BOSTON UNIVERSITY Global Development Policy Center

GCI WORKING PAPER 003 • 10/2018

Estimating Chinese Foreign Investment in the Electric Power Sector

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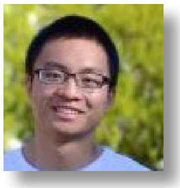

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ABSTRACT

This paper provides initial estimates of the generation capacity of Chinese overseas investment in the electric power sector. We analyze the spatial and technological distribution of China's overseas electric power investments around the world, and the pollution intensity of Chinese coal fired power plants relative to those held by non-Chinese entities. We find that Chinese firms hold approximately $115 billion USD in electric power assets globally, with a power capacity of 81 GW. Chinese electric power plants span the globe but are largely found in emerging markets and developing countries, particularly in Asia and Latin America. The vast majority of Chinese investment goes to coal, hydropower, and gas while the share of solar and wind is relatively small but may be rising. The majority of Chinese greenfield investment in coal plants use subcritical technologies (55 percent), though 84 percent of non-Chinese coal plants are subcritical. Chinese investors have introduced more efficient core technologies and less polluting end-of-pipe technologies than non-Chinese firms. Seventy-one percent of all Coal plants with participation by Chinese firms through merger & acquisitions are subcritical plants (71 percent) that deploy relatively strong end-of-pipe technologies.

1. Introduction

For many developing countries, inward foreign direct investment (FDI) fills the local financial gap in the power sector and helps fuel the economy. In the 1980s, China suffered from severe power shortages as state investment alone could not meet the soaring demand. The government later removed its regulatory barriers and restructured feed-in-tariff schemes to allow and attract private and foreign direct investment (Victor and Heller, 2007). China is now both the major destination of FDI inflows in the world and the second largest source of FDI outflows in the world (UNCTAD 2017). Through outward direct investment, Chinese corporate investors own a diverse portfolio of power projects in both developing and developed countries. There is a burgeoning literature covering Chinese outward direct investment in the world's electric power sector, including both greenfield investment (investors building new power plants from the ground up) and merger & acquisition investment (M&A, shares of existing power plants or power generating companies acquired by investors). In south and southeast Asia, Chinese firms are actively engaged in developing the hydro power resources in the Greater Mekong Sub-region (Urban et al., 2013). In the European market, China has also acquired power generating assets and participated in greenfield projects, especially in the renewable energy sector (Alcaraz 2017; Conrad and Kostka 2017; Gippner and Torney 2017). In the Latin-American market, electricity generation assets have also attracted billions of US dollars of Chinese investment, particularly in the Brazilian hydro electric sector (Ray and Gallagher, 2017). In Africa, Chinese energy investment focuses more on resource extraction, and Chinese firms invest in few power generation projects directly (Jiang, 2009; Wiig and Kolstad, 2011).

Disaggregated data on outward investment flows at the energy sub-sector level are limited, especially in the case of China. To close these knowledge gaps, various institutions and researchers have attempted to collect as much information elsewhere as possible to present the global presence of Chinese energy investment. At the aggregate level, among the first estimates of China's overseas energy investments is by Kong and Gallagher (2018). For the period 2000-2014, these authors estimated that Chinese firms invest approximately $221 billion USD in the global energy sector, of which roughly $101 billion USD flow into electricity generation. Using data from Heritage Foundation and other sources and examining the period 2000-2017, Wei estimates the 'announced' value of Chinese overseas investment (those plants in operation or announced as under contract) in the power sector to be upwards of $150 billion USD (Heritage Foundation, 2017; Wei, 2018). Gopal et al. (2018) examine Chinese overseas energy investment and find $96 billion USD of Chinese investment in the global electricity generation sector. There are also some sector-specific estimations of Chinese overseas investment. The Natural Resource Defense Council (NRDC) estimated that China's overseas policy banks has provided $15 Billion USD to overseas coal projects between 2013 to 2016, the most of any country. China was followed by Japan ($10 Billion USD), Germany ($4 Billion USD), Russia ($3 Billion USD), and South Korea ($2 Billion USD) (Chen and Schmidt 2017). Gallagher et al. similarly study Chinese policy bank loans and estimate that overseas coal plant projects have received $43.6 Billon USD of Chinese development loans since 2002 (Gallagher et al, 2018). Considering both bank loans and foreign direct investment, the Climate Policy Initiative estimate that China has financed $21-38 billion USD for overseas coal plants (Herve-Mignucci and Wang, 2015). For solar and wind power, the World Resources Institute has estimated that China, from 2000 to 2012, invested $40 Billion USD overseas across the entire value chain with electricity generation being the largest subsector (Tan et al., 2013).

Whereas Gallagher et al. (2018), have estimated the value of Chinese overseas policy bank loans, which stand at $101 billion USD and support roughly 77 GW, there is not yet a known estimate of the total power capacity controlled by Chinese foreign firms. Hannam et al. (2015), estimate that Chinese companies have built, operated, consulted on or exported approximately 241 GW worth of power plants These estimates show from various perspectives that China, over the last two decades, has provided approximately $100 billion USD of finance to the global electric power sector.

This paper attempts to trace Chinese outward direct finance and investment to Chinese ownership of power plants around the world. We build our database using an inclusive robust methodology, taking advantage of existing commercial and public databases, information disclosed by publically listed companies, government and non-government entities, and the trade and business press. Relying on the plant level database we compile, we further analyze the spatiotemporal pattern, technology portfolio, and the primary environmental impact of Chinese overseas electric power investment.

2. Data and Methodology

Our objective is to create a comprehensive plant-level list of all the power plants in which Chinese firms have invested around the world. For each power plant, we provide basic information regarding its name, location, fuel type, capacity, year it came online, primary Chinese investor, investment amount and percentage of shares owned by Chinese firms. The core approach we use to compile our database is to adapt the Platts World Electric Power Database to account for the foreign ownership of China's overseas power plants. Platts is an electric power unit-level database; its first global version was published in the early 1990s. Platts includes a comprehensive list of all power plants in the world derived from a variety of sources including direct surveys, power company financial and statistical reports, vendor reference lists, and trade and business press. For every power generating unit, Platts provides information regarding its name, operational status, capacity (MW), year-on-line, primary fuels, pollution control equipment, owner company, location data and additional attributes (Platts, 2015). While Platts does include the name of the company that has the majority ownership in a particular plant, it does not indicate the country of origin where the firm is based. In addition, there is a variety of subsidiaries or affiliates of the same holding companies, especially for China, and Platts makes limited effort to record them in a clear and consistent manner. Therefore, in order to better understand the reach of Chinese influence in the global power sector, we expand the ownership attributes of the Platts database and identify all power plants outside of China that have at least 20% of Chinese ownership. Our approach is a five-step process. The endpoint of our data collection is December 31st, 2017.

2.1 Generation of Chinese company list

We first generate a list of Chinese power companies that may invest globally by surveying a wide variety of online databases and public reports. Four online databases are intensively utilized, including FDiMarket (2017), Dealogic (2017), Coal Plant Tracker (2017), and Global Coal Exit List (2017). Combining these sources, we create an initial list of more than 100 Chinese companies that we consider to be potential Chinese investors in foreign power markets. Later during our internet search, we found that several additional companies are missing from these sources but are also making investments. We added them to the list and acknowledge that there could be more missing Chinese companies, especially small to medium-sized private companies. The complete list is provided in the supplementary information.

2.2 Direct matching of Chinese companies within Platts

After compiling a list of Chinese firms that invest globally in the power sector, we then match our company list with companies listed in the Platts database. We use a simple matching algorithm that searches the Platts database for names of firms in our company list and variations thereof. For every Chinese company, we generate one to three keywords that are representative of all possible names that Platts uses for the same company.-We tag power plants with the name of a holding company when at least one of the keywords are found in the Platts database indicating it is the original owner. We then put all of the power plants obtained via this matching process together into a new list. Examples of keywords are included in the supplementary information. After the direct match, we also check the list of Chinese overseas power plants and remove the false-positive matches: plants that are not Chinese-owned but were wrongly captured by matching keywords.

2.3 Indirect matching for Chinese companies within Platts

In terms of capacity, approximately two thirds of Chinese overseas power plants in our database are found to directly match power plants in the Platts database. For another one third of power plants, Platts fails to record their Chinese ownership. For instance, after merger and acquisition deals when Chinese companies acquired overseas assets, Platts does not update the original corporate owner with the new Chinese owner in a timely manner. There are also cases where Platts wrongly recorded a local partner as the owner when the primary investment in the power plant is in fact a Chinese company. To generate a more inclusive list of power plants that includes not only those Chinese plants indicated by Platts but also those Chinese plants that Platts missed, we conducted an internet search for all Chinese companies in our original list. We looked for those company's overseas power generating assets and then identified and tagged the corresponding records in Platts. We call this indirect matching. The internet resources we access include annual reports of publically listed firms, official websites of companies and governments, and trade and business press. For instance, Huaneng's website and business press show that Huaneng acquired a 50% share of Ozgen from InterGen in 2003 via competitive bidding and now holds a majority stake in 1800 MW power generating assets in Australia. The amount of investment was $227 million USD. In Platts, as we expect, there are also records of power plants with a total capacity of 1800 MW under Ozgen but they are still recorded as solely owned by InterGen. Therefore, we label these missing matches where Platts fails to update with Chinese ownership and in a similar fashion, we complete the list of Chinese owned power plants overseas. We use a 20% threshold to define Chinese ownership and exclude any investment below 20%. All links for websites we used for indirect matching are recorded and are available in the SI.

2.4 Expand project level detail

In addition to identifying and validating all Chinese plants outside of China that are included in Platts, we also expand the record of power plant attributes with additional details, including the type of investment (greenfield vs. merger & acquisition), percentage of Chinese ownership, and amount of investment in USD. Using the same Huaneng example as in section 2.3, we record Chinese ownership as 50% and the deal completion year as 2003 in separate columns. A total investment of $227 million USD is also recorded. However, for many other deals, the investment amount is unavailable. There is general consistency among sources. If there are contradictions or inconsistencies, we give more weight, in order, to government websites, company websites and annual reports, trade and business press.

2.5 Project status verification

A power plant project could take as long as a decade from its announcement to the day it starts operating. Many announced projects end up canceled or delayed and an incorrect recording of Chinese outward investment could wrongly include these "zombie deals". The most famous example is the Myitsone hydroelectric power project in Myanmar. In 2009, $3.6 billion USD of investment was announced but it was never realized as the project has been suspended since 2011. Inclusion of such zombie projects would lead to an overestimation of Chinese investment. For merger and acquisition investment, we only include deals that are registered as completed by Dealogic or by multiple trade and business presses. Deals that were announced but have not been confirmed as completed are not included. For greenfield projects, we use the project status information provided by Platts, which records power plants as in operation, under construction, under planning, deferred, canceled or retired. In our analysis, we only include greenfield projects that are either in operation or under construction as valid investments. Investments at other project stages are excluded to avoid zombie deals. Since every investment is traced down to the power plant level, double counting is avoided.

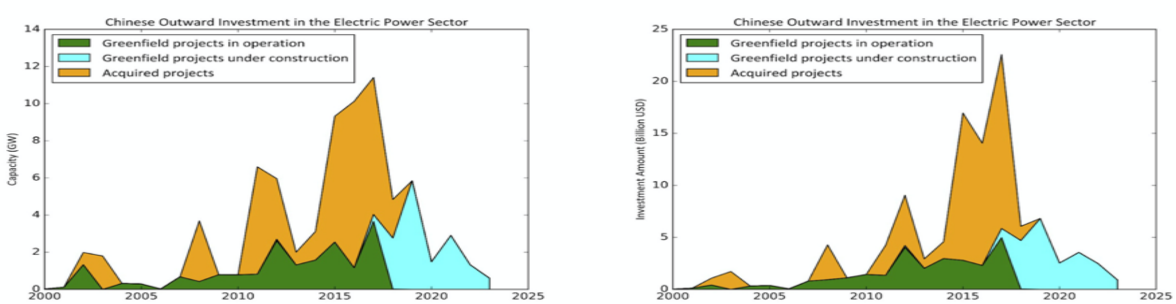
2.6 Coal power plant technologies

Platts provides important information on the technologies adopted by every coal plant, including types of steam engine (subcritical/supercritical/ultra-supercritical) and types of end-of-pipe control technologies (SO_2, NO_x, particulate matter). In section 3.4, we use this information to analysis the pollution intensity of coal plants owned by Chinese firms versus other developers.

3. Results

We estimate that between 2000 and 2017 Chinese firms invested approximately $115 billion USD in 462 overseas power plants, with a generation capacity of 81 GW. $115 billion USD is an approximate estimate of the capital cost of all projects based on the average capital cost per kW of new power projects. A table of capital costs for various energy technologies (coal, gas, oil, hydro power, wind, solar and biomass power) is in the supplementary information. Section 3.1 discusses China's overseas power plant technology mix. Of the 81GW of plant capacity, 39 GW are greenfield projects while 42 GW of Chinese ownership has been obtained through merger and acquisition (M&A) deals. Figure 1a and 1b show these trends over time, and reveal that the bulk of these investments have occurred after 2008.

Figure 1 Historical trend of Chinese outward investment in the electric power sector by capacity (left) and by investment amount (right). For greenfield projects, the project date is defined as the first operation year or expected operation year. For acquired projects, the date is defined as the year when the deal is completed. Planned projects are not included.



Although outward investment via a "Going Out" policy-- China's policy of encouraging flagship national firms to invest abroad-- started in China in the 1990s, there were very few cases of Chinese overseas investments in the power sector before 2012 (Kong and Gallagher, 2017). Huaneng Group is the Chinese pioneer in acquiring overseas power generating assets. In 2003, Huaneng acquired a 50% share of Ozgen from InterGen via competitive bidding and took control of 1800 MW of coal-fired power plants in Australia. Later in 2008, Huaneng acquired 100% ownership of Tuas Power, a Singapore power company which owns 3 GW of gas and oil power plants. Around the same time, the Shweli Hydro Power station came online in Myanmar, which marks the beginning of more than 4 GW of Chinese greenfield investment in Southeast Asian hydro projects. Coal came relatively late and the first coal power plants, 400 MW, were built in Indonesia by Shenhua Group in 2011.

One four year period (2014-2017) saw a surge in Chinese overseas investment in the power sector. For greenfield investment, the Hinkley Point nuclear station in the United Kingdom is the most famous example of Chinese power companies entering the European market. In addition, China has also acquired several offshore wind farms in the United Kingdom and Germany, and a 28% share of Energias de Portugal (EDP). Brazil also rose to be the largest target for Chinese investment. Chinese companies, the State Grid Corporation of China and China Three Gorges Corporation, collectively acquired 12 GW of hydro power projects in Brazil through sales of the Brazilian government and Duke Energy, a US firm.

In addition to Hinkley Point, there are another 17 GW of power projects under construction which will come online in the next several years. The majority of these projects, 11 GW, are coal-fired power plants in Asia and the Middle East. A large solar project, 600 MW, will also come online very soon in Pakistan in addition to the existing 300 MW utility scale solar PV unit. In 2019, a 588 MW offshore wind farm in Scotland is expected to come online with 25% of Chinese ownership.

3.1 Technology mix

Although China's domestic energy mix is currently dominated by coal (58%), China's overseas portfolio is much more diverse and similar to the world average. According to World Energy Outlook 2016, in the power generating market outside of China, there is a total of 5032 GW installed capacity including solar, wind, coal, gas, nuclear, hydro, oil and biomass (IEA 2016). Thus, 81 GW of Chinese investment represents only 1.6% of the global market with the rest owned by local and other international investors. In Figure 2, we compare the technology mix of China's overseas power plants with other plants owned by non-Chinese entities throughout the rest of the world (ROW). In both cases, three major fossil fuel technologies represent approximately 60% of total capacity with hydro power the largest source of non-fossil generation. The carbon intensity of Chinese investment is still relatively high because coal dominates the deployed Chinese fossil technologies. China invests more in hydro power plants and wind farms, and less in nuclear and biomass plants than the rest of the world (ROW). From the perspective of ownership, we find that coal accounts for 30% of China's overseas financial flows into power plants, less that the share of other types of Chinese overseas involvement (Hannam et al., 2015; Hervé -Mignucci and Wang, 2015; Chen and Schmidt 2017; Gallagher et al., 2018), such as bank loans, equipment exports and engineering services. For many coal projects, especially those in south and southeast Asia, Chinese firms only provide the equipment or are the engineer construction contractors while the local government or company operates the power plant and takes ownership.

The technology mix of Chinese investment also varies by investment type (eg. greenfield versus merger and acquisition). As shown in Figure 2, the majority (48%) of greenfield investment is in coal plants, followed by gas (14%), hydro (13%) and nuclear (9%) plants, a pattern which is very similar to the Chinese domestic market. Merger & acquisition investment, on the other hand, is more equally shared by gas (36%), hydro (30%), coal (15%) and wind (12%) power plants.

Figure 2. Electricity generation technology mix of (a) Chinese outward greenfield investment, (b) M&A investment, (c) greenfield and M&A combined and (d) the electricity generation technology mix of the entire world excluding China's domestic market for the year 2016. The percentage is calculated by capacity (MW).

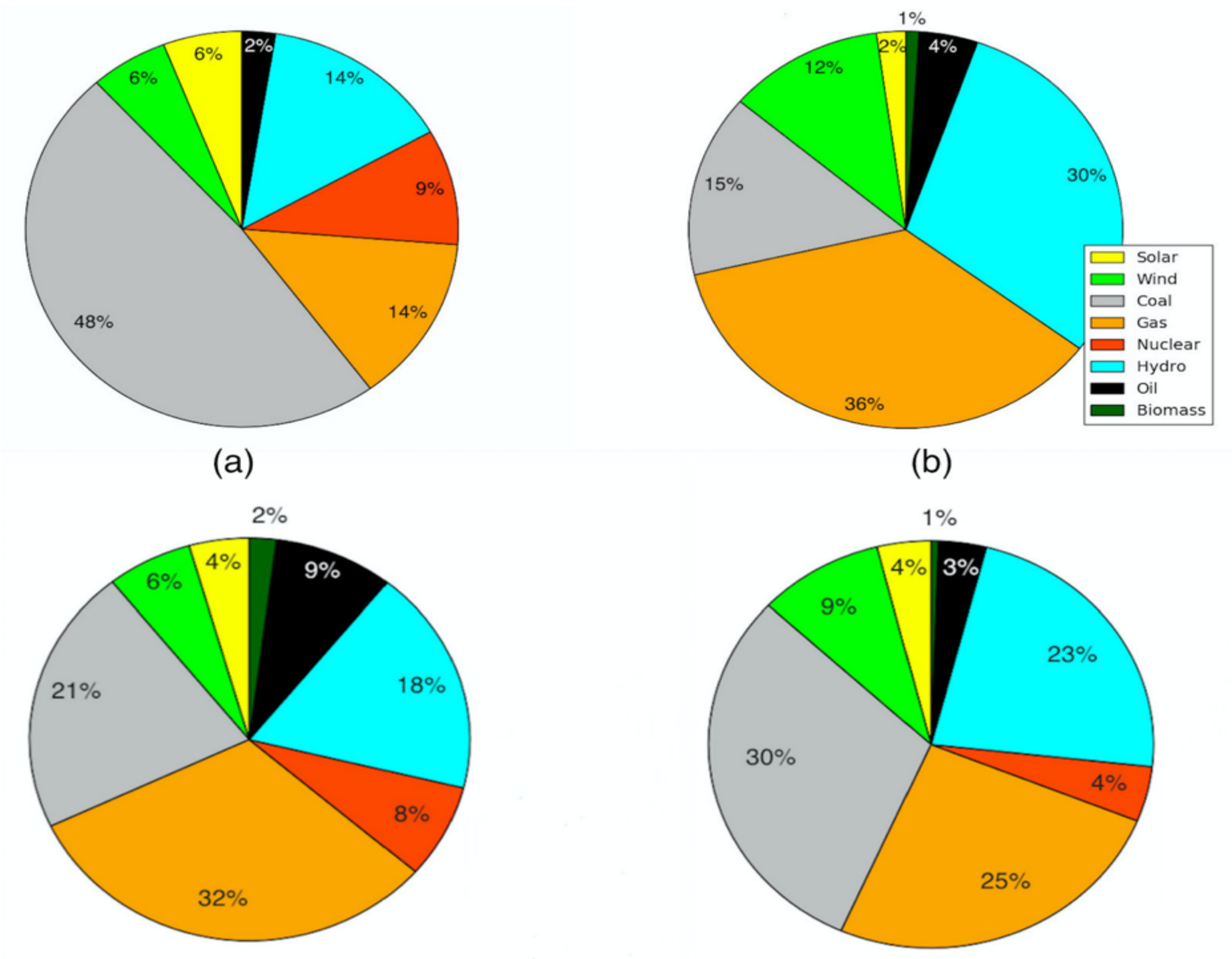
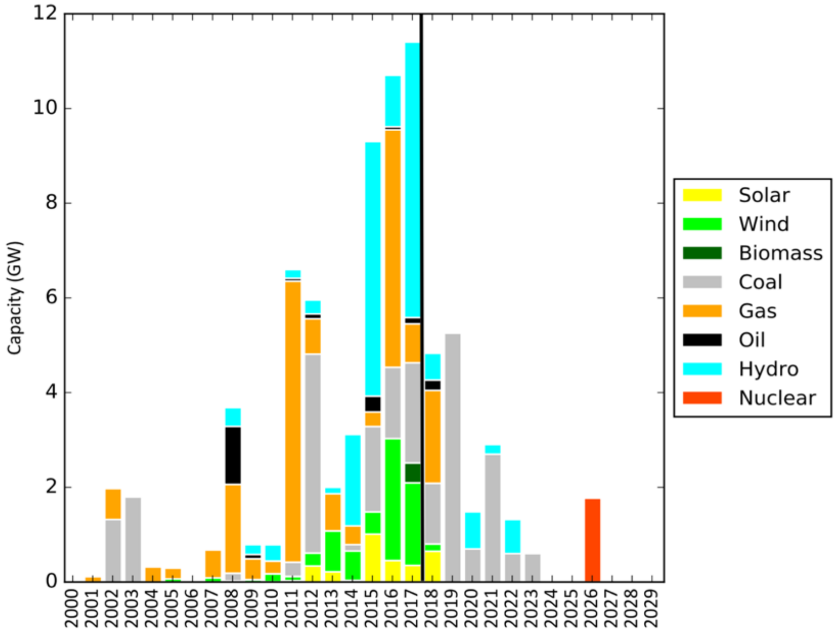


Figure 3 shows the mix of different power generating technologies of Chinese foreign direct investment since 2000. For greenfield projects, the year is defined as the year in which the power plants came online or are expected to come online. For M&A deals, the year is defined as the year in which the deal is completed. From 2000 to 2011, fossil fuel technologies dominate Chinese foreign investments while hydro and wind power take minor shares. From 2012 to 2017, solar and wind as well as large hydro power investment started to grow rapidly to be as important as carbon-intensive investments. Moving forward, Figure 3 shows that the majority of planned investments are in coal and hydropower. That said, it should be noted that the average construction time needed for renewable projects, six to twelve months, is substantially shorter than traditional fossil power plants or large hydro power plants, which takes two to five years or even longer. Therefore, our database includes no Chinese investment in renewables after 2018 because all projects under construction in 2017, the last year of our data search, are expected to come online before 2018. Similarly, future M&A deals completed after 2018 is also missing from the database. The revolving trend of carbon-intensive investment after 2018 could be misleading as the future trend is biased towards non-renewable projects and greenfield projects.

Figure 3. Time-series trend of Chinese outward greenfield and M&A investment in the electric power sector by types of technology from 2000 to 2029 based on data collected through 2017. For greenfield projects, the project date is defined as the first operation year or expected operation year. For acquired projects, the date is defined as the year when the deal is completed. Planned projects are not included. Beyond 2017, only greenfield investment projects under construction are included and shown.



3.2 Spatial distribution

Chinese power investment spans the entire globe and involves a wide spectrum of countries, from the most to least developed and from the most to least politically stable. Besides the diversified portfolio, there are two clear features of Chinese investment, a strong interest in emerging economies particularly in Asia, and a technology preference strongly linked to local resource availability. Table 1 shows Chinese investment portfolios in various regions and in Belt and Road Initiative (BRI) countries. South Asia and Southeast Asia receive 41% of Chinese investment, followed by Latin American countries (LAC). As shown in Figure 4a, the vast majority of top recipient countries are emerging economies with the only exceptions being UK and Australia. This is also consistent with the general pattern of Chinese overall foreign direct investment (MOFCOM, 2017). Although Africa has received much Chinese government aid and development loans, it is a much less important destination for Chinese outward investment than emerging economies with more mature markets.

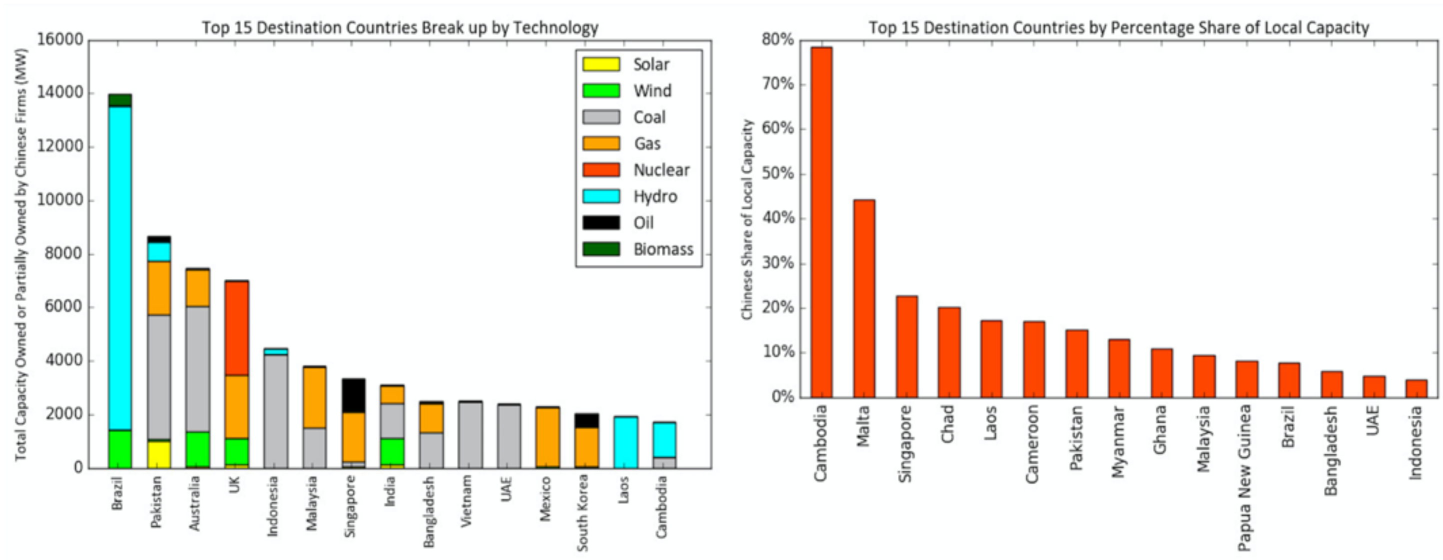
Table 1. Chinese Electric Power Investment Portfolio in Various Regions (unit: capacity in MW)

Region	Coal	Gas/LNG	Hydro	Nuclear	Oil	Solar	Wind	Bio	Percent
Africa	0	2446	285	0	145	42	449	0	4%
East Asia	1320	1476	0	0	507	231	0	0	4%
Europe/Central Asia	0	4689	24	3540	350	578	2541	0	15%
North America	0	2505	0	0	0	962	331	0	5%
LAC	0	21	12806	0	168	1	1535	420	19%
Middle East	2400	0	0	0	0	0	0	0	3%
South Asia	7260	3757	800	0	320	1120	1211	0	18%
Southeast Asia	8820	4280	4372	0	1226	168	0	0	23%
Oceania	4685	1368	45	0	91	60	1301	0	9%
BRI Countries	18480	10409	5196	0	1562	1676	1731	0	48%

China has invested overseas in all major types of electricity generating assets and local resource availability has a strong impact on Chinese technology preference, particularly for hydro and coal. In Brazil, Laos and Cambodia, the majority of Chinese investment goes to hydro power plants where the local hydro power potential is large and fossil fuel resources are relatively poor. In Australia, Pakistan, Indonesia and many other Asian countries, where there are large coal reserves, China invests more in coal-fired power plants. Renewable investment, especially wind, has a higher penetration in more mature markets with favorable government support policies, such as UK, Australia, Brazil and India.

Chinese investment is an important component of generating capacity in the developing countries shown in Figure 4b. In Cambodia, as the most extreme example, almost 80% of the generating capacity is owned by Chinese companies. For the countries in Figure 4b, the penetration of Chinese ownership is large enough to have considerable impact on the local power market and on local energy policies. In turn, the performance and profitability of Chinese companies are also very sensitive to local policy and regulation.

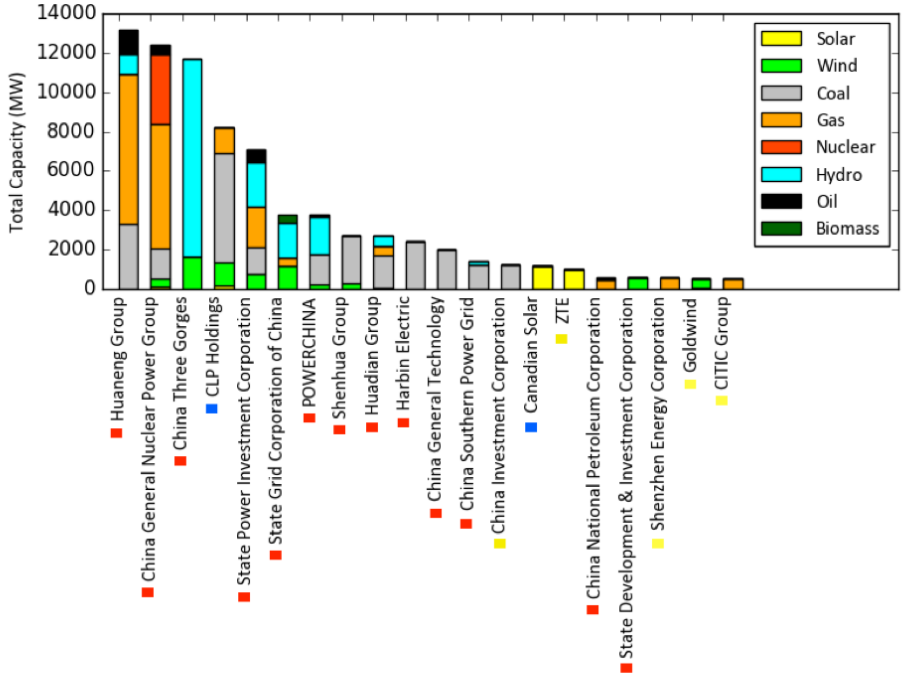
Figure 4 Top destination countries of Chinese outward investment by total capacity (left) and by share of local capacity (right). The share of local capacity is calculated by dividing total local generating capacity in a given country by Chinese total investment in the same country



3.3 Investing companies

Chinese state-owned enterprises (SOEs) are the dominant investor in the overseas market. Central SOEs (those that are directly controlled by the Chinese State-owned Asset Supervision and Administration Committee (SASAC)) have collectively invested in 64 GW of generating capacity overseas, which is 80% of Chinese total investment. Such a high level of state involvement is a unique feature of Chinese investment compared to its western counterparts. Figure 5 shows the top 20 Chinese investing companies. The top three Chinese central SOEs are responsible for almost half of the investment and the top 10 companies are responsible for more than 80%. There is a slight correlation between the companies' domestic expertise and its overseas investment but there are also many outliers. For instance, China Three Gorges Corporation is the owner of the Chinese Three Gorges dam and its overseas assets are also dominated by hydro power. Similar cases are Harbin Electric (top coal plant equipment manufacturer), Goldwind (wind manufacturer and developer), Canadian Solar (solar manufacturer and developer), and China National Petroleum Corporation. These companies have a stronger technology preference with respect to their domestic focus, or less technology flexibility to a certain extent, when they are making overseas investment. The other companies have more diverse investment portfolios.

Figure 5. Top Chinese companies investing in overseas electricity generation by total capacity. Companies are categorized into central SOEs (red), other SOEs (yellow), and non-SOEs (blue). SOE: State-Owned-Enterprises.



3.4 Analyzing China's overseas coal plants

This section of the paper examines the efficiency and pollution intensity of those coal-fired power plants in our database—separately comparing Chinese greenfield and M&A investments in the database with those owned by non-Chinese entities, or the rest of world (ROW). Since 2002, our database shows that Chinese investors have owned a total of 23.4 GW of coal plants in overseas markets. According to Platts, there is a total of 455.1 GW of new coal plants outside China which came online after 2002 or are still under construction. Therefore, Chinese overseas direct investment in coal plants stands for 5.1% of the total growth globally since 2002. Among them, 12.3 GW of coal plants have already come online and 11.1 GW are under construction. In addition, another 17.3 GW of coal plants are planned and are very likely to come online in the next few years. The average capital cost of a coal plant in our database is around $1500 USD per megawatt. Therefore, these coal plant investments, if all of them come to fruition, would account for $61 billion USD investment. $35 billion USD of investment is already in place while the remaining $26 billion USD is still under the planning phase. For various reasons, another 10.5 GW of coal plants are deferred or canceled and are not likely to be realized.

Although coal power plants have significantly negative impacts on climate, public health and water resources, successful development of cleaner coal technologies can partially mitigate some of these impacts such as those related to public health and water. For instance, application of end-of-pipe pollution controls (e.g. sulfur scrubbers; particle filters; selective catalytic reduction to remove NO_x) can reduce reactive air pollutant emissions by more than 90% and they are key drivers for recent air pollution mitigation in China. Whereas end-of-pipe technology is usually a function of host country regulations when it comes to criteria air pollutants, carbon intensity is more a function of core technology (Gallagher, 2007). More efficient supercritical power plants can also reduce carbon emissions by as much as 20% (Franco et al., 2009; Schreifels et al., 2012). In this section, we evaluate the technological parameters of Chinese overseas coal-fired power plants and compare them with their local counterparts to discuss whether China's power plants are less pollution intensive than their counterparts.

In Table 2, we compare the technology parameters of coal plants owned by Chinese firms with coal plants built in the same countries and during the same period, but by local or other non-Chinese entities. Given that information on utilized technology is only comprehensive for plants that have already come online, we include only operational coal plants and exclude those under construction or in earlier phases of development. The earliest greenfield coal project China has ever developed overseas came online in 2011 and a total of 4.4 GW of new coal plants (thirteen power generating units in five coal plants) have come online through Chinese outward investment in Indonesia, Cambodia, Pakistan and Vietnam. Another 25.4 GW of new coal plants have also come online through investments by non-Chinese entities, so Chinese investments represent roughly 15 percent of those during the period.

With respect to efficiency and carbon intensity, the majority (55 percent) of Chinese overseas power plants deploy subcritical technologies while the remaining 45 percent are equipped with more efficient supercritical technologies. There are no ultra-supercritical coal plants in any of the groups. In comparison, the vast majority (84 percent) of the coal plants from non-Chinese investment are less efficient subcritical plants. From another perspective, although Chinese has only invested in 15 percent of the total coal capacity during the period, one-third of the cleaner supercritical coal plants are invested by China, making Chinese greenfield investment in coal is less carbon intensive than the investments of its counterparts.

In terms of reactive pollution intensity, we find Chinese greenfield investment in coal also applies cleaner technologies than the investments of its counterparts. Although the four countries above have relatively loose local environmental regulations, we find that Chinese overseas greenfield coal plants tend to have more capacity with Sulfur, NO_x, and particulate matter controls than other local and foreign power power plants. This includes a much higher percentage of installed supercritical steam engines, and higher installation rates for particle control, NO_x control and sulfur control systems. Our findings lend some support to anecdotal messages from Chinese government officials that they have been voluntarily bringing cleaner coal technologies than non-Chinese entities to developing countries (Gallagher and Qi, 2018).

In addition to greenfield investment, China has also invested in overseas coal through M&A deals. Since 2003, Chinese firms have purchased 6.3 GW of coal plant assets in Australia, Singapore and Malaysia. As we do not have data on M&A deals made by other major coal investing countries, we could not form a valid comparison group and do not know the relative role China has been playing comparing to non-Chinese entities. Table 3 further shows Chinese M&A investment in coal at the unit level. There are four M&A deals with 14 coal power generating units involved. Since those acquired plants are relative older, with the oldest one dating back to 1973, the share of supercritical technology, 29 percent, is smaller than Chinese greenfield investment. The penetration rates of various end-of-pipe control technologies for those acquired projects, however, are at similar levels as greenfield investments. Chinese greenfield coal projects apply a higher rate of sulfur control but a lower rate of particulate matter control facilities than Chinese M&A coal plants. This is likely due to a stricter regulation on sulfur emissions in these three more developed recipient countries. Of course, the technology choices of these plants are made by their former developers but Chinese companies are now responsible for their emission. China could potentially retrofit these coal plants by installing more end-of-pipe control equipment that could mitigate some of the localized air pollutants associated with those plants.

Table 2 Summary of Chinese Overseas Coal Plants and Recipient Countries' Coal Plants Developed by non-Chinese entities.

	Chinese Greenfield Investment[1]	Non-Chinese Greenfield Investment[2]	Chinese M&A Investment[3]
Recipient Countries	Indonesia, Pakistan, Vietnam, Cambodia	Indonesia, Pakistan, Vietnam, Cambodia	Australia, Singapore, Malaysia
Time Period[4]	2011-2017	2011-2017	2003-2016
Total Capacity of coal plants	4.4 GW (100%)	25.4 GW (100%)	6.3 GW (100%)
Capacity of Subcritical Plants	2.4 GW (55%)	21.1 GW (84%)	4.5 GW (71%)
Capacity of Supercritical Plants	2.0 GW (45%)	4.1 GW (16%)	1.8 GW (29%)
Capacity of Plants with Sulfur Controls	4.1 GW (93%)	20.2 GW (79%)	3.9 GW (62%)
Capacity of Plants with NOx Controls	1.3 GW (30%)	3.3 GW (13%)	1.8 GW (29%)
Capacity of Plants with Particulate Controls	3.6 GW (82%)	18.9 GW (74%)	6.2 GW (98%)

Table 3 List of Chinese M&A deals in coal power plants from 2003 to 2016

Deal Year	Recipient Country	Online Year	Capacity	Steam Engine
2003	Australia	2001	460	Supercritical
2003	Australia	2001	460	Supercritical
2003	Australia	2002	440	Supercritical
2003	Australia	2003	440	Supercritical
2008	Singapore	2013	102	Subcritical
2008	Singapore	2014	60	Subcritical
2012	Australia	1993	700	Subcritical
2012	Australia	1996	700	Subcritical
2012	Australia	1973	360	Subcritical
2012	Australia	1975	360	Subcritical
2012	Australia	1981	380	Subcritical
2012	Australia	1982	380	Subcritical
2016	Malaysia	2009	752.5	Subcritical
2016	Malaysia	2009	752.5	Subcritical

4. Discussion

Building on earlier work, this paper is the first to provide estimates of Chinese overseas investments in global power plants. China began investing in overseas power projects in 2003 and has been accelerating those investments ever since. After a steady growth period from 2003 to 2013, the past four years have witnessed a substantial increase in the volume of Chinese investment. In terms of capacity, there is a total of 81 GW power plants outside China owned or partially owned by Chinese firms. The absolute amount is equivalent to the total generating capacity in Iran for the year of 2015, which ranks 14th in the world. It also equals approximately 5% of Chinese domestic generating capacity, or 1.2% of the global generating capacity. We find that China has been investing in a diverse portfolio of electricity generating assets, covering all major electricity generation technologies. Coal projects represent 30% of the total capacity, followed by gas and hydro power projects. Chinese energy investments span the entire globe but are largely found in emerging markets and developing countries, particularly in Asia and Latin America. A handful of Chinese state-owned enterprises dominate China's overseas markets.

When it comes to new greenfield investments, while the majority of Chinese owned coal plants use more carbon intensive core technology, Chinese investors have introduced more efficient core technologies and less polluting end-of-pipe technologies than are typically used in a given recipient country. In terms of mergers and acquisitions (M&As) the vast majority of coal fired M&As by both China and firms from the rest of the world are subcritical and tend to have less criteria pollution control technology than their counter-parts.

Although our results indicate that China introduce less carbon-intensive and pollution-intensive technologies through greenfield coal investment, any further investment in coal is still threatening our remaining carbon budget (Davis and Socolow 2014; Pfeiffer et al., 2018). Scientists have also shown that there is very little room for any new coal, even cleaner coal, if the world is to limit global warming to 2 degrees Celsius above pre-industrial levels. Eight-eight percent of known coal reserves are unburnable and one third of planned construction of new coal plants would burst the allowable 'carbon budget' that calibrates the 2-degree target (McGlade and Ekins, 2015).

In addition to compiling estimates of Chinese overseas investment we develop a new accounting method for tracking such investments which may lend itself to broader global and policy analyses. Linking foreign investments to emissions in power plants by nationality would allow analysts and policy makers to obtain a fuller picture of a nation's carbon footprint. While a significant amount of work has estimates a nation's carbon footprint with respect to a given nations international trade, there is at present no analogous work with respect to foreign investment. Several recent high profile studies reveal that significant carbon emissions in China occur to support export of goods to the US and other countries (Peters et al., 2011; Du et al., 2011). In addition, recently China is also offshoring many of its carbon intensive industries to developing countries and thus exporting its domestic emissions through south-south trade (Meng et al., 2018). In addition to consumption-based accounting, an ownership-based accounting system could provide a new viewpoint of carbon emissions in the context of globalization and will be the subject of further research. Investors from developed countries, with technology and capital advantages, are actively engaged in the power market of many developing countries. Quantifying such ownership-based carbon footprint could expose potentially huge cross-border carbon leakage. In the coal sector, for instance, Japan and Germany have long been recognized as major coal investors in developing countries although they have successfully cut down domestic carbon emission. In this paper, we introduce a novel approach to combine publically accessible information with a commercial database and identify, at the unit level, Chinese ownership global power projects. In the future, the methodology could be used to track ownership of other nationalities and to estimate the global carbon footprint of major power investing countries.

REFERENCES:

Chen, H. and Schmidt, J., 2017. Power shift: shifting G20 international public finance from coal to renewables. *Natural Resources Defense Council (NRDC), December*.

Heritage Foundation., 2017. China Global Investment Tracker. https://www.heritage.org/asia/report/china-global-investment-tracker.

Conrad, B. and Kostka, G., 2017. Chinese investments in Europe's energy sector: Risks and opportunities?

Dealogic., 2017. Online database*, accessed October*, *2017*.

Davis, S.J. and Socolow, R.H., 2014. Commitment accounting of CO2 emissions. *Environmental Research Letters*, *9*(8), p.084018.

Du, H., Guo, J., Mao, G., Smith, A.M., Wang, X. and Wang, Y., 2011. CO2 emissions embodied in China–US trade: Input–output analysis based on the emergy/dollar ratio. *Energy Policy*, *39*(10), pp.5980-5987.

Gallagher K. and Qi Q., 2018. Policies Governing China's Overseas Development Finance Implications for Climate Change, The Center for International Environmental & Resource Policy.

Franco, A. and Diaz, A.R., 2009. The future challenges for "clean coal technologies": joining efficiency increase and pollutant emission control. *Energy*, *34*(3), pp.348-354.

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Gallagher K. Rohini K., Junda J., Yanning C., and Xinyue M., 2018. Energizing Development Finance? The benefits and risks of China's development finance in the global energy sector. *Energy Policy*, 122, pp.313-321.

Gallagher, K., 2007. Toward a Theory of Innovation and Industrial Pollution: Evidence from Mexican Manufacturing, *Industrial Innovation and Environmental Regulation*, Saeed Parto and Brent Herbert-Copley (eds), New York, United Nations University Press.

Gippner, O. and Torney, D., 2017. Shifting policy priorities in EU-China energy relations: Implications for Chinese energy investments in Europe. *Energy Policy*, *101*, pp.649-658.

Global Coal Exit List., 2018. Online database, accessed March, 2018.

Gopal S., Gallagher K., Pitts J., Li Z., Chinese overseas investment in the energy sector. Forthcoming.

Hannam, P.M., Liao, Z., Davis, S.J. and Oppenheimer, M., 2015. Developing country finance in a post-2020 global climate agreement. *Nature Climate Change*, *5*(11), p.983.

Hervé-Mignucci, M. and Wang, X., 2015. Slowing the Growth of Coal Power Outside China: The Role of Chinese Finance. *Climate Policy Initiative*.

IEA., 2016. World Energy Outlook 2016. Organisation for Economic Co-operation and Development, OECD.

IRENA., 2018, Renewable Power Generation Costs in 2017, International Renewable Energy Agency, Abu Dhabi.

Jiang, W., 2009. Fuelling the dragon: China's rise and its energy and resources extraction in Africa. *The China Quarterly*, *199*, pp.585-609.

Kolstad, I. and Wiig, A., 2011. Better the devil you know? Chinese foreign direct investment in Africa. *Journal of African Business*, *12*(1), pp.31-50.

Kong, B. and Gallagher, K.P., 2017. Globalizing Chinese Energy Finance: The Role of Policy Banks. *Journal of Contemporary China*, *26*(108), pp.834-851.

Lin, L.W. and Milhaupt, C.J., 2013. We are the (national) champions: Understanding the mechanisms of state capitalism in China. *Revista Chilena de Derecho*, *40*, p.801.

McGlade, C. and Ekins, P., 2015. The geographical distribution of fossil fuels unused when limiting global warming to 2 C. *Nature*, *517*(7533), p.187.

Meng, J., Mi, Z., Guan, D., Li, J., Tao, S., Li, Y., Feng, K., Liu, J., Liu, Z., Wang, X. and Zhang, Q., 2018. The rise of South–South trade and its effect on global CO 2 emissions. *Nature communications*, *9*(1), p.1871.

Ministry of Commerce People's Republic of China., 2017. Zhongguo Zhijie Duiwai Touzi Tongji Gongbao 2016.

Pareja-Alcaraz, P., 2017. Chinese investments in Southern Europe's energy sectors: Similarities and divergences in China's strategies in Greece, Italy, Portugal and Spain. *Energy Policy*, *101*, pp.700-710.

Peng, R., Chang, L. and Liwen, Z., 2017. China's involvement in coal-fired power projects along the belt and road. *Global Environmental Institute*.

Peters, G.P., Minx, J.C., Weber, C.L. and Edenhofer, O., 2011. Growth in emission transfers via international trade from 1990 to 2008. *Proceedings of the national academy of sciences*, p.201006388.

Pfeiffer, A., Hepburn, C., Vogt-Schilb, A. and Caldecott, B., 2018. Committed emissions from existing and planned power plants and asset stranding required to meet the Paris Agreement. *Environmental Research Letters*, *13*(5), p.054019.

Platts 2015. "Data Base Description and Research Methodology UDI World Electric Power Plants Data Base". McGraw Hill Financial, Washington DC.

Ray, R., Gallagher, K., 2017. China-Latin America economic bulletin 2017 edition. *Global Economic Governance Initiative, Boston University: Boston*.

Schreifels, J.J., Fu, Y. and Wilson, E.J., 2012. Sulfur dioxide control in China: policy evolution during the 10th and 11th Five-year Plans and lessons for the future. *Energy Policy*, *48*, pp.779-789.

Tan, X., Zhao, Y., Polycarp, C. and Bai, J., 2013. China's overseas investments in the wind and solar industries: trends and drivers. *World Resources Institute Working Paper*.

Times, F., 2017. fDiMarkets. *Online database, accessed October*, *2017*.

Tracker, G.C.P., 2017. Global coal plant tracker.

UNCTAD, U., 2017. World Investment Report 2017: Investment and the Digital Economy.

Victor, D.G. and Heller, T.C. eds., 2007. *The political economy of power sector reform: the experiences of five major developing countries*. Cambridge University Press.

Wei, Hanyang., 2018. Chinese Power Companies' Global Investment Strategies: Seeking returns and managing risks. *Bloomberg New Energy Finance*.

(FOOTNOTES)

1 Direct investment by China in new coal power plants which became operational between 2011-2017. 2011 is the first year when Chinese greenfield coal projects came online. Operational coal plants with Chinese investment only occurred in Indonesia, Pakistan, Vietnam and Cambodia. There are more coal plants with Chinese investment under construction in other countries but we exclude them in this table.

2 Direct investment by non-Chinese entities in new coal power plants which became operational between 2011-2017 in Indonesia, Pakistan, Vietnam and Cambodia.

3 Chinese M&A of power plants has only occurred in Australia, Singapore and Malaysia. The first M&A deal involving a coal plant was completed in 2003. The latest M&A deal involving a coal plant was completed in 2016.

4 For greenfield projects, the project date is defined as the first operation year. For M&A projects, the date is defined as the year when the deal is completed. Projects under construction or planning are not included.

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