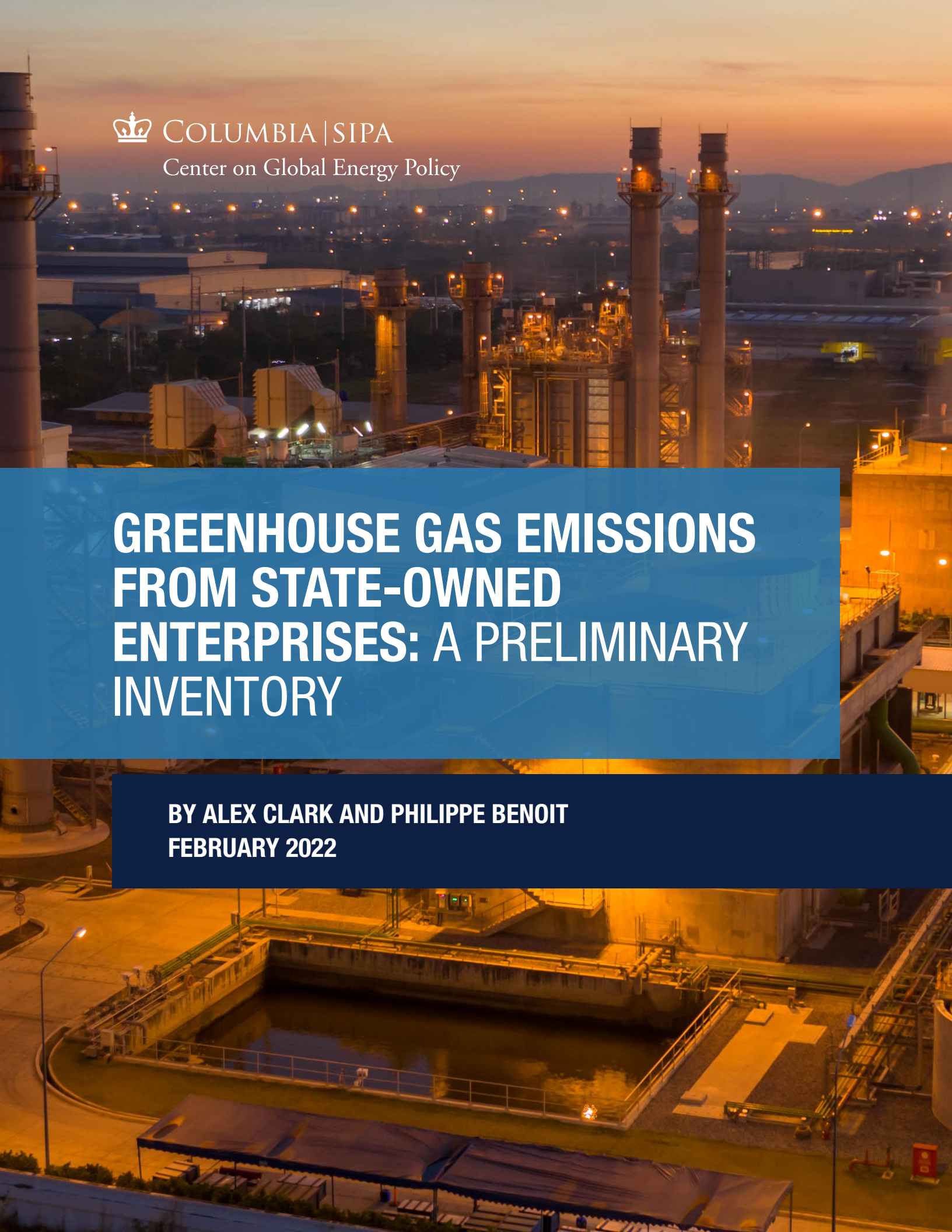

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GREENHOUSE GAS EMISSIONS FROM STATE-OWNED ENTERPRISES: A PRELIMINARY INVENTORY

BY ALEX CLARK AND PHILIPPE BENOIT
FEBRUARY 2022

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

State-owned enterprises (SOEs) play a major role in the production of goods and services across many of the world's largest economies, particularly in electricity generation, oil and gas, and heavy industry. SOEs (defined in this report as companies for which 50 percent or more of voting shares are held by a government) are also major sources of greenhouse gas emissions.

The governments that control these SOEs are also signatories to the Paris Agreement on climate change. State ownership provides these governments with a major direct point of control over the climate and energy outcomes of these companies, both in terms of reducing emissions and directing future investment into low-carbon technologies and infrastructure. Improving the measurement of SOEs' contribution to both national and global-level emissions provides important information to help understand to what extent SOEs should be targeted and to design strategies to maximize their potential role in the broader energy transition.

This report provides an accounting of direct emissions associated with SOEs globally. It is challenging to comprehensively identify every SOE, as the total is estimated at well over 100,000. In addition, most identified SOEs do not disclose their emissions nor are estimates of these emissions available in the public domain. Despite these limitations, data compiled for this report covering almost 300 major SOEs suggest that SOEs globally are responsible for at least 7.49 gigatons of carbon dioxide equivalent ($GtCO_2e$) annually in direct (Scope 1) emissions. While the true scale of SOE-related emissions is likely to be substantially higher, particularly when accounting for national oil companies and iron and steel manufacturers that do not currently report their emissions, this figure is over 1 $GtCO_2e$ greater than various previous estimates, and larger than the total annual emissions of any country except China.

Additional findings from this report include the following:

- Geographically, the SOE emissions inventoried in this report are highly concentrated among entities controlled by the Chinese government (69 percent share, 5.16 $GtCO_2e$). Other governments with major contributions include Russia and India (4 percent each); Indonesia, South Africa, and South Korea (3 percent each); and Saudi Arabia and Mexico (2 percent each). Most of the remaining emissions are associated with SOEs domiciled in Taiwan, Sweden, the United States, Brazil, and Poland, at about 1 percent each, and 20 other countries with smaller shares.
- The power sector is the dominant source of the inventoried emissions (85 percent share, 6.39 $GtCO_2e$), with additional significant contributions from oil and gas production and distribution (10 percent, 0.78 $GtCO_2e$), transport (1.8 percent, 0.14 $GtCO_2e$), cement (1.4 percent, 0.11 $GtCO_2e$), and chemicals (0.6 percent, 0.05 $GtCO_2e$). Three-quarters of power sector emissions are attributable to Chinese SOEs, with the "Big Five" power generation companies alone making up over 20 percent of total SOEs emissions across all sectors.

- SOE emissions also represent a significant share of national greenhouse gas emissions in a number of countries, including China, India, Indonesia, Mexico, Saudi Arabia, South Africa, and South Korea.
- The absence of direct emissions data for many prominent SOEs suggests that further data gathering and estimation is required, particularly in the oil and gas as well as iron and steel sectors, where emissions disclosures are scarce. This indicates the potential for a significantly higher total for SOE direct emissions. (An example of possible further estimation includes emissions assessed on the basis of production and emissions intensity for firms in these sectors for which direct emissions data are not available, as described in Appendix I.)
- While SOEs are large sources of emissions, they are also major providers of low-carbon alternatives. A comprehensive assessment of the impact of government-owned assets on emissions would ultimately also acknowledge emissions avoided by governments through investment in low- or zero-carbon alternatives.

INTRODUCTION

In many of the world's largest economies, including several that are growing rapidly, the state itself owns sizable companies in sectors of strategic importance to its development and energy security. The sectors in which government ownership is most prominent include power generation, industrial production, and oil and gas, although national governments are also present as shareholders in the airline, agriculture, and public transport industries. These state-owned enterprises (SOEs) tend to be emissions intensive, based largely on the production or consumption of hydrocarbons. SOEs are defined in this report as companies for which 50 percent or more of voting shares are held by a government, either directly or through one or more state-owned entities, such as sovereign wealth funds.[1]

The governments that control these SOEs are also signatories to the Paris Agreement on climate change. State ownership provides these governments with a major direct point of control over the operations and strategy, and therefore the emissions footprints, of these firms. Improving the measurement of SOEs' role in the decarbonization process and crafting policies designed to maximize their decarbonization potential could support the broader energy transition.

This report seeks to provide an accounting of direct emissions associated with SOEs globally. This can help to provide a more complete picture of how SOE emissions are distributed across countries and sectors and can illuminate where governments might most effectively apply pressure in pushing or pulling their SOEs toward achieving climate and green development objectives. The authors then consider future expansion of the inventory into other sources of public sector emissions as well as the potential for the inclusion of investments in low- or zero-emissions assets in a holistic accounting of SOEs' climate-related activity.

BACKGROUND

SOEs are major economic players. The Organisation for Economic Co-operation and Development (OECD) finds that SOEs represent over 10 percent of the world's 2,000 largest public companies, with sales of $3.6 trillion in 2011.[2] This is larger than every national economy in the world today other than those of the United States, China, Japan, and Germany. A subsequent study of 34 countries, 30 of which are OECD members, identified 2,111 SOEs with an estimated market value of $2 trillion and with 6 million employees.[3] The International Monetary Fund estimates that China alone may have up to 150,000 SOEs, including 50,000 centrally owned SOEs and 100,000 local SOEs, in addition to 110 large conglomerates under the direct supervision of the State-Owned Assets Supervision and Administration Commission.[4] While state ownership of key industrial sectors is prevalent in emerging and developing economies (China, Indonesia, Mexico, and Saudi Arabia, for instance), large government-controlled companies are also present in advanced economies (notably in power and urban transit), including those of Canada, France, and the Republic of Korea (South Korea).

SOEs play major roles in high-emitting, energy-intensive sectors, including power generation, steel and cement manufacturing, air transport, and public transport. A 2019 estimate of SOE greenhouse gas emissions found that they emit at least 6.2 gigatons (billion tons) of carbon dioxide equivalent ($GtCO_2e$) annually, which, for perspective, is more than any single country except China.[5]

The national-level government owners of SOEs are also signatories to the Paris Agreement on climate change.[6] Under the agreement, governments commit themselves to holding the rise in global temperature to "well below" 2°C above preindustrial levels, with an aspirational target of 1.5°C.[7] As of December 2021, over 130 countries have either proposed or legislated for economy-wide net-zero emissions targets, including Canada (2050), the European Union (2050), Japan (2050), South Korea (2050), the United Kingdom (2050), the United States (2050), China (2060), Indonesia (2060), and India (2070).

Achieving these goals will require rapidly reducing, and then virtually eliminating, national emissions, including from the SOEs generating significant shares of those emissions. In their roles as sole or majority shareholders of SOEs, governments may be able to exercise considerable, if not dominant, influence over the climate strategies and policies of SOEs. Their ability to do so is strongly determined by the local political-economic context defining how a government and its SOEs interact and also by the legal status of the SOE and the constraints within which it operates, which include but are not limited to fiduciary duties, obligations to pursue financial returns, and constraints on capital investments.

Policies, legislation, and institutions also govern the activities of private companies and individuals but in a less direct and targeted manner than is typically available to governments in influencing the actions of their own SOEs. In addition, market-based policies designed to change the behavior of profit-maximizing firms may have a more muted effect on SOEs, in part because SOEs are often expected to meet socioeconomic targets rather than simply

maximize profits. Examples of such targets include contributing to national economic growth, ensuring secure supplies of key goods and services, and generating employment.[8]

Emissions disclosures by the universe of publicly traded companies (both state-owned and private) are incomplete, being almost exclusively voluntary. For SOEs, the lack of emissions data is even more severe. Some SOEs are owned wholly and directly by the government, while for others the government holds a majority or near-majority share and other financial SOEs (e.g., public pension funds, social security funds, or public investment funds) hold smaller shares—with the remainder floated on the stock market or held by private investors. Among those SOEs that are publicly listed—only one-third of the 2,000-plus firms in the 34-country OECD study[9]—some disclose their emissions. Among the unlisted majority, very few do, and reported figures can be difficult to verify. Previous attempts to quantify emissions have been limited to the small number of large companies for which such data is readily available.[10]

QUANTIFYING SOE EMISSIONS: GLOBAL, NATIONAL, AND SECTORAL

The inventory compiled in this report draws from a broad range of sources to gather company-specific figures for almost 300 SOEs across the globe to estimate carbon dioxide equivalent emissions on national and sectoral levels. The methodology used in making these calculations is presented in Appendix I (with a summary presented in Box 1). Details on the SOEs with the highest disclosed emissions are listed in Appendix II.

Box 1: Methodology Summary *(see Appendix I for details)*

The analysis in this report reflects Scope 1 emissions data reported directly by SOEs (outside of China's power sector, for which data was gathered differently, as explained below) in financial or sustainability reports or other public documents (45 companies), as well as data reported by third parties: Arabesque S-Ray and Carbon Dioxide Management in Power Generation (CARMA) via the International Energy Agency (IEA) (240 companies). Public transit emissions are obtained from a variety of additional sources listed in Appendix I. Only parent company emissions are counted in cases where subsidiaries are also SOEs to avoid double counting, and when multiple governments are shareholders, the SOE is associated with the country in which it is headquartered. Emissions from these sources total 2.78 $GtCO_2e$.

Chinese coal power emissions are estimated using a top-down approach based on total coal power generation emissions of 4.9 $GtCO_2e$ in 2019, scaled by the estimated 94 percent share of state ownership in national coal power generation capacity. This results in estimated SOE emissions from Chinese coal power of 4.61 $GtCO_2e$. A similar approach is used to estimate SOE emissions from the Chinese gas power sector (74 percent of 0.13 $GtCO_2e$), resulting in 0.09 $GtCO_2e$. Total power sector SOE emissions in China are therefore estimated at 4.7 $GtCO_2e$ annually.

The total direct emissions identified and analyzed in this report are the sum of these two figures, 7.49 $GtCO_2e$ per year. (Adding emissions derived from production and emissions intensity estimates in cases where there is no reported data—a methodology not employed in this paper's total figure because it is less robust than using reported amounts—would raise the total SOE emissions to 8.87 $GtCO_2e$ per year [see Appendix I].)

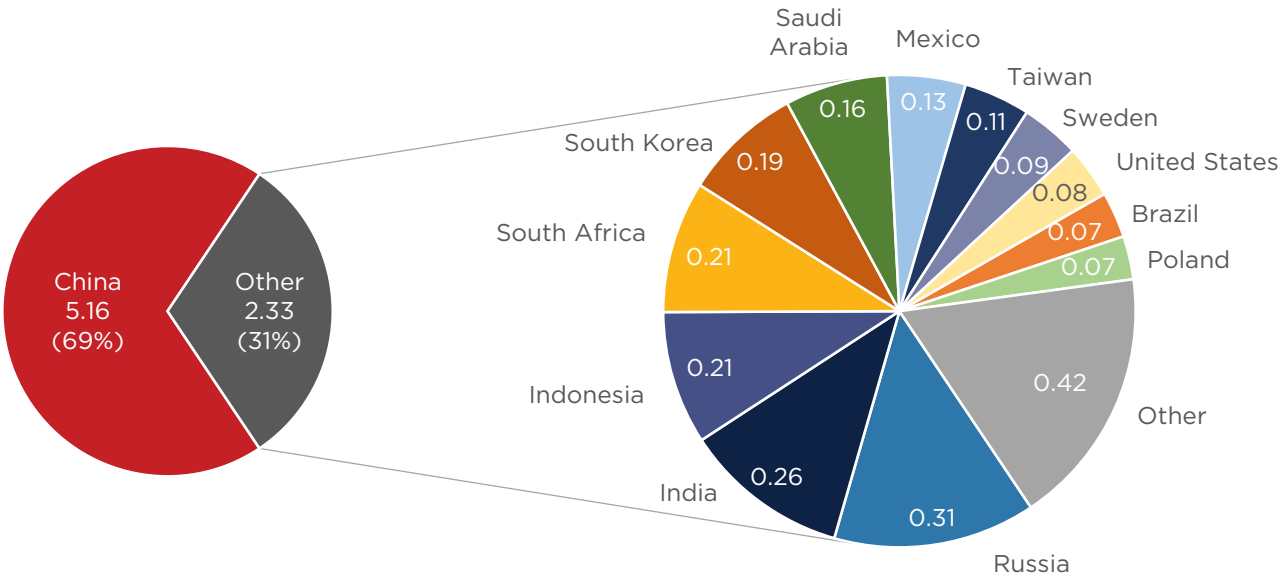
Overall SOE Emissions

The detailed inventory of direct emissions[11] by SOEs used in this report estimates that SOEs emit at least 7.49 $GtCO_2e$ annually, based on the most recently reported year. This figure is greater than the emissions of any single country except China and makes up over 16 percent of the 2017 global total.[12] The figure is also over 1 $GtCO_2e$ per year greater than the 6.2 $GtCO_2e$ estimate previously reported by one of the authors of this report,[13] resulting from a more detailed and extensive inventory of companies.

Distribution of SOE Emissions by Government Owner

Geographically, SOE emissions are highly concentrated in entities controlled by governments in China (69 percent share, 5.16 $GtCO_2e$), as shown in Figure 1. This is followed by Russia and India (4 percent each); Indonesia, South Africa, and South Korea (3 percent each); and Saudi Arabia and Mexico (2 percent each). Most of the remaining emissions are linked to SOEs domiciled in Taiwan, Sweden, the United States, Brazil, and Poland (1 percent each), with the remaining 6 percent distributed across 20 other countries.

Figure 1: Direct SOE emissions by country of ownership ($GtCO_2e$/year)



Source: Authors' calculations; see sources in the Appendix.

Although this inventory is incomplete due to the absence of emissions data for the majority of SOEs identified in the database, the dominant contribution of Chinese SOEs to direct emissions is clearly visible. China's SOEs are responsible for over three-quarters of total direct emissions, largely from coal-fired electricity generation. Of the 58 SOEs with direct emissions of over 10 million tons (Mt) of CO_2e annually (as reported either by companies or third parties), more than one-quarter are Chinese SOEs in the power, oil and gas, and cement sectors (see Appendix II). This finding is unsurprising given China's contribution to global emissions and the centrality of SOEs across most of the country's industrial sectors.

SOEs from large developing economies comprise much of the remaining emissions. Notably, three of the four remaining BRICS (Brazil, Russia, India, China, and South Africa) economies rank in the top 15 emitters, representing 12 percent of the total and 37 percent of non-Chinese emissions. Post–Soviet Russia, the largest share after China, retains state control over a number of entities in the power and oil and gas sectors (e.g., Gazprom, Rosneft, and

Inter RAO). India represents the next-largest share; its partly privatized power and industrial sectors still include large SOEs (e.g., NTPC Ltd). South Africa's power sector emissions are overwhelmingly attributable to its state-run utility, Eskom. The last of the BRICS economies, Brazil, makes a significantly lower contribution at 1 percent of the total, partly due to the steady privatization of emissions-intensive industries and the relatively high proportion of hydroelectric and renewable power in its electricity grid.

Economies hosting individual SOEs with reported emissions of over 10 $MtCO_2e$ annually are summarized in Table 1 (see Appendix II for greater detail on specific emissions figures, sources, and reporting years for each SOE). While China is home to by far the largest number of high-emitting SOEs, a significant number are located in upper-middle and high-income countries, with the only lower-middle income countries on the list being India and Indonesia. A fuller accounting of direct emissions from national oil companies (NOCs) and steel and cement SOEs, both of which are underrepresented, would add to this list.

Table 1: Economies hosting SOEs with annual emissions exceeding 10 $MtCO_2e$/year (most recently reported)

Economy	World Bank income group	SOEs emitting >10$MtCO_2e$ annually
Argentina	Upper middle	YPF
Australia	High	Stanwell
Austria	High	OMV Group
Brazil	Upper middle	Petrobras
China	Upper middle	Huaneng, Datang, CEIC, Huadian, PetroChina, State Power Investment Corporation (SPIC), Shenhua, China Resources, Sinopec, State Grid Corporation, Guangdong Yudean, Zhejiang Energy, SDIC, China Southern Airlines, Air China, COSCO, and Yitai Coal
Czech Republic	High	CEZ
Finland	High	Fortum
France	High	*Electricité de France* (EDF)[14]
Greece	High	PPC
Hong Kong	High	China Everbright
India	Lower middle	NTPC, Mahagenco, and Indian Oil
Indonesia	Lower middle	PLN, PT Semen, and Pertamina
Israel	High	IEC
Japan	High	Hokuriku
Malaysia	Upper middle	YTL
Mexico	Upper middle	CFE and Pemex
Norway	High	Equinor [formerly Statoil]
Poland	High	PGE

Continued on next page

Economy	World Bank income group	SOEs emitting >10 $MtCO_2e$ annually
Russia	Upper middle	Gazprom, Inter RAO, Rosneft, RusHydro, and Aeroflot
Saudi Arabia	High	Saudi Electricity and Saudi Basic Industries
Singapore	High	Singapore Airlines
South Africa	Upper middle	Eskom
South Korea	High	KEPCO
Sweden	High	Vattenfall Group
Taiwan	High	Taiwan Power
Thailand	Upper middle	PTT
United States	High	Tennessee Valley Authority

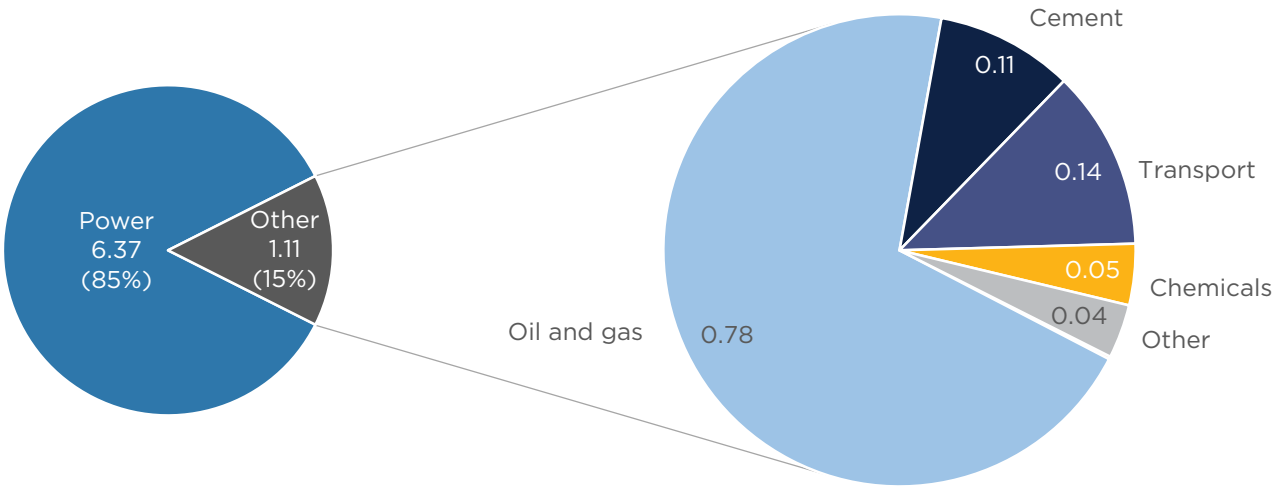
It is important to note that emissions under this inventory are allocated to countries according to the country to which the SOE belongs, in full or in part. Although some individual SOEs may record emissions from operations abroad, most SOE emissions are largely domestic and are consequently a good estimate for national emissions from each country's SOEs, with some exceptions.[15]

Sectoral Distribution of SOE Emissions

Power Generation

The power sector makes up 85 percent of the direct SOE emissions identified in this inventory (see Figure 2), at 6.4 $GtCO_2e$, followed by oil and gas[16] at 10 percent (0.78 Gt), transport at 1.8 percent (0.14 Gt), cement at 1.4 percent (0.11 Gt), and chemicals at 0.6 percent (0.05 Gt). As noted above, emissions from oil and gas are likely to be heavily underestimated due to the lack of disclosure by SOEs in both sectors. There is no disclosed emissions data available for SOEs in the iron and steel sectors.

Figure 2: Direct SOE emissions by sector ($GtCO_2e$/year)



Note: Iron and steel SOE emissions are not included because they are not reported directly or available from third parties.

Source: Authors' calculations; see sources in the Appendix.

In power generation, Chinese SOEs, heavily reliant on coal, make up three-quarters of the sector's global contribution. The "'Big Five" Chinese power generators (Huadian [including subsidiary Huadian Power International], Huaneng, Datang, CEIC, and SPIC) alone make up over 20 percent of estimated global SOE emissions across all sectors. India, Indonesia, South Korea, Mexico, South Africa, Saudi Arabia, Russia, Taiwan, Sweden, and the United States comprise much of the remainder—all of which, except Sweden, rely heavily on fossil fuels (coal, gas, and oil) for electricity generation.

Oil and Gas

The measurement of oil and gas emissions presents particular challenges not only because of incomplete and inconsistent reporting by NOCs but also because of the uncertainties and measurement challenges inherent in methane emissions estimates, which generate a significant proportion of total greenhouse gas emissions in the sector.[17] Consequently, the figures in this report for direct oil and gas emissions from NOCs are incomplete and require further analysis. Moreover, NOCs, as well as state-owned coal mining companies, produce a significant portion of the world's fossil fuels and have correspondingly large Scope 3 emissions from the combustion of these fuels. They therefore play a significant role in total global emissions across multiple sectors.

Other Contributors

The two sectors contributing over 1 percent of nonpower direct emissions are cement and transport. Both are high-emitting sectors, but they at least partly externalize their operating

emissions to the power sector through the consumption of fossil-fueled electricity. The transport figure primarily covers state-owned airlines and public transport systems. As noted above, the authors were unable to locate emissions disclosures by state-owned iron and steel producers (see Appendix I for a possible approach to deriving these unreported emissions).

SOES PLAY A KEY ROLE IN MEETING NATIONALLY DETERMINED CONTRIBUTIONS

In many countries, SOE emissions constitute a significant portion of national emissions.[18] For these countries, achieving their emissions reduction targets will require SOEs to be major instruments of climate action.

China's SOEs, for example, generate about half of the country's total greenhouse gas emissions.[19] In addition, China's national oil and gas companies and large state-owned coal mines supply a significant portion of its domestically consumed fossil fuels.[20] The implication is that SOEs control value chains for sectors responsible, directly or indirectly, for the majority of China's emissions: coal, electricity, oil, and gas. Consequently, any major steps toward China's goal of carbon neutrality by 2060 will require addressing emissions generated by the country's SOEs.

Other countries in which SOEs contribute significantly to national emissions include India, Indonesia, Mexico, Saudi Arabia, South Africa, and South Korea. If these countries are to achieve their Nationally Determined Contributions to the Paris Agreement, SOE climate action is imperative.

Moreover, SOEs are frequently responsible for providing a significant share of low- and zero-carbon electricity, even in countries where they also operate a large proportion of the fossil-fired fleet. China's SPIC, for example, operated a 165 GW portfolio in 2020, 47 percent of which was coal-fired capacity.[21] It is also considered the world's largest generator of renewable power from solar and wind installations, with 12 GW and 14 GW, respectively, in installed capacity in 2020, as well as 22 GW of hydroelectric capacity.[22] The contribution of SOEs to low-carbon generation is particularly evident in strategically significant, capital-intensive, and sometimes politically controversial infrastructure projects such as large-scale hydroelectric dams and nuclear power plants. In France, for example, the low carbon intensity of its electricity sector is largely the result of the nuclear power plant fleet owned by its power sector SOE, EDF. Similarly, as other countries look to expand low-carbon-generation alternatives (including nuclear power), SOEs will play an important role in the effort and, consequently, in delivering on national emissions reduction pledges.

BEYOND SOES: ENHANCING AND EXPANDING THE ANALYSIS OF EMISSIONS TO OTHER PUBLIC SECTOR INSTITUTIONS

The SOE emissions accounting exercise conducted in the preparation of this report uncovered a significant amount of emissions for which the state has ultimate responsibility, but the picture is incomplete. In addition to difficulties in identifying SOEs and obtaining information on their emissions, there are emissions under public sector control that fall outside the coverage of this report.

This analysis has focused on clearly identifiable industrial sectors where state ownership can be relatively easily ascertained and, within these sectors, on corporate institutional structures. Oil and gas, as previously mentioned, is an area that merits further close analysis, including of methane emissions from NOCs. Another is the agricultural sector where more research is required, particularly for methane as well as other non-CO_2 greenhouse gas emissions.

There are, importantly, other sectors/activities with assets managed by noncorporate institutions that are controlled by the government and that potentially generate significant emissions. One example is public buildings, for which data are typically reported only in aggregate through city-level or national inventories.

Another case of government-owned assets generating emissions outside corporate structures is the military sector, which contributes to emissions through both oil (particularly jet fuel) and electricity consumption. Brown University research suggests the United States military emits 59 $MtCO_2e$ annually (predominantly direct Scope 1 emissions) and has emitted well over 1 $GtCO_2e$ since 2001.[23] The same analysis estimated that emissions from the military industry meeting United States military demand approximate 153 $MtCO_2e$ annually. Emissions from air force, army, and navy operations disclosed by the Defense Logistics Agency totaled 23.3 $MtCO_2e$ in 2017.[24] This disclosure alone would place the US military in the top 50 state-owned emitters. Further studies suggest annual military emissions for the United Kingdom, including arms sales, total 11 $MtCO_2e$ annually,[25] and those of the European Union total almost 25 $MtCO_2e$ annually.[26] Based on these figures, the authors conservatively estimated that direct military emissions on a global scale are likely to significantly exceed 100 $MtCO_2e$.

EVALUATING "AVOIDED EMISSIONS"

While SOEs and the public sector are responsible for large sources of emissions and power sector SOEs continue to invest heavily in coal, they are also—as indicated previously—major direct investors in low-carbon technologies.[27] In nominal terms, SOE investments in fossil and non-hydro renewables were approximately equal in 2015. OECD research shows that while SOEs in the power sector own well over half the world's fossil fuel generation capacity, they also control about 75 percent of hydro and nuclear capacity.[28] These energy sources produce very low-emissions electricity relative to fossil fuel-fired alternatives, helping to displace emissions that would otherwise occur.

The promotion of low-carbon generation is sometimes characterized by the emissions it avoids[29]—or "nega-emissions," similar to the concept of "negawatts,"[30] which is used to measure the avoided power generation yielded by energy efficiency investments. The inventory presented in this report could in principle be extended to include complementary information on the amount of "avoided emissions" generated by SOEs, including renewable and other low-carbon capacity investments, as well as investments in energy efficiency and electrification measures that are prerequisites for decarbonization in nonpower sectors.

To the extent possible, this analysis has minimized double counting of emissions by restricting aggregate figures to Scope 1 emissions. However, the purpose of this inventory is not just to aggregate direct emissions in each sector but also to understand where the key leverage points for governments are in using their SOEs to meet climate policy objectives—even where the supply chains, hence the emissions footprints, of these SOEs overlap. Understanding the combination of Scope 1, 2, and 3 emissions, as well as avoided emissions, under state control would provide a fuller picture of the potential latitude for climate action by governments.

CONCLUSION

Direct emissions under government control through majority-state-owned companies total at least 7.49 $GtCO_2e$[31] annually. For perspective, this equates to more than any single country's Scope 1 emissions except China's. Limited disclosure in several major sectors suggests the real total is considerably higher. The majority owners of these companies are governments that are also signatories to the Paris Agreement, making their management and direction of these companies (in their shareholding and policy-making roles) critical for meeting their net-zero emissions targets. The purpose of this analysis has been to take initial steps toward addressing the lack of comprehensive aggregate data on emissions associated with state-owned entities.

By elucidating the distribution and size of state-controlled sources of emissions, this preliminary analysis can support governments in using their SOEs as a tool for achieving climate policy objectives. It can also assist nongovernmental actors in holding their governments to account for the emissions under states' control in their role as majority shareholders of high-emitting entities. Expanding the research to map emissions controlled by governments outside SOEs (e.g., from public sector buildings and the military) and the potential of government-controlled entities to pivot to low-carbon alternatives across multiple sectors could provide further insight into the role that government owners can play in advancing the low-carbon transition.

APPENDIX I: METHODOLOGY

While some SOEs are listed companies and more likely to disclose their emissions (and are increasingly doing so as sustainability rules in stock markets and regulatory disclosure requirements become more prevalent), many are not, and obtaining information of any kind for these companies is extremely challenging.

In this report, only direct (Scope 1) emissions are counted in the total figure for SOEs to avoid any double counting of emissions associated with electricity consumption. This is particularly relevant when companies in both the power sector and industrial sector that consume large amounts of electricity are state owned.

Definitions and Classifications

The following data points were collected in identifying and assessing SOEs:

- **Ownership**: A company is considered state owned if 50 percent or more of its voting shares are held by a government, either directly or through a fully state-owned entity, such as a sovereign wealth fund. To avoid double counting, emissions information is collected only for the parent company where majority-owned subsidiaries exist.
- **Country**: Each company is associated with the country in which it is headquartered. In cases where an entity is owned by several governments, none of which hold a majority share, it is still associated with the location of its headquarters. Note that this implies emissions can be generated beyond the country in which the SOE is domiciled.
- **Sector**: Sectoral categorization varies across sources, and there is no standardized classification database on which to draw for all companies covered. Many companies in the inventory are diversified. In all cases, sectors were coded according to the entity's primary line of business. The sectors covered are grouped into "power," "oil and gas," "cement," "iron and steel," "infrastructure," "transport," "defense," "agriculture and forestry," "metals and minerals," "chemicals," "coal," "manufacturing," "water," "retail," and "real estate." Holding companies and investment entities are classified as "holding," "finance," or "other."
- **Emissions**: The inventory aggregates only Scope 1 emissions. To avoid double counting, Scope 2 emissions (from power or heat produced off site but consumed on site) and Scope 3 emissions (related to activities upstream and downstream of the SOE) are not included in the aggregated figures. Depending on the case, this can mean that fugitive emissions from upstream or downstream infrastructure not directly owned by an SOE (e.g., methane leakage from gas pipelines, as opposed to on-site production activities) are not included.

Calculating SOE Emissions

- "Reported" (i.e., bottom-up) direct emissions by the 285 SOEs for which company-level emissions information was available amount to 5.01 $GtCO_2e$. This "reported" descriptor includes emissions data reported directly by SOEs and gathered from annual financial or sustainability reports where available (45 companies, totaling 1.80 $GtCO_2e$) and otherwise from the International Energy Agency, which derives many of its figures from the CARMA database (240 companies, totaling 3.21 $GtCO_2e$). For reported direct emissions of SOEs in the transport sector, a range of sources were used.[32] This 5.01 figure includes 2.23 $GtCO_2e$ in emissions from SOEs in China's power sector, which are subsequently subsumed into the "top-down" sectoral estimates described in the next two bullets. Consequently, reported emissions outside of the Chinese power sector totaled 2.78 $GtCO_2e$.
- Given the dominance of SOEs in China's coal power generation sector, Chinese SOE emissions from coal power were estimated using a top-down approach. Total coal power sector emissions for China in 2019 were reported by the IEA in the World Energy Outlook 2020 at 4.90 $GtCO_2$. This total is adjusted to reflect the estimated share of state ownership in coal power generation capacity of approximately 94 percent.[33] The resulting top-down estimate for China's emissions from state-owned coal power generation is 4.61 $GtCO_2$.
- A similar approach was used to estimate Chinese state-owned gas power generation emissions, which are substantially smaller. Total gas power sector emissions for China in 2019 were reported by the IEA in the *World Energy Outlook 2020* at 0.13 $GtCO_2$, with SOEs estimated to own 74 percent of gas-fired generation capacity.[34] The resulting top-down estimate for China's SOE emissions from gas power generation is 0.09 $GtCO_2$.

Once the combined adjustments for coal- and gas-fired power generation in China were included, and reported emissions for Chinese power sector SOEs removed to avoid double counting, the total direct emissions were 7.49 $GtCO_2e$ (5.01 – 2.23 + 4.61 + 0.09).

Sourcing Reported Emissions Data

The inventory described in this report primarily uses publicly available information (in some cases preaggregated by third parties) to construct a list of 3,826 SOEs and associate them with sector, country, and emissions information where available. Of this larger amount, reports from 285 companies were identified, including many of the larger SOEs. The most recent emissions data was used in all cases, although differences in the availability of sources mean the most recently reported year ranges from 2009 to 2020. The ability to identify SOEs and the availability of emissions data for them varies considerably across sectors (see Table A1).

Table A1: Coverage by sector and emissions

Sector	Ability to identify state-owned enterprises	Sources (companies and ownership)	Emissions data availability for state-owned enterprises identified	Sources (emissions/ emissions factors)
Cross-sectoral company data	Moderate[35]	Ginting and Naqvi (2020) Prag et al. (2018) Kowalski et al. (2013) Forbes (2020) Various (public sources)	Moderate	Arabesque S-Ray (2021) Various (public sources and company reports)
Country- and sector-level emissions data	Excellent	ClimateWatch (2020) International Energy Agency (2019)		
Power (electricity generation)	Good	Adkins et al. (2016) Herve-Mignucci et al. (2015)	Moderate	Arabesque S-Ray (2021) Adkins et al. (2016)
Cement	Good	Adkins et al. (2016)	Poor	Arabesque S-Ray (2021) Adkins et al. (2016) Global Cement and Concrete Association (2018)
Steel	Good	Adkins et al. (2016) World Steel Association (2020)	Poor	-
Oil and gas	Good	National Resource Governance Institute (2019)	Poor	Masnadi et al. (2018)
Airlines	Good	International Civil Aviation Organization (2016)	Poor	Warwick Business School (2016)
Airports	Good	Pek and Caldecott (2020)	Very poor	-
Public transport	Poor	-	Moderate	Doll and Balaban (2013) Li et al. (2018) Andrade and D'Agosto (2016) MacWhinney (2019) Creutzig et al. (2016) Office of Rail and Road (2020) RATP Group (n.d.) Wang et al. (2015)
Agriculture	Very poor	-	Very poor	-

Estimating Derived Emissions

In some cases, it was possible to estimate emissions in industrial sectors based on production and emissions intensity figures. In many more, this was not possible and further efforts will be needed to source and verify information on nondisclosing SOEs (including by accessing documents written in languages other than English).

These "derived" emissions, which were calculated as part of a broader inventory exercise, were not included in the total figure presented in this paper since they are less robust than reported emissions and were generated using a different methodology. In the continued absence of emissions reporting, though, this approach can be used in future work to infer some portion of missing emissions by applying emissions coefficients (typically available at the country level) to production data in the oil and gas, iron and steel, and cement sectors. The sources used for constructing derived emissions but that were not included as part of the analysis of this paper are listed in Table A2.

Table A2: Sources for production and emissions intensity estimates for select sectors

Sector	Sources (production figures)	Sources (emissions factors)
Cement	Adkins et al. (2016)	Adkins et al. (2016) Global Cement and Concrete Association (2018)
Iron and steel	Adkins et al. (2016) World Steel Association (2020)	Hasanbeigi et al. (2016) Bellona Europa (2019) World Steel Association (2020)
Oil and gas	National Resource Governance Institute (2019)	Masnadi et al. (2018)

Table A3 shows how additional sector-level emissions could be found by applying this approach. Adding derived emissions would raise total estimated SOE emissions to 8.87 $GtCO_2e$ per year (the sum of inventoried SOE emissions of approximately 7.49 $GtCO_2e$ and derived emissions of approximately 1.39 $GtCO_2e$, rounded).

Table A3: Additional emissions obtained when deriving from production and emissions intensity figures ($GtCO_2e$/year)

Scope 1 emissions	Additional derived	Reported total (for comparison)	Total including derived estimates
Iron and steel	0.80	0.00	0.81
Oil and gas	0.53	0.78	1.31
Cement	0.05	0.11	0.16
Total	**1.39**	**0.89**	**2.27**

Note: Totals may not sum up exactly due to rounding.
Source: Authors' calculations; see sources in the Appendix.

APPENDIX II: SUMMARY RESULTS

A list of entities with annual emissions exceeding 10 $MtCO_2e$ reported (either directly or by third parties) is presented in Table A4. This list does not include many major NOCs and other companies (particularly in the iron and steel and cement sectors) for which reported emissions data were not available.

Table A4: Emissions reported for SOEs generating over 10 $MtCO_2e$ (Scope 1) annually

Company	Country	Gov't share	Sector	Direct emissions ($MtCO_2e$)	Reporting year	Source	Link (URL)
Aeroflot	Russia	51%	Transport	13.1	2020	Arabesque	https://www.arabesque.com/s-ray/
Air China	China	53%	Transport	23.2	2020	Arabesque	"
CEIC (formerly Guodian)	China	100%	Power	313.0	2009	CARMA	https://www.cgdev.org/topics/carbon-monitoring-action
CEIC (formerly Shenhua)	China	100%	Power	90.8	2009	CARMA	"
CEZ	Czech Republic	70%	Power	27.4	2020	Arabesque	"
CFE	Mexico	100%	Power	73.9	2009	CARMA	"
China Datang	China	100%	Power	325.7	2009	CARMA	"
China Everbright	Hong Kong	>50%	Power	10.3	2017	Arabesque	"
China Huadian	China	100%	Power	306.9	2009	CARMA	"
China Huaneng	China	100%	Power	402.3	2009	CARMA	"
China Resources Cement	China	69%	Cement	58.7	2019	China Resources Cement Holdings	https://www.crcement.com/home/Investorrelations/Resultsannouncement/Annual_performance/202004/P0 20200409424377511255.pdf
China Resources Power	China	63%	Power	117.4	2009	CARMA	"

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Company	Country	Gov't share	Sector	Direct emissions ($MtCO_2e$)	Reporting year	Source	Link (URL)
China Southern Airlines	China	63%	Transport	28.5	2020	Arabesque	"
COSCO	China	>50%	Transport	21.6	2020	Arabesque	"
Ecopetrol	Colombia	88%	Oil and gas	10.6	2020	Arabesque	"
EDF	France	84%	Power	33.1	2020	Arabesque	"
Equinor	Norway	67%	Oil and gas	13.3	2020	Equinor	https://sustainability.equinor.com/climate-tables
Eskom	South Africa	100%	Power	206.0	2018	2018	https://www.eskom.co.za/wp-content/uploads/2021/02/Eskom_Factor_2.0.pdf
Fortum	Finland	52%	Power	19.1	2020	Arabesque	"
Gazprom	Russia	52%	Oil and gas	112.2	2017	Arabesque	"
Gazprom Neft	Russia	50%	Oil and gas	21.9	2020	Arabesque	"
Guang-dong Yudean	China	100%	Power	44.8	2009	CARMA	"
Hokuriku	Japan	>50%	Power	17.0	2018	Arabesque	"
Huadian Power Int'l	China	61%	Power	167.9	2019	Huadian Power	http://www.hdpi.com .cn/webfront/fileDownLoad.do?fileId=88640
IEC	Israel	100%	Power	29.8	2019	IEC	https://www.iec.co.il/Sustainability/Documents/IEC2019SustainabilityReport.pdf
Indian Oil	India	52%	Oil and gas	19.0	2020	Arabesque	"
Inter RAO	Russia	66%	Power	64.8	2020	Inter Rao	https://www.interrao.ru/en/sustainable-develoment/environmental-protection gre enhouse-gas-emissions/

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Company	Country	Gov't share	Sector	Direct emissions ($MtCO_2e$)	Reporting year	Source	Link (URL)
KEPCO	South Korea	62%	Power	175.6	2020	National GHG Mgmt. System	https://ngms.gir.go.kr/link do?menuNo=3 0130103&link=/websquare/websqu are.html%3Fw2xPath% 3D/cm/bbs/OGCMBBS023V.xml%26menu%3D30130103
Mahagenco	India	100%	Power	46.7	2009	CARMA	"
NTPC	India	54%	Power	179.8	2009	CARMA	"
OMV	Austria	56%	Oil and gas	10.6	2020	Arabesque	"
Pemex	Mexico	100%	Oil and gas	48.0	2019	Pemex	https://www.pemex.com/en/responsibility/sustainable/reports/Paginas/default.aspx
Pertamina	Indonesia	100%	Oil and gas	24.9	2010	Pertamina	https://www.unitar.org/sites/default/files/Presentation_TP.%20Pasaribu.pdf
Petrobras	Brazil	51%	Oil and gas	59.0	2019	Petrobras	https://sustentabilidade.petrobras.com.br/en/src/assets/pdf/Sustainability-Report.pdf
PetroChina	China	86%	Oil and gas	174.1	2019	PetroChina	http://www.petrochina.com.cn/ptr/xhtml/images/2019kcxfzbgen.pdf
PGE	Poland	57%	Power	58.7	2016	CARMA	"
PLN	Indonesia	100%	Power	157.7	2019	PLN	https://www.dropbox.com/s/jinblt7thnrsmbv/pln_2019-sustainability-report-41.pdf?dl=0
PPC	Greece	55%	Power	30.4	2019	Arabesque	"
PT Semen	Indonesia	51%	Cement	28.0	2020	Arabesque	"
PTT	Thailand	51%	Oil and gas	11.6	2020	Arabesque	"
Rosneft	Russia	50%	Oil and gas	60.9	2020	Rosneft	https://www.rosneft.com/Development/Sustainability_Reports/

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Company	Country	Gov't share	Sector	Direct emissions ($MtCO_2e$)	Reporting year	Source	Link (URL)
RusHydro	Russia	66%	Power	35.3	2020	Arabesque	"
Saudi Basic Industries	Saudi Arabia	>50%	Chemicals	37.0	2020	Arabesque	"
Saudi Electricity	Saudi Arabia	81%	Power	124.9	2019	Saudi Electricity	https://www.se.com.sa/en-us/Lists/SustainabilityReport/Attachments/2/ESG_English_SEP.pdf
SDIC	China	100%	Power	32.6	2009	CARMA	"
SGCC	China	100%	Power	93.4	2009	CARMA	"
Shenhua	China	92%	Power	126.7	2020	China Shenhua Energy	http://www.csec.com/zgshwwEn/csrrpt2020/20210323/72e4f8a7bfa94686b23cacbdf7c2ca87/files/ba0dc29d97e04253afc4e850db3d15ea.pdf
Singapore Airlines	Singapore	54%	Transport	16.3	2020	Arabesque	"
Sinopec Ltd	China	90%	Oil and gas	128.6	2020	Sinopec	http://www.sinopec.com/listco/En/investor_centre/reports/sd_report/
SPIC	China	100%	Power	167.6	2009	CARMA	"
Stanwell	Australia	100%	Power	17.1	2020	Clean Energy Regulator	http://www.cleanenergyregulator.gov.au/NGER/National%20greenhouse%20and%20energy%20reporting%20data/Corporate%20emissions%20and%20energy%20data/corporate-emissions-and-energy-data-2019-20
Taiwan Power	Taiwan	100%	Power	92.7	2020	Taiwan Power	https://www.taipower.com.tw/en/page.aspx?mid=4501&cid=2894&cchk=217cfc9a-d41a-42d5-bef5-8be36f62cbc8

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Company	Country	Gov't share	Sector	Direct emissions ($MtCO_2e$)	Reporting year	Source	Link (URL)
TVA	United States	100%	Power	75.4	2009	CARMA	"
Vattenfall	Sweden	100%	Power	89.8	2009	CARMA	"
Yitai Coal	China	>50%	Metals and minerals	15.2	2020	Arabesque	"
YPF	Argentina	51%	Oil and gas	17.0	2020	Arabesque	"
YTL	Malaysia	>50%	Power	10.6	2020	Arabesque	"
Zhejiang Energy	China	>50%	Power	37.0	2009	CARMA	"

Note: Data and sources accurate as of July 22, 2021 (Arabesque, CARMA) and January 18, 2022 (all others). Reported emissions data are updated and revised regularly by disclosing companies and third parties publishing estimated emissions figures.

NOTES

1. In practice, governments can exercise de jure or de facto control over firms with less than 50 percent ownership, with the degree of control subject to the political, economic, and legal environment in which the firm operates. Given that each case is context specific, we use 50 percent as a conservative threshold in this analysis.
2. This is the most recent such study available and is reported in Przemyslaw Kowalski, Max Büge, Monika Sztajerowska, and Matias Egeland, "State-Owned Enterprises: Trade Effects and Policy Implications," *OECD Trade Policy Papers*, no. 147 (2013), https://doi.org/10.1787/18166873.
3. OECD, *The Size and Sectoral Distribution of SOEs in OECD and Partner Countries* (Paris: OECD Publishing, 2017).
4. W. Raphael Lam and Alfred Schipke, "State-Owned Enterprise Reform," in *Modernizing China: Investing in Soft Infrastructure*, eds. W. Raphael Lam, Markus Rodlauer, and Alfred Schipke (Washington, DC: International Monetary Fund, 2017).
5. Philippe Benoit, "Engaging State-Owned Enterprises in Climate Action," Center on Global Energy Policy, Columbia University, 2019, https://energypolicy.columbia.edu/research/report/engaging-state-owned-enterprises-climate-action.
6. For a list of signatories to and ratifications of the Paris Agreement, see the following: https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27&clang=_en.
7. United Nations Framework Convention on Climate Change, *Adoption of the Paris Agreement* (Paris: 2015).
8. Benoit, "Engaging State-Owned Enterprises."
9. OECD, *The Size and Sectoral Distribution*.
10. Liwayway Adkins et al., *Energy, Climate Change and Environment: 2016 Insights* (Paris: OECD/IEA, 2016).
11. "Direct emissions" in this report means Scope 1 emissions as defined under the Greenhouse Gas Protocol. Scope 1 refers to direct greenhouse gas emissions from company facilities and vehicles. Scope 2 emissions refer to indirect emissions embodied in the energy used by the company (electricity, heating, and cooling) that is generated off site by energy suppliers (e.g., emissions associated with electricity purchased from a separate power utility). Scope 3 emissions encompass all other sources of emissions associated with company activities, including employee travel, operational waste, transportation and distribution, emissions from the use of products sold, and emissions from other goods and services purchased.

12. SOEs contributed the equivalent of 17.5 percent of global 2017 emissions in CO_2e, excluding land use change and forestry or 16.3 percent if including them. ClimateWatch, "Historical GHG Emissions," 2020, https://www.climatewatchdata.org/ghg-emissions.

13. Philippe Benoit, "State-Owned Enterprises: No Climate Success without Them," *Journal of International Affairs* 73, no. 1 (2019), https://www.jstor.org/stable/10.2307/26872783.

14. While the generation profile of EDF (Electricité de France) within France is almost exclusively from low-carbon nuclear and hydroelectric plants, its significant emissions footprint stems from its foreign installed capacity, which includes (as of 2020) 12 GW of gas capacity, 3.6 GW of oil capacity, and 3.7 GW of coal capacity. EDF, *2020 Annual Results: Appendices* (Paris: EDF, 2021), 131, https://www.edf.fr/sites/default/files/contrib/groupe-edf/espaces-dedies/espace-finance-en/financial-information/publications/financial-results/2020-annual-results/pdf/annual-results-2020-appendices-20210304.pdf.

15. Sweden's SOE emissions primarily reflect those from Vattenfall, which owns power generation assets in several countries other than Sweden. Consequently, Vattenfall's direct emissions are approximately twice those of Sweden's power sector. In China's case, while the majority of SOE emissions are domestic, the magnitude of these emissions means that even a small percentage of emissions from foreign operations can be significant. "Big Five" state-owned generator State Power Investment Corporation (SPIC), for example, has investments in over 10 GW of power generation assets and a range of other services across 41 countries.

16. Note that this is Scope 1 emissions only. It does not include Scope 2 emissions associated with energy and electricity consumption, nor indirect Scope 3 emissions associated with the consumption of products. See endnote 11 for further details.

17. For a breakdown of greenhouse gas emissions by type from oil and gas production, see Figure 11.8 in International Energy Agency, *World Energy Outlook 2018*, (Paris: 2018), 491.

18. ClimateWatch, "Historical GHG Emissions."

19. China's national emissions totaled 11.78 $GTCO_2e$ in 2017. ClimateWatch, "Historical GHG Emissions."

20. Erica Downs, "Green Giants? China's National Oil Companies Prepare for the Energy Transition," Center on Global Energy Policy, Columbia University, 2021, https://www.energypolicy.columbia.edu/research/report/green-giants-china-s-national-oil-companies-prepare-energy-transition.

21. Reuters, "China's SPIC Aims to Cap Domestic Carbon Emissions by 2023," 2020, https://www.reuters.com/article/china-spic-climatechange-idUSL4N2IQ0R4.

22. Energy Iceberg, "All You Need to Know about the Chinese Power Companies," 2019, last accessed September 17, 2020, https://energyiceberg.com/state-owned-power-utilities/.

23. Neta C. Crawford, "Pentagon Fuel Use, Climate Change, and the Costs of War," Watson Institute, Brown University, 2019.

24. Oliver Belcher, Patrick Bigger, Ben Neimark, and Cara Kennelly, "Hidden Carbon Costs of the 'Everywhere War': Logistics, Geopolitical Ecology, and the Carbon Boot-Print of the US Military," *Transactions of the Institute of British Geographers* 45, no. 1 (2020), https://doi.org/10.1111/tran.12319. The US Department of Defense reported 7 $MTCO_2e$ in additional Scope 3 emissions in 2016. See Crawford, "Pentagon Fuel Use."

25. Stuart Parkinson, *The Environmental Impacts of the UK Military Sector* (Halton, Lancaster, UK: Scientists for Global Responsibility and Declassified UK, 2020).

26. Stuart Parkinson, *Under the Radar: The Carbon Footprint of Europe's Military Sectors*, (West Yorkshire and Lancaster, UK: Conflict and Environment Observatory and Scientists for Global Responsibility, 2020), https://www.peacelink.it/disarmo/docs/5387.pdf.

27. SOEs were responsible for over 23 percent of renewable capacity additions in 2014. See Andrew Prag, Dirk Röttgers, and Ivo Scherrer, "State-Owned Enterprises and the Low-Carbon Transition" *OECD Environment Working Papers*, no. 129 2018), https://doi.org/10.1787/06ff826b-en.

28. Prag, Röttgers, and Scherrer, "State-Owned Enterprises."

29. How these are quantified and the choice of benchmarks for comparison is a matter of considerable debate.

30. Several of the companies surveyed report "avoided emissions" based on the performance of low-emissions assets against a benchmark emissions intensity figure. Differences in the benchmarks used and methods for calculating avoided emissions mean they are not comparable in aggregate. Avoided emissions may also be termed "nega-emissions" and are similar in concept to the term "negawatt," popularized in the energy efficiency discourse by Amory Lovins (Rocky Mountain Institute) as measuring a "hypothetical unit of power for . . . the amount of energy saved . . . because of efficient power consumption." Techopedia, "Negawatt," 2021, https://www.techopedia.com/definition/16548/negawatt.

31. As described in Appendix I, estimates of emissions for nonreporting companies in the iron and steel, cement, and oil and gas sectors can be derived by combining production and emissions intensity data. Adding these derived emissions, the total rises to 8.87 $GTCO_2e$ per year.

32. These include Ye Li et al., "Calculation of Life-Cycle Greenhouse Gas Emissions of Urban Rail Transit Systems: A Case Study of Shanghai Metro," *Resources, Conservation and Recycling* 128 (2018), https://doi.org/10.1016/j.resconrec.2016.03.007; Christopher N. H. Doll and Osman Balaban, "A Methodology for Evaluating Environmental Co-Benefits in the Transport Sector: Application to the Delhi Metro," *Journal of Cleaner Production* 58 (2013), https://doi.org/10.1016/j.jclepro.2013.07.006; Carlos Eduardo Sanches de Andrade and Márcio de Almeida D'Agosto, "Energy Use and Carbon Dioxide Emissions Assessment in the Lifecycle of Passenger Rail Systems: The Case of the Rio de Janeiro Metro," *Journal of Cleaner Production* 126 (2016), https://doi.org/10.1016/j.jclepro.2016.03.094; Ross MacWhinney, "Inventory of New York City Greenhouse Gas Emissions in 2017," Mayor's

Office of Sustainability, 2019, https://www1.nyc.gov/assets/sustainability/downloads/pdf/GHG_Inventory_2017.pdf; Zijia Wang, Feng Chen, and Taku Fujiyama, "Carbon Emission from Urban Passenger Transportation in Beijing," *Transportation Research Part D: Transport and Environment* 41 (2015), https://doi.org/10.1016/j.trd.2015.10.001; Felix Creutzig et al., "Urban Infrastructure Choices Structure Climate Solutions," *Nature Climate Change* 6, no. 12 (2016), https://doi.org/10.1038/nclimate3169; and Office of Rail and Road, "Rail Emissions 2019–20," (2020), https://dataportal.orr.gov.uk/media/1843/rail-emissions-2019-20.pdf.

33. Morgan Herve-Mignucci, Xueying Wang, David Nelson, and Uday Varadarajan, *Slowing the Growth of Coal Power in China: The Role of Finance in State-Owned Enterprises* (Climate Policy Initiative, 2015), https://www.climatepolicyinitiative.org/wp-content/uploads/2015/12/Slowing-the-Growth-of-Coal-Power-in-China-%E2%80%93-the-Role-of-Finance-in-State-Owned-Enterprises.pdf.

34. Yan Qin, "Natural Gas in China's Power Sector: Challenges and the Road Ahead," Oxford Institute for Energy Studies, 2020, https://www.oxfordenergy.org/publications/natural-gas-in-chinas-power-sector-challenges-and-the-road-ahead/.

35. Edimon Ginting and Kaukab Naqvi, *Reforms, Opportunities, and Challenges for State-Owned Enterprises* (Asian Development Bank, 2020).

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