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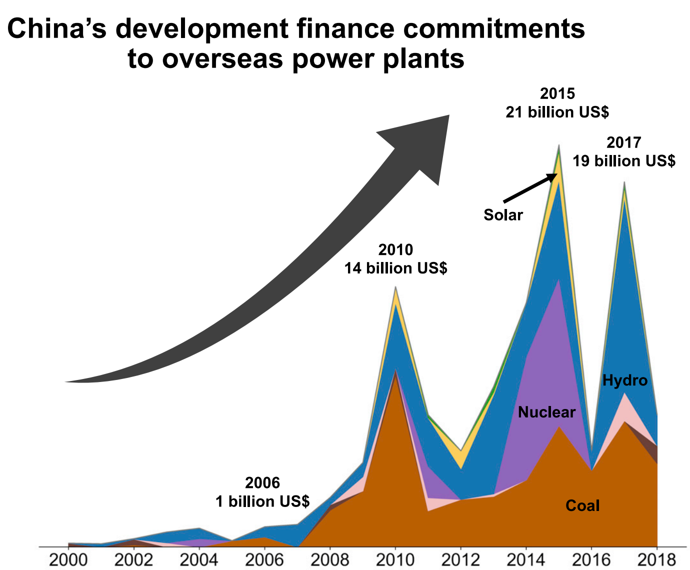
Chinese Overseas Development Financing of Electric Power Generation: A Comparative Analysis

Graphical Abstract



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In Brief

The Paris climate goals require rapid decarbonization of the global power generation sector. To achieve this goal, it is critical to redirect international development finance away from fossil fuel toward renewable energy technologies. We find that East Asian national DFIs have committed to finance a new generation of coal power plants. However, China's new domestic decarbonization goal, if extended to its overseas finance, will be enormously valuable in reducing future carbon emissions from recipient countries.

Highlights

- Chinese DFIs have become the largest public financiers of global power development
- Chinese DFIs are the largest public financiers of coal power globally
- East Asian DFIs' overseas financing has fueled a new generation of coal power
- It is critical to align East Asian DFIs' financing with decarbonization goals

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Chinese Overseas Development Financing of Electric Power Generation: A Comparative Analysis

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SCIENCE FOR SOCIETY The Paris Agreement aims to keep global warming to "well below 2°C above pre-industrial levels" and pursue efforts to limit it "even further to 1.5°C." To achieve this objective, the global power sector must undergo major structural transformation and rapidly decarbonize. Development finance institutions (DFIs) at the multilateral and national levels have pivotal roles to play in catalyzing such a transition given their policy-oriented missions. While the largest multilateral DFIs have made major strides decarbonizing their power portfolios, we find that East Asian national DFIs have become the largest public financiers of the global power generation sector, including substantial financing of fossil fuel power generation. The alignment of East Asian DFI finance with the Paris goals, and particularly of Chinese overseas finance with China's new domestic goal of national decarbonization, is crucial for the future decarbonization of the global power sector.

SUMMARY

Global power generation must rapidly decarbonize by mid-century to meet the goal of stabilizing global warming below 2°C. To meet this objective, multilateral development banks (MDBs) have gradually reduced fossil fuel and increased renewable energy financing. Meanwhile, globally active national development finance institutions (DFIs) from Japan and South Korea have continued to finance overseas coal plants. Less is known about the increasingly active Chinese DFIs. Here, we construct a new dataset of China's policy banks' overseas power generation financing and compare their technology choices and impact on generation capacity with MDBs and Japanese and South Korean DFIs. We find that Chinese DFI power financing since 2000 has dramatically increased, surpassing other East Asian national DFIs and the major MDBs' collective public sector power financing in 2013. As most Chinese DFI financing is currently in coal, decarbonization of their power investments will be critical in reducing future carbon emissions from recipient countries.

INTRODUCTION

To meet the United Nations Sustainable Development Goals and the Paris Agreement on climate change, net global carbon dioxide (CO_2) emissions must approach zero by mid-century.[1–3] To meet this goal, the global power sector must rapidly decarbonize.[1,3,4] Development finance institutions (DFIs)—publicly sponsored finance institutions with the official mission of promoting public policy objectives—can provide and catalyze financing to facilitate this transition.[5–7] To date, most attention on DFIs has focused on established, Western-led multilateral development banks (MDBs).[6,8–12] Since 2013 MDBs have reduced their fossil fuel power generation financing in developing countries, discouraged financing of upstream oil and gas extraction and coal-fired power plants, and prioritized financing of renewable energy.[6,12,13] Between 2007 and 2015, ten major MDBs facilitated 118 GW (57 GW of fossil fuel and 53 GW of renewable generation) of additional power generation capacity globally, with the fraction of renewable financing increasing over time.[12] However, national DFIs that promote national public policies through domestic and foreign markets collectively hold more assets globally than the MDBs.[14] Between 2007 and 2016, Chinese banks and funds provided development finance for overseas energy-related projects equivalent to that of all major Western-backed MDBs.[15] In the power generation sector, Chinese, Japanese, and South Korean DFIs have become prominent sources of overseas financing for coal power plants at a time when decarbonization must be a priority.[16–19] However, little is known about the impact of their financing on power generation capacity across technology types. Power generation infrastructure investments today financially commit future generations.[20] Additionally, fossil fuel-based power plants emit air pollutants and challenge climate targets.[21–23] Despite DFIs' critical roles in global power infrastructure development, quantitative analyses of their actual impacts are limited.

For the first time, we quantify the contribution of DFI financing to fossil fuel and renewable technology capacity additions around the world by constructing a new database. We utilize comprehensive power financing data available from 2000 through 2018[12,19,24] and map DFI power financing to individual power plants. We examine power generation capacity additions facilitated by overseas financing from two Chinese national policy banks, the China Development Bank (CDB) and the Export-Import Bank of China (CHEXIM), as well as their Japanese and South Korean DFI counterparts, including the Japan Bank for International Cooperation (JBIC), the Japan International Cooperation Agency (JICA), the Korea Development Bank (KDB), and the Export-Import Bank of Korea (KEXIM). We further expand our analyses of coal power financing to investigate the extent to which the East Asian national DFIs support their domestic coal power industry to operate abroad. Additionally, we assess the efficiency and installation of air pollutant emission control devices of new coal power plants financed by the national DFIs and the MDBs. Finally, we evaluate the lifetime CO_2 emissions that result from DFI-financed new power generation.

We find that new overseas power generation facilitated by DFI financing committed between 2013 and 2015 from China, Japan, and South Korea is larger than the contribution of major MDBs. Since 2015, Chinese DFI financing has continued to increase while Japanese and South Korean DFI financing has remained stable. While the MDBs' overseas power financing portfolio has become increasingly focused on renewables, East Asian national DFIs still largely finance coal power plants. We identify this difference through comparative analyses of Chinese DFIs and other major DFIs. In the following sections we present our findings and conclude with policy implications.

RESULTS

Assessing DFIs' Financing of Global Power Generation

DFIs, unlike commercial banks with profit-maximization goals, are established by governments to fulfill public policy objectives. As mandated by the governments, DFIs facilitate the development of key sectors such as infrastructure and trade by offering a variety of financial instruments such as loans, guarantees, and equity.[7] Due to government backing, DFIs are instrumental in mitigating perceived political risks[25] and as a result attract additional public and private investments that might not otherwise occur.

Both multilateral and national DFIs provide significant financing of global power generation development. Here we analyze CDB and CHEXIM, the two policy banks designated by the Chinese government for overseas development financing and promotion of global strategies. We compare CDB and CHEXIM with two groups of DFIs. The first group comprises the ten MDBs examined by Steffen and Schmidt,[12] covering all relevant MDB financing of global power generation between 2006 and 2015. These ten MDBs include the World Bank (WB), the International Finance Corporation (IFC), the Multilateral Investment Guarantee Agency (MIGA), the African Development Bank (AfDB), the Asian Development Bank (AsDB), the European Bank for Reconstruction and Development (EBRD), the European Investment Bank (EIB), the Inter-American Development Bank (IADB), the Development Bank of Latin America (CAF), and the Islamic Development Bank (IsDB). The second group comprises CDB and CHEXIM's East Asian counterparts, namely the Japanese and South Korean national policy institutions that provide overseas financing, including JBIC, JICA, KDB, and KEXIM.

MDBs have been financing power plants around the world for over 50 years,[26] whereas national DFIs are newcomers to the global power generation financing stage. In their first decades the MDBs invested heavily in fossil fuel-intensive power generation projects,[27,28] but began to shift their positions just over a decade ago.[12] National DFIs from developed East Asian economies, Japan and South Korea, have been active power plant financiers since the 1990s, especially for overseas coal plants.[18,28,29] In contrast, CDB and CHEXIM became globally active starting in the 2000s, with power finance primarily concentrated in coal and hydroelectric plants.[16,17,30–32] CDB and CHEXIM have become among the largest DFIs in the world economy with total assets of US$2.4 trillion and US$0.6 trillion in 2018, respectively.[33,34] Japanese and South Korean DFIs' total assets are all less than US$0.3 trillion.[35–38] Total assets of the ten MDBs, in comparison, are US$1.5 trillion (calculated based on individual MDB's total assets; data collected from the banks' websites and/or annual reports[39–46]). CDB and CHEXIM also differ from other DFIs in aspects of financing instruments and investment recipients. Financing instruments from MDBs and Japanese and South Korean DFIs include loans, equity, grants, and guarantees, whereas CDB and CHEXIM only provide loans and grants to overseas projects and are less apt to provide guarantees or equity financing. As for recipients of DFIs' financing support, MDBs and Japanese and South Korean DFIs lend both to public and private sectors, whereas lending from Chinese DFIs is largely to public institutions, such as governments and state-owned enterprises.

DFIs' overseas financial involvement in the power generation sector ranges from providing export credit, to supporting international trade, to financing the entire capital cost of a power plant. Whether providing partial or full financing to the power project, their involvement can be pivotal in enabling the plant's commissioning. In view of this instrumental role of DFIs' financing, we evaluate their impact on new power generation capacity by accounting for the total nameplate generation capacity of new power plants with DFIs' financing involvement, regardless of the amount of financing provided. We label this impact on power generation capacity as "facilitated generation capacity additions."

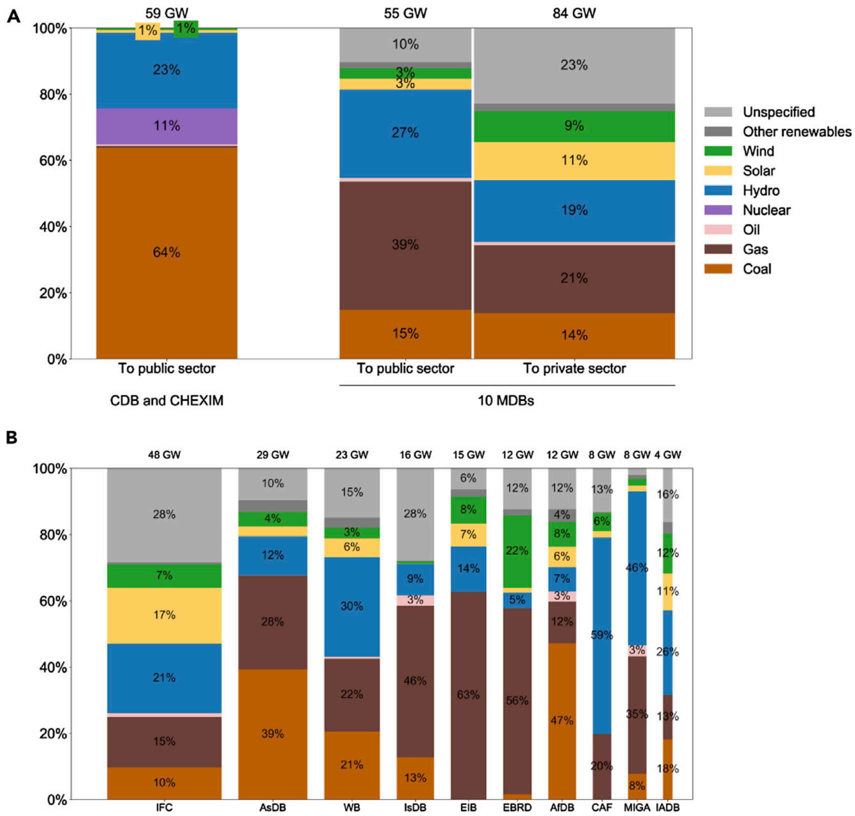

Figure 1. Power Generation Capacity Additions Facilitated by Financing Committed between 2006 and 2015 by Two Chinese DFIs—CDB and CHEXIM—and by Ten Major MDBs

Abbreviations for Chinese DFIs and the MDBs: CDB, China Development Bank; CHEXIM, Export-Import Bank of China; IFC, International Finance Corporation; AsDB, Asian Development Bank; WB, World Bank; IsDB, Islamic Development Bank; EIB, European Investment Bank; EBRD, European Bank for Reconstruction and Development; AfDB, African Development Bank; CAF, Development Bank of Latin America; MIGA, Multilateral Investment Guarantee Agency; IADB, Inter-American Development Bank. Contributions by CDB and CHEXIM to the public sector are presented because their contributions to the private sector are negligible. Contributions by the MDBs are (A) divided into public and private sectors, and (B) shown individually for each MDB. The colors and percentages represent each fuel type. "Other renewables" include geothermal, biomass, and waste-to-energy. Numbers on top of the columns indicate the facilitated capacity additions (unit: GW). The widths of the columns are proportional to the facilitated capacity additions. Data sources: CDB and CHEXIM data constructed from the CGEF Database from Boston University[24] and the World Electric Power Plants Database[47] (WEPP); MDB data from Steffen and Schmidt.[12]

Contribution to Global Generation Capacity Additions

CDB's and CHEXIM's overseas financing of power generation has grown rapidly since the late 2000s. In 2008, CDB and CHEXIM together surpassed the WB and its regional counterparts to annually become among the largest global power generation financiers. Between 2008 and 2015 their financing exploded, annually increasing from twice (US$3 billion) to ten times (US$21 billion) the financing of any other DFIs (Figure S1). Japanese and South Korean DFIs have also been influential sources of power generation finance, annually contributing about US$1 billion and US$0.4 billion, respectively, to overseas coal power plants between 2013 and 2017.

We construct a power plant-level database of CDB's and CHEXIM's overseas power financing by mapping their financing commitments to individual power plants in the global power plant inventory, the World Electric Power Plants Database (WEPP).[47] We quantify the facilitated generation capacity additions from CDB's and CHEXIM's overseas financing and compare them with the MDBs and Japanese and South Korean DFIs. Data for MDBs' financing commitments are available for 2006–2015, for all technologies including renewables and non-renewables.[12] Data for Chinese DFIs are available for 2000–2018, also including all technologies.[24] Data for Japanese and South Korean DFIs are available from January 2013 to August 2017, and only for coal, solar, wind, and geothermal plants,[19] thus their contributions to other technologies such as hydro, gas, oil, and nuclear plants are unknown. Therefore, when comparing CDB and CHEXIM with MDBs, we use the time interval 2006–2015 when data are available for both groups. When comparing Chinese, Japanese, and South Korean DFIs with MDBs, we use the 3-year time interval 2013–2015 because this is the only interval for which data are available for all of the DFIs.

We find that CDB's and CHEXIM's financing commitments between 2006 and 2015 facilitated 59 GW total capacity additions with the largest fraction devoted to coal, hydro, and nuclear power. Their contribution together is larger than that of any individual MDB, and is equivalent to 42% of total power capacity additions collectively contributed by the ten major MDBs over the same time period (Figure 1; see also Table S1 for annual comparison). In contrast to CDB's and CHEXIM's coal power-dominated portfolio, the ten MDBs collectively, and most of them individually, have a more technologically diverse capacity portfolio. Among the MDBs, the largest share of facilitated capacity additions of AsDB and AfDB were devoted to coal power; WB, CAF, and MIGA to hydro power; and IsDB, EIB, and EBRD to gas plants. Collectively, between 2006 and 2015 the ten major MDBs' financing commitments facilitated substantial capacity additions in gas (39 GW) and hydroelectric generation (31 GW). Among the total 140 GW capacity additions facilitated by MDB financing, 55 GW were through public lending and 84 GW through private lending. In contrast, all CDB's and CHEXIM's financing commitments were to public borrowers except for one loan to a private company for a 100-MW wind farm in Pakistan. Therefore, public lending from the two Chinese DFIs facilitated more power capacity additions, specifically more coal and nuclear plant capacity, than all ten MDBs' public lending combined.

During the period of analysis, Chinese, Japanese, and South Korean DFIs overtook the MDBs' role as the most important

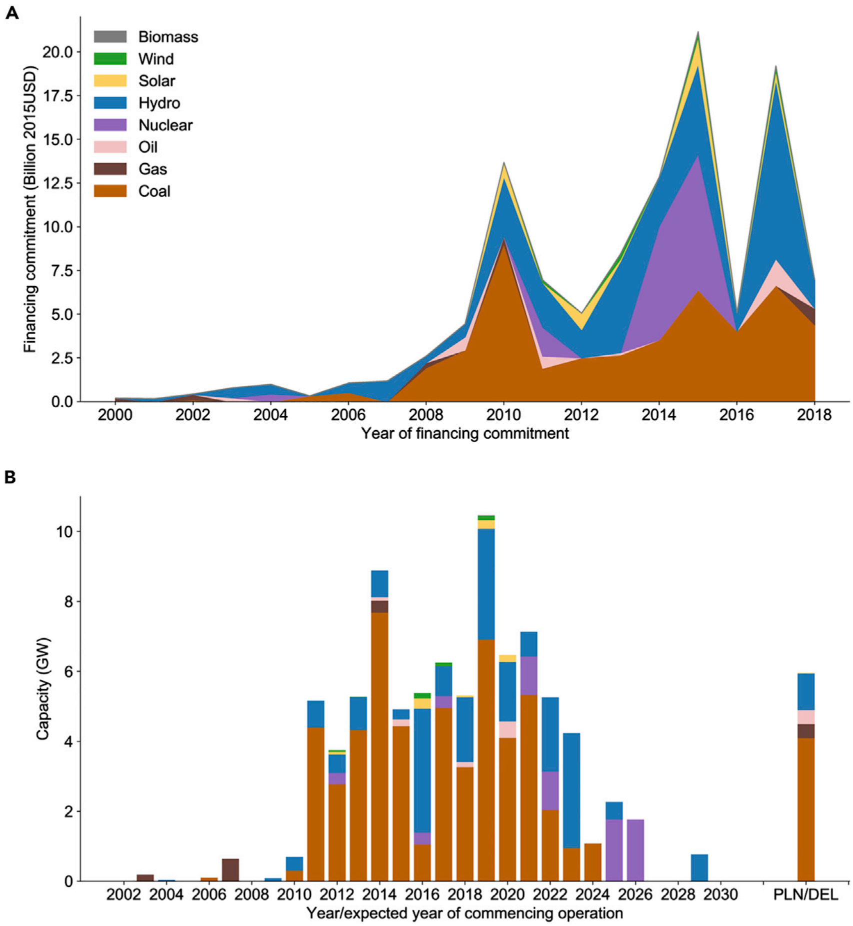

Figure 2. CDB and CHEXIM Annual Financing Commitments and Facilitated Capacity Additions in Overseas Power Generation

(A) CDB and CHEXIM overseas financing commitments in the power generation sector by technology type from 2000 to 2018 (year corresponds to when financing commitment is made). CDB and CHEXIM overseas financing is counted in the year in which financing commitment was made rather than spread out and allocated across years of investment. Variation of their financing commitments across years is influenced by the number of newly approved projects and the financing amounts of these projects each year. In reality, annual financial flows are smoother than appear in the figure because the bank's total commitment is allocated across years and distributed by the bank each year.

(B) CDB- and CHEXIM-facilitated overseas power generation capacity additions by year (year corresponds to commencement or expected commencement of operation year). PLN/DEL, planned or delayed power plants that do not yet have an estimated commissioning year.

power generation financiers. Table S2 summarizes these DFIs' facilitated capacity additions over various periods. While some of the MDBs have diversified their balance sheets toward cleaner energy, East Asian national DFIs have filled the coal financing gap by continuing to fund overseas coal plants. Between 2013 and 2015, ten MDBs together facilitated 42 GW of power capacity additions, of which 12 GW were through lending to public borrowers. In comparison, CDB's and CHEXIM's contributions were 32 GW (of which 17 GW were coal power), almost entirely to the public sector. Financing commitments between 2013 and 2015 from Japanese DFIs facilitated 10 GW of coal power capacity additions and 1 GW of solar, wind, and geothermal capacity additions. Meanwhile, South Korean DFIs facilitated 2 GW of coal, and 0.2 GW of solar and wind power capacity additions. Together, even neglecting any contributions from Japanese and South Korean DFIs to potential hydro, gas, oil, or nuclear plants, Chinese, Japanese, and South Korean DFIs' overseas development finance between 2013 and 2015 facilitated more power generation capacity additions and more coal additions than the ten MDBs' total contributions.

Power Capacity Additions Facilitated by Chinese DFIs

We unravel the technology mix and regional distribution of CDB's and CHEXIM's overseas power financing since 2000 and its impact on generation capacity growth. Tracking CDB and CHEXIM finance at the power plant level, we find that these two Chinese policy banks committed US$112 billion to overseas power generation projects between 2000 and 2018. As a result, they facilitated past and expected future commissioning of 163 power plants with total capacity of 90 GW in operation, under construction, or planned (Table S3).

Figure 2 summarizes CDB's and CHEXIM's annual financing commitments to overseas power plants since 2000, and their contribution to generation capacity additions. CDB's and CHEXIM's financing commitments in the power sector increased greatly, rising from less than US$1 billion per year before 2006 to a peak in 2015 at US$21 billion. In 2018 their financing commitments decreased to US$7 billion. This tremendous cumulative investment since 2000 led to new power generation capacity additions overseas of 3 to 9 GW each year between 2011 and 2018, with coal and hydroelectric power plants making up the majority. In addition, CDB and CHEXIM financed a small amount of nuclear power and a smaller amount of gas, oil, solar, wind, and biomass technologies. About 43 GW of generation capacity is still in the pipeline (under construction or planned) as of March 2019, most of which is coal, hydro, and nuclear power, which is expected to commence operation within 5 years. According to the WEPP database, from 2011 to 2018 on average 82 GW of new power plants came online annually in non-OECD countries excluding China, so CDB and CHEXIM were involved in approximately 7% of these capacity additions. The vast majority of CDB's and CHEXIM's overseas finance is to developing economies (87%) and countries that participate in China's Belt and Road Initiative (BRI) (87%) (Figure S2; see also Table S4 for a complete list of recipient countries).

CDB's and CHEXIM's financing commitments typically provide a substantial fraction of the capital costs of their facilitated

Table 1. Summary of Regional Distribution of Facilitated Generation Capacity Additions by CDB and CHEXIM across Technology Types between 2000 and 2018 (Unit: MW)

Technology Type	Africa	Europe and Central Asia	Latin America and Caribbean	Middle East	South Asia	Southeast Asia	Total	BRI % as of 2019
Coal	10,850	3,180	350	0	15,960	26,106	56,446	99
Gas	829	343	0	0	400	0	1,572	100
Oil	200	0	100	470	0	156	926	100
Nuclear	0	3,540	0	0	3,205	0	6,745	48
Hydro	10,214	375	4,808	0	3,809	4,140	23,345	88
Solar	55	85	368	0	400	0	908	61
Wind	324	0	17	0	99	0	440	100
Biomass	0	0	20	0	0	0	20	0
Total MW	22,472	7,523	5,663	470	23,873	30,402	90,401	92
% by region	25	8	6	1	26	34	100	

The capacity additions include power plants that are currently in operation, under construction, and planned.

capacity additions. We find that they provide more than half of the total capital costs for the majority of the power plants they co-finance with other banks. The degree of their financial involvement, evaluated by the fraction of a power plant's capital cost that is financed by CDB or CHEXIM, varies by plant and by technology type (Figure S3). On average, CDB's and CHEXIM's financing commitments support approximately 50% of the total cost of coal power plants and 70% of the total cost of hydroelectric dams. Hydroelectric power plants' average capital cost per unit capacity is higher than that of coal power. Hence, CDB's and CHEXIM's facilitated coal capacity additions are more than twice their facilitated hydroelectric power capacity even though their financing to coal and hydroelectric plants are comparable.

Table 1 summarizes the regional distribution of CDB- and CHEXIM-facilitated generation capacity additions across technology types. CDB's and CHEXIM's primary contribution to coal power capacity is concentrated in South and Southeast Asia, where electricity demand is increasing rapidly with economic growth and industrialization. Their contributed hydropower capacity is concentrated in Africa, where energy access is among the top development priorities, and in African countries where water resources are abundant. The few projects of gas, oil, nuclear, solar, wind, and biomass plants are scattered around the world.

CDB's and CHEXIM's financing commitments between 2000 and 2018 facilitated the most capacity additions in Indonesia, Vietnam, South Africa, Pakistan, and India (Figure 3). Around 10% of each of these countries' total power generation capacity (except India at 2%) received some CDB or CHEXIM financing. In South Africa and Ecuador, almost 50% of their new generation capacity added since 2000 received some CDB or CHEXIM financing. CDB's and CHEXIM's contributions to the top ten recipient countries are mostly coal, hydro, or nuclear power generation. These technologies appear to align with the recipient countries' energy resources and their domestic capacity portfolios, where coal and hydro power has long served the goal of expanding reliable and affordable electricity access.[48]

Coal Power Financing of the DFIs

In 2013, the WB announced it would no longer finance coal power except under exceptional circumstances,[49] and other MDBs gradually adopted similar policies due to shareholder and stakeholder concerns about the impact of coal on global CO_2 emissions and climate change.[6] Meanwhile, East Asian national DFIs filled the resulting gap and further expanded coal power financing. Between 2013 and 2017, Chinese, Japanese, and South Korean DFIs committed financing to 49 GW of coal power capacity overseas. Figure 4 shows the eight countries with the largest coal power generation capacity additions facilitated by financing commitments from the DFIs between 2013 and 2015. Chinese and Japanese DFIs' overseas financing dominates the facilitated coal power generation additions in the recipient countries, with the MDBs contributing only to Pakistan and Morocco and South Korean DFIs only contributing to Vietnam.

CDB's and CHEXIM's overseas finance supports Chinese firms to go abroad.[50–52] Japanese and South Korean DFIs are also by nature national development banks with the policy objective of globalizing their firms. Our analyses of equipment manufacturer, construction contractor, and ownership of East Asian DFI-financed coal power plants confirm that these national DFIs' overseas coal power financing support the global expansion of their domestic coal power industry. Among CDB- and CHEXIM-financed overseas coal plants, 77% imported boilers, steam turbines, and/or generators from Chinese equipment manufacturers, 65% of these plants hired Chinese construction contractors, and 13% are majority or jointly owned by a Chinese project developer (Figure S5). Similar dynamics are observed in the cases of Japanese and South Korean DFIs. The overseas expansion of Chinese coal power companies has been linked with their cost advantages in labor, technology, and financing, demand for coal plants from recipient countries, and China's domestic overcapacity in coal power.[17,53–55] Based on the linkage between CDB's and CHEXIM's overseas coal power financing and Chinese coal power companies, studies such as that by Kong and Gallagher[55] further advance the idea that China's globalization of its coal industry through DFI financing is part of a "domestic adjustment" program to ease the industry of domestic overcapacity and environmental regulation.

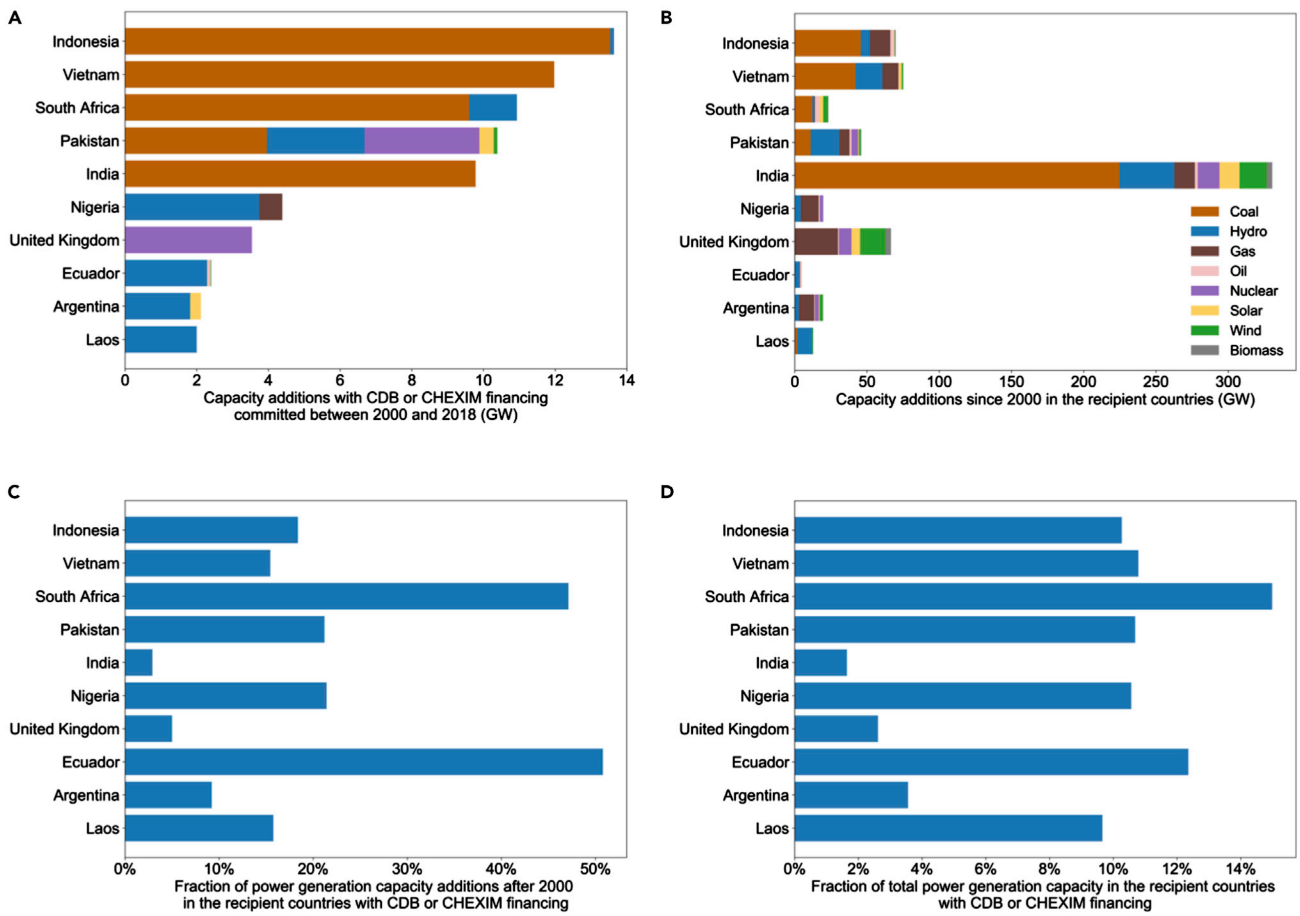

Figure 3. Ten Recipient Countries with the Most Power Capacity Additions Facilitated by CDB and CHEXIM Financing

(A) Capacity additions facilitated by CDB and CHEXIM financing commitments between 2000 and 2018 (in operation, under construction, and planned; see also Figure S4 for each category separately). The colors indicate technology types.

(B) Power generation capacity added in or after 2000 in the ten recipient countries (currently in operation, under construction, and planned). The colors indicate technology types.

(C) Fraction of the recipient countries' power generation capacity additions in or after 2000 that received at least partial financing from CDB or CHEXIM.

(D) Fraction of the recipient countries' total power generation capacity (currently in operation, under construction. and planned) that received at least partial financing from CDB or CHEXIM.

Technology Choices of DFI-Financed Coal Plants

The technology—subcritical, supercritical, ultra-supercritical—used in a coal power plant influences the efficiency of coal burning and the resulting CO_2 and air pollutant emissions per unit electricity generated. We explore the technology choices of DFI-financed coal plants by analyzing the technology configurations documented in the WEPP database. We find that of the DFIs, CDB and CHEXIM finance has facilitated the largest capacity addition of subcritical coal-fired power plants (Tables S5 and S6). Japanese DFIs have financed the largest fraction of more efficient supercritical (47%) and ultra-supercritical (45%) plants. South Korean DFIs also devoted over 90% of their facilitated capacity additions to supercritical and ultra-supercritical technology. MDBs' portfolio includes 35% subcritical coal technology capacity. In reality, we find that coal-fired power plants can experience a lag of 1–9 years between the announcement of financing and commencement of plant operations. A coal plant's technological configuration may evolve with technology improvements occurring during the project development period, especially for plants that are still in the planning stage.

Installing end-of-pipe emission control devices in coal power plants efficiently reduces emissions of air pollutants such as SO_2, NO_x, and particulate matter (PM) and the resulting ambient air pollution and associated adverse health impacts while slightly increasing CO_2 emissions due to the energy necessary to operate the control devices. However, there exist no comprehensive data on the installation of coal plants' pollution control devices worldwide, with WEPP being the only indicative source of such information. According to data reported to WEPP by electric power producers, coal power plants financed by East Asian national DFIs have installed less pollution control technology than the MDBs (Tables S5 and S6). This indicates either lower installation rates, less reporting of pollution controls, or lower availability of data. Compared with national DFIs, MDB-financed plants either more frequently install pollution control devices or have a better and more transparent reporting system.

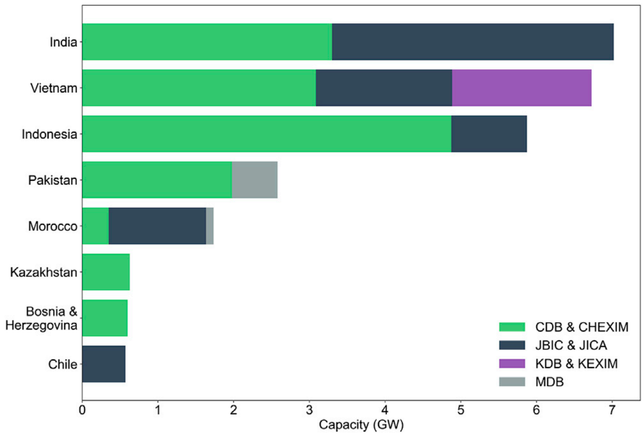

Figure 4. Recipient Countries with the Most Coal Power Capacity Additions Facilitated by Financing from the National and Multilateral DFIs

Financing committed between 2013 and 2015. Bar colors indicate financing sources.

Committed CO_2 Emissions from DFI-Financed Power Plants

Fossil fuel-based power generation infrastructure will lock in CO_2 emissions for decades. Accounting for the committed emissions—CO_2 emissions expected over the power plants' lifetime—demonstrates the long-term consequences of past and current investment decisions. We quantify the total committed CO_2 emissions expected from coal, oil, and gas power plants supported by the DFIs' financing commitments, assuming a 40-year lifetime (Table 2).

The power plants that CDB and CHEXIM committed to finance between 2000 and 2018 will emit 12 Gt of CO_2 between commencement of operations and closure. Most of these committed emissions will come from coal-fired power plants. Over their lifetime these coal plants will emit as much CO_2 as the total annual emissions from all coal-fired power plants in operation around the world in 2018. Over 90% of the emissions will occur in the future given that almost half of these plants are still in the pipeline (Table S7). The coal plants that Japanese and South Korean DFIs committed to finance between 2013 and 2017 will emit 3 Gt and 1 Gt of CO_2, respectively. Taking into account coal plants that were pending for Japanese and South Korean DFI financing as of the end of 2017, another 3 Gt of committed CO_2 emissions will occur. The MDBs, although having financed more gas than coal power capacity additions between 2006 and 2015, have more committed CO_2 emissions from their facilitated coal than gas generation capacity. Among the recipient countries, India, Indonesia, Vietnam, and South Africa have the most committed CO_2 emissions from power plants financed by the DFIs (Tables S7–S10).

DISCUSSION

Our analyses of overseas development finance by CDB and CHEXIM (compared with Japanese and South Korean DFIs and the MDBs) and their contribution to power generation capacity additions reveal the key role played by these institutions in global power infrastructure development. Between 2013 and 2015, financing commitments from the Chinese, Japanese, and South Korean national DFIs together facilitated more generation capacity additions worldwide than the collective contribution of major MDBs. Over the last decade, ten major MDBs have financed a variety of power technologies with a growing share of renewable power generation.[12] However, when juxtaposed with overseas financing from East Asian national DFIs, we find a different picture. The national DFIs' overseas power plant financing committed before 2018 fueled a new generation of fossil fuel power currently in operation or in the pipeline. Overseas financing by CDB and CHEXIM, committed between 2000 and 2018, facilitated 56 GW of coal power, 23 GW of hydroelectric power, and 7 GW of nuclear generation capacity additions worldwide. Furthermore, as a result of financing committed between 2013 and 2017, Japanese and South Korean DFIs facilitated 15 GW and 4 GW of overseas coal power capacity additions, respectively.

East Asian national DFIs have become public lenders of last resort for financing coal plants in developing countries after recipient countries' domestic sources have been utilized. In 2013 the United States government and the WB announced they would restrict lending for development of coal power plants out of concerns for climate impacts.[49] Since then, over 100 global financial institutions have adopted coal power and/or coal mining financing restriction policies, including MDBs, European national DFIs, insurers, and some commercial banks.[13] In 2018, the MDBs and the International Development Finance Club, of which CDB, JICA, and KDB are members, declared that they would align member balance sheets with the Paris Agreement.[56,57] In 2020, South Korea and Japan announced plans to further phase out public financing of new overseas coal plants. While CDB and CHEXIM have not yet moved to restrict overseas coal power financing, their overall energy financing overseas has decreased since 2017 due to a variety of domestic and global factors such as trade and financial instability on the mainland and debt sustainability concerns in borrowing countries, among others.[58] Nevertheless, no policies have been announced by China, Japan, or South Korea on divestment from coal power plants that are already in the pipeline, which we show will commit large future CO_2 emissions.

These national DFIs' overseas financing commitments are inconsistent with a climate target of well below 2°C global average warming by the end of the century. To meet the Paris Agreement goals, little or no additional CO_2-emitting infrastructure can be commissioned, and existing infrastructure will need to be retired early to reduce projected lifetime emissions.[22] Of the coal power capacity that CDB and CHEXIM have committed to finance through 2018, half is expected to commence operations in the future with over 90% of their committed CO_2 emissions occurring after 2018. This will greatly reduce the potential to decarbonize the global power generation sector by mid-century. Reducing committed CO_2 emissions of new fossil power plants will require either major retrofits to permit carbon capture and storage or early retirement of operational plants, both of which are costly options. It is important that DFIs implement more restrictive policies on fossil fuel financing to ensure that their overseas commitments are aligned with the

Table 2. Committed CO_2 Emissions from Power Plants with Partial or Full Financing from the DFIs (Unit: Gt CO_2)

Committed CO_2 Emissions by Fuel Type	DFIs and Year of Financing Commitments			
	Chinese DFIs (2000–2018)	Japanese DFIs (2013–2017)	South Korean DFIs (2013–2017)	Ten MDBs (2006–2015)
Coal	11.81	3.25	1.20	5.00
Oil	0.14	NA	NA	0.15
Gas	0.08	NA	NA	3.41
Total	12.03	–	–	8.56

NA, data not available. Financing commitments over various available time intervals. Data for Japanese and South Korean DFIs' financing of oil and gas plants is unavailable and are therefore not included. See also Tables S7–S10 for the breakup of committed emissions into realized emissions and remaining committed emissions, and the breakup of emissions by country for the DFIs separately.

Paris Agreement while serving other development goals such as infrastructure and trade.

In addition to the climate risks, East Asian DFIs' enormous capacity portfolios in coal power also expose them to financial risks. Costs of renewable technologies are decreasing rapidly. By 2028, in markets such as Vietnam and Indonesia where coal power has long been prioritized, operating existing coal power plants will likely be more costly than building new solar power.[59] This may lead to DFIs having stranded coal power assets and, thus, trouble recouping their loans. Therefore a critical evaluation of their fossil fuel investments versus renewable energy options, to account for decreasing costs of renewable technologies and the possibility of future stranded coal power assets, will be valuable for the DFIs' financial security.

Our study, for the first time, illuminates Chinese DFIs' overseas power financing portfolio relative to other major DFIs and finds them to be the most significant international development financiers for power generation capacity expansion in developing countries. While we focus on DFI financing, commercial banks and institutional investors are also important financiers for global power generation. Although a number of commercial banks have introduced policies to cease lending to new coal power plants,[13] recent tracking by the Non-Governmental Organization community revealed that commercial banks from Japan, Europe, United States, and China have continued to provide significant support for coal power through direct loans and underwriting.[60–62] With profit-maximization goals, commercial banks may still perceive coal plants in developing countries as steady sources of cash flow that generate greater returns than renewable technologies.[63] However, growing coal power generation capacity and increasing competitiveness of renewables are reducing utilization rates of existing coal plants,[64] which in turn undermines coal plants' profitability. To meet long-term sustainable development goals and avoid committed CO_2 emissions from fossil fuel plants, a major increase in low carbon technology investment is needed.[65] Moreover, national determined contributions submitted by developing countries to the Paris Agreement suggest a vast investment need for renewable energy in power generation.[66] DFIs can play pivotal roles in this regard. Redeployment of some coal power financing with renewable technologies has the potential to substantially increase renewable deployment.

Here we find national DFIs' overseas financing of power generation to be a prominent driver of fossil fuel generation capacity expansion globally and to have the potential to drive the expansion of renewable power capacity. However, further questions remain regarding the political economy of how national DFIs make investment decisions on various technology options, what barriers they may face financing non-hydro renewable energy, and what approaches they may take to increase renewable energy financing. Future research that addresses these questions is needed, as increased global investment in non-fossil energy is crucial for global sustainability while DFIs play an important role in facilitating power financing. In addition to DFI financing, power generation development in developing countries is influenced by a variety of other factors. Continuous research is required to understand how to steer the developing countries' power sector to a low carbon pathway and how DFIs can facilitate the transition. For example, we find that CDB's and CHEXIM's overseas financing portfolio is typically aligned with the recipient countries' energy resources and domestic capacity portfolios. AsDB and AfDB, with many countries in their membership lists that have cheap coal resources and favor coal power projects, have also devoted higher portfolios to coal power capacity additions compared with other MDBs. This indicates a strong connection between DFI financing and the recipient countries' development priorities and demand for power capacity. In some developing countries where energy access and affordability are the top development priorities, or where subsidies and other incentives distort market prices, coal power may still appear to be the cheapest and most stable power source, although renewable energy is becoming increasingly competitive. Future research that examines the recipient countries' development strategies and energy policy and regulation is crucial to identify the bottleneck and shift global financing away from fossil fuel. Additionally, we find that some CDB and CHEXIM financing of coal power supports the expansion of Chinese coal power companies, including equipment manufacturers, construction contractors, and project developers, into overseas coal power markets. To explain Chinese coal power companies' global expansion, hypotheses have been raised regarding their advantages in labor, technology, and financing costs over international competitors,[17,54] China's domestic coal power overcapacity,[17,55] and "pull" factors from the demand side such as recipient countries' requests for coal power and high profitability of coal plants.[17,53,55] Yet questions remain about how CDB and CHEXIM interact with China's coal power companies and make financing decisions. While Chinese companies' overseas involvement in power generation has been coal intensive,[67] they also have the potential to expand foreign markets for renewable technologies.[66,68] To understand how to realize this potential, quantitative and case studies that utilize our database to further explore the relationship between Chinese overseas development financing and China's domestic power industry development will be valuable.

EXPERIMENTAL PROCEDURES

Resource Availability

Lead Contact

Further information and requests for data should be directed to the Lead Contact, Denise L. Mauzerall (mauzerall@princeton.edu).

Materials Availability

This study did not generate new unique materials.

Data and Code Availability

The datasets and code generated during this study are available at: https://doi.org/10.34770/3yxs-4588. The dataset of Chinese DFIs is also available at: www.bu.edu/cgp. Part of our datasets utilize the World Electric Power Plants Database purchased from S&P Global Market Intelligence. Therefore, we provide WEPP unit IDs for the power plants that we examine in our paper. With these IDs, additional information about each power unit can be obtained via subscription to the full WEPP database.

Study Scope and Data Sources

To analyze the impacts of CDB's and CHEXIM's overseas power generation financing, we construct a new project-level database that documents both the financing commitments of CDB and CHEXIM to overseas power plants and the corresponding nameplate generation capacity and technology type of these plants. We choose CDB and CHEXIM because, out of China's three policy banks, they are two banks designated by the Chinese government for overseas development financing and promotion of global strategies. The third policy bank, the Agricultural Development Bank of China, is not included in our study because it does not provide overseas financing. The China Export & Credit Insurance Corporation (Sinosure), though highly involved in Chinese companies' overseas power project investments, is not included in our study because it is an insurance company. Sinosure provides insurance against non-payment risks in China's foreign trade and investment but does not provide direct lending. To construct the database for CDB and CHEXIM, we adopt a bottom-up approach by utilizing project-level financing data and plant-level power generation and technology configuration data. National DFIs from China, Japan, and South Korea do not officially publish their project-level financing data. Therefore, most existing studies on international power finance focus only on DFIs' financial flows to various technologies. Our study goes one step further by mapping the financial flows to individual power plants and quantifying new power generation capacity additions triggered by DFIs' financing commitments. With the newly constructed database, we further investigate DFI-financed coal plants' technology efficiency (subcritical, supercritical, or ultra-supercritical), installation of these coal plants' air pollutant emission control devices, and DFI-financed power plants' committed CO_2 emissions.

For project-level financing data, we deploy the China Global Energy Finance Database (CGEF) (accessed in April 2019) from Boston University that documents CDB's and CHEXIM's overseas financing of energy projects.[24] The CGEF database is the most comprehensive document available of Chinese overseas energy finance and has coverage starting in 2000. We select CDB's and CHEXIM's financing of power generation projects in this database and exclude other types of energy financing such as those for transmission, mining, or irrigation projects. The CGEF database provides information including the recipient country, fuel type of financed power generation projects, year of financing commitments, amount of financing commitments in US dollars, and a brief description of the projects. It does not include the project's corresponding generation capacity, specific technology configurations (such as the efficiency or end-of-pipe air pollutant emission control technology of a coal plant), or information on the manufacturer, construction contractor, or ownership of the power plant.

To obtain plant-level power generation and technology configuration data not available in CGEF, we exploit the WEPP database[47] (March 2019 version), which documents generation and technology information of the global power plant inventory. The process of mapping financing commitments to specific power plants in WEPP is as follows: for each entry of project financing in CGEF, we first screen WEPP by selecting the recipient country identified for the project by CGEF. We next search WEPP for the power plant(s) receiving the financing commitment based on CGEF's description. To facilitate the searching process, we develop a search tool based on two algorithms to identify the closest matches of power plants in WEPP: one built on the longest substring matching mechanism,[69] another built on the Levenshtein distance mechanism.[70] The search tool allows for minor differences between a power plant's name described in CGEF and that documented in WEPP. The search tool returns the top matches of power plants it finds in WEPP; we then manually choose the correct one using additional information documented in CGEF including fuel type, location, and year of financing commitment. When the search tool does not return the correct power plant, we manually search for the power plant in WEPP after a web search for additional information about the project finance (about 10% of the entries). We further manually code four power plants with fuel type and generation capacity because there are multiple web sources confirming the existence of these power plants that WEPP fails to document. Five (3%) of CGEF's power generation financing projects do not have sufficient information to identify the power plant or generation capacity; thus, our estimation of total associated generation capacity is conservative. There are cases when several financing commitments documented in CGEF are devoted to the same power plant. By mapping financing commitments to power plants in WEPP, we avoid double counting when calculating generation capacity additions facilitated by CDB and CHEXIM financing. The constructed database combining CGEF and WEPP provides complete information of CDB's and CHEXIM's financing commitments, the corresponding power plants, the technology choices, air pollutant emission control device installation, equipment manufacturer, construction contractor, and plant ownership.

We use published databases for Japanese and South Korean national DFI and MDB financing. We use the Consolidated Coal and Renewable Energy Database[19] that covers Japanese and South Korean DFIs' financing commitments in overseas power generation projects from January 2013 to August 2017. This database only includes coal, solar, wind, and geothermal power technologies. Therefore, our analysis of Japanese and South Korean DFIs does not include their potential financing to overseas oil, gas, hydro, nuclear, or biomass plants. The Consolidated Coal and Renewable Energy Database provides estimated share of plant capacity associated with financing from JBIC, JICA, KDB, and KEXIM, but does not document the total nameplate generation capacity of associated power plants. We locate Japanese and South Korean DFI-financed power plants in the WEPP database using the same searching method as we do for CGEF, and obtain the nameplate generation capacity of these power plants, as well as other information documented in WEPP.

We use the MDB power generation financing database from Steffen and Schmidt,[12] which includes ten major MDBs' financing between 2006 and 2015. This database documents both the financing commitments of the MDBs and the capacity of the power plants. It does not document the technology or ownership information of coal plants. Therefore, we use this database for financing commitments and generation capacity but apply the search tool for MDB-financed coal power plants to obtain information about the technology, air pollutant emission control devices, manufacturer, construction contractor, and plant ownership.

Inflation/Deflation

Financing commitments in three databases—CGEF, the Consolidated Coal and Renewable Energy Database, and the MDB database from Steffen and Schmidt[12]—are documented in US dollars. To convert the financing over a variety of years to 2015 US dollars, we use the International Monetary Fund's International Financial Statistics on Consumer Price Index of the United States.

DFIs' Contribution to Power Generation Capacity Additions

We quantify DFIs' contribution to power generation capacity additions around the world by accounting for the nameplate generation capacity of all the power plants with partial or full financing from the DFIs. In cases where the DFIs devote multiple financing commitments to one power plant, we only account for the capacity additions once to avoid double counting. We focus on incremental generation capacity associated with financing, so we do not account for the capacity additions in retrofitting or revamping projects (projects that improve an existing power plant) but account for the capacity additions in rehabilitation projects (projects that return retired power plants to operation). Often DFIs co-finance power plants together with local banks or local governments in the recipient country. Under this circumstance the DFI provides partial financing less than the total capital cost of the power plant. Whether CDB and CHEXIM provide partial or full financing to overseas power plants, their commitments can be pivotal in enabling the commissioning of a power plant. To better understand the degree of CDB's and CHEXIM's financing involvement in power generation, we estimate their financial contributions relative to the total capital costs of the power plants by quantifying the fraction of financing that originate with CDB or CHEXIM. Because information about the total capital costs of the power plants is not available, we estimate the power plants' capital costs assuming an average capital cost per kW for each fuel type following Li et al.[71] For each fuel type, a power plant's actual capital cost per kW is determined by many technological and non-technological factors. For example, the cost varies by specific technology configuration: ultra-supercritical and supercritical coal plants have higher capital costs per kW than subcritical coal plants; the cost of a coal plant's boiler depends on its temperature and pressure configurations; and installation of advanced pollution control devices increases the cost of coal plants. Furthermore, a power plant's total capital cost depends on its location (e.g., construction and labor costs vary with the location of the power plants), varies by its equipment manufacturer and construction contractor (e.g., Chinese coal power manufacturers and contractors are reported to have lower costs[17,54]), and changes with construction time (costs of renewable technologies have decreased rapidly with time). Moreover, the political and economic environment may also influence the plant's capital costs. Because the actual capital cost per kW may vary largely across power plants, our estimations of the power plants' capital costs and the fraction of CDB's and CHEXIM's financing contribution are indicative of the degree of CDB's and CHEXIM's financial involvement across fuel types on average, but not definitive. A detailed description of our estimation and uncertainty is presented in Figure S3 and Table S11.

Top Recipient Countries with the Most Facilitated Generation Capacity Additions by All Examined DFIs

In Figure 4 we rank the recipient countries by facilitated generation capacity additions contributed by financing commitments from DFIs. This order differs from the ranking of countries receiving the most financing commitments due to differences in generation cost by technology type and in distribution of financing. Most DFIs have committed finance to different power plants in the recipient countries, and their facilitated capacity additions directly add up to total facilitated capacity additions contributed by all examined DFIs. However, in Vietnam, as DFIs from China, Japan, and South Korea have co-financed the same coal plant, they all facilitated commissioning of this power plant. To avoid double counting of capacity additions, we separate the capacity additions of this power plant weighted by financing commitments from the DFIs and label them as facilitated capacity additions contributed by each DFI. Via this step, total facilitated capacity additions in Vietnam reflect the actual additional generation capacity contributed by all DFIs. Another coal plant in Vietnam is co-financed by JBIC and KEXIM, and a plant in Morocco is co-financed by JBIC and IsDB. We process the facilitated capacity additions for these two plants following the same procedure.

National DFIs' Financial Support of Coal-Fired Power Plants

We analyze whether and how national DFIs make financing commitments to overseas coal power plants to support the DFI country's domestic coal power industry by examining the equipment manufacturer, construction contractor, and plant ownership of the financed coal plants. WEPP labels coal power plants with the companies that produce the main components (steam turbines, boilers, and engines), the contractors that construct the power plant, and the parent companies that hold majority or joint ownership of the power plant. WEPP also documents the nationality of all manufacturing and construction companies. We conduct web searches and manually label the nationality of the parent companies. Combining information of company names and their nationalities, we then label whether a coal plant financed by a national DFI (e.g., CDB or CHEXIM) has imported equipment (steam turbine, boiler, and engine) manufactured by a Chinese company, whether the plant has hired a Chinese construction contractor, and whether the plant is majority or joint owned by a Chinese firm. When a coal plant has imported at least one component among the steam turbine, generator, and boiler from a Chinese manufacturer, we label it as utilizing equipment manufactured in China.

Coal-Fired Power Plant Technologies

We use information documented in WEPP to analyze DFI-financed coal-fired power plant technology (subcritical, supercritical or ultra-supercritical) and end-of-pipe air pollutant emission control technology (SO_2, NO_x, and PM control). For a large number of power plants worldwide, WEPP is the only compiled database documenting these technologies, although it does not have perfect data coverage. WEPP has 100% data coverage on the technology for coal plants financed by non-Chinese DFIs but only 85% coverage for coal plants financed by CDB and CHEXIM. This is likely due to the recently planned coal plants financed by CDB and CHEXIM for which the technology is unknown or unclear. WEPP collects data based on self-reported surveys, interviews with manufacturers, and documents about the power plants. In many cases entries of installed pollution devices are left blank or are marked with "NA" in WEPP. In both cases we interpret it to mean that no information is available and cannot determine in which of these cases pollution devices are actually installed. We make the heuristic assumption that missing data in WEPP corresponds to a lack of reporting of pollution control installation. We note that WEPP is likely underestimating installation rates of SO_2, NO_x, and PM control technologies in coal power plants because of imperfect access to information. Various technologies exist to remove each of the key pollutants emitted from coal-fired power plants. Each of these technologies results in different removal rates for these pollutants. We do not differentiate between these technologies in this study but instead focus on whether any control device for SO_2, NO_x, or PM is in place.

Committed Carbon Dioxide Emissions

DFI-financed power plants examined in this study have mostly been built over the past decade or will be built in the future. No comprehensive data about these power plants' actual CO_2 emissions or emission intensity are available. To calculate the committed CO_2 emissions of these DFI-financed power plants, we estimate each power generator's annual emission based on their nameplate generation capacity, burned fuel, and country following the method in Davis and Socolow,[72] assume a 40-year lifetime for all power plants, and assume their annual emissions will stay the same following previous studies.[22,72,73] Committed CO_2 emissions of each fossil fuel-based power plant is calculated based on the following equation:

$$E_p = G_p \times CF_p \times h \times I_p \times y \qquad \text{(Equation 1)}$$

where p represents the power plant or power generator. E_p is lifetime committed emissions, G_p is generation capacity (unit: MW), CF_p is capacity factor, which can be interpreted as the fraction of hours that the power plant operates in 1 year, h is the number of hours in one year, which is 8,760 h, I_p is emission intensity (unit: Gt CO_2/MWh), and y is the power plant/generator's lifetime in years, which equals 40 in our estimation. The emission intensity, I_p, of a power plant is determined by its efficiency or heat rate (heat rate is inversely related to efficiency) and its emission factor (determined by the carbon content of consumed fuel).

Our estimation relies on the WEPP database and the Carbon Monitoring for Action (CARMA) database (v3.0).[74] For each DFI-financed power plant, we estimate its capacity factor and emission intensity based on the same or similar power plants documented in CARMA (see Supplemental Experimental Procedures for a more detailed description). After calculating total committed CO_2 emissions for each power plant, we then separate them into realized emissions (CO_2 emitted before the end of 2018) and remaining committed emission (future emissions after 2018) based on the plants' commencement of operation year. The commencement year is available from WEPP for national DFI-financed power plants. The information is not available for MDB-financed power plants. Thus we follow Steffen and Schmidt[12] and assume that MDB-financed power plants would commence operation 2 years after the financing commitment.

CO_2 emissions from power plants that use the same type of fuel are aggregated in Tables 2 and S7–S10. "Coal" plants include power plants that use anthracite coal, bituminous coal, lignite, or sub-bituminous coal as fuel. "Gas" plants include plants that use conventional gas, liquefied natural gas, or liquefied petroleum gas. "Oil" plants include plants that use conventional oil or oil shale.

The average estimated capacity factor and emission intensity of power generators or power plants covered in this study are in good agreement with estimates in other studies (Table S12). Nevertheless, the estimation of committed CO_2 emissions is subject to uncertainties and limitations beyond capacity factor and emission intensity. A power plant's annual emissions will likely vary throughout its lifetime, depending on the actual future utilization rate and energy efficiency.[22,23] With decreased cost of renewable technologies, fossil fuel-based power plants may run fewer hours in a year in the future than power plants did in 2009 as documented in CARMA, leading to lower emissions than those calculated based on the assumptions above. If the power plants retire earlier than has been the case in the past, it will also result in lower emissions. For gas plants, we only consider their CO_2 emissions in this study but not emissions of other greenhouse gases such as methane leakage during gas-extraction processes.[75] Therefore, the climate impact from the gas plants is likely underestimated.

SUPPLEMENTAL INFORMATION

Supplemental Information can be found online at https://doi.org/10.1016/j.oneear.2020.09.015. The underlying data for this study is part of a broader web-based interactive dataset that is regularly updated at www.bu.edu/cgp.

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AUTHOR CONTRIBUTIONS

Conceptualization, X.C., K.P.G., and D.L.M.; Methodology, X.C. and K.P.G.; Formal Analysis, X.C.; Writing – Original Draft, X.C. and K.P.G.; Writing – Review & Editing, X.C. and D.L.M.; Visualization, X.C.; Supervision, D.L.M.; Funding Acquisition, K.P.G. and D.L.M.

DECLARATION OF INTERESTS

The authors declare no competing interests.

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Supplemental Information

Chinese Overseas Development Financing of Electric Power Generation: A Comparative Analysis

Xu Chen, Kevin P. Gallagher, and Denise L. Mauzerall

Supplemental Information

Supplemental Data Items

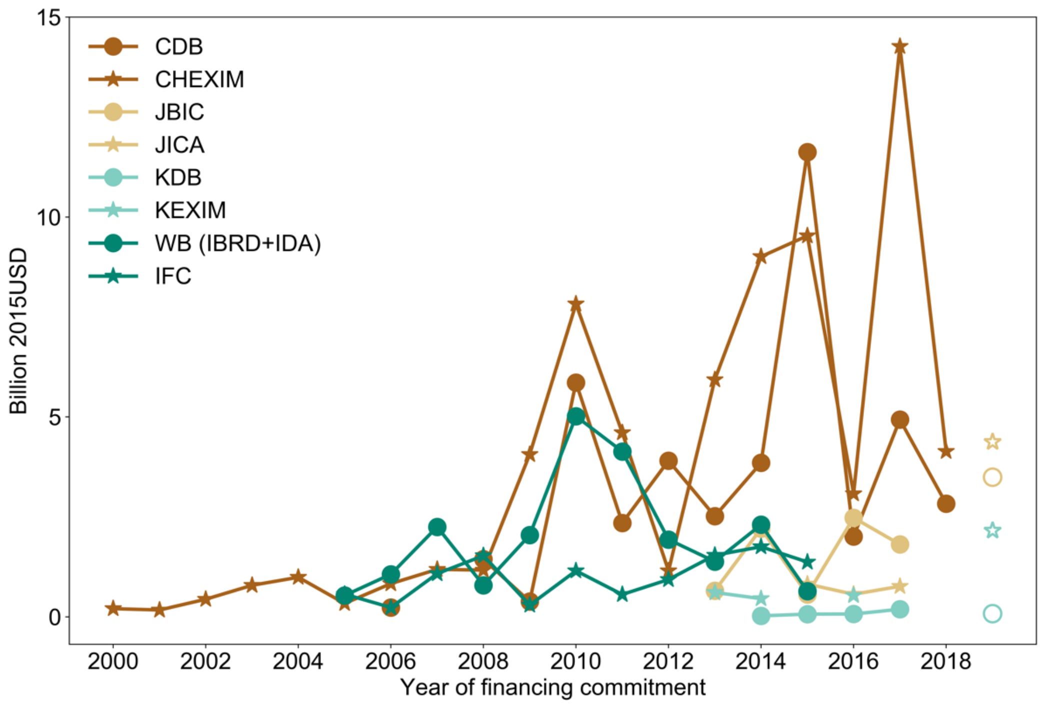

Figure S1. Major DFIs' financing in the global power generation system. National DFIs data is limited to their overseas financing. Data source: China's policy banks (CDB and CHEXIM) financing data[a] (2005-2018) from China Global Energy Finance Database (CGEF) from Boston University[1]; WB and IFC financing data (2005-2015) from Steffen and Schmidt[2]; Japanese and South Korean policy banks (JBIC, JICA, KDB, and KEXIM) financing data (January 2013-August 2017) from the Consolidated Coal and Renewable Energy Database from Natural Resource Defense Council (NRDC)[3,b]. Numbers after 2018 (open marks) indicate financial commitments that were pending as of August 2017).

Notes:

[a] When CDB and CHEXIM co-financed the same power generation project but no information of their respective financing share is available, we divide the financing equally between CDB and CHEXIM.

[b] The Consolidated Coal and Renewable Energy Database from NRDC includes only financing to coal, solar, wind and geothermal power. Data for Japanese and South Korean DFIs' financing of gas, oil, hydro, nuclear, or biomass plants is not available.

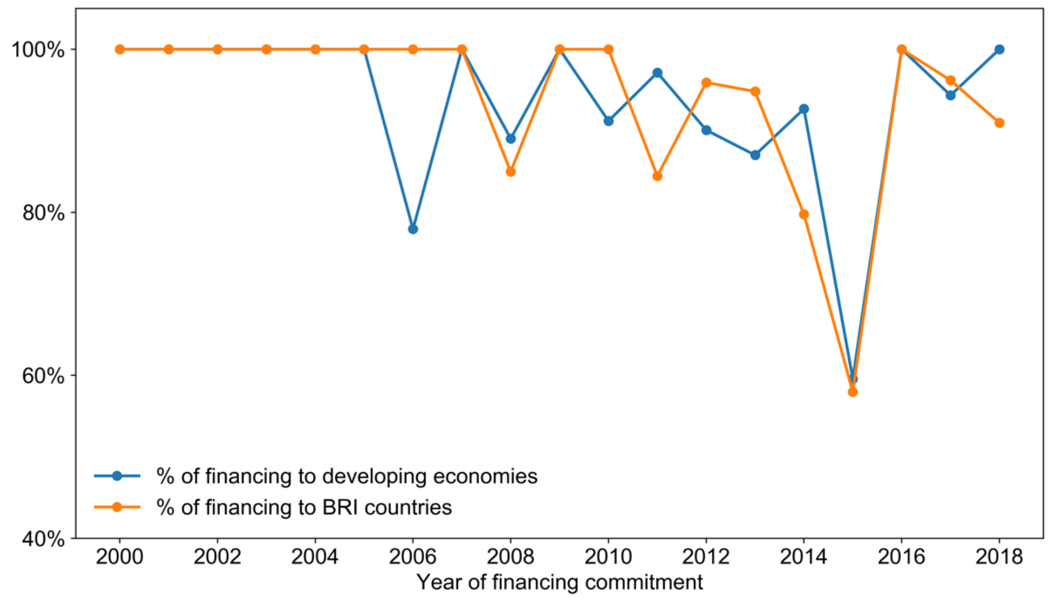

Figure S2. CDB and CHEXIM financing to developing economies and to BRI participating countries. Blue: Percentage of CDB and CHEXIM financing to developing economies[a]. **Orange**: Percentage of CDB and CHEXIM financing to countries that participate in the BRI[b]. The dips in 2015 in both trends are due to CDB's financing commitment to build a nuclear plant in the United Kingdom that year.

Notes:

[a] Countries' economic development status is based on United Nations country classification in 2019[4].

[b] BRI country membership status in April 2019 is used. When BRI was first announced in 2013, the fraction of CDB's and CHEXIM's financing to BRI countries was negligible. In 2017, when 70 countries had joined the BRI, the fraction of CDB's and CHEXIM's financing to BRI countries increased tremendously. At present, 87% of CDB's and CHEXIM's cumulative financing between 2000-2018 is devoted to 42 BRI countries (among a total of 126 BRI countries as of April 2019). With more countries joining China's BRI, the fraction of CDB's and CHEXIM's financing to BRI countries is likely to increase further. As of April 2019, CDB's and CHEXIM's cumulative financing commitments have facilitated 83 GW power generation capacity additions that are in operation, under construction or planned in Belt and Road countries, and 7 GW in non-BRI countries. CDB's and CHEXIM's contributions in non-BRI countries is located in Latin America (e.g. coal fired power plants in Brazil and hydroelectric dams in Argentina), Africa (e.g. hydroelectric dams in Mali and Malawi), and Europe (e.g. a nuclear power plant in United Kingdom).

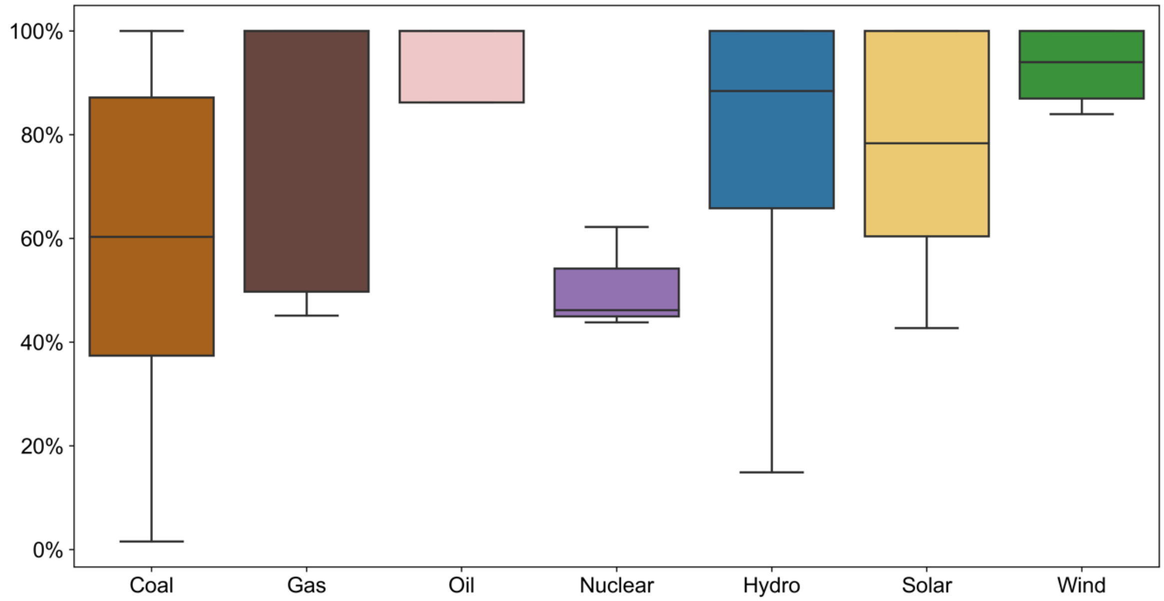

Figure S3. Box plot of percentages of overseas power plant's capital costs financed by CDB and CHEXIM across technologies[a,b]. The box limits indicate first quartile (Q_1) and third quartile (Q_3). The band inside each box denotes the median percentage. Whiskers of each box extend to the largest datum below $Q_3 + 1.5 \times IQR$ and the smallest datum above $Q_1 - 1.5 \times IQR$, where $IQR = Q_3 - Q_1$.

Note:
[a] To estimate the percentage of each power plant's capital cost financed by CDB and CHEXIM, we assume the capital cost per kW for each power generation technology following Li et al.[5] The percentage of CDB's and CHEXIM's financial contribution to each power plant (pp) is calculated as:

$$F_{pp} = \frac{CDB\ or\ CHEXIM's\ financing\ commitments\ to\ pp}{Nameplate\ generation\ capacity\ of\ power\ plant\ pp \times average\ capital\ cost\ per\ kW\ of\ pp's\ fuel\ type} \quad (1)$$

In cases where the calculated financial contribution by CDB and CHEXIM to a power plant, $F_{power\ plant\ pp}$, is larger than 100%, we assume CDB's and CHEXIM's financial contribution is 100%.

The fraction of CDB's and CHEXIM's financial contribution to each fuel type (f) is calculated as:

$$F_f = \frac{CDB\ and\ CHEXIM's\ total\ financing\ commitments\ to\ power\ plants\ of\ fuel\ type\ f}{Total\ facilitated\ capacity\ additions\ of\ fuel\ type\ f \times average\ capital\ cost\ per\ kW\ of\ fuel\ type\ f} \quad (2)$$

[b] The box plot generated based on calculations following Equation (1) is only indicative of the degree of CDB's and CHEXIM's financial involvement across power plants and fuel types on average, but not definitive, because a power plant's actual capital cost per kW is determined by many technological and non-technological factors. For example, the cost varies by specific technology configuration: ultra-supercritical and supercritical coal plants have higher capital costs per kW than subcritical coal plants; the cost of a coal plant's boiler depends on its temperature and pressure configurations; installation of advanced pollution control devices increases the cost of coal plants; etc. Furthermore, a power plant's total capital cost depends on its location (e.g. construction and labor costs vary with the location of the power plants), varies by its equipment manufacturer and construction contractor (e.g. Chinese coal power manufacturers and contractors are reported to have lower costs[6,7]), and changes with construction time (costs of renewable technologies have decreased rapidly). Moreover, the political and economic environment may also influence the plant's capital costs. To illustrate the uncertainty of capital costs, minimum and maximum estimates of power plants' capital costs of each fuel type from other studies are listed in Table S11, against the average capital costs used in this study.

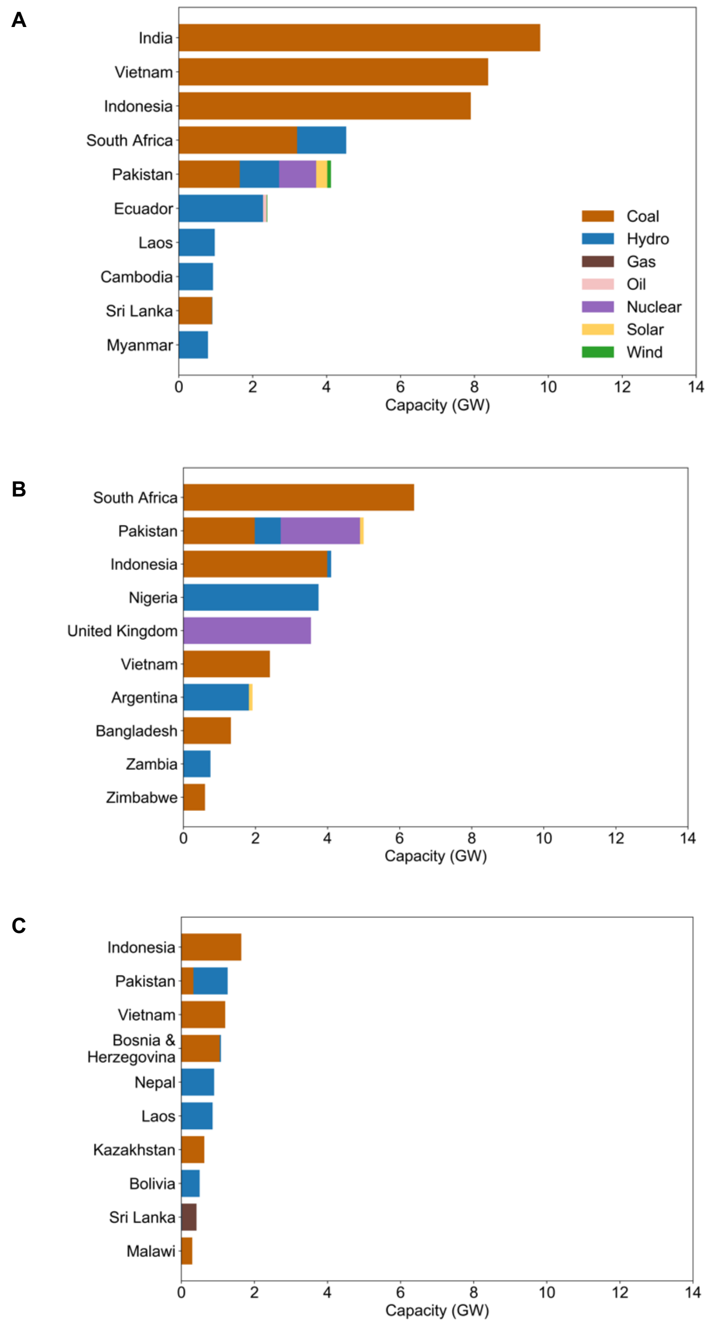

Figure S4. Ten countries with most power generation capacity additions that are (A) in operation, (B) under construction, and (C) planned facilitated by CDB and CHEXIM, related to Figure 3. Financing committed by CDB and CHEXIM between 2000-2018. Colors indicate different technologies.

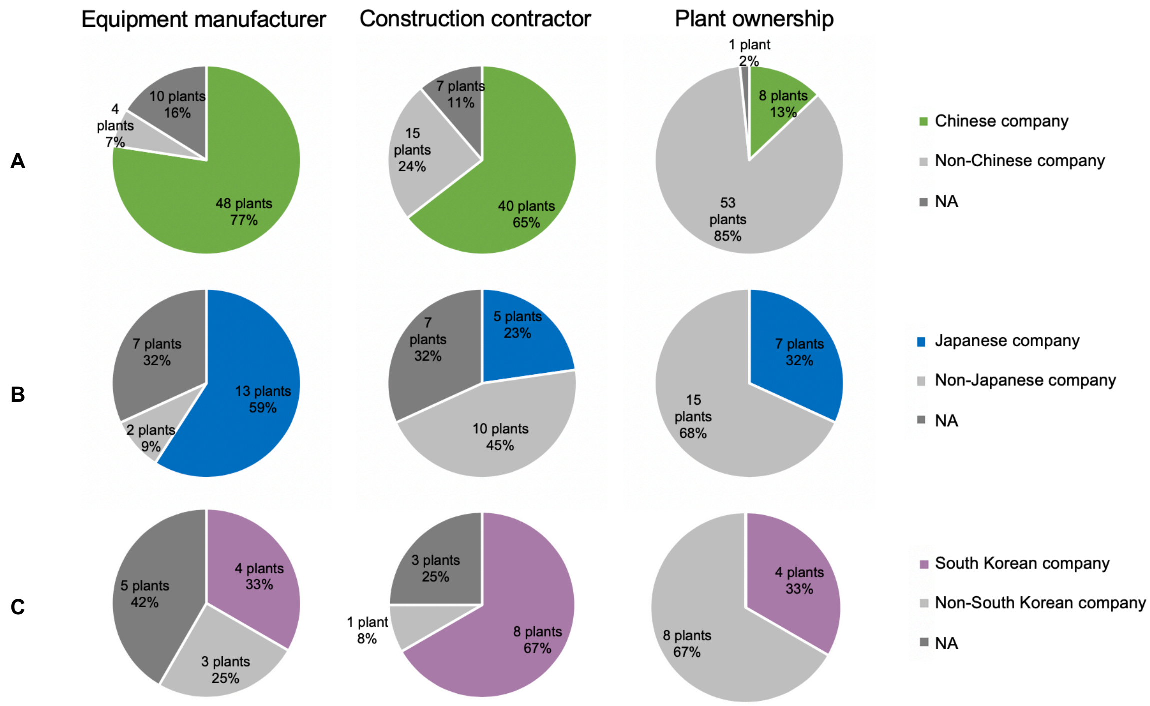

Figure S5. Summary of Chinese and Japanese DFIs' overseas coal power finance to support their domestic industry to go abroad. Equipment manufacturer, construction company and plant ownership[a] of coal fired power plants (**A**) that received financing commitments from CDB or CHEXIM between 2000-2018[b], (**B**) that were financed or under consideration for financing by JICA or JBIC[c] between 2013-2017, and (**C**) that were financed or under consideration for financing by KDB or KEXIM[d] between 2013-2017.

Notes:

[a] Power plant ownership includes both majority ownership and joint ownership. The ownership data from WEPP[8] has been added since 2011 and is not definitive. The ownership data may change over time with the transfer of plant ownership.

[b] Between 2000 and 2018, CDB and CHEXIM each committed finance to 33 and 34 overseas coal plants, respectively (among these plants, CDB and CHEXIM co-financed 5 of them). The patterns of their support for Chinese and non-Chinese equipment manufacturers, construction contractors, and plant ownership are similar with each other. Thus we only present their aggregate figure here.

[c] From January 2013 to August 2017, JICA and JBIC committed financing to 12 coal fired power plants. As of August 2017, another 10 plants were under consideration by JICA or JBIC for financing. A total of 22 coal plants involving or potentially involving JICA or JBIC finance are examined here.

[d] From January 2013 to August 2017, KDB and KEXIM committed financing to 4 coal fired power plants. Another 8 plants were under consideration for their financing as of August 2017. A total of 12 coal plants involving or potentially involving KDB or KEXIM's finance are examined here.

Table S1. Power generation financing by CDB and CHEXIM (2000-2018) and by ten major MDBs combined (2005-2015), related to Figure 1: their financing commitments (billion 2015USD), facilitated generation capacity additions (unit: GW), and fraction of facilitated coal power capacity additions. The largest number in each column is in bold.

Year	Financing commitments (billion 2015USD)		Facilitated capacity additions (GW)[a]		Fraction of facilitated coal power capacity additions	
	CDB and CHEXIM	**10 MDBs**	**CDB and CHEXIM**	**10 MDBs**	**CDB and CHEXIM**	**10 MDBs**
2000	0.2					
2001	0.2					
2002	0.4					
2003	0.8		0.2		0%	
2004	1.0		0.0		0%	
2005	0.3	5.4	0.0		-	
2006	1.1	4.2	0.1		100%	
2007	1.2	7.8	0.6	9.5	0%	15%
2008	2.6	7.2	0.0	12.1	-	**37%**
2009	4.4	12.6	0.1	10.5	0%	16%
2010	13.7	**14.1**	0.7	16.5	43%	24%
2011	7.0	12.1	5.2	11.1	85%	26%
2012	5.1	9.6	3.8	**23.0**	74%	21%
2013	8.4	11.1	5.3	11.9	82%	0%
2014	12.9	11.9	8.9	12.9	86%	0%
2015	**21.2**	9.1	4.9	9.7	**90%**	0%
2016	5.1		5.4	20.0	20%	10%
2017	19.2		6.3	11.7	79%	0%
2018	7.0		5.3		61%	
2019			**10.5**		66%	
2020			6.5		63%	
After 2020[b]			28.5		47%	
Total	**111.7**	**105.2**	**92.1**	**149.0**	**63%**	**14%**

Notes:

[a] Year of facilitated capacity additions corresponds to the commissioning year of power plants. For CDB- and CHEXIM-facilitated capacity additions, data of power plant commissioning year comes from the WEPP database. For MDB facilitated capacity additions, data of actual power plant commissioning year is not available. Following Steffen and Schmidt[2], an assumption of a two-year lag between MDBs' financing commitment and power plants' commissioning is made.

[b] 31 power plants to which CDB and CHEXIM committed financing are expected to commence operation after 2020. Among these power plants, 22.5 GW will come online between 2021 and 2029; another 6 GW do not yet have an estimated commissioning year including 2 plants currently delayed.

Table S2. Power generation capacity additions contributed by major DFIs' financing commitments presented over various available time intervals of financing (unit: MW).

Technology Type	CDB & CHEXIM (2000-2018)	JICA & JBIC (2013-August 2017)	KDB & KEXIM (2013-2017)	10 MDBs[a] (2005-2015)	IFC (2005-2015)	AsDB (2006-2015)	WB (2005-2015)
Coal	56,446	14,681	3,800	21,269	4,660	11,360	4,800
Gas	1,572	NA	NA	40,406	7,421	8,210	5,129
Oil	926	NA	NA	1,595	670	6	152
Nuclear	6,745	NA	NA	0	0	0	0
Hydro	23,345	NA	NA	36,611	10,360	4,561	7,102
Solar	908	74	1,088	11,487	8,083	845	1,317
Wind	440	609	447	9,727	3,450	1,289	768
Biomass	20	NA	NA	346	176	6	30
Geothermal	0	1,248	0	1,979	72	560	665
Waste	0	NA	NA	557	57	460	0
Unspecified	0	NA	NA	25,024	13,586	2,774	3,485
Total	**90,401**	**16,612**[b]	**5,335**[c]	**149,000**	**48,534**	**30,070**	**23,447**

Notes:

[a] Ten MDBs' collective contributions are listed, as well as three MDBs with the largest total contributions – IFC, AsDB, and the WB.

[b] Includes only power plants that reached 'financial close' status by August 2017. As of 2017, another 10,471 MW coal fired power plants were pending for financing consideration by JICA or JBIC.

[c] Same as data of Japan, capacity additions include only power plants that reached "financial close" status by August 2017. As of 2017, another 7,639 MW power plants were pending for financing consideration by KDB or KEXIM, including 7,340 MW coal power.

Table S3. Summary of CDB and CHEXIM overseas finance between 2000 and 2018 in the power sector by technology type: their financing commitments (billion 2015USD), number of financed power plants, and facilitated generation capacity additions that are operating, under construction, and planned (unit: GW)

Technology type	Financing commitments (billion 2015USD)	Number of financed power plants	Facilitated capacity additions (GW)
Coal	47.05 (42%)	62 (38%)	56.45 (62%)
Gas	2.15 (2%)	6 (4%)	1.57 (2%)
Oil	3.33 (3%)	5 (3%)	0.93 (1%)
Nuclear	16.37 (15%)	3 (2%)	6.75 (7%)
Hydro	37.92 (34%)	73 (45%)	23.35 (26%)
Solar	3.86 (3%)	9 (6%)	0.91 (1%)
Wind	0.94 (1%)	4 (2%)	0.44 (0%)
Biomass	0.06 (0%)	1 (1%)	0.02 (0%)
Total	**111.67 (100%)**	**163 (100%)**	**90.40 (100%)**

Table S4. Recipient countries of CDB and CHEXIM oversea power generation financing: CDB's and CHEXIM's financial commitments between 2000-2018 (million 2015USD), facilitated capacity additions that are operating, under construction and planned (unit: MW), and recipient country's BRI membership.

Recipient country	Financing commitments (million 2015USD)	Facilitated capacity additions (MW)	BRI membership (as of April 2019)
Argentina	3,540	2,117	0
Bangladesh	2,094	1,476	1
Belarus	896	383	1
Benin, Togo	550	147	0
Bolivia	988	500	1
Bosnia & Herzegovina	2,136	1,385	1
Brazil	392	350	0
Bulgaria	128	85	1
Cambodia	1,961	927	1
Cameroon	743	225	1
Chile	929	18	1
Cote d'Ivoire	953	387	1
Cuba	118	70	0
DRC	1,082	390	0
Ecuador	4,209	2,402	1
Equatorial Guinea	302	120	1
Ethiopia	1,110	675	1
Fiji	77	40	1
Gabon	330	160	1
Ghana	334	403	1
Guinea	1,462	690	1
India	8,363	9,780	1
Indonesia	10,150	13,642	1
Italy	794	0	1
Jordan	1,530	470	1
Kazakhstan	642	930	1
Kenya	131	55	1
Kyrgyzstan	393	300	1
Laos	2,212	1,997	1
Malawi	630	300	0
Mali	537	165	0
Morocco	300	350	1
Myanmar	258	790	1
Nepal	2,794	1,047	1
Nigeria	6,062	4,387	1
Pakistan	18,899	10,386	1
Papua New Guinea	251	51	1

Peru	353	206	0
Philippines	536	600	1
Republic of Congo	307	120	1
Serbia	609	350	1
South Africa	4,304	10,932	1
Sri Lanka	2,818	1,340	1
Sudan	1,182	390	1
Tajikistan	332	400	1
Uganda	1,943	783	1
United Kingdom	7,772	3,540	0
Uzbekistan	401	150	1
Vietnam	9,528	11,974	1
Zambia	2,042	1,110	1
Zimbabwe	1,268	908	1
Total	**111,672**	**90,401**	**-**

Table S5. Summary of technology (ultra-supercritical, supercritical, or subcritical) and pollution controls (SO_2 control, NO_x control, and PM control) of coal power plants financed by national DFIs (unit: GW). For comparison among national DFIs, we choose coal plants with financing commitments made between 2013-2017.

	Year of financing commitments: 2013-2017					
Financing DFIs	**China (CDB & CHEXIM)**		**Japan (JBIC & JICA)**		**Korea (KDB & KEXIM)**	
Total coal power capacity (GW)	34.0	(100%)	14.7	(100%)	3.8	(100%)
Ultra-supercritical	1.3	(4%)	6.9	(47%)	1.2	(32%)
Supercritical	20.5	(60%)	6.6	(45%)	2.4	(63%)
Subcritical	7.1	(21%)	1.2	(8%)	0.2	(5%)
SO_2 control[a]	19.9	(58%)	8.4	(57%)	2.6	(68%)
SO_2 control excl. CF[b]	11.1	(33%)	4.4	(30%)	2.6	(68%)
NO_x control	10.0	(29%)	1.9	(13%)	1.2	(32%)
PM control	19.6	(58%)	11.0	(75%)	2.4	(63%)

Notes:

[a] We aim to compare DFIs' financing to coal power plants and these coal plants' installation of pollution control devices. However the change in installation rates of SO_2 control devices in coal plants financed by CDB and CHEXIM between two periods (2013-2017 vs. 2005-2014) indicates data inconsistencies. Generally, a higher fraction of coal fired power plants have pollution control devices installed in recent years due to increasingly stringent emission and air quality standards and due to concerns about air pollution and its adverse health impacts in recipient countries. Therefore air pollutant emission control data from WEPP is likely underestimating the installation rates, because according to WEPP data, CDB- and CHEXIM-financed coal plants between 2013-2017 have lower installation rates than coal plants financed between 2005-2014. We note that numbers listed here are likely the lower bound of actual installation rates as lack of data coverage in WEPP may indicate lack of installation of pollution control devices, incomplete reporting of control devices installed, or lack of data access. Therefore it is difficult to draw definitive conclusions. The imperfect data coverage highlights the need for a more transparent and complete reporting system for coal fired power plants.

[b] Compliance fuel (CF) is a SO_2 control strategy that requires that coal burned in the power plants meet certain standards (e.g. sulfur content level of coal). CF is listed as SO_2 control in WEPP when it is the only known control strategy for a coal plant and there is no other physical equipment of end-of-pipe control. We exclude CF in order to examine the installation of end-of-pipe control devices.

Table S6. Summary of steam conditions and pollution control technologies of coal power plants financed by Chinese DFIs vs. by the MDBs (including MDBs collectively, and AsDB and AfDB separately) (unit: GW). For comparison between Chinese DFIs and the MDBs, we choose coal plants with financing commitments made between 2005-2014.

Year of financing commitments: 2005-2014								
Financing DFIs	**China (CDB & CHEXIM)**		**MDBs[a]**		**AsDB**		**AfDB**	
Total coal power capacity (GW)	31.5	(100%)	20.3	(100%)	10.4	(100%)	5.5	(100%)
Ultra-supercritical	0.0	(0%)	1.4	(7%)	0.0	(0%)	0.0	(0%)
Supercritical	13.4	(42%)	12.2	(60%)	6.6	(64%)	4.8	(87%)
Subcritical	17.8	(57%)	6.7	(33%)	3.8	(36%)	0.7	(13%)
SO_2 control	27.5	(87%)	20.0	(99%)	10.4	(100%)	5.5	(100%)
SO_2 control excl. CF	11.1	(35%)	6.0	(30%)	1.9	(18%)	0.6	(11%)
NO_x control	5.7	(18%)	10.2	(50%)	4.0	(39%)	4.8	(87%)
PM control	27.3	(87%)	19.1	(94%)	9.3	(90%)	5.5	(100%)

Notes:
[a] MDBs examined here include the WB, IFC, AsDB, AfDB, EBRD, IsDB, IADB and MIGA. CAF and EIB did not finance any coal plants during 2005-2014.

Table S7. CO_2 emissions from power plants with partial or full financing from Chinese DFIs (CDB and CHEXIM) (unit: Gt CO_2), related to Table 2. Total committed emissions are separated into realized emissions before the end of 2018 and remaining committed emissions afterwards. Emissions are summarized by fuel and by recipient country. The power plants are facilitated by CDB's and CHEXIM's financing commitments between 2000-2018.

	Committed emissions (Gt CO_2)	**Realized emissions**	**Remaining committed emissions**
By fuel type			
Coal	11.81	0.88	10.93
Oil	0.14	0.00	0.14
Gas	0.08	0.01	0.06
By country			
India	3.50	0.47	3.03
Indonesia	3.01	0.21	2.80
Vietnam	1.99	0.12	1.87
South Africa	1.82	0.04	1.78
Rest of world	1.72	0.06	1.65
Total	**12.03**	**0.89**	**11.14**

Table S8. CO_2 emissions from power plants with partial or full financing from Japanese DFIs (JBIC and JICA) (unit: Gt CO_2), related to Table 2. The power plants are facilitated by JBIC and JICA's financing commitments between 2013-2017[a]. Data for JBIC and JICA's financing of gas and oil plants is unavailable, therefore we only include emissions from financed coal plants. Emissions summarized by recipient country.

	Committed emissions (Gt CO_2)	Realized emissions	Remaining committed emissions
By fuel type			
Coal	3.25	0.06	3.19
By country			
Indonesia	1.09	0.00	1.09
India	1.04	0.03	1.00
Vietnam	0.69	0.01	0.68
Morocco	0.32	0.01	0.31
Rest of world	0.12	0.01	0.11

Note:

[a] Power plants that were pending for financing are not included in the table. Coal fired power plants that JBIC or JICA were considering financing as of August 2017 will emit another 1.99 Gt CO_2 after 2018.

Table S9. CO_2 emissions from power plants with partial or full financing from South Korean DFIs (KDB and KEXIM) (unit: Gt CO_2), related to Table 2. The power plants are facilitated by KDB and KEXIM's financing commitments between 2013-2017[a]. Data for KDB and KEXIM's financing of gas and oil plants is unavailable, therefore we only include emissions from financed coal plants. Emissions summarized by recipient country.

	Committed emissions (Gt CO_2)	**Realized emissions**	**Remaining committed emissions**
By fuel type			
Coal	1.20	0.01	1.19
By country			
Vietnam	0.76	0.01	0.76
Kazakhstan	0.38	0.00	0.38
Indonesia	0.06	0.00	0.06

Note:
[a] Power plants that were pending for financing are not included in the table. Coal fired power plants that KDB or KEXIM were considering financing as of August 2017 will emit another 1.47 Gt CO_2 after 2018.

Table S10. CO_2 emissions from power plants with partial or full financing from the MDBs (unit: Gt CO_2), related to Table 2. Emissions are summarized by fuel and by recipient country. The power plants are facilitated by MDBs' financing commitments between 2005-2014. "Coal" plants include plants that use hard coal or lignite as fuel.

	Committed emissions (Gt CO_2)	**Realized emissions**	**Remaining committed emissions**
By fuel type			
Coal	5.00	1.11	3.89
Oil	0.15	0.02	0.12
Gas	3.41	0.54	2.87
By country			
India	2.60	0.65	1.95
South Africa	1.10	0.19	0.91
Egypt	0.77	0.12	0.66
Vietnam	0.45	0.10	0.35
Rest of world	3.63	0.61	3.02
Total	**8.56**	**1.67**	**6.89**

Table S11. Capital costs of power plants across fuel types (unit: US$/kW), related to Figure S3. To illustrate the uncertainty of capital costs of power plants, minimum and maximum estimates from IEA and IRENA reports are presented[a].

Fuel type	**Capital costs used in this study[5,a] (US$/kW)**	**Estimates of average capital costs from alternative sources (US$/kW)**			
		IEA report[9]		IRENA report[10,b]	
		min	max	min	max
Coal	1,500	813	3,067	-	-
Gas	1,000	500	1,289	-	-
Oil	1,000	-	-	-	-
Nuclear	4,756	1,807	6,215	-	-
Hydro	2,186	598	9,400	800	>5,500
Solar	2,500	728	2,563	772	>5,500
Wind	2,354	1,200	2,999	1,120	3,060
Biomass	4,200	587	8,667	500	>10,000

Note:

[a] Average capital costs of power plants used in this study are estimated by Li et al.[5] based on the same IEA report listed here and an older version of the IRENA report listed here.

[b] Maximum estimates of the average capital costs of hydro, solar, and biomass power plants are not directly available from the IRENA report, thus rough ranges are listed instead. They are still indicative of the large range between minimum and maximum estimates of capital costs.

Table S12. Estimated capacity factor and emission intensity. Capacity factor and emission intensity estimated in this study represent the average capacity factor and emission intensity of power plants covered in this study, weighted by nameplate generation capacity.

	Capacity factor		Emission intensity ($kg\ CO_2/MWh$)	
Fuel type	**This study**	**Other studies**	**This study**	**Other studies**
Coal	57%	44% - 61%[11,12]	1,072	889 - 1,668[11,13,14]
Gas	42%	35% - 39%[11,12]	610	453 - 713[11,13,14]
Oil	39%	28%[12]	778	657 - 869[13,14]

Supplemental Experimental Procedures

Committed CO_2 emissions: estimating the capacity factor and emission intensity of DFI financed power plants using CARMA

CARMA contains information of 68,931 power plants worldwide[15]. It estimates these power plants' annual power generation (MWh) and annual CO_2 emission (Mt CO_2) in 2004, in 2009 or for a future year. CARMA includes the power plants' names but not their fuel type or generation capacity. To obtain information about the fuel type and generation capacity of power plants documented in CARMA, we first merged CARMA with WEPP (2012 version). Through this process we also divided the power plants in CARMA into individual power generators (each power plant documented in WEPP can have one or more generators). We used WEPP 2012 version because it has the highest degree of overlap with CARMA (89% of the power plants in CARMA were found in WEPP 2012).

Second, we searched for the power plants financed by East Asian national DFIs in CARMA. If the power plant was found in CARMA and has a non-zero value for annual CO_2 emissions in 2009 or estimated for a future year, we used CARMA's estimation of its annual CO_2 emissions if the power plant's documented nameplate capacity stays the same between WEPP 2012 and WEPP 2019 databases. For power plants whose capacity changed from WEPP 2012 version to WEPP 2019 version we scaled the emissions based on the capacity change. Scaling is necessary because CARMA was developed in 2012 and new generator(s) may have been added to the same plant after that. We did not use CARMA's annual emission data in 2004 because the majority of DFI financed plants commenced or will commence operation after 2004.

Third, if the East Asian national DFI financed power plant was not found in CARMA, we estimated the capacity factor and emission intensity of this plant's individual generators according to the average capacity factor and emission intensity of power generators in CARMA (i) that are located in the same country, (ii) that use the same fuel type (e.g. coal, gas, or oil) and the same fuel (e.g. anthracite coal, bituminous coal, lignite, or sub-bituminous coal; conventional gas, liquefied natural gas, or liquefied petroleum gas), and (iii) whose nameplate capacity is within ± one standard deviation range of the DFI financed generators (standard deviation is calculated based on power generators in CARMA that meet requirements (i) and (ii)). If no eligible power generator was found in CARMA that met these three requirements, we relaxed the second requirement to include power generators that use the same fuel type but not necessarily exactly the same fuel. If there was still no eligible power generator, we further relaxed the third requirement and included power generators of all sizes that are in the same country and use the same fuel type. If still no generator was eligible, we estimated the emissions based on the average capacity factor and emission intensity of power generators burning the same type of fuel around the world. In this step, uncertainty is introduced with the relaxation of screening constraints in order to construct a sample for our estimation.

Fourth, we estimated the capacity factor and emission intensity of MDB financed plants. The MDB database from Steffen and Schmidt[2] documents power generation projects' total capacity and fuel type (coal, lignite, gas, or oil) but not the capacity of each generator or specific fuel used (e.g. different types of gas or oil). To estimate the CO_2 emissions from MDB financed power plants, we therefore applied a similar procedure to the third step described above but largely relaxed the conditions when screening eligible power generators in CARMA. For each MDB financed fossil fuel plant, we estimated its capacity factor and emission intensity based on the average capacity factor and emission intensity of power plants (rather than generators) in CARMA (i) that are in the same country, (ii) that use the same fuel type (with the exception of MDB financed plants that use lignite as fuel, for which we chose plants in CARMA that also use lignite as fuel as our sample), and (iii) with similar nameplate generation capacity (defined as nameplate capacity within ± one standard deviation). Similar to the third step, when no eligible plant was found in CARMA, we relaxed the screening constraints step by step in the analysis.

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