from a mix of Chinese government and industry associations as well as open-source databases, described in the appendix. The author identified corporate emissions reduction targets through keyword searches of corporate WeChat channels (Chinese firms); reviews of corporate websites and independent target-tracking databases (international firms); and examination of corporate ESG reports and annual reports (both Chinese and international firms). The author also performed a broader document review to establish context for firm behavior, examining policy documents from national government authorities; press releases and public statements from industry associations; and academic literature, research reports, and news articles. Expert interviewees included former senior executives at Chinese heavy industry and energy firms; sector researchers at Chinese government and corporate research institutes and at international research institutions; market participants, analysts, and consultants in Chinese heavy industry and energy; senior trade publication journalists in heavy industry; and a former Chinese government official.

5. See appendix, section B, part i.

6. Lauri Myllyvirta and Xinyi Shen, "China Plans to Cut Coal Heating Again, but Can It Avoid Another Crisis?," Greenpeace, October 1, 2018, accessed May 10, 2021, https://unearthed.

greenpeace.org/2018/01/10/china-coal-heating-winter-crisis-pollution/; Eric Yep and Cindy Liang, " China proposal to replace coal in over 7 million homes may boost winter LNG demand," S&P Global Platts, September 30, 2020, accessed August 5, 2021, https://www.spglobal.com/platts/en/market-insights/podcasts/focus/050621-costs-policy-competition-us-nuclear-generation.

7. Energy Foundation China, "China's New Growth Pathways: From the 14th Five-Year Plan to Carbon Neutrality," December 2020, accessed May 10, 2021, 43, https://www.efchina.org/Reports-en/report-lceg-20201210-en.

8. Peter Levi, Tiffany Vass, Hana Mandová, and Alexandre Gouy, "Tracking Industry 2020," IEA, June 2020, accessed May 2, 2021, https://www.iea.org/reports/tracking-industry-2020.

9. China National Building Materials Group chief engineer Peng Shou stated in March 2021 that the building materials industry comprised 20 percent of national emissions; official data from the China Building Materials Federation reports that cement was responsible for around 85 percent of sectoral emissions, or 1.32 billion tons of CO2, with more than 90 percent of those emissions from clinker production and coal combustion as opposed to electricity. China Building Materials Federation, "China Building Materials Industry Emissions Report (2020)" (中国建筑材料工业碳排放报告（2020年度）), Digital Cement WeChat channel (数字水泥网), April 19, 2021, accessed April 19, 2021, https://mp.weixin.qq.com/s?__biz=MzA5NjA4ODExNQ==&mid=2654118726&idx=5&sn=d5bf6337eb5fb1fb4446ce3a75698ffd&chksm=8b737a1abc04f30c5d378269ca13d93f7979fd8a8d5c0b422c7a182b7d159cdcab9d7b68a73c#rd (hereafter referred to as the "CBMF 2020 Emissions Report"). Steel industry representatives frequently state that the sector is responsible for more than 15 percent of national emissions. See, for instance, comments by China Iron and Steel President He Wenbo in March 2021. China Iron and Steel Association (hereafter referred to as "CISA"), "Committee Member He Wenbo Talks Hot Topics in the Steel Industry including Reducing Carbon Emissions and Controlling Production" (何文波委员谈碳减排、控产量等当前钢铁行业热点问题), CISA WeChat channel (中国钢铁工业协会), March 3, 2021, accessed March 12, 2021, https://mp.weixin.qq.com/s?__biz=MzAwNDMzMDQyMg==&mid=2650918057&idx=1&sn=15816fba86f6e5af4144137a7ac51ef6&chksm=80d8ea70b7af6366fc745a6ff0e13848e692f347b4e081cebd43970a980284ff86d04f04ffae#rd.

10. Calculated from 2017 data in Yuli Shan, Qi Huang, Dabo Guan, and Klaus Hubacek, "China CO_2 Emission Accounts 2016–2017." *Scientific Data* 7, no. 54 (2020), https://doi.org/10.1038/s41597-020-0393-y. "Smelting and pressing of ferrous metals" is estimated to account for 1,677 mt of CO_2 emissions (18.0 percent), while "nonmetal mineral products" are responsible for 1,171 mt (12.5 percent). The contents of these sections are defined in China's *Industrial Classifications for National Economic Activities* handbook. "Smelting and pressing of ferrous metals," in addition to steelmaking, also includes the production of other iron alloys. "Nonmetal mineral products," in addition to cement production, also includes several industries with more modest carbon footprints, including glass and ceramics manufacturing. See P.R.C. National Standard GB/T 4754-2017, *Industrial Classifications for National Economic Activities* (国民经济行业分类), effective October 1, 2017, accessed May 10, 2021, http://www.stats.gov.cn/tjsj/tjbz/hyflbz/201710/

P020180402592793000880.pdf.

11. The subsequent discussion of steelmaking processes relies upon Ali Hasanbeigi and Cecilia Springer, "How Clean Is the U.S. Steel Industry? An International Benchmarking of Energy and CO_2 Intensities," Global Efficiency Intelligence, November 2019, accessed May 11, 2021, 36–39, https://static1.squarespace.com/static/5877e86f9de4bb8bce72105c/t/602f46b2474168392c11e8c0/1613711096033/How+Clean+is+the+U.S.+Steel+Industry.pdf (hereafter referred to as "Hasanbeigi and Springer 2019") as well as worldsteel, "About Steel," accessed May 3, 2021, https://www.worldsteel.org/about-steel.html.

12. Hasanbeigi and Springer 2019, 22.

13. Orth et al. (2007) estimate that 70 percent of CO_2 emissions in the BF-BoF route come from blast furnace operation. Hasanbeigi and Springer (2019, 21) note that significance of fuel mixes in blast furnaces for determining carbon footprints; Canada and Mexico, which use large shares of natural gas in blast furnace reduction, have carbon emissions intensities of around 1.5 tC/ton.

14. See, e.g., Marcus Kirschen, Karim Badr, and Herbert Pfeifer, "Influence of Direct Reduced Iron on the Energy Balance of the Electric Arc Furnace in Steel Industry," *Energy* 36 (2011): 6146–55, 6148; Fan and Friedmann, 833.

15. For instance, Indian authorities' 2030 target emissions intensity for DRI-EAF/induction furnace production (2.6–2.7 tCO_2/ton) exceeds their targets for BF-BoF production (2.2–2.4 tCO_2/ton) because of the high footprint of coal-based DRI production. Ministry of Steel of the Government of India, "Template on INDC—Mitigation," accessed May 3, 2021, https://steel.gov.in/sites/default/files/TEMPLATES-%20MITIGATION_0.pdf.

16. Global Concrete and Cement Association, "About Cement & Concrete," accessed April 23, 2021, https://gccassociation.org/our-story-cement-and-concrete/.

17. International Energy Agency and the Cement Sustainability Initiative, "Technology Roadmap: Low-Carbon Transition in the Cement Industry," 2018, accessed May 10, 2021, 12, https://www.wbcsd.org/contentwbc/download/4586/61682/1.

18. The author reviewed a number of firm-level and sectoral estimates for shares of CO_2 emissions in cement production from electricity generation, all of which suggested a share below 10 percent:

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    - Hasanbeigi and Springer's benchmarking report on CO_2 emissions from cement production in California estimates a 5 percent emissions share for electricity from total carbon emissions. Ali Hasanbeigi and Cecilia Springer, "California's Cement Industry:

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- Masanet et al. (2021) estimate that electricity consumption drives 9.2 percent of total cement product emissions in China. Zhi Cao, Eric Masanet, Anupam Tiwari, and Sahil Akolawala, "Decarbonizing Concrete: Deep Decarbonization Pathways for the Cement and Concrete cycle in the United States, India, and China," Northwestern University Industrial Sustainability Analysis Laboratory, March 2021, accessed July 13, 2021, 13, https://www.climateworks.org/wp-content/uploads/2021/03/Decarbonizing_Concrete.pdf.

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    - 4,772 TWh of gross coal electricity generation in China

    - 11,238 TWh of gross electricity generation worldwide by OECD countries and 15,492 TWh by non-OECD countries, totaling 26,730TWh

    - A 38 percent share for coal in global gross electricity production, implying around 10,500 TWh of coal generation

Taken together, these figures imply that Chinese coal generation comprises around 47 percent of global coal generation. IEA, "Electricity Information: Overview," July 2020, accessed April 22, 2021, https://www.iea.org/reports/electricity-information-overview; IEA Data and Statistics Data Browser, "Energy Topic: Electricity and Heat, Indicator: Electricity Generation by Source, Country or Region: People's Republic of China," accessed April 22, 2021, https://www.iea.org/data-and-statistics?country=CHINA&fuel=Electricity%20and%20

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86. See appendix, part D. Taiwan Cement group states that it is "aiming for carbon neutral concrete products" by 2050 but does not specify whether it seeks to offer these exclusively or to achieve carbon neutrality across its entire supply chain. The Transition Pathways Initiative's December 2020 assessment, several months after TCC's announcement of its 2050 aim in September 2020, did not assess the company's targets as including achieving net-zero carbon intensity in cement production by 2050. See Transition Pathways Initiative, "Taiwan Cement," accessed May 11, 2021, https://www.transitionpathwayinitiative.org/companies/taiwan-cement; Taiwan Cement Corporation, "Taiwan Cement Aspires to Achieve Carbon Neutral Products in 2050," September 7, 2020, accessed May 11, 2021, https://www.prnewswire.co.uk/news-releases/taiwan-cement-

aspires-to-achieve-carbon-neutral-products-in-2050-803756401.html.

87. "Both global and national studies consistently call for China's emissions to peak almost immediately in order to limit temperature change to 1.5°C ... Scenarios that limit warming to 2°C may peak toward 2030." Energy Foundation China, "China's New Growth Pathway: From the 14th Five-Year Plan to Carbon Neutrality," Synthesis Report 2020 on China's Carbon Neutrality, December 2020, accessed May 28, 2021, 16–17, https://www.efchina.org/Reports-en/report-lceg-20201210-en. For the relative ease of peaking emissions before 2030, see also Bing Han and Lara Dong, "China's New 2030 Climate Commitments: Beyond Peak Emissions," IHS Markit, December 15, 2020, accessed May 28, 2021, https://ihsmarkit.com/research-analysis/chinas-updated-2030-climate-targets-beyond-carbon-peak.html; Carbon Brief, "Q&A: What's Does China's 14th Five-Year Plan Mean for Climate Change?," March 12, 2021, accessed May 28, 2021, https://www.carbonbrief.org/qa-what-does-chinas-14th-five-year-plan-mean-for-climate-change.

88. See Energy Foundation China, "China's New Growth Pathway: From the 14th Five-Year Plan to Carbon Neutrality," Synthesis Report 2020 on China's Carbon Neutrality, December 2020, accessed May 28, 2021, 16, https://www.efchina.org/Reports-en/report-lceg-20201210-en.

89. See, for instance, Patrick J. Callery and Eun-Hee Kim, "Moving Targets: Aggressiveness, Attainment, and Temporal Dynamics in Corporate Carbon Targets," working paper, November 30, 2020, accessed May 10, 2021, 15–16, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3822553.

90. Frederik Dahlmann, Layla Branicki, and Stephen Brammer, "Managing Carbon Aspirations: The Influence of Corporate Climate Change Targets on Environmental Performance," *Journal of Business Ethics* 158 (2019): 1–24, table 2.

91. Patrick J. Callery and Eun-Hee Kim, "Moving Targets: Aggressiveness, Attainment, and Temporal Dynamics in Corporate Carbon Targets," working paper, November 30, 2020, accessed May 10, 2021, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3822553. Freiberg et al. (2021, 29) discuss evidence in the literature about companies setting targets they cannot or do not intend to achieve.

92. Freiberg et al. (2021) find that firms with targets requiring larger annual emissions reductions report larger investments with greater CO_2-reducing impacts as part of their emissions reduction activities than firms whose targets are less demanding. Dahlmann et al. (2019) and Ioannou et al. (2016) find that targets involving higher percentage emissions reductions over the target period drive larger carbon emissions declines. But Callery and Kim (2020), working with 2011–19 CDP data, find that targets with shorter time horizons and smaller percentage reductions are more likely to be met and that firms that attain their targets (based upon actual emissions data) tend to show smaller annual emissions reductions than firms that do not attain them. Patrick J. Callery and Eun-Hee Kim, "Moving Targets: Aggressiveness, Attainment, and Temporal Dynamics in Corporate Carbon Targets," working paper, November 30, 2020, accessed May 10, 2021, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3822553; Frederik Dahlmann, Layla Branicki, and Stephen Brammer, "Managing Carbon Aspirations: The Influence of Corporate Climate Change Targets on Environmental Performance," *Journal of Business Ethics* 158

(2019): 1–24; David Freiberg, Jody Grewal, and George Serafeim, "Science-Based Carbon Emissions Targets," working paper, March 28, 2021, accessed May 10, 2021, https://papers.ssrn.com/abstract=3804530; Ioannis Ioannou, Shelley Xin Li, and George Serafeim, "The Effect of Target Difficulty on Target Completion: The Case of Reducing Carbon Emissions," *Accounting Review* 91, no. 5 (2016): 1467–92.

93. Kiron et al. (2017): "As with any strategic initiative, the success of a sustainability strategy depends on implementation. Companies need strong leadership to implement sustainability strategies, which often demand significant changes in how companies operate. To manage implementation, leaders need to establish KPIs tied to important tangible goals, with clear assignment of responsibilities. Without measurable goals and accountability, sustainability efforts will founder." Sroufe (2017): "Participants highlighted the importance of setting sustainability focused goals. Our respondents are monitoring over 20 different performance metrics and usually a smaller number of KPIs (the top five are noted in the table above). These metrics function as enablers for gauging if activities and processes are producing progress toward sustainability goals. Leading organizations are involved in assessment beyond financial performance and see opportunity to capturebenefits through integrated reporting." David Kiron, Gregory Unruh, Nina Kruschwitz, Martin Reeves, Holger Rubel, and Alexander Meyer Zum Felde, "Corporate Sustainability at a Crossroads: Progress towards our Common Future in Uncertain Times," *MIT Sloan Management Review*, May 23, 2017; Robert Sroufe, "Integration and Organizational Change towards Sustainability," *Journal of Cleaner Production* 162 (2017): 315–29.

94. "Several interviewees highlighted how the adoption of science-based standards inspired collaboration between different functions (e.g., operations, sustainability, finance etc.) and increased information exchange, and joint efforts, projects and investments across teams to reduce emissions." David Freiberg, Jody Grewal, and George Serafeim, "Science-Based Carbon Emissions Targets," working paper, March 28, 2021, accessed May 10, 2021, 29, https://papers.ssrn.com/abstract=3804530.

95. World Benchmarking Alliance, "Methodology," Climate and Energy Benchmark, accessed May 10, 2021, https://www.worldbenchmarkingalliance.org/publication/electric-utilities/methodology/.

96. Science-Based Targets Initiative, Companies Taking Action database, accessed May 19, 2021, https://sciencebasedtargets.org/companies-taking-action#table. Asia Cement Corporation is listed as having an SBTi target of cutting emissions intensity by 8 percent from 2019 levels by 2025. However, the company's announcement of this target states that it applies specifically to Taiwan-based plants. Asia Cement Corporation, "Asia Cement Carbon Reduction Target: Ascending to World Level" (亞泥減碳目標 躋身世界級), accessed May 19, 2021, https://www.acc.com.tw/news-center/latest-news/635-2021-03-30-06-54-51.

97. Greenhouse gas emissions are usually grouped within one of three "scopes." Scope 1 emissions are direct emissions from facilities owned or controlled by a company. Scope 2 emissions are indirect emissions from the generation of purchased energy. Scope 3 emissions are indirect emissions not included in scope 2 that occur in the value chain of the reporting company, including both upstream and downstream emissions. See

Greenhouse Gas Protocol, "FAQ," accessed June 4, 2021, https://ghgprotocol.org/sites/default/files/standards_supporting/FAQ.pdf.

98. Steel accounting regulations require reporting of emissions from fuel combustion, industrial processes, purchased heat and electricity, and carbon sequestered in sold products like crude steel and methanol (固碳产品). Cement accounting regulations require firms to report of emissions from fuel combustion, industrial processes, and purchased heat and electricity as well as the production of noncement products. NDRC, "Greenhouse Gas Emissions Accounting Methods and Reporting Instructions for Chinese Steel-Producing Firms (Trial)" (中国钢铁生产企业温室气体排放核算方法与报告指南（试行）), attachment 3 to "National Development and Reform Commission Office Circular on the Publication of Greenhouse Gas Accounting Methods and Reporting Instructions for Enterprises in the First Set of 10 Sectors (Trial)" (国家发展改革委办公厅关于印发首批10个行业企业温室气体排放核算方法与报告指南（试行）的通知), October 15, 2013, accessed May 31, 2021, 3, 5–13, https://zfxxgk.ndrc.gov.cn/web/iteminfo.jsp?id=1776; NDRC, "Greenhouse Gas Emissions Accounting Methods and Reporting Instructions for Chinese Cement-Producing Firms (Trial)" (中国水泥生产企业温室气体排放核算方法与报告指南（试行）), attachment 3 to "National Development and Reform Commission Office Circular on the Publication of Greenhouse Gas Accounting Methods and Reporting Instructions for Enterprises in the First Set of 10 Sectors (Trial)" (国家发展改革委办公厅关于印发首批10个行业企业温室气体排放核算方法与报告指南（试行）的通知), October 15, 2013, accessed May 31, 2021, 4–6, https://zfxxgk.ndrc.gov.cn/web/iteminfo.jsp?id=1776.

99. worldsteel, "World Steel Association Elects New Officers and Welcomes New Members," October 12, 2016, accessed May 11, 2021, http://www.worldsteel.org/media-centre/press-releases/2016/world-steel-association-elects-new-officers.html; Worldsteel, "World Steel Association Elects New Officers and Welcomes New Members," October 18, 2017, accessed May 11, 2021, http://www.worldsteel.org/media-centre/press-releases/2017/world-steel-association-elects-new-officers.html; worldsteel, "World Steel Association Elects New Officers and Welcomes New Members," October 18, 2018, accessed May 11, 2021, http://www.worldsteel.org/media-centre/press-releases/2018/world-steel-association-elects-new-officers.html; worldsteel, "World Steel Association Elects New Officers and Welcomes New Members," October 16, 2019, accessed May 11, 2021, http://www.worldsteel.org/media-centre/press-releases/2019/world-steel-association-elects-new-officers.html; worldsteel, "Governance," accessed April 29, 2021, http://www.worldsteel.org/about-us/who-we-are/worldsteel-governance.html.

100. worldsteel, "Governance," accessed April 29, 2021, http://www.worldsteel.org/about-us/who-we-are/worldsteel-governance.html.

101. See appendix, part D. A fourth Big 5 firm, Datang, made an ambiguous statement in January that was interpreted in some quarters as entailing a 2025 carbon peaking pledge. The firm said that it "到2025年非化石能源装机超过50%，提前5年实现"碳达峰"; this phrase could be translated in English in two ways:

- "Have nonfossil installed capacity exceeding 50 percent by 2025 and achieve carbon peaking five years early," implying that the firm would seek both 50 percent nonfossil capacity and carbon peaking by 2025

- "Have nonfossil installed capacity exceeding 50 percent by 2025, achieving carbon peaking five years early," implying disingenuously that achieving 50 percent nonfossil capacity by 2025 was carbon peaking (since it meant a peak share of fossil fuels in the firm's capacity mix.

A number of media outlets and analysts interpreted the statement using the former meaning. See, e.g., Bernadette Lee, "Chinese state-owned energy companies fast-track peak carbon emissions plans," IHSMarkit, April 21, 2021, https://ihsmarkit.com/research-analysis/chinese-stateowned-energy-companies-fasttrack-peak-carbon-emis.html. But Datang's peaking and neutrality action plan outline, released in June, only spoke of "guaranteeing carbon peaking before 2030 and striving to peak early." For this reason, the author excludes them from the list.

102. See appendix, section C and section D, part ii.

103. See appendix, section C, part ii.

104. Beyond coal production and electricity generation itself, CEIC has holdings in associated sectors like rail and port transportation and coal-based chemicals. See China Energy Investment Corporation, "Business System" (业务体系), accessed July 2, 2021, https://www.ceic.com/gjnyjtww/chnywtx/chnywtx.shtml. Coal plants comprised 99 percent of the company's total thermal installed capacity as of 2020. See appendix, section B, part ii.

105. China Building Materials Federation, "Action Declaration for Advancing Carbon Peaking and Carbon Neutrality in Building Materials" (《推进建筑材料行业碳达峰、碳中和行动倡议书》), accessed April 28, 2021, http://www.cnggg.cn/news/shownews.php?lang=cn&id=229.

106. Esther Whieldon, "Path to Net Zero: 70% of Biggest US Utilities Have Deep Decarbonization Targets," S&P Global Market Intelligence, December 9, 2020, accessed April 28, 2021, https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/path-to-net-zero-70-of-biggest-us-utilities-have-deep-decarbonization-targets-61622651; Yannic Rack, "As Net-Zero Pressure Grows in Europe, Some Utilities Enjoy 'Head Start,'" S&P Global Market Intelligence, April 13, 2021, accessed April 28, 2021, https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/as-net-zero-pressure-grows-in-europe-some-utilities-enjoy-head-start-63596140. On the timing of US utility pledges, see Stanley Porter, Jim Thomson, Marlene Motyka, Christine Lacroix, Kate Hardin, and Carolyn Amon, "Utility Decarbonization Strategies: Renew, Reshape, and Refuel to Zero," Deloitte Insights, September 21, 2020, accessed April 28, 2021, https://www2.deloitte.com/us/en/insights/industry/power-and-utilities/utility-decarbonization-strategies.html.

107. JSW Group, "JSW | Carbon Neutrality by 2050," August 18, 2020, accessed April 29, 2021, https://www.facebook.com/JSWGroupOfficial/videos/jsw-carbon-neutrality-by-2050/777671752978674/; J-POWER, *J-POWER Group Integrated Report 2020*, accessed May 11, 2021, 29, https://www.jpower.co.jp/english/ir/pdf/2020.pdf; Tata Power, "Tata Power Climate Commitment," accessed May 11, 2021, https://www.tatapower.com/pdf/sustainability/tp-climate-commitment.pdf. Hong Kong's China Power and

Light also has a long-term deep decarbonization target. See China Power and Light, "Decarbonisation," accessed April 29, 2021, https://www.clpgroup.com/en/sustainability/strategic-priorities/decarbonisation.html.

108. Data available at Transition Pathways Initiative, accessed April 28, 2021, https://www.transitionpathwayinitiative.org/sectors/cement.

109. World Cement Association, "Largest Cement Producers," accessed April 21, 2021, https://www.worldcementassociation.org/images/info-graphics/facts/worlds-largest-cenment-producers.jpg; LafargeHolcim, "Becoming a Net Zero Company: Our Pledge in Numbers," accessed April 28, 2021, https://www.lafargeholcim.com/our-climate-pledge.

110. Portland Cement Association, "Portland Cement Association," accessed April 28, 2021, https://www.cement.org/about; Portland Cement Association, "Portland Cement Association to Further Sustainability Goals by Creating Carbon Neutrality Roadmap for the Cement and Concrete Industry," November 17, 2020, accessed April 28, 2021, https://www.prnewswire.com/news-releases/portland-cement-association-to-further-sustainability-goals-by-creating-carbon-neutrality-roadmap-for-the-cement-and-concrete-industry-301174836.html; UltraTech Cement, "SBTi Validates UltraTech's CO_2 Emissions Reduction Targets," March 12, 2021, accessed April 28, 2021, https://www.ultratechcement.com/about-us/media/press-releases/sbti-validates-ultratech-s-co2-emissions-reduction-targets.

111. ThyssenKrupp, "ThyssenKrupp Sets Clear Targets: Group Aims to Be Climate Neutral by 2050—30 Percent Emissions Reduction Planned for 2030," accessed April 28, 2021, https://www.thyssenkrupp.com/en/newsroom/press-releases/thyssenkrupp-sets-clear-targets--group-aims-to-be-climate-neutral-by-2050------30-percent-emissions-reduction-planned-for-2030-12803.html; Tata Steel Europe, "Tata Steel's European operations take major step towards becoming carbon neutral," October 16, 2018, accessed April 28, 2021, https://www.tatasteeleurope.com/ts/corporate/news/tata-steel-european-operations-take-major-step-towards-becoming-carbon-neutral.

112. POSCO, "POSCO Pledges to Achieve Carbon Neutrality by 2050 and Lead Low Carbon Society," December 16, 2020, accessed April 28, 2021, https://newsroom.posco.com/en/posco-pledges-to-achieve-carbon-neutrality-by-2050-and-lead-low-carbon-society/; Nippon Steel, "Nippon Steel Corporation Announces Medium- to Long-Term Management Plan," March 5, 2021, accessed April 28, 2021, https://www.nipponsteel.com/en/ir/library/pdf/20210305_100.pdf.

113. Target data available from the Transition Pathways Initiative, accessed April 28, 2021, https://www.transitionpathwayinitiative.org/sectors/steel. JFE Steel's production volume in 2019 (27.35 mt) was around the same as Shandong Iron and Steel (27.51mt), China's seventh-largest producer. JSW Steel's (16.26 mt) was around the same as Bengang Group (16.18 mt), China's ninth-largest producer. See appendix, section C, part ii.

114. Interviewees #6, #8, #17, #18. For an example of such an agreements, see China Energy Investment Corporation, "China Energy Investment Corporation Launches Research on Carbon Peaking & Carbon Neutrality Strategies"
(国家能源集团启动碳达峰碳中和战略研究), China Coal Association WeChat

channel (煤炭工业网), accessed June 25, 2021, https://mp.weixin.qq.com/s?__biz=MzA3NTcwMDg0Mg==&mid=2650318869&idx=6&sn=1cee86e6d3e4c36af6a0a843393b57a0&chksm=87608710b0170e0638c33531182d313d88df2353a3b7c0abedaab2429a92928bfc187104a74c#rd.

115. Interviewee #3.

116. Shan Jie, Lu Yameng, and Li Qiao, "State-Owned Companies Face Challenges in Achieving China's Carbon Neutrality Goal," *Global Times*, January 13, 2021, accessed April 29, 2021, https://www.globaltimes.cn/page/202101/1212692.shtml.

117. Lucille Liu and Jing Li, "The Secret Origins of China's 40-Year Plan to End Carbon Emissions," Bloomberg, November 23, 2020, accessed April 28, 2021, https://phys.org/news/2020-11-secret-china-year-carbon-emissions.html.

118. Michal Meidan, "Unpacking China's 2060 Carbon Neutrality Pledge," Oxford Institute for Energy Studies, December 2020, accessed April 21, 2021, 2, https://www.oxfordenergy.org/wpcms/wp-content/uploads/2020/12/Unpacking-Chinas-carbon-neutrality-pledge.pdf.

119. On the CEWC's significance, see Frank Tang, "China's Top Policy Panel Says Government Will Continue 'Necessary Support' for Economy," *South China Morning Post*, December 18, 2020, accessed June 25, 2021, https://www.scmp.com/economy/china-economy/article/3114571/chinas-top-policy-panel-says-government-will-continue.

120. Xinhua, "The Central Economic Work Conference Is Held in Beijing; Xi Jinping and Li Keqiang Make Important Speeches" (中央经济工作会议在北京举行 习近平李克强作重要讲话), December 18, 2020, accessed April 28, 2021, http://www.12371.cn/2020/12/18/ARTI1608287844045164.shtml.

121. Xinhua, "The Central Economic Work Conference Is Held in Beijing," December 12, 2019, accessed April 28, 2021, https://baijiahao.baidu.com/s?id=1652710915417261692&wfr=spider&for=pc.

122. SASAC, "Central SOE Leaders' Meeting Held in Beijing; Thoroughly Implement Central Decisions and Deployments; Show Forth the Mission and Responsibility of Centrally-Owned SOEs in Guaranteeing the Comprehensive Construction of a Moderately Prosperous Society" (中央企业负责人会议在京召开 贯彻落实党中央决策部署 在确保全面建成小康社会中展现国资央企使命担当), December 25, 2019, accessed April 29, 2021, http://www.sasac.gov.cn/n2588020/n2877938/n2879597/n2879599/c13269476/content.html.

123. SASAC, "Central SOE Leaders' Meeting Held in Beijing; Resolutely and Unswervingly Make State-Owned Capital and State-Owned Enterprises Strong, Excellent, and Big; Take Advantage of the Situation to Launch a New Journey of Struggle in the 14th Five-Year Plan" (中央企业负责人会议在京召开 坚定不移做强做优做大国有资本和国有企业 乘势而上开启"十四五"奋斗新征程), December 25, 2020, accessed April 29, 2021, www.sasac.gov.cn/n2588020/n2877938/n2879597/n2879599/c16316697/content.html.

124. See appendix, part D.

125. See appendix, part D. For an example of a prior year CEWC debrief meeting by CEIC leadership, see "What Has CEIC Done to Thoroughly Implement the Spirit of the Central Economic Work Conference?" (贯彻落实中央经济工作会议精神，国家能源集团做了啥？), CEIC WeChat channel (国家能源之声), accessed June 25, 2021, https://mp.weixin.qq.com/s/EEI4jhqZzD-ZWTPkTsGI8A.

126. See appendix, part D.

127. The date of release for both was March 12, 2021. People's Republic of China, "Outline of 14th Five-Year Plan and Long-Term 2035 Goals for the Economic and Social Development of the People's Republic of China" (中华人民共和国国民经济和社会发展第十四个五年规划和2035年远景目标纲要), March 12, 2021, accessed May 11, 2021, http://www.gov.cn/xinwen/2021-03/13/content_5592681.htm (hereafter referred to as "14th Five-Year Plan Outline"). See also appendix, part D.

128. The 14FYP spoke of "vigorously raising [*dali tisheng* 大力提升] the scale of wind and PV power generation" and "reasonably controlling the rhythm of the construction and development of coal-fired power." The 13th Five-Year Plan, by contrast, called for "continuing to advance [*jixu tuijin* 继续推进] the scale of wind and PV power generation" and "vigorously advancing the clean, high-efficiency utilization of coal" (13th Five-Year Plan Outline, 57; 14th Five-Year Plan Outline, 10, 29–30). The author thanks Sally Qiu for pointing out these shifts.

129. Ministry of Ecology and Environment, "Notice regarding the Publication of Implementation Plan for Total Determination and Distribution of National Carbon Emissions Permit Allocation in 2019–2020 (Electricity Generation), List of Key Emitting Units Included in Administration of National Carbon Emissions Permit Allocation in 2019–20, and Work for Carrying Out Electricity Industry Permit Volume Allocation" (关于印发《2019-2020年全国碳排放权交易配额总量设定与分配实施方案（发电行业）》《纳入2019-2020年全国碳排放权交易配额管理的重点排放单位名单》并做好发电行业配额预分配工作的通知), December 31, 2020, accessed May 3, 2021, http://mee.gov.cn/xxgk2018/xxgk/xxgk03/202012/t20201230_815546.html; NDRC, "Construction Plan for a National Carbon Emissions Trading Market (Electricity Generation)" (全国碳排放权交易市场建设方案（发电行业）), December 18, 2017, accessed May 3, 2021, https://www.ndrc.gov.cn/xxgk/zcfb/ghxwj/201712/W020190905495689305648.pdf; Hongqiao Liu, "In-Depth Q&A: Will China's Emissions Trading Scheme Help Tackle Climate Change?," *Carbon Brief*, June 24, 2021, accessed July 12, 2021, https://www.carbonbrief.org/in-depth-qa-will-chinas-emissions-trading-scheme-help-tackle-climate-change.

130. The ETS allocates allowances for free to firms based upon historical generation data and standard carbon intensity benchmarks; as a result, for a given generation total, efficient generators whose carbon intensity falls below the benchmark may enjoy allowances to sell to their less efficient counterparts. A carbon market consultant interviewed noted that larger firms tended to operate larger and more efficient coal units, while smaller and less efficient units were more common among, for instance, industrial users with captive self-generation capacity. Interviewee #6. A financial analyst at an American investment firm noted likewise that China's largest cement firms tend to operate more efficient capacity than their smaller competitors, a further advantage for their competitive

position once the ETS is extended to the sector. Interviewee #22. Note that some of these industrial users have large coal holdings themselves, as in the aluminum producer Weiqiao, China's 10th-largest coal capacity owner. Weiqiao owns more than 17 GW of inefficient subcritical coal capacity, per analysis by the climate think tank Ember. Muyi Yang, "China's Aluminum Production Surged by 5% in 2020, Producing More Emissions than Indonesia," Ember, February 7, 2021, accessed May 31, 2021, https://ember-climate.org/commentary/2021/02/07/china-aluminium-2020-emissions/. For more on the debate about the ETS's likely impact, see Hongqiao Liu, "In-Depth Q&A: Will China's Emissions Trading Scheme Help Tackle Climate Change?," *Carbon Brief*, June 24, 2021, accessed July 12, 2021, https://www.carbonbrief.org/in-depth-qa-will-chinas-emissions-trading-scheme-help-tackle-climate-change.

131. "Controlling total emissions" had been identified as a "supplement" to carbon intensity targets by the plan outline: *tan paifang zongliang kongzhi wei fu* 碳排放总量控制为辐. 14th Five-Year Plan Outline, 93.

132. On the positive reception to these policies by Chinese officials, see IEA, *Energy Efficiency Market Report 2016*, October 2016, accessed May 11, 2021, 44, https://eef.se/wp-content/uploads/2017/10/mediumtermenergyefficiency2016.pdf. Scholars debate these programs' effectiveness at driving efficiency gains. Chen et al. (2021), for instance, finds evidence that large firms subject to top-1,000 mandates during the 11FYP met targets by cutting energy consumption rather than improving efficiency, compensating partially for lost output by shifting output to less productive firms exempt from the mandates. Qiaoyi Chen, Zhao Chen, Zhikuo Liu, Juan Carlos Suàrez Serrato, and Daniel Yi Xu, "Regulating Conglomerates: Evidence from an Energy Conservation Program in China," working paper, May 24, 2021, accessed June 29, 2021, https://www.jcsuarez.com/Files/Top_1000.pdf. The author thanks an anonymous reviewer for noting these policies as a potential example of a regulatory approach that authorities might take around carbon emissions.

133. "Full Text: Remarks by Chinese President Xi Jinping at Leaders Summit on Climate" (习近平在"领导人气候峰会峰"上的讲话（全文）), Xinhua, April 22, 2021, accessed April 29, 2021, http://www.xinhuanet.com/english/2021-04/22/c_139899289.htm (Chinese), http://www.xinhuanet.com/english/2021-04/22/c_139899289.htm (English).

134. See appendix, section B, part i.

135. Data is estimated based upon Mengjia Ren, Lee Branstetter, Brian Kovak, Daniel Armanios, and Jiahai Yuan, "China Overinvested in Coal Power: Here's Why," VoxEU, March 16, 2019, accessed June 29, 2021, https://voxeu.org/article/china-overinvested-coal-power-here-s-why.

136. Xi Jinping, "Xi Jinping's Speech at the Climate Ambition Summit (Full Text)" (习近平在气候雄心峰会上的讲话（全文）), accessed July 12, 2021, http://www.xinhuanet.com/2020-12/12/c_1126853600.htm.

137. *Energy Law of the People's Republic of China (Draft for Comments)* (中华人民共和国能源法（征求意见稿）), article 115 ("Legal Interpretation of Terms") April 3, 2020, accessed April 29, 2021, http://www.nea.gov.cn/138963212_15864798260741n.docx.

138. Both renewable and nonfossil energy also include geothermal and tidal energy.

139. See Xiaoying You, "China Issues New 'Single-Game' Instructions to Guide its Climate Action," Carbon Brief, August 4, 2021, accessed August 12, 2021, https://www.carbonbrief.org/china-issues-new-single-game-instructions-to-guide-its-climate-action.

140. The company only reports targeting 2 GW of gas additions and 5 GW of additional shareholding participation in nuclear facilities for the period, so it would enjoy room to add more than 30G W of coal capacity without missing its 28.8 percent renewable generation target.

141. China's enormous 2020 additions of wind (72.4 GW) and solar (49.3 GW) likely would have included some amount of new wind and solar capacity from these firms that may make these commitments more straightforward for these firms. But those minimum figures also do not reflect coal additions completed during 2020 or projects under construction—Huadian, in particular, had 5.4 GW of coal under construction as of January 2021, per the GCPT database. See appendix, section B, part iii and China Electricity Council, "Data Report Table of National Electricity Industry Statistics for 2020" (2020年全国电力工业统计快报数据一览表), January 22, 2021, accessed April 23, 2021, https://www.cec.org.cn/detail/index.html?3-292820.

142. See appendix, section B, part iii and section D, part ii.

143. Ivy Yin and Eric Yep, "China's Big 5 Power Producers Face Uphill Battle in Meeting Peak Emissions Targets," S&P Global Platts, June 7, 2021, accessed June 27, 2021, https://www.spglobal.com/platts/en/market-insights/latest-news/coal/060721-chinas-big-5-power-producers-face-uphill-battle-in-meeting-peak-emissions-targets.

144. See appendix, section B, part ii.

145. Interviewees #4, #7 (Lucas Liutong Zhang, director, WaterRock Energy Economics), #9. China Resources (42.6 GW) and China Power International Development (26.4 GW), the largest listed subsidiary of SPIC, report plant-level capacity data for their holdings that suggests larger project sizes in wind than solar within their portfolios, as described in the table below.

Type	Average Size (MW)	Median Size (MW)
China Resources		
Wind	93.1	55.8
PV	23.1	20.8
SPIC International		
Wind	372.2	106.3
PV	219.6	100.0

Calculations based upon China Resources Power Holdings Company Ltd., *Annual Report 2019*, 5–7; China Power International Development Limited, *2019 Annual Report*, 9–10.

146. CITIC Securities, "'Carbon Neutrality': The Full View" ("碳中和"全景图") March 3, 2021, 4; Han Shulin (韩舒淋) and Xu Peiyu (徐沛宇) "Carbon Neutrality: China's Ambition and Weak Spot" (碳中和，中国的雄心与软肋), *Caijing* (财经), accessed April 29, 2021, https://mp.weixin.qq.com/s?__biz=MjM5NDU5NTM4MQ==&mid=2653393548&idx=2&sn=2b8aa1b46d5ac1bc2e090622cc83632f&chksm=bd5665d68a21ecc0ddbc1269b62964745b76d8cdaa853a2fb5d039dbb1a6f65ecf746d6a8374#rd. The Chinese Photovoltaic Industry Association projected 70–90 GW of growth over the 14FYP annually in a February 2021 presentation. Wang Bohua, "China Photovoltaic Industry 2020 Lookback and 2021 Forecast" (中国光伏行业2020年回顾与2021年展望), China Photovoltaic Industry Association WeChat channel (中国光伏行业协会CPIA), February 3, 2021, https://mp.weixin.qq.com/s?__biz=MzA5NjQwMjE4NA==&mid=2649640207&idx=1&sn=c052929a47ed924b846781dbd520038e&chksm=88aa4368bfddca7ed108282d9ef8dc8abd8725a6aae53e92a281b4f26a7fc3ee6fd34f5e15e1#rd. Xie Changjun, former vice general manager of CEIC predecessor China Guodian, stated in a December 2020 interview that the wind industry should achieve at least 50 GW of average annual growth in the coming five years to meet China's goal of 12 GW of installed wind and solar by 2030. Zhou Xiaoyan (周小彦), "Coffee Talk | Xie Changjun: Opportunities and Challenges for the Wind Industry's Development during the 14th Five-Year Plan" (大咖说丨谢长军：“十四五”风电产业发展的机遇与挑战), Beijixing Electric Power Online WeChat channel (北极星电力网), December 23, 2020, accessed April 29, 2021, https://mp.weixin.qq.com/s/str5sXIG3QKgIGSuC1qrxw.

147. Global Energy Interconnection Development and Cooperation Organization, "Research on a 2030 Energy and Electricity Development Plan for China and 2060 Forecast" (中国2030年能源电力发展规划研究及2060年展望), March 2021, accessed June 4, 2021, 21, https://www.geidco.org.cn/html/pdfpreview/web/viewer.html?file=source/%E3%80%8A%E4%B8%AD%E5%9B%BD2030%E5%B9%B4%E8%83%BD%E6%BA%90%E7%94%B5%E5%8A%9B%E5% 8F%91%E5%B1%95%E8%A7%84%E5%88%92%E7%A0%94%E7%A9%B6%E5%8F%8A2060%E5%B9%B4%E5%B1%95%E6%9C%9B%E3%80%8B.pdf.

148. 14th Five-Year Plan Outline, 30. See appendix, section B, part ii for list of firm-level capacity information sources.

149. See Appendix, section B, part i.

150. Yuki Yu, "China's Solar Market: Renewable Investors' Critical Battlefield," Energy Iceberg, October 14, 2020, accessed May 11, 2021, https://energyiceberg.com/china-solar-market-shift/.

151. Interviewees #4, #7 (Lucas Liutong Zhang, director, WaterRock Energy Economics), #9.

152. See, for instance, Rocky Mountain Institute and Energy Transitions Commisson "China Zero-Carbon Electricity Growth in the 2020s," accessed June 5, 2021, chap. 4, https://rmi.org/insight/zero-carbon-electricity-growth-in-the-2020s/; Yuan Jiahai (袁家海), Xi Xingxuan (席星璇), Meng Zhixu (孟之绪), Zhang Weirong (张为荣), and Zhang Jian (张健), "Research on Diverse Routes to Raising Power System Flexibility in China" (中国电力系统灵活性的多元提升路径研究1中国电力系统灵活性的多元提升路径研究), Greenpeace,

October 2020, accessed July 12, 2021, https://www.greenpeace.org.cn/wp-content/uploads/2020/11/%E3%80%902020%E5%B9%B411%E6% 9C%88%E6%9B%B4%E6%96%B0%E7%89%88%E6%8A%A5%E5 %91%8A%E4%B8%8B%E8%BD%BD%E3%80%91.pdf; Ben Caldecott, Geraldine Bouveret, Gerard Dericks, Lucas Kruitwagen, Daniel J. Tulloch, and Xiawei Liao, "Managing the Political Economy Frictions of Closing Coal in China," discussion paper with the University of Oxford Smith School of Enterprise and the Environment Sustainable Finance Programme, February 2017, accessed July 12, 2021, https://www.smithschool.ox.ac.uk/research/sustainable-finance/publications/Managing-the-political-economy-frictions-of-closing-coal-in-China-SFP-Working-Paper.pdf.

153. Morgan Stanley, "Carbon Neutrality: Supply-Side Reform 2.0," March 23, 2021, 49; CITIC Securities, "'Carbon Neutrality': The Full View" (“碳中和”全景图) March 3, 2021, 4.

154. Zhang Yanan (张亚楠), "Exclusive | Li Shen: China's Cement Industry Can Peak Carbon Emissions Early" (专访丨李琛：中国水泥行业有望提前实现碳达峰), *China Building Materials News* (中国建材报), January 14, 2021, accessed April 30, 2021, https://www.thepaper.cn/newsDetail_forward_10787817.

155. Interviewees #5, #16.

156. Xinhua, "Chomping Down on the Hard Bone, Creating New Advantages—MIIT Minister Xiao Yaqing Discusses the Drivers of the Industry and Information Technology Sectors in 2021" (“啃下“硬骨头” 锻造新优势——工信部部长肖亚庆谈2021年工业通信业发力点”), January 4, 2021, accessed April 30, 2021, http://www.xinhuanet.com/2021-01/04/c_1126944382.htm.

157. "Chinese steel production data over the past few years has been subject to increased uncertainty due to underreporting, particularly at illegal induction furnaces ('IF's) after most were closed during 2017. Since IF production was mostly unrecorded in the official figures previously, and this production has moved to mills whose production is recorded officially, it led to official estimates of production growing more strongly than actual production output as estimated by ArcelorMittal. Although the Company believes that the most recent production data is broadly accurate, it estimates that production was under-recorded until mid-2018, meaning that the World Steel Association's growth rate of 8.3% in 2019 is overstated (as are growth rates in 2017 and 2018). [*Author note: official Chinese data shared in this report give a 7.1% growth rate in steel output in 2019*.] ArcelorMittal's crude steel production estimates are consistent with its belief that Chinese steel demand grew just over 3%" (ArcelorMittal, *Annual Report 2019*, 9).

158. See, for instance, Amanda Lee, "China Invests US$163.2 Billion in Infrastructure to Stave Off Economic Slowdown and Effect of Trade War," *South China Morning Post*, January 29, 2018, accessed May 11, 2021, https://www.scmp.com/economy/china-economy/article/2183977/china-ramps-infrastructure-spend-stave-economic-slowdown-and; Amanda Lee, "China Doubles Value of Infrastructure Project Approvals to Stave Off Economic Slowdown amid Trade War," *South China Morning Post*, October 21, 2019, accessed May 11, 2021, https://www.scmp.com/economy/china-economy/article/3033564/china-doubles-value-infrastructure-project-approvals-stave.

159. See, for instance, Zeng Lingke (曾凌轲), Luo Guoping (罗国平), and Zhou Meilin (周美霖), "Overcapacity Returns in Steel" ("钢铁再过剩"), *Caixin* (财新), September 23, 2019, accessed April 30, 2021, http://weekly.caixin.com/2019-09-21/101464638.html; CCA, "Action Plan for Reducing Capacity in the Cement Industry (2018–20)" (水泥行业去产能行动计划（2018～2020）), December 11, 2017, accessed April 30, 2021, http://www.ccement.com/news/content/9284065789596.html?ti=1553484926401 (hereafter referred to as "CCA Action Plan for Reducing Capacity 2018–2020").

160. CCA Industry Performance and Forecast Report 2020–21; "Spotlight on China Steel: New Crude Steel Capacity Expansion Slowing in 2020," S&P Global Platts, January 30, 2020, accessed April 30, 2021, https://www.spglobal.com/platts/en/market-insights/latest-news/metals/013029-spotlight-china-steel-new-capacity-slowing.

161. Zeng Lingke (曾凌轲), Luo Guoping (罗国平), and Zhou Meilin (周美霖), "Overcapacity Returns in Steel" (钢铁再过剩), *Caixin* (财新), September 23, 2019, accessed April 30, 2021, http://weekly.caixin.com/2019-09-21/101464638.html; "Spotlight on China Steel: New Crude Steel Capacity Expansion Slowing in 2020," S&P Global Platts, January 30, 2020, accessed April 30, 2021, https://www.spglobal.com/platts/en/market-insights/latest-news/metals/013029-spotlight-china-steel-new-capacity-slowing.

162. A former executive of a Chinese cement firm stated in an interview that senior executives at a top-10 firm suggested that the stimulus had set back a production decline that would have otherwise begun in 2020. Interviewee #5.

163. For output levels, see appendix, section C, part i. For the Tangshan situation, see Su-Lin Tan, "Chinese Steel Production Powers Ahead despite Curbs in Industry's Heartland," *South China Morning Post*, April 10, 2021, accessed April 30, 2021, https://www.scmp.com/economy/china-economy/article/3129052/chinese-steel-production-powers-ahead-despite-curbs-industrys.

164. Liang Qian (梁倩), "Steel Industry Carbon Emissions Peaking and Reduction Action Plan Takes Shape" (钢铁行业碳达峰及降碳行动方案成型), *Economic Information Daily* (经济参考报), March 30, 2021, accessed April 28, 2021, http://www.jjckb.cn/2021-03/30/c_139845634.htm.

165. See appendix, section D.

166. See appendix, section D.

167. Luo Guoping (罗国平) and Zhao Xuan (赵煊), "Baowu's Big Expansion" (宝武大扩张), *Caixin* (财新), March 1, 2021, accessed April 29, 2021, https://weekly.caixin.com/2021-02-27/101667969.html?p0#page2; Olivia Zhang and Hongmei Li, "M&As Embedded in China Baowu's Next 5-Year Strategy," Mysteel, September 21, 2020, accessed June 5, 2021, https://www.mysteel.net/article/5018572-0504/M-and-As-embedded-in-Chinas-Baowus-next-5-year-strategy.html; "Shandong Iron and Steel Co. Ltd., "Shandong Iron and Steel Co. Ltd. Disclosure Announcement about Shandong Iron and Steel Group Strategic Restructuring" (山东钢铁股份有限公司 关于涉及山东钢铁集团有限公司战略重组的提示性公告),

July 15, 2021, accessed August 13, 2021, http://static.sse.com.cn/disclosure/listedinfo/announcement/c/new/2021-07-15/600022_20210715_1_BTNm7dnD.pdf.

168. See appendix, section D.

169. See appendix, section D.

170. The firm's interim target of 50 percent emissions reduction by 2042 implies an aim to squeeze 50 percent emissions cuts into eight years. This can reasonably be viewed as a concern, allowing a worrying amount of slack to the firm around near-term reductions. On the other hand, depending upon the age of Baotou's assets, a concentrated wave of blast furnace retirements in the 2040s could fit well with expected facility lifetimes. "Baotou Formally Announces its Carbon Peaking and Carbon Neutrality Plan Goals! Striving to Peak in 2023, Striving for Neutrality in 2050" (包钢碳达峰、碳中和规划目标正式发布！力争2023年碳达峰、力争2050年碳中和), Baotou Iron and Steel WeChat channel (包钢集团), May 15, 2021, accessed May 20, 2021, http://mp.weixin.qq.com/s?__biz=MjM5NDc5NDk4MQ==&mid=2649751021&idx=1&sn=fc813f5fb9bf1372c50a68c38fd0abb0&chksm=be99016789ee88713ae24ada6e6c5b5536bb913cb8e84caa974d84334e401f136ed0f44a53ab#rd.

171. Luo Guoping (罗国平) and Zhao Xuan (赵煊), "Baowu's Big Expansion" (宝武大扩张), *Caixin* 财新, March 1, 2021, accessed April 29, 2021, https://weekly.caixin.com/2021-02-27/101667969.html?p0#page2.

172. Interviewee #21.

173. Calculated using data from IHS Global Ltd. presented in the US Department of Commerce Enforcement and Compliance Division, Global Steel Trade Monitor, accessed March 26, 2021, https://www.trade.gov/data-visualization/global-steel-trade-monitor.

174. Ding Bo (丁波) and Cai Xinhua (蔡新华), "China Baowu Strives to Achieve Carbon Neutrality 10 Years in Advance" (中国宝武力争提前10年实现碳中和), *China Environment News* (中国环境报), April 8, 2021, http://epaper.cenews.com.cn/html/1/2021-04/08/07B/2021040807B_pdf.pdf.

175. CISA, "Notice on the Planned Establishment of an Expert Committee for Advancing Low-Carbon Work and a Search for Member Institutions and Expert Participants" (关于拟成立"中国钢铁工业协会低碳工作推进委员会"并征集委员单位和专家组成员的通知), CISA WeChat channel (中国钢铁工业协会), January 20, 2021, accessed April 30, 2021, http://mp.weixin.qq.com/s?__biz=MzAwNDMzMDQyMg==&mid=2650917218&idx=1&sn=7044cea51ddf6625e9d31285b9547683&chksm=80d8efbbb7af66ad6fb4fe47216f8a9e2bf4922d5426de50fe986e57711693e68620979aa974#rd. "HBIS Chairman Yu Yong Discusses the European Union Carbon Border Tax: If There Are Not Large Changes in Our Carbon Emissions in the Short Term, We Will Face New Challenges around Issues of Carbon Taxes and Barriers" (河钢董事长于勇谈欧盟碳边境税：如果我们的碳减排量在短期内没有大的变化，我们在碳税壁垒问题上，将面临新的挑战), China Chamber of Commerce for Metallurgical Enterprises WeChat channel (全联冶金商会), accessed May 20, 2021, https://

mp.weixin.qq.com/s/_hIeDkAG1KN1q7MmmK_L7A; "High-Level Businessmen Dialogue | Hu Wangming Talks Freely on China Baowu's Carbon Peaking and Carbon Neutrality Experience (Video Attached)" (企业家高端对话 | 胡望明畅谈中国宝武践行碳达峰碳中和（附视频）), Baowu Group WeChat channel (中国宝武), accessed May 21, 2021, https://mp.weixin.qq.com/s?__biz=MjM5MDEzNzA5Ng==&mid=2654866845&idx=2&sn=d652f2aa8bf2f67118a7c86d0656251f&chksm=bd83c3fa8af44aecee59e5ec296810fedb1dad5d187c7cef5936666bd1eae340fc877b6784e8#rd.

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177. Interviewee #20; Morgan Stanley, "Iron Ore's Rising Scrap Threat," November 25, 2020. The author thanks interviewee #20 for pointing him to this report.

178. In an article promoted by the Ministry of Ecology and Environment, Chinese scholar He Kebin reported that steel firms' 2017 emissions comprised 20 percent, 10 percent, and 7 percent of national particulate matter, NOx, and SO_2 emissions, respectively. He Kebin (贺克斌), "Explainer 1: The Influence of Steel Firms' Concentrated Emissions on Urban Air Pollution is Clear; There Is Still Lots of Space for Emissions Reduction in the Industry" (解读①丨钢铁企业集中排放对城市空气质量影响显著 行业减排仍有较大空间（贺克斌）), accessed April 30, 2021, https://baijiahao.baidu.com/s?id=1632723126679018193&wfr=spider&for=pc.

179. "China's Top Steel City Tangshan Summons 48 Firms over Air Pollution," Reuters, July 17, 2019, https://www.reuters.com/article/us-china-pollution-tangshan/chinas-top-steel-city-tangshan-summons-48-firms-over-air-pollution-idUSKCN1TI0SV; Interviewee #19 (Li Hongmei, Head of English Editorial, Mysteel Global, April 2021).

180. China Iron and Steel Association (hereafter referred to as "CISA"), "Committee Member He Wenbo Talks Hot Topics in the Steel Industry including Reducing Carbon Emissions and Controlling Production" (何文波委员谈碳减排、控产量等当前钢铁行业热点问题), CISA WeChat channel (中国钢铁工业协会), March 3, 2021, accessed March 12, 2021, http://mp.weixin.qq.com/s?__biz=MzAwNDMzMDQyMg==&mid=2650918057&idx=1&sn=15816fba86f6e5af4144137a7ac51ef6&chksm=80d8ea70b7af6366fc745a6ff0e13848e692f347b4e081cebd43970a980284ff86d04f04ffae#rd.

181. MIIT, "Implementation Methods for Steel Industry Capacity Replacement" (钢铁行业产能置换实施办法), April 17, 2021, article 7, accessed June 25, 2021, http://www.gov.cn/zhengce/zhengceku/2021-05/07/content_5605092.htm.

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183. Caitlin Swalec and Christine Shearer, "Pedal to the Metal: No Time to Delay in Decarbonizing the Global Steel Sector," Global Energy Monitor, June 2021, accessed June 28, 2021, 26, https://globalenergymonitor.org/wp-content/uploads/2021/06/Pedal-to-the-Metal.pdf.

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186. See, e.g., He Wenbo (何文波), "Guiding Low-Carbon, Green, High-Quality Development; Accelerating Advancement on the Goal of Achieving Carbon Peaking" (引领低碳绿色高质量发展 加快推进实现碳达峰目标), China Chamber of Commerce for Metallurgical Enterprises WeChat channel (全联冶金商会), April 29, 2021, accessed May 20, 2021, https://mp.weixin.qq.com/s/2_OQiXnN-CHUNxxgT0XCFQ; China Iron and Steel Association (hereafter referred to as "CISA"), "Committee Member He Wenbo Talks Hot Topics in the Steel Industry including Reducing Carbon Emissions and Controlling Production" (何文波委员谈碳减排、控产量等当前钢铁行业热点问题), CISA WeChat channel (中国钢铁工业协会), March 3, 2021, accessed March 12, 2021, https://mp.weixin.qq.com/s __biz=MzAwNDMzMDQyMg==&mid=2650918057&idx=1&sn=15816fba86f6e5af4144137a7ac51ef6&chksm=80d8ea70b7af6366fc745a6ff0e13848e692f347b4e081cebd43970a980284ff86d04f04ffae#rd.

187. MIIT, "Guiding Opinions on the High-Quality Development of the Iron and Steel Industry" (关于推动钢铁工业高质量发展的指导意见), December 31, 2020, accessed April 30, 2021, https://www.miit.gov.cn/api-gateway/jpaas-web-server/front/document/file-download?fileUrl=/cms_files/

filemanager/1226211233/attach/202012/5ab69a6a953 943ab98e5cb415aa42887.pdf&fileName=%E5%85%B3%E4%BA%8E% E6%8E%A8%E5%8A%A8%E9%92%A2%E9%93%81%E5%B7%A5%E4 %B8%9A%E9%AB%98%E8%B4%A8%E9%87%8F%E5%8F%91%E5% B1%95%E7%9A%84%E6%8C%87%E5%AF%BC%E6%84%8F%E8%A7%81%EF%BC%88%E5%BE%81%E6%B1%82%E6%84%8F%E8%A7%81%E7%A8%BF%EF%BC%89.pdf. (hereafter referred to as "MIIT Guiding Opinions on Steel Development"). MIIT Guiding Opinions on Steel Development, 3–4; Jing Zhang and Sylvia Cao, "China's Resumption of Scrap Imports Seen Unlikely to Help Costs, EAF Development," S&P Global Platts, January 13, 2021, accessed April 30, 2021, https://www.spglobal.com/platts/en/market-insights/latest-news/metals/011321-chinas-resumption-of-scrap-imports-seen-unlikely-to-help-costs-eaf-development.

188. See, e.g., Frank Tang, "Explainer | What Is China's Dual Circulation Economic Strategy and Why Is It Important?," *South China Morning Post*, November 19, 2020, accessed June 4, 2021, https://www.scmp.com/economy/china-economy/article/3110184/what-chinas-dual-circulation-economic-strategy-and-why-it.

189. Frank Zhong, "Blog: How Hydrogen Is Gaining Momentum in the Chinese Steel Industry," worldsteel, September 16, 2020, accessed April 30, 2021, http://www.worldsteel.org/media-centre/blog/2020/hydrogen-technology-momentum-Chinese-steel-industry.html. CISA chairman He Wenbo, in an April 2021 speech, cited Baowu, HBIS, Shougang, Jianlong, Jiuquan Iron and Steel, and Rizhao Iron and Steel as firms "actively exploring the establishment of hydrogen metallurgy demonstration projects." He Wenbo, "Guiding Low-Carbon Green High-Quality Development, Advancing the Achievement of the Carbon Peaking Goals" (引领低碳绿色高质量发展　加快推进实现碳达峰目标), CISA WeChat channel (中国钢铁工业协会), April 29, 2021, https://mp.weixin.qq.com/s/so8uAKRN2Qef1iG5lTs6Xw.

190. Kevin Jianjun Tu, *Prospects of a Hydrogen Economy with Chinese Characteristics*, Institut français des relations internationales, October 2020, accessed May 10, 2021, 49, https://www.ifri.org/sites/default/files/atoms/files/tu_china_hydrogen_economy_2020_1.pdf.

191. Hebei was one of more than 10 provinces to mention hydrogen in its 14th Five-Year Plan, and a tally of firms involved in hydrogen by reporters at *21st Century Economic Report* found Hebei as having the seventh-most such firms among 34 provinces nationwide. "A Picture of Hydrogen in China During the 14FYP: 10+ Provinces with Major Deployments; Guangdong, Jiangsu, Shandong with the Most Firms" (十四五中国氢能版图：超10个省份重点布局，广东、江苏、山东企业最多), *21st Century Economic Report* (21世纪经济报道), accessed April 30, 2021, https://m.21jingji.com/article/20210406/herald/512da7191cb43c36ae7e3fcd4438bd5b_zaker.html. Shell recently formed a JV with a company owned by the city of Zhangjiakou in Hebei to deploy a 20 MW electrolyzer for green hydrogen production. Zhangjiakou, which will cohost the 2022 Olympic Games with Beijing, was selected by central authorities as China's first National Renewable Energy Development Zone in 2015, and its 2019–35 Hydrogen Construction Strategy envisions developing 50,000 tpa of hydrogen production capacity by 2035. Xinhua, "Zhangjiakou Accelerates the Construction of Renewable Energy Demonstration Zone" (张家口加快建

设可再生能源示范区), July 26, 2019, accessed April 30, 2021, http://www.xinhuanet.com/info/2019-07/26/c_138259488.htm; "Zhangjiakou in Hebei: Become an Internationally-Famous Hydrogen Capital in 2035 with Production Value of 170 bn RMB"(河北张家口：2035年成国际知名氢能之都，产值1700亿), *The Paper* (澎湃新闻), accessed April 30, 2021, https://baijiahao.baidu.com/s?id=1636133141334843451&wfr=spider&for=pc; Shell (China) Limited and Zhangjiakou City Transport Construction Investment Holding Group, "Zhangjiakou City Transport and Shell New Energy Co., Limited Formed to Develop Hydrogen Value Chain," November 13, 2020, accessed April 30, 2021, https://www.shell.com.cn/en_cn/media/media-releases/2020-media-releases/zhangjiakou-city-transport-and-shell-new-energy-co-limited-formed-to-develop-hydrogen-value-chain.html.

192. Hebei Development and Reform Commission, "Notice regarding the Publication of *Hebei Province 2020 Hydrogen Industry Key Project List (First Batch)*" (关于印发《河北省2020年氢能产业重点项目清单（第一批）》的通知), Hebei DRC Energy Office [2020] No. 387, accessed May 10, 2021, http://hbdrc.hebei.gov.cn/common/ueditor/jsp/upload/20200331/26291585636899167.pdf; Sebastian Lewis, "N China Hydrogen Push Led by Hydrogen as By-Product, Renewables," S&P Global Platts, June 11, 2020, accessed April 30, 2021, https://www.spglobal.com/platts/en/market-insights/latest-news/metals/061120-n-china-hydrogen-push-led-by-hydrogen-as-by-product-renewables.

193. "Achieving Carbon Peaking in 2022: This Is How HBIS Will Do It" (2022年实现碳达峰 河钢集团这样"干"), World Metals Report WeChat channel (世界金属导报), March 14, 2021, accessed April 29, 2021, https://mp.weixin.qq.com/s?__biz=MzA5ODEzMjgwNA==&mid=2656702107&idx=2&sn=3c51e422b51f0cadcaf9abde2a802736&chksm=8b3898b0bc4f11a6cb6bc5dd965cdf302f974be42fc56fa184d1a6f8c8adaa65187267a6c86b#rd. The term "hydrogen metallurgy" is somewhat vague. It could indicate the use of hydrogen as a reduction agent in DRI facilities or in blast furnaces, with varying carbon footprints depending upon the share of green hydrogen used—DRI facilities can accept 100 percent shares of hydrogen for reduction, whereas blast furnaces are more limited. Friedmann and Fan report around a 20 percent potential reduction in carbon footprint from the use of hydrogen in blast furnaces, as opposed to around 60 percent for DRI facilities. Friedmann and Fan 2021, 840.

194. Tenova SpA, "First Hydrogen Based ENERGIRON DRI Plant for Tenova in China," November 23, 2020, accessed April 30, 2021, https://www.tenova.com/news/press-media/press-releases/detail/first-hydrogen-based-energiron-dri-plant-for-tenova-in-china/.

195. Kevin Jianjun Tu, *Prospects of a Hydrogen Economy with Chinese Characteristics*, Institut français des relations internationales, October 2020, accessed May 10, 2021, 36, https://www.ifri.org/sites/default/files/atoms/files/tu_china_hydrogen_economy_2020_1.pdf; Sinopec Target Announcement.

196. Sinopec Target Announcement.

197. "Tangshan City Carries Out Actions and Reforms in an Upright Fashion, Strictly Implements Heavy Pollution Weather Emergency Response Steps, Comprehensively Improves Air Quality" (唐山市立行立改，严格落实重污染天

气应急响应措施，全面改善空气质量), Tangshan City WeChat channel (唐山发布), March 13, 2021, accessed July 2, 2021, http://mp.weixin.qq.com/s?__biz=MzA3MzA1ODE3MQ==&mid=2650100926&idx=1&sn=93e4aa4ea71ce74b04a94bdfb46e58e1&chksm=871526aab062afbce0d3afc7206fe4d8b033ce432ec4fc15c366b1a1ae089314881fb87858da#rd.

198. See, for instance, "A Difficult Decade for a Big High-Carbon Province: How Big a Price Will Inner Mongolia Pay to Peak Carbon Emissions?" (高碳大省的艰难十年：内蒙古将为碳达峰付出多大的代价？), *China News Weekly* (中国新闻周刊), June 1, 2021, accessed July 2, 2021, http://www.ce.cn/cysc/stwm/sy/yw/202106/01/t20210601_36609541.shtml.

199. Sinopec Target Announcement. Before its net-zero announcement in late March 2020, the firm was saying that during the 14FYP period, it wished to "accelerate the advancement of the transition of hydrogen sources from grey hydrogen to blue and green hydrogen." Gray hydrogen generally refers to hydrogen produced from fossil fuels (via steam-methane reforming, for instance) without carbon capture technology; blue hydrogen is hydrogen produced from fossil fuels at facilities with carbon capture technology installed; and green hydrogen is hydrogen produced via electrolysis using zero-carbon electricity. The author has reviewed Sinopec's WeChat channel and has not been able to identify any statements since the company's neutrality pledge with more detailed timelines. See "A Dialogue with CEO Ma Yongsheng: Sinopec's Future Deployments Are Closely Linked to You!" (对话总经理马永生，中国石化未来布局与你息息相关！), Sinopec WeChat channel (中国石化), March 9, 2021, accessed June 27, 2021, https://mp.weixin.qq.com/s/FARdiMvX9BWi8o8G8hIRyA.

200. Laszlo Varro and An Fengquan, "China's Net-Zero Ambitions: The Next Five-Year Plan Will Be Critical for an Accelerated Energy Transition," IEA, October 29, 2020, accessed April 30, 2021, https://www.iea.org/commentaries/china-s-net-zero-ambitions-the-next-five-year-plan-will-be-critical-for-an-accelerated-energy-transition.

201. See, for instance, Matthew Walsh, "What's Holding Back Carbon Capture In China?," *Caixin Global*, December 21, 2020, accessed July 12, 2021, https://www.straitstimes.com/asia/whats-holding-back-carbon-capture-in-china.

202. A 2021 IEA on CCUS notes that annual investment in CCUS has "consistently accounted for less than 0.5% of global investment in clean energy and efficiency technologies" and that current global CCUS capacity (around 40 mt) is just 13 percent of the target laid out by the agency in its 2009 road map for the sector (around 300 mt). IEA, "Special Report on Carbon Capture Utilisation and Storage: CCUS in Clean Energy Transitions," Energy Technology Perspectives 2020, September 2020, accessed July 12, 2021, 28, https://www.iea.org/fuels-and-technologies/carbon-capture-utilisation-and-storage.

203. Wang Zhenbang (王振邦), "First Time Worldwide! Bayi Hydrogen-Rich Carbon Recycling Blast Furnace Achieves Major Technological Breakthrough" (全球首次！八钢富氢碳循环高炉实现重大技术突破), Baowu WeChat channel (中国宝武), accessed July 2, 2021, https://mp.weixin.qq.com/s/4UCIlnDHqdym1WUMNEYgIA.

204. For more on alternative cement compositions, see International Energy Agency and the

Cement Sustainability Initiative, "Technology Roadmap: Low-Carbon Transition in the Cement Industry," 2018, accessed May 10, 2021, 41–46, https://www.wbcsd.org/contentwbc/download/4586/61682/1; and Johanna Lehne and Felix Preston, "Making Concrete Change: Innovation in Low-Carbon Cement and Concrete," Chatham House, June 2018, accessed July 13, 2021, 42, 46–47, https://www.chathamhouse.org/2018/06/making-concrete-change-innovation-low-carbon-cement-and-concrete. Information on Chinese market prospects is based upon discussions with interviewees #5, #6, and #15 (Karen Scrivener, full professor, Construction Materials Laboratory, École polytechnique fédérale de Lausanne).

205. CCA, "13th Five-Year Development Plan for the Cement Industry," June 5, 2017, accessed April 30, 2021, http://www.dcement.com/article/201706/156678.html.

206. Interviewee #14.

207. Interviewee #16; "Cement in China steering towards sustainability," FLSmidth, accessed April 30, 2021, https://www.flsmidth.com:443/en-gb/discover/cement-2020/cement-in-china-steering-towards-sustainability; Du Sisi and Chen Xuewan, "China's Untested Carbon Market" (中国碳市场待考), *Caixin* (财新), January 25, 2021, accessed April 23, 2021, http://weekly.caixin.com/2021-01-23/101654673.html; Jeroen de Beer, Jan Cihlar, and Igor Hensing, "Status and Co-processing of Waste in EU Cement Plants," Ecofys, May 2017, accessed April 30, 2021, 4, http://www.cembureau.eu/media/ldfdotk0/12950-ecofys-co-processing-waste-cement-kilns-case-studies-2017-05.pdf.

208. CBMF 2020 Emissions Report, 5–6.

209. Han Qianwei of Huaxin Cement, a top-10 cement firm by clinker capacity, told Caixin reporters that the firm could achieve 50 percent AF shares and, in doing so, lower their carbon footprint from 0.86 tC/ton to 0.74 tC/ton, a 14 percent decline. The author thanks interviewee #5 who noted the assumption of zero-carbon biomass in this estimate. Du Sisi (杜偲偲) and Chen Xuewan (陈雪婉), "China's Untested Carbon Market" (中国碳市场待考), *Caixin* (财新), January 25, 2021, accessed April 23, 2021, http://weekly.caixin.com/2021-01-23/101654673.html. The estimate of a roughly 15 percent decline in carbon intensity also accords with a back-of-the-envelope calculation from the standard share of heating emissions in cement production of 30–40 percent, as reported by the IEA; 50 percent AF shares would cut that share in half.

210. Xinhua, "Chairman Xi Jinping Holds the 9th Meeting of the Central Economic and Financial Committee" (习近平主持召开中央财经委员会第九次会议), March 15, 2021, accessed May 3, 2021, http://www.gov.cn/xinwen/2021-03/15/content_5593154.htm.

211. The author was unable to access its website, http://www.ged.com.cn/, as identified by Guangdong Energy Group, "Guangdong Electric Power Development Co. Ltd." (广东电力发展股份有限公司), accessed May 11, 2021, https://www.geg.com.cn/site/gdyd/kgqy/info/2013/4191.html, but found no ESG reports from stock disclosure records or keyword searches through Baidu.

212. The author was unable to access its website, www.chinavalin.com, but found no ESG reports from keyword searches through Baidu.

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