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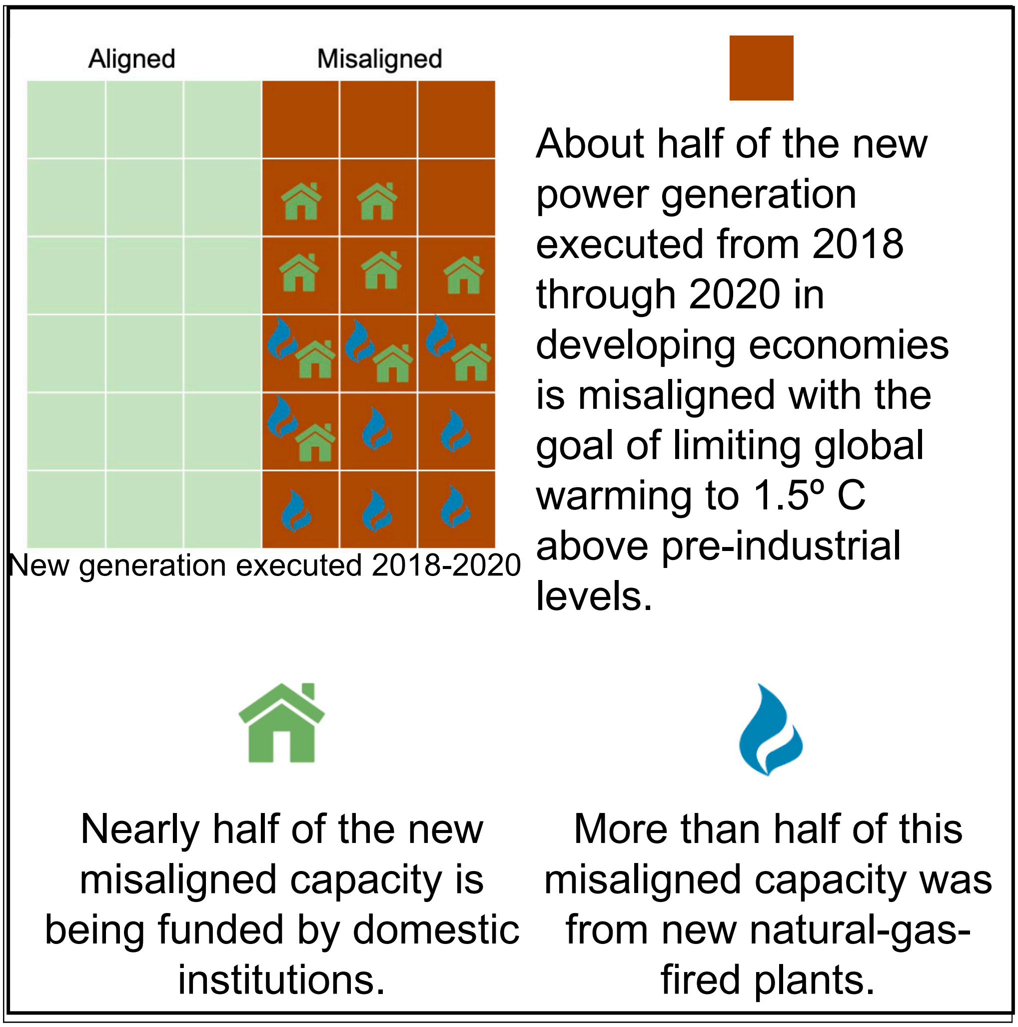

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Highlights

New data yields insights on climate impact of developing-world infrastructure finance

52% of power generation added in developing world from 2018 through 2020 is climate-misaligned

Climate benefits of falling coal financing eclipsed by surging natural-gas financing

Much high-carbon developing-world finance comes from domestic, not foreign, investors

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Hot money: Illuminating the financing of high-carbon infrastructure in the developing world

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SUMMARY

Major infrastructure financiers will have to significantly decarbonize their investments to meet mounting promises to cut carbon emissions to "net-zero" by mid-century. We provide new details about those needed shifts. Using two World Bank databases of infrastructure projects throughout the developing world, and applying a methodology for imputing the projects' likely future carbon output, we assess the emissions profile of power-plant projects executed from 2018 through 2020 — the three years immediately preceding the spate of net-zero pledges. We find that approximately half the generation executed in those years is too carbon-intensive to align with keeping Earth's average temperature from exceeding 1.5°C above pre-industrial levels, largely because of the prevalence of new natural-gas–fired power plants. We also find new evidence of host countries' agency in shaping carbon trajectories: Much of the climate-misaligned financing is not foreign but domestic. And we find different institutions are financing infrastructure portfolios with significantly differing carbon intensities.

INTRODUCTION

The carbon intensity of infrastructure being financed and built in emerging and developing economies will shape the trajectory of global climate change (International Energy Agency, 2021a). In recent months, institutions including national governments and global financiers have pledged to slash their carbon emissions to "net-zero" by the middle of this century. Scientists agree that such actions are necessary to prevent Earth's average global temperature from surpassing 1.5°C above pre-industrial levels (Masson-Delmotte et al., 2018). As the Intergovernmental Panel on Climate Change noted in August 2021 in the first installment of its Sixth Assessment Report, failure to meet this goal would be expected to trigger especially disastrous consequences from global warming (Masson-Delmotte et al., 2021).

Cutting emissions to this extent would require radically decarbonizing infrastructure investment in emerging and developing economies — ensuring that new power plants, transmission lines, roads, and the like were optimized to lock in low-carbon growth patterns for decades to come. The International Energy Agency (IEA) estimates that annual investment in renewable energy infrastructure must more than triple from current levels in order to potentially keep the global temperature rise below 1.5°C (International Energy Agency, 2021b). This presents a compelling opportunity, as more than 75% of the necessary global infrastructure through 2050 is yet to be built, creating an imperative to build the next generation of low-carbon energy infrastructure (United Nations, 2019). Financing for low-carbon energy in emerging and developing economies, though increasing, remains significantly below the levels necessary to materially curb carbon emissions (International Energy Agency, 2021a). This imperative to decarbonize infrastructure projects in emerging and developing economies was at the top of policymakers' agenda when they met in November 2021 in Glasgow for a key international climate conference, the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 26). But COP 26 left the issue largely unresolved.

Given the importance of the carbon impact of infrastructure in emerging and developing economies, an increasingly rich literature is exploring it. Some of that scholarship has analyzed the flow of investment in renewable-energy projects, assessing which financiers invest in which projects and why (Mazzucato and Semieniuk, 2018). Additional work has assessed crucial deficiencies in financing, including risk-mitigation measures that are stymieing clean-energy investment in emerging and developing economies (International Energy Agency, 2021a). But focusing on investment in low-carbon infrastructure, while invaluable, is insufficient. Despite the very real increase in investment in low-carbon infrastructure, and despite the

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need to significantly accelerate that investment, the climate continues to be shaped by the high-carbon infrastructure still being financed and built.

Of the literature that examines this continuing investment in high-carbon infrastructure, much focuses on the role of the financing of power plants that burn coal, the most carbon-intensive fossil fuel. Some studies have analyzed the investment by certain large Chinese banks financing coal-fired power plants in emerging and developing economies (Gallagher, 2017). Others have sought to apportion responsibility for financing coal-fired power plants in emerging and developing economies among the myriad overseas financiers globally (Global Energy Monitor, 2021a). Still others have considered the climate implications of the full range of Chinese overseas foreign direct investment (Liu et al., 2020). More recently, studies have begun to explore the influence that not just foreign financing institutions but also recipient countries have in shaping the carbon intensity of the infrastructure, notably coal-fired power plants, built within their borders (Gallagher et al., 2021) (Hale et al., 2020) (Ball, 2021).

The focus on coal-fired infrastructure reflects its outsized contribution to total greenhouse gas emissions. In 2020, emissions from coal-fired power generation produced 29% of total global CO_2 emissions (International Energy Agency, 2021c). Increasingly, however, that focus on coal is insufficient, given the speed with which large infrastructure financiers are pledging to dial back their overseas coal financing. In September 2021, Chinese President Xi Jinping announced to the United Nations that China would stop financing coal-fired power plants abroad, a significant shift from China's practice under the Belt and Road Initiative, the country's massive international infrastructure financing program (UN News, 2021). China's announcement followed similar declarations by Japan and South Korea — like China, both major cross-border coal-plant financiers — and by the Group of Seven leading economies (Sheldrick and Obayashi, 2021) (Moon, 2021) (G7, 2021).

Stopping all international coal financing would be a monumental achievement — and yet it would not achieve global climate goals. A more comprehensive assessment of the carbon intensity of infrastructure finance has been needed — one that looks beyond coal and beyond projects financed with foreign money.

In scoping this study, we examined publicly available databases and studies from Boston University, Johns Hopkins University, the Inter-American Dialogue, Agence Française de Développement, Tsinghua University, and the American Enterprise Institute. We also examined private databases from Refinitiv Eikon and Sichuan University. Each of these databases, by design, focuses on a specific slice of international infrastructure finance rather than on the whole universe of it. (See STAR Methods section for further details about each database's focus.)

We concluded that substantial gaps in knowledge remained — gaps that could begin to be addressed by constructing an analytical framework based on two datasets from the World Bank's Infrastructure Finance, PPPs, and Guarantees (IPG) Group: the Public Participation in Infrastructure (PPI) dataset, which has long been publicly available, and State Participation in Infrastructure (SPI) dataset, which the World Bank expects to release before the end of 2021. Our analytical framework assesses the likely future carbon emissions from projects in these two datasets. As an initial matter, we analyze power generation, but the datasets and the analytical method could in the future be used to assess the climate implications of investment in other infrastructure types. We believe the analysis we have built using these two datasets advances the understanding of the climate impact of infrastructure financed in emerging and developing economies in four ways.

First, we provide a timely snapshot of the enormity of the challenge faced by the entities now promising net-zero emissions by mid-century. Our analysis provides new quantitative evidence that crimping coal-plant financing will not be enough to solve climate change. Indeed, natural-gas–fired plants represent the biggest source of new electricity capacity and generation in our dataset; we estimate that they will emit 80% as much carbon annually as will new coal-fired plants. (Estimates are subject to variability based on emission and capacity factor estimates. See STAR Methods section for further details). Although coal-fired power has been the focus of most scholarship assessing the climate impact of infrastructure, our data underscores that, as the percentage of coal-fired generation declines, climate progress also will require mitigating or significantly minimizing gas-fired generation.

Second, we examine not just the portion of infrastructure in emerging and developing economies that is financed by foreign players, which has been the focus of much recent analysis, but also the portion financed by players based in recipient countries. Several large and economically advanced developing countries continue to build high-carbon infrastructure within their borders despite their recent pledges to decarbonize their cross-border infrastructure spending. Many poorer emerging and developing economies also continue to invest their own funds in high-carbon infrastructure at home. In quantifying these trends, we offer new evidence of the agency that certain emerging and developing economies are exerting — and, with strategic global action, could increasingly exert — in shaping the carbon intensity of infrastructure built within their borders, a finding with significant implications for policymaking.

Third, our analysis deconstructs how financiers structure their investments in climate-relevant infrastructure in emerging and developing economies. It elucidates how co-financiers in a given project work together to allocate among themselves different and carefully planned levels of risk. It reveals that the financiers that have bankrolled the most climate-misaligned infrastructure have been repeatedly supported in their investments by certain key institutions. Understanding these nuances in the workings of infrastructure finance is important in redirecting investment to lower-carbon projects.

Fourth and finally, our inquiry nevertheless suffers from data gaps. That points up an urgent need for global infrastructure actors to disclose significantly more climate-related financial information if the world is to be able to credibly monitor progress toward lofty-sounding climate promises.

We analyze three years: 2018 through 2020. Those three years were dictated by the World Bank data, but given that these three years immediately preceded the spate of new net-zero pledges, they illuminate the extent and the nature of the shift that global financiers would have to achieve to realize their net-zero pledges. Indeed, our analysis suggests that players now pledging to achieve net-zero emissions by mid-century may find the high-carbon infrastructure projects they financed from 2018 through 2020 ending up as stranded assets.

Taken as a whole, our findings offer context that helps address a looming question: Given that the price of building new renewable-energy plants such as solar and wind farms to generate effectively zero-carbon electricity has plummeted in recent years, why are some of the emerging and developing economies in which energy consumption is growing fastest continuing to build fossil-fueled infrastructure? Cost, typically expressed as the levelized cost of energy (LCOE), often is not the only determinant of decisions about what sort of new power-generation infrastructure to build. (LCOE is a measure of the average net-present cost of electricity generation for a generating plant over its lifetime.) Crucial too is a country's political economy, which is to say the interests of its potent constituencies. Quite often, those constituencies perceive their interests as still aligned with fossil fuel (International Energy Agency, 2021a).

RESULTS AND DISCUSSION

Overview

The World Bank datasets we analyze include infrastructure projects that the World Bank defines as having been "executed" in a given year. In the case of most projects, the World Bank defines the date of execution as the date the project reached "financial close" – in essence, the stage at which financing necessary to realize the project came together. Further detail on the calculation of financial closure has been included in STAR Methods.

Using this data, we reach several conclusions about the climate implications of the investment flowing into electricity-generation projects in emerging and developing economies.

Of the new power generation financed in emerging and developing economies in 2018, 2019, and 2020 whose participants disclosed sufficient data for us to analyze it, approximately half, or 52 percent, is inconsistent, or "misaligned," with climate goals, as Figure 1A shows. We define "misalignment" as inconsistency with the goal of keeping average global temperatures from exceeding 1.5°C above pre-industrial levels, the threshold scientists have identified as crucial. Based not on projected generation but on capacity, the misaligned portion is 42%; based on investment, it is 40%. These percentages, moreover, almost certainly underestimate the extent of misalignment. Many institutions that are, according to other studies, among the world's largest financiers of high-carbon energy infrastructure did not disclose sufficient data about projects they financed for us to include their participation in those projects in our analysis. Likely underestimated in our database because of inadequate data disclosure from entities financing projects are, notably, entities in China and in South Korea, two countries that other studies have identified as the world's top financiers of coal-fired power plants in the developing world (Global Energy Monitor, 2021b).

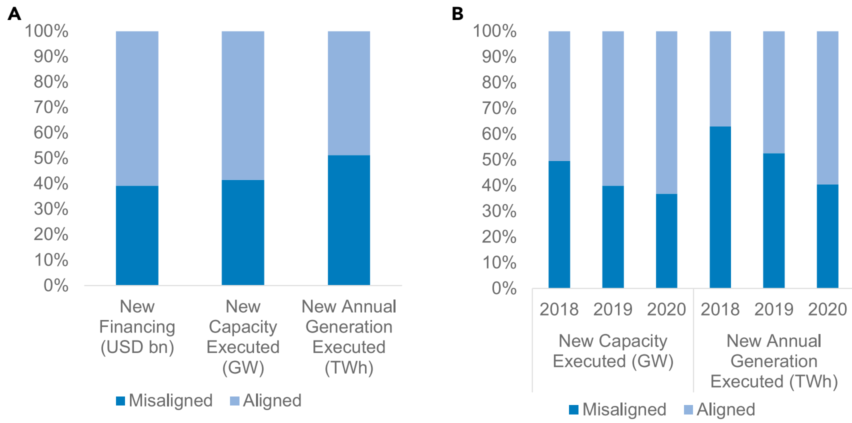

Figure 1. Climate alignment of power-generating infrastructure in emerging and developing economies, 2018–2020 and annually

(A) Cumulative proportion of financing, capacity, and generation in emerging and developing economies that was executed from 2018 through 2020 that is either aligned or misaligned with a 33% chance of limiting global warming below 1.5°C above pre-industrial levels. Almost as much misaligned generation is being financed as aligned generation.

(B) Proportion of financing, capacity, and generation in emerging and developing economies that was executed from 2018 through 2020 and that is either aligned or misaligned with a 33% chance of limiting global warming below 1.5°C above pre-industrial levels. Misaligned capacity and generation additions were at their highest in 2018 and have since declined.

We assess hundreds of financiers of power generation infrastructure in emerging and developing economies by the carbon intensity of their investment portfolios, as measured by generation, capacity, and investment. We find powerful quantitative evidence of host-country agency in determining the carbon intensity of the infrastructure that is built: Nearly as much financing for climate-misaligned infrastructure in emerging and developing economies is coming from institutions within those countries as outside them. We find important differences among financiers. Entities in certain countries, notably Japan, China, and South Korea, finance significantly carbon-intensive infrastructure portfolios in emerging and developing economies. We also find revealing patterns of behavior by important groups of financiers: several large multilateral financiers, including the Asian Development Bank (ADB) and the Japan Bank for International Cooperation (JBIC), commonly act as keystone financiers for consortia that also bring in smaller banks to invest together in high-carbon infrastructure deals. Those keystone financiers thus exert outsized influence not just through the *number* of dollars they invest but also through the *type* of dollars they provide as lead investors.

Our analysis illuminates the pressing global need for better data on the climate implications of infrastructure finance. Even our data is incomplete, a result of insufficient transparency by both providers and recipients of power generation project financing. Because many institutions actively financing infrastructure in emerging and developing economies fail to report key data on certain of their projects, we have excluded those transactions from our quantitative analysis, which has the effect of shielding these financiers from scrutiny of at least some of their contributions to planet-warming development. This data gap points up a problem that is significant but also, with political will, solvable.

Broad trends in carbon intensity of infrastructure

Approximately half, or 52 percent, of estimated power generation from infrastructure that was executed in 2018, 2019, or 2020 was misaligned with global climate goals. The percentage of misalignment was somewhat lower when measured not by generation but by generating capacity (42%) and by investment (40%). The percentage of misalignment is somewhat higher when measured by generation because coal- and gas-fired plants typically operate more regularly than renewable energy plants do.

On one hand, this result offers reason for hope, both because approximately half of the infrastructure was climate-aligned and because the percentage of alignment of both capacity and generation improved, albeit marginally, during the three years in our analysis. Figure 1B illustrates the changes.

Table 1. Capacity additions executed in emerging economies, by fuel type, estimated generation, and projected emissions, 2018–2020

	New capacity		Estimated annual generation		Estimated annual emissions	
	GW	% of Total	TWh/year	% of Total	MT CO_2 per year	% of Total
Fossil fuel generation						
Natural gas	23.0	26.5	104.5	34.5	49.1	44.0
Coal	15.6	18.0	61.3	20.2	61.6	55.3
Oil	0.5	0.5	1.5	0.5	0.7	0.7
Non- fossil fuel generation						
Solar PV	21.7	25.0	51.1	16.9	–	–
Wind	11.2	12.9	21.4	7.1	–	–
Large hydro	10.7	12.3	43.2	14.2	–	–
Nuclear	2.4	2.8	9.5	3.1	–	–
Geothermal	1.4	1.6	9.3	3.1	–	–
Small hydro	0.3	0.3	1.2	0.4	–	–
Total	86.6	100.0	303.1	100.0	111.5	100.0

Large Hydro reflects projects >50 MW.

On the other hand, the misalignment of approximately half the infrastructure in our analysis shows how far off-track global efforts are in reckoning with climate change. Given that the misalignment was not spread evenly among financing institutions or among recipient countries — it was high among certain financiers and in certain places, as explained below — our analysis highlights the significant challenge of transforming the political economies in certain fast-growing nations to shift investment from high-carbon to low-carbon activities more than they have thus far.

In addition, the means by which the infrastructure in our dataset increased marginally in climate alignment from 2018 through 2020 raises its own long-term concern. The increasing alignment reflects a reduction in coal-fired generation and an increase in both natural-gas-fired and renewable generation. But, as shown in Table 1, gas-fired plants represent the biggest source of newly executed capacity and generation in our dataset. Newly executed gas-fired plants are so dominant that they are estimated to emit 80% as much carbon annually as newly executed coal-fired plants.

This surfaces a crucial finding: Although coal-fired power has been the focus of most scholarship assessing the climate impact of infrastructure, our data emphasizes that as market and regulatory pressures drive down the percentage of coal-fired generation, assessing progress toward climate-aligned infrastructure increasingly will require mitigating or minimizing new gas-fired generation. Rising numbers of emerging and developing economies are pledging to shift to cleaner fuels and, in the process, backing away from certain planned coal-fired plants they previously had welcomed (Wang, 2021). Studies indicate that gas-fired plants, under the best circumstances, typically emit approximately half as much carbon dioxide (CO_2) as do coal-fired ones for each unit of electricity they produce (U.S. Energy Information Administration, 2021). But that figure excludes the potentially significant carbon emissions from flaring and from leaks of methane in the natural gas system, realities that in some circumstances could render electricity produced from gas as carbon-intensive as that produced from coal (Brandt et al., 2014). Ultimately, gas-fired plants will likely be inconsistent with the mission of achieving net-zero emissions by 2050 absent substantial advancements in carbon-capture technology.

The three years in our dataset encompassed the onset of the COVID-19 pandemic. How the pandemic might have affected the data is unclear. Almost certainly, the pandemic-induced global economic slowdown reduced the number of emerging-economy infrastructure projects that otherwise would have been executed during the three years. But there is no way of knowing whether the pandemic had any effect on the carbon intensity of the mix of projects that remained.

Table 2. Financing, by financier type, of executed emerging-economy generation, 2018–2020

	Capacity executed (GW)			Annual generation executed (TWh)		
Financier type	Aligned	Misaligned	Total	Aligned	Misaligned	Total
State-owned non-bank company	9.9	10.6	20.4	37.2	48.4	85.6
Non-state-owned corporation	8.2	3.3	11.5	19.2	13.3	32.5
Commercial bank	8.9	9.1	18.1	23.5	34.1	57.6
Multilateral development bank	5.9	3.3	9.2	17.9	17.2	35.1
Bilateral DFI	3.6	3.8	7.4	10.6	14.2	24.8
Financial investor	3.4	0.6	4.0	7.4	2.6	10.0
State-owned bank	3.4	4.9	8.3	6.4	22.1	28.5
Sovereign	2.6	0.3	2.9	11.7	2.4	14.2
Regional Development Bank	1.4	0.4	1.8	4.2	2.2	6.5
Undisclosed and excluded	2.8	0.3	3.1	7.5	1.0	8.5
Total	50.1	36.5	86.6	145.5	157.5	303.1
% Of total	57.9%	42.1%	100.0%	48.0%	52.0%	100.0%

The sources of misaligned money

Much of the existing scholarship about the climate impact of emerging and developing economies infrastructure investment has focused on overseas investment, notably by banks (Gallagher, 2017). Though such overseas bank financing is significant, our data shows that nearly half — 44% — of financing for high-carbon infrastructure in emerging and developing economies originates elsewhere: with entities based not outside a given emerging or developing country but within it — and not with banks but with state-owned non-bank companies such as utilities. We also identify significant differences in the carbon intensities of the projects financed by institutions of differing types, as Table 2 details, and of differing home countries. These findings suggest potential new nuances in strategy for policymakers seeking to decarbonize infrastructure investment with maximal economic efficiency.

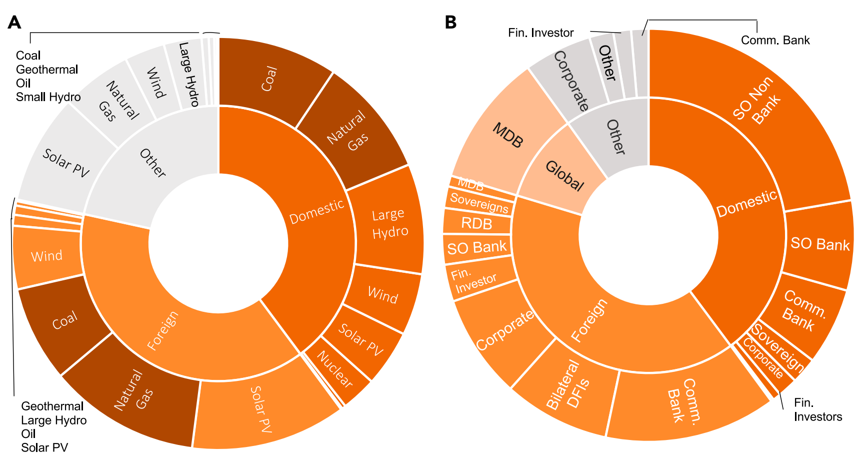

Figure 2. Generating capacity in emerging and developing economies by fuel type and by financier type, 2018–2020

(A) Quantity of capacity additions in emerging and developing economies that was executed from 2018 through 2020 by fuel type and by financier type (domestic and foreign). "Other" includes financing from multilateral development banks and regional development-finance institutions, as well as transactions for which scope could not be determined.

(B) Quantity of capacity additions in emerging and developing economies that was executed from 2018 through 2020 by type of financier with details on the type of financial institution. "Other" includes transactions for which scope could not be determined.

Note on acronyms: SO = state-owned; Comm. Bank = commercial banks; Fin. Investor = financial investor; DFI = development-finance institution; RDB = regional development bank; MDB = multilateral development bank.

Table 3. Financing, by domestic-foreign split and financier type, of executed emerging-economy generation, 2018-2020

	Capacity executed (GW)			Annual generation executed (TWh)		
Financier type	Aligned	Misaligned	Total	Aligned	Misaligned	Total
Domestic financing						
State-owned non-bank company	9.8	9.8	19.6	36.8	46.0	82.7
Commercial bank	4.0	2.2	6.1	8.3	6.2	14.5
State-owned bank	2.5	3.6	6.1	4.0	19.9	23.8
Non-state-owned corporation	2.0	0.8	2.8	4.5	3.5	8.1
Sovereign	1.4	0.3	1.7	5.5	2.4	7.9
Financial investor	0.7	0.3	1.0	1.3	1.1	2.4
Bilateral DFI	0.2	–	0.2	0.2	–	0.2
Regional development bank	0.0	–	0.0	0.0	–	0.0
Multilateral development bank	–	–	–	–	–	–
Total	20.5	17.0	37.6	60.7	79.1	139.8
Foreign financing						
Commercial bank	5.0	6.9	11.9	15.2	27.9	43.1
Multilateral development bank	5.9	3.3	9.2	17.9	17.2	35.1
Non-state-owned corporation	6.2	2.5	8.7	14.7	9.7	24.4
Bilateral DFI	3.4	3.8	7.2	10.3	14.2	24.5
Financial investor	2.7	0.3	3.0	6.1	1.5	7.5
Regional development bank	1.4	0.4	1.8	4.2	2.2	6.4
State-owned bank	0.8	1.3	2.2	2.4	2.3	4.6
Sovereign	1.2	–	1.2	6.2	–	6.2
State-owned non-bank company	0.1	0.7	0.8	0.4	2.4	2.8
Total	26.8	19.2	46.0	77.4	77.4	154.8
Undisclosed	2.8	0.3	3.1	7.5	1.0	8.5
Total	50.1	36.5	86.6	145.5	157.5	303.1

The importance of domestic money

Across the three years of our dataset for projects for which we were able to identify the base country of a financier, approximately 44% of generating capacity was financed not by foreign financiers but by domestic ones. As Figure 2A shows, domestic financiers supported as much new coal and natural gas capacity as foreign financiers did. This finding drives home the importance of leveraging the agency of host countries in shifting infrastructure development to a lower-carbon path.

The importance of non-bank money

The financiers responsible for the greatest proportion of misaligned capacity in our 2018–2020 analysis were not banks but state-owned non-bank companies, most of them utilities. They provided the bulk of their financing to projects within their home countries. Figure 2B and Table 3 offer two views on the roles of different sorts of institutions in financing power-generation infrastructure in emerging and developing economies. Expressed one-way, state-owned non-bank companies operating domestically financed 29% of all the misaligned generation in our analysis. Expressed another way, approximately 57% of the developing-world generation these institutions financed was misaligned.

Misaligned money from multilateral development banks

According to our data, commercial banks, multilateral development banks (MDBs), and corporate players each financed smaller percentages than did state-owned non-bank players of the developing world's climate-misaligned infrastructure from 2018 through 2020. Taken together, these three types of players

Table 4. Capacity additions executed in emerging economies and financed by multilateral development banks, 2018–2020

	Capacity executed (MW)			
	2018	2019	2020	Total
Aligned				
World Bank Group (IDA)	381	210	718	1,313
World Bank Group (IFC)	270	608	267	1,145
Asian Development Bank	331	223	490	1,044
World Bank Group (IBRD)	22	113	550	684
European Bank for Reconstruction and Development	129	350	160	639
African Development Bank	63	9	375	383
Green Climate Fund	–	25	137	162
Asian Infrastructure Investment Bank	–	48	114	161
World Bank Group (CIF)	28	40	32	116
Black Sea Trade and Development Bank	16	40	–	56
LEAP	7	16	13	36
Total aligned capacity	1,246	1,680	2,856	5,739
Misaligned				
World Bank Group (IFC)	168	488	747	1,402
Asian Development Bank	556	200	121	877
European Bank for Reconstruction and Development	732	–	–	732
LEAP	119	91	–	210
Asian Infrastructure Investment Bank	49	–	–	49
Total misaligned capacity	1,624	778	868	3,271
Total capacity funded	2,871	2,475	3,665	9,010
% Aligned	43.4%	67.9%	77.9%	63.7%
% Misaligned	56.6%	31.4%	23.7%	36.3%

The four World Bank Group entities referred to in this table are as follows: IDA = International Development Association; IFC = International Finance Corporation; IBRD = International Bank for Reconstruction and Development; CIF = Climate Investment Funds.

financed more of the developing world's misaligned generating capacity — approximately 43% of it — than state-owned non-bank institutions did on their own, as shown in Table 3. World Bank entities financed the largest amounts of both aligned and misaligned infrastructure in our database; the ADB financed the second-largest amounts of both, as shown in Table 4.

Unlike the dominant state-owned non-bank players, which focused their financing domestically, commercial banks, MDBs, and corporate players concentrated their financing on overseas projects. Figures 3A and 3B show, for domestic investment and foreign investment, respectively, the relative distribution of the quantity and the carbon intensity of generation financed by various types of players in our database. State-owned non-bank players tended to finance higher-carbon infrastructure regardless of its location. MDBs, as a group, tended to finance lower-carbon infrastructure, though there were important exceptions to this, notably in some MDBs' continued financing of coal-fired power plants and in MDBs' increasing financing of gas-fired power plants. What is clear is that decarbonizing infrastructure investment by overseas financiers remains a high priority.

The geography of misaligned financiers

The largest financiers of misaligned generating capacity in the developing world, according to our data, are entities in Japan, China, and India. Broadly, this is consistent with prior scholarship that has identified China and Japan as among the top financiers of coal-fired power plants in emerging and developing economies. But our data reveals additional detail.

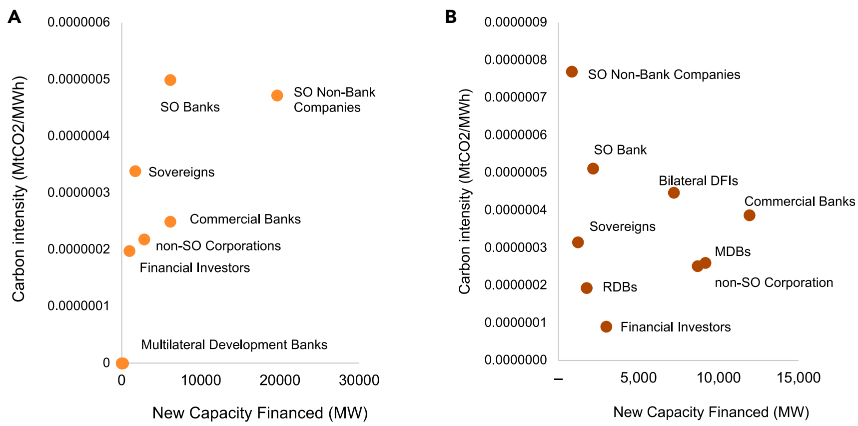

Figure 3. Domestic and foreign investment in generating capacity in emerging and developing economies by financier type, 2018–2020

(A) Cumulative carbon intensity of institutions' financing of domestic generating capacity in emerging and developing economies that was executed from 2018 through 2020. Overall, state-owned non-bank companies (e.g., utilities) are domestically financing the most carbon-intensive generation. Note on acronyms: SO = state-owned.

(B) Cumulative carbon intensity of institutions' financing of foreign generating capacity in emerging and developing economies that was executed from 2018 through 2020. Overall, commercial banks, multilateral development banks, and non-state-owned corporations are financing the most carbon-intensive generation abroad. Note on acronyms: SO = state-owned; DFIs = development finance institutions; RDBs = regional development banks; MDBs = multilateral development banks.

First, according to our data, as shown in Figure 4 and in Table 5, an outsized portion of China's and India's financing of infrastructure in emerging and developing economies is directed at domestic projects. The finding in the data that China finances less misaligned power-generating capacity than does Japan is likely influenced by insufficient disclosure of foreign investment by certain Chinese financiers. Nevertheless, Japan's

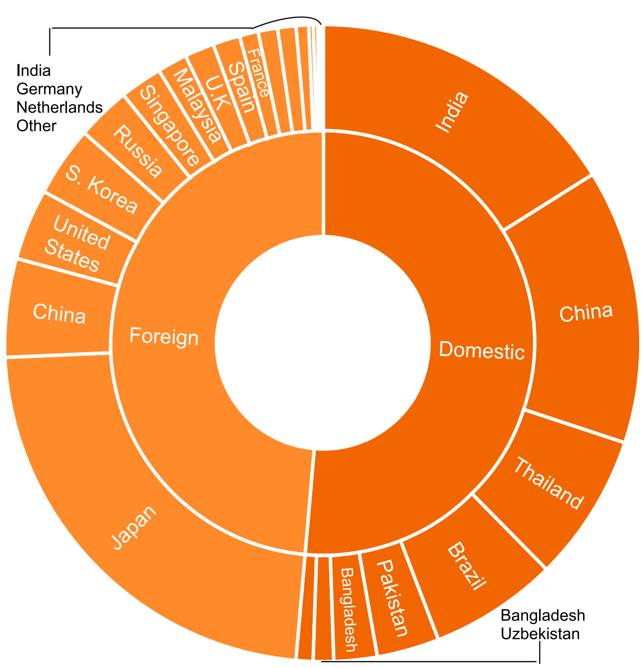

Figure 4. Misaligned generating capacity additions in emerging and developing economies by financier country, 2018–2020

Domestic and foreign actors that financed misaligned capacity in emerging and developing economies executed from 2018 through 2020. Domestically, India and China are financing the most misaligned capacity. Japanese actors operating abroad are financing the most misaligned new capacity.

key role in financing high-carbon infrastructure abroad is, as noted above, consistent with the findings of prior research.

Among domestic financiers, entities based in China and India financed the most misaligned infrastructure. Together, they were responsible for 50% of all domestically financed misaligned power-generation capacity. China, despite its recent pledge to stop financing coal-fired power plants abroad, continued through 2020 to finance infrastructure projects at home that were misaligned with global climate goals.

Among non-MDB overseas financiers, entities based in Japan and China collectively financed more than half of misaligned generating capacity in our database. Collectively, they financed more than half of all foreign-financed misaligned capacity. Entities based in each of those countries collectively provided many times more financing for misaligned infrastructure overseas than they did for aligned infrastructure overseas. Japanese institutions, in particular, financed almost 20% of all new coal capacity in our dataset.

Figures 5A and 5B show the quantity and the carbon intensity of investments by entities based in various countries, for domestic and foreign investment, respectively. The two countries whose entities are financing the highest-carbon portfolios are Bangladesh domestically and South Korea in terms of overseas investment; both are countries with robust coal interests. Still, certain MDBs, as discussed above, remain significant financiers of high-carbon infrastructure in emerging and developing economies.

How financiers work together to finance misaligned infrastructure

The *number* of dollars it invests is only one determinant of a financial institution's responsibility for an infrastructure project. Because infrastructure financiers commonly work in consortia, the *type* of dollars that each invests also is relevant to the question of influence. The so-called "stack" of capital for an infrastructure project offers different slots for investor participation, each with its own level of risk and influence. Certain slots — in particular the anchor-debt and -equity ones — often are more catalytic than others in spurring other parties to contribute money toward a project, whether that project is high-carbon or low-carbon.

Table 5. Top foreign financiers of misaligned generating capacity executed in emerging economies, 2018–2020

	New capacity financed (MW)				
Institution	Base country	Aligned	Misaligned	Total	% Misaligned
Japan Bank for International Cooperation	Japan	52	2,748	2,800	98.2%
Japan International Cooperation Agency	Japan	21	989	1,011	97.9%
Mizuho Financial Group	Japan	78	628	706	89.0%
Sumitomo Mitsui Banking Corporation	Japan	556	582	1,138	51.1%
Korea Electric Power Company	South Korea	32	519	551	94.1%
Sumitomo Mitsubishi Trust bank	Japan	–	451	451	100.0%
China Development Bank	China	–	414	414	100.0%
CIMB Group	Malaysia	–	403	403	100.0%
MUFG Bank	Japan	1,070	395	1,465	27.0%
Industrial and Commercial Bank of China	China	69	385	455	84.7%
Marubeni Corporation	Japan	8	382	390	97.8
Sumitomo Corporation	Japan	–	334	334	100.0
Shanghai Electric	China	–	330	330	100.0
Export-Import Bank of Korea	South Korea	35	325	360	90.2
OCBC Bank	Singapore	–	274	274	100.0
DBS Bank	Singapore	66	258	324	79.6
Export-Import Bank of China	China	149	248	396	62.5
Bank of China	China	10	188	197	95.2
Bangkok bank	Thailand	50	131	181	72.5
Hana Bank	South Korea	–	131	131	100.0
Korea Development Bank	South Korea	10	131	142	92.7

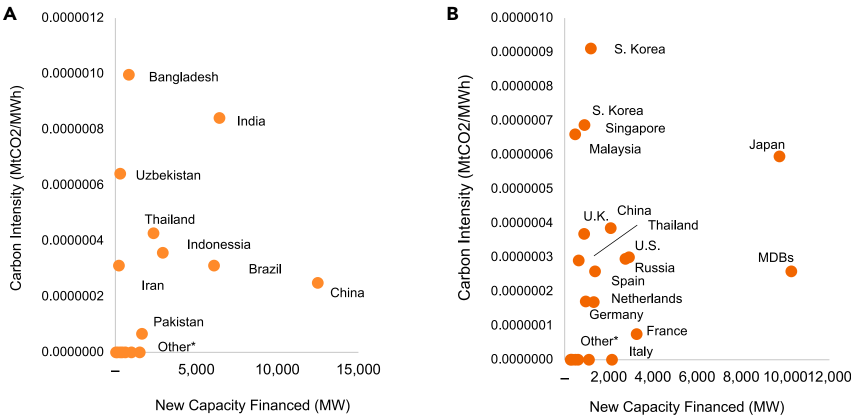

Figure 5. Domestic and foreign investment in generating capacity in emerging and developing economies by financier country, 2018–2020

(A) Carbon intensity of the quantity of generation additions in emerging and developing economies that was executed from 2018 through 2020 and that was financed by domestic actors. China and India were financing the most carbon-intensive generating capacity. In Bangladesh, India, Indonesia, Thailand, Uzbekistan, and Vietnam, the generation being financed from 2018 through 2020 was so high-carbon that it has a less-than-33% chance of remaining in alignment with the 1.5°C goal.

(B) Carbon intensity of the quantity of new generation in emerging and developing economies that was executed from 2018 through 2020 and that was financed by foreign actors. Japan financed the most carbon-intensive generation capacity. South Korea, although a relatively smaller player in terms of volume of capacity financed, also financed overwhelmingly carbon-intensive infrastructure abroad. Notably, multilateral development banks play a crucial role in financing infrastructure in emerging and developing economies, and though their portfolios perform better in terms of carbon intensity than other players' do, they need to do far more to reduce the carbon intensity of their financing.

Key to the development of an infrastructure project is the allocation of risk among investors. Without an investment by certain anchor investors that sends a signal to the market, other project lenders usually will not invest in a project. Typically, one large entity in a project consortium invests what amounts to the anchor investment. Only after that anchor investment do others commit smaller investments. Anchor investors, therefore, are influential well beyond the number of dollars they invest.

Our data reveals that the financiers that bankrolled the most misaligned infrastructure were repeatedly supported in those investments by certain other key institutions. Importantly, our data shows that this reliance on consortia to spread risk occurs not just for the most-expensive infrastructure projects but for less-expensive ones too. As Figure 6 shows, even financiers that, on average, invest in relatively small projects tend to do so with large numbers of co-investors — a finding that points to the importance of addressing the consortium, not just an individual member of it, in seeking to decarbonize infrastructure investment.

In particular, the catalytic role of the JBIC, the ADB, and the Export-Import Bank of Korea (KEXIM) in financing high-carbon projects in the developing world is noteworthy and illustrative of how these consortia work. These institutions provided anchor investments that attracted consistent consortia of other investors in deals for several large, misaligned coal and natural-gas projects in Southeast Asia, notably in Thailand, Vietnam, and Indonesia.

For example, in the financing of two large natural-gas–fired plants in Thailand developed by Gulf Energy, a Thai utility, and Mitsui Corp., a Japanese company, the JBIC and the ADB provided substantial debt financing and, more importantly, arranged the syndication of project debt to more than a dozen international and regional commercial banks and arranged financing insurance.

The JBIC and the KEXIM played similar roles in the financing of two 1.2-gigawatt coal-fired power plants in Vietnam that Japanese and Korean contractors were developing. The JBIC and the KEXIM also arranged insurance and co-financing for these projects with many of the same international commercial banks. Several Japanese commercial banks — Mizuho, Mitsubishi UFJ Financial, Sumitomo Mitsui Banking Corp. (SMBC), and Sumitomo Mitsui Trust Bank (SMTB), among others — only rarely provided money to

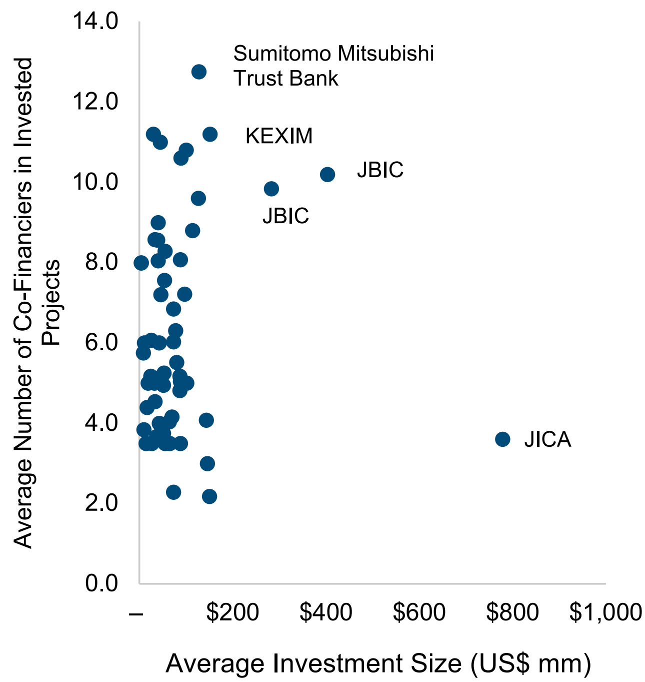

Figure 6. Comparison of average investment size with average number of participants in financed projects
Contextualization across two dimensions of financiers of power plants in emerging and developing economies that was executed from 2018 through 2020: First, the average number of co-financiers with which they participate in a deal; and, second, the amount of money invested in a project. The institutions named in the figure are those that are, in one of those respects, outliers. We find that large numbers of co-financiers exist even in projects in which the total investment is comparatively small. This finding supports the observation that project financiers tend to operate in consortia with one another to distribute risk. Labels in the figure refer to the institution in a particular project that acted as the lead financier.

projects in which JBIC was not the anchor investor. Furthermore, among anchor investors, according to our data, the JBIC both wrote the largest average investment and appears to have had influence over one of the widest universe of potential co-investors.

Differences among recipient countries

Our data points to two overarching conclusions about the role of emerging and developing economies in decisions about the carbon intensity of infrastructure built within their borders.

The first, as shown in Figures 7A and 7B, is distressing: Some of the highest-carbon infrastructure is being built in countries with the fastest-growing energy systems (International Energy Agency, 2021b). In other words, many of the countries whose carbon emission trajectories will be most crucial to the world's climate challenge have been allowing the development of infrastructure whose carbon intensity is inconsistent with that goal (Jun and Zadek, 2019).

Our analysis reveals that in eight emerging and developing economies, the power plants executed from 2018 through 2020 were so high-carbon that they have a less-than-33% chance of remaining in alignment with the 1.5°C goal. Of those eight countries, six — Bangladesh, India, Indonesia, Thailand, Uzbekistan, and Vietnam — were among the 15 emerging and developing economies with the greatest quantity of power generation executed in those three years (International Energy Agency, 2021b).

A second conclusion from our analysis is more hopeful: Emerging and developing economies have more agency than is widely recognized in determining whether their new infrastructure will be low- or high-carbon. Evidence of the influence that host countries have in shaping the infrastructure built within their borders comes from deconstructing infrastructure-finance flows in our database along two dimensions: The homogeneity of infrastructure types within recipient countries that house large portfolios of internationally

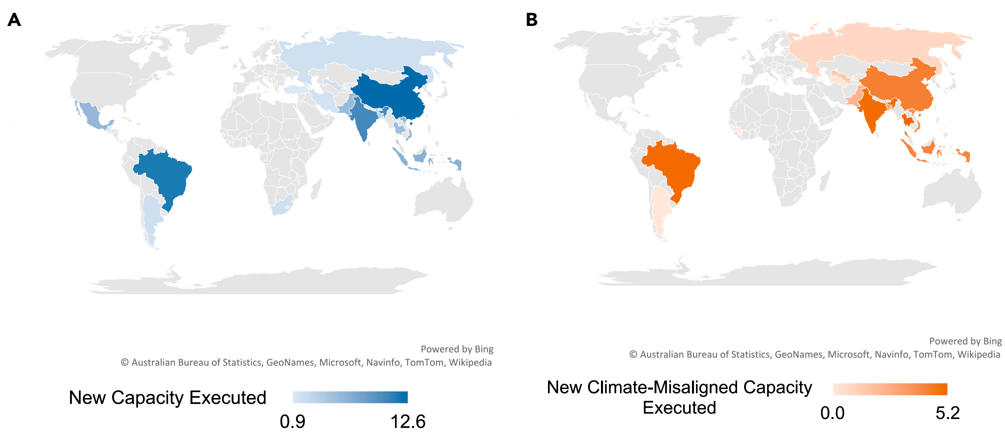

Figure 7. Geographic concentrations of newly executed capacity, total and misaligned, 2018–2020

(A) Geographic spread of generating capacity in emerging and developing economies executed from 2018 through 2020. Most new capacity additions were concentrated in China, India, and Brazil.

(B) Geographic spread of climate-misaligned generating capacity in emerging and developing economies executed from 2018 through 2020. Most new misaligned capacity additions were concentrated in China, India, and Brazil, which supports the finding that the countries where most misaligned generation is being financed are also the countries where most generation additions are taking place. This places additional emphasis on the need to decarbonize the generating portfolios in these countries if the world is to meet its climate goals.

financed infrastructure projects, and the heterogeneity of infrastructure types in the portfolios of individual institutions that finance large portfolios of infrastructure in emerging and developing economies.

Logic would suggest that if financing institutions were dictating the carbon intensity of the infrastructure projects they built abroad, a given institution would finance projects of similar carbon intensities across multiple countries, and a given recipient country would accept a portfolio with projects of widely varying carbon intensity. In fact, our data indicates, the opposite is happening.

A given financing institution, our data shows, tends to invest in a project portfolio that is, in a carbon-intensity sense, varied. Take as examples three of the infrastructure financiers with the largest power-generation portfolios in our database as measured by capacity. The JBIC's portfolio included a coal-fired power plant in Vietnam, a gas-fired power plant in Thailand, and a wind project in Morocco. SMBC invested in a portfolio that included the same three-country mix as well as solar projects in India and Mexico. The Industrial and Commercial Bank of China had a similarly varied portfolio of high- and low-carbon assets, including a coal-fired plant in Pakistan, a gas-fired plant in Thailand, and a wind farm in Turkey.

By contrast, the project portfolio of a typical emerging or developing economy that is hosting a significant number of foreign-financed projects tends, in its carbon profile, to be notably uniform. Pakistan and Vietnam hosted mostly coal-fired power plants. Thailand attracted primarily gas-fired plants. Mexico hosted, in the main, solar farms.

Most of the emerging or developing economy with the most new infrastructure activity — measured as quantity of, capacity for, or investment in electricity generation — also are the countries in which the greatest percentage of that infrastructure activity is misaligned with global carbon-reduction goals. In other words, the countries the world most needs to cement the trajectory of low-carbon infrastructure — the countries that are adding the most infrastructure — are precisely the ones in which the mix of new infrastructure is the most carbon-intensive.

The need for data disclosure

Among the most-concerning findings of our analysis is the extent to which major global actors in the financing of infrastructure in emerging and developing economies are failing to disclose sufficient data about their financing activities to allow regulators, investors, and other parties with stakes in the outcome to ascribe responsibility for high-carbon investment flows. Earlier analysis has pointed to this lack of comparably reported data (International Energy Agency, 2021a). Our research provides new granularity about the extent of the problem.

In particular, crucial information about the terms, financing structures, and risk-underwriting processes behind many large infrastructure projects often is undisclosed. Many public databases attribute responsibility to various financing institutions for the money those institutions spend on projects (Boston University, 2021) (Global Energy Monitor, 2021a) (Agence Française Développement, 2021) (Johns Hopkins University, 2021) (American Enterprise Institute, 2021). But none, including ours, has so far been able to provide sophisticated insight into how financiers deploy different financing structures and risk-allocation agreements across different infrastructure types and in different countries. Such answers are crucial, because understanding the structure — not just the quantity — of dollars that investors are spending in these infrastructure deals is key to assessing how major financiers are apportioning risk and thus enabling climate-misaligned infrastructure development. In an example of the inadequacy of current disclosure, the Task Force on Climate-related Financial Disclosures found that only 13% of companies are reporting on the metric it calls "most useful" to investors: the resilience of the company's business strategy to climate risks (FSB, 2021). One key question with implications not just for the atmosphere but also for national treasuries is how financiers are using risk-shifting mechanisms that might affect underwriting decisions — mechanisms such as ways to offload risk to public entities.

Conclusions and recommendations

Our analysis marks an initial step in a reexamination of the key drivers of the financing of high-carbon infrastructure in the part of the world in which most of that infrastructure is being built: emerging and developing economies. New power-generation infrastructure appears most carbon-intensive in the countries adding the most of it, precisely the countries the world most needs to cement a low-carbon infrastructure path.

We provide new insights into the financial flows underpinning this infrastructure, including the actions of institutions financing the projects and of countries hosting them. We advance previous scholarship by exploring the wide-reaching effect of investing high-carbon infrastructure beyond coal; by underscoring the importance of high-carbon investment coming from within, not just from outside, emerging and developing economies in which infrastructure is being built; by elucidating ways in which different financiers work together to facilitate the financing of high-carbon infrastructure; and by highlighting key data gaps that policymakers should and could ensure are filled.

As additional data is released by the World Bank, by governments, and by commercial institutions, our framework will provide an ongoing means of analyzing the financing activities of major foreign and domestic financiers, including state-owned actors, in the developing world — highlighting, among other things, the continued development of coal- and natural-gas–fired electricity generation projects in certain recipient countries.

Four of our findings in particular point up opportunities for policymakers to help shift infrastructure investment onto a lower carbon path.

- First, we find that even as financing for coal-fired capacity is on the wane, approximately half of the generation from power plants in emerging and developing economies executed in those three years is too carbon-intensive to align with the global goal of keeping Earth's average temperature from exceeding 1.5°C above pre-industrial levels, largely because of the prevalence of new natural-gas–fired power plants.
- Second, we find quantitative evidence of host-country agency in determining the carbon intensity of the infrastructure that is built: the largest part of the money financing climate-misaligned infrastructure in emerging and developing economies is coming from institutions not outside those countries but within them.
- Third, we find significant differences in the carbon intensity of infrastructure in emerging and developing economies financed by different types of investors and by foreign investors from different countries. In particular, we highlight the importance of key financial actors from Japan, South Korea, and China that appear to facilitate the participation of commercial institutions in high-carbon projects.

- Fourth, our dataset, while comparatively comprehensive, remains incomplete, a result, in notable part, of insufficient data disclosure by myriad financing institutions. Policymakers could and should press for more-sufficient data.

Our inquiry considers only one climate-relevant sector of infrastructure in emerging and developing economies: power plants. A useful next step would be to apply this methodology to other types of infrastructure, including transportation.

This inquiry sets the stage, too, for a more-foundational investigation: How and why, in a number of emerging economies whose fast-growing energy consumption makes them critical determinants of the world's climate future, is significant financing still going to high-carbon technologies, including but not limited to coal? Transitioning the political economies of such countries to incentivize low-carbon technologies will be a monumental task. But it will be crucial, because decisions about the carbon intensity of new energy infrastructure—installations that will dictate greenhouse-gas emissions for decades —are made on the basis not just of cost but also of perceived political interest. The mix of energy, in other words, depends on the balance of power.

In the meantime, this initial analysis prompts four main policy-relevant recommendations.

- First, although significant scholarship and policy-making dealing with the decarbonization of emerging economy infrastructure has focused on the role of overseas financiers, particularly banks, increased focus on domestic actors will be important. A crucial challenge relates to the political economies of key emerging and developing economies. In recent months, a striking number of key emerging and developing economies have announced their intent to promote lower carbon infrastructure. Capitalizing on such green intentions would require a shift in economic incentives in those countries. Companies and citizens that have profited from high-carbon activities will need to see new avenues of profit in low-carbon pursuits. They also will need policies to cushion the economic blow of the decarbonization drive (Ball, 2021).
- Second, as analysts and policymakers monitor the trajectory of carbon emissions from power generation in the developing world, they must broaden their technological focus. Coal-fired power plants have sparked the greatest concern and regulatory attention. But an end to coal-fired generation, even in the unlikely event it occurred, would not by itself solve climate change. Gas-fired plants, which are fast gaining popularity in emerging and developing economies, constitute a massive and growing emissions source. If they are not offset by some sort of large-scale carbon-capture technology, they will block the global bid for the sort of deep societal decarbonization that scientists agree is crucial. The oft-repeated claim that natural-gas–fired power plants are a "bridge" to clean-energy future rings hollow given that our data indicates that 80% of the natural-gas–fired plants executed in emerging and developing economies from 2018 through 2020 are climate-misaligned.
- Third, the net-zero stampede — the crush of pledges by governments, corporations, and financiers to cut their emissions to net-zero by mid-century — needs radically more detail and a workable mechanism of enforcement if it is to become more than sloganeering. As our analysis shows, the financing of climate-relevant infrastructure in emerging and developing economies involves innumerable players, each acting in its own interests and interacting in complex ways with others. Clarity is crucial on what an individual player means by its net-zero pledge, on how that pledge impacts the promises of other players, and, as a result, on how that pledge is likely to affect the atmosphere. Though an assortment of industry alliances and non-governmental organizations are working toward such clarity, regulators likely will need to step in both to promulgate standards to assess these net-zero pledges and to enforce those standards. They will need to do so quickly, given how critical scientists say the next decade will be in curbing carbon emissions.
- Fourth, and relatedly, policymakers have a responsibility to push for greater transparency and more-complete data related to the financing of infrastructure projects in emerging and developing economies (Masson-Delmotte et al., 2021). Historically, long-term institutional capital has shied away from participating in infrastructure projects in emerging and developing economies projects given its perception of the sector's difficult-to-control risks; in 2018, it financed less than 1% of infrastructure projects in emerging and developing economies (World Bank Group, 2018). To catalyze the private sector to fill what has been identified as a $1 trillion infrastructure-financing gap, standardizing

and increasing the transparency of the terms of financing for these projects will be critical in promoting best practices for underwriting and reporting that allow for the long-term alignment of these private financial flows with global infrastructure-resiliency and emissions goals. This points up an important task for policymakers: require better data to monitor institutions' progress toward their green promises. Such data-driven pressure is a prerequisite to a 1.5°C pathway for the world.

Limitations of the study

Our analysis is subject to several limitations. A detailed discussion of the limitations appears in the STAR Methods section. A summary of the limitations follows here.

Certain limitations flow from the World Bank data on which we base our analysis. Despite their collective breadth, even the PPI and SPI databases fail to include certain projects. By design, they exclude projects in industrialized countries. By necessity, they exclude projects in emerging and developing economies for which, according to the World Bank, information is not publicly available. Importantly, projects with missing financing and generation information have been excluded from our analysis sample.

Nevertheless, we believe, for two reasons, that our dataset is likely to capture the bulk of projects in emerging and developing economies and thus to give reasonable estimates of the investments associated with them. One reason is that the World Bank itself estimates that its PPI and SPI databases cover 80% of all infrastructure projects executed in emerging and developing economies in a year covered by the database. Another reason is that we augmented the World Bank data with additional project-level information by undertaking a thorough review of available information and literature.

For approximately 5% of the financial transactions in our database, certain elements of the funding flows are missing. We opted to remove these projects from our sample. Because they represent such a small percentage of the transactions, removing them did not significantly affect the robustness of our results. However, our dataset lacks more information for some financiers than for others, owing in large part to differences in financial- and climate-disclosure requirements across the globe.

In addition, a lack of certain data in the World Bank's PPI and SPI databases limits the specificity of our analysis. In particular, in calculating CO_2-emission factors and capacity factors, we are limited in our ability to distinguish among projects whose underlying technology differs in certain nuanced ways.

An additional limitation relates to the structure of our model. For several reasons detailed in the STAR Methods section, our model likely underestimates both the carbon intensity and the actual emissions of a project and of a portfolio of projects. Thus, the climate implications of the infrastructure financing we trace in this analysis are likely even more severe than we calculate.

STAR★METHODS

Detailed methods are provided in the online version of this paper and include the following:

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  - Materials availability
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  - Calculating the carbon intensity per dollar invested for a project and for a portfolio of projects
  - Determining the Paris alignment of each project
  - Carbon intensity thresholds to determine Paris alignment of new electricity-generation assets

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AUTHOR CONTRIBUTIONS

J.B. conceptualized, structured, and supervised the research and wrote the majority of the paper. A.O.P. led emissions methodology development, software, and data analysis. D.L. led data refinement and validation and contributed to data analysis. E.D. contributed to methodology development and software. A.O.P. and D.L. led data visualization, oversaw methodology, and assisted with writing.

DECLARATION OF INTERESTS

The authors declare no competing interests.

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STAR★METHODS

KEY RESOURCES TABLE

REAGENT OR RESOURCE	SOURCE	IDENTIFIER
Deposited data		
Private Participation in Infrastructure Database	World Bank	https://ppi.worldbank.org/en/ppi
State Participation in Infrastructure Database	World Bank	N/A
Historical GHG Emissions	World Resources Institute	N/A
CO_2Emissions from Fuel Combustion Statistics Database	International Energy Agency	N/A
Life Cycle Assessment of a Natural Gas Combined-Cycle Power Generation System	U.S Environmental Protection Agency	N/A
Global Power Plant Database	World Resources Institute	N/A
IPCC's Global Warming of 1.5°CGlobal Carbon Budget	Intergovernmental Panel on Climate Change	N/A
World Energy Outlook Stated Policy Scenario	International Energy Agency	N/A

RESOURCE AVAILABILITY

Lead contact

Further information and requests for resources and materials should be directed to the lead contact, Jeffrey Ball (jeffball@stanford.edu).

Materials availability

No materials were used in this study.

Data and code availability

Two sources of underlying data were used in this study. One, the World Bank's Public Participation in Infrastructure database, is available at https://ppi.worldbank.org/en/ppi. The other, the World Bank's State Participation in Infrastructure database, was provided to us by the World Bank and is expected to be made publicly available by the World Bank by summer 2022. (World Bank Group, 2019) Due to data-sharing restrictions, we are unable to share the underlying SPI database before the World Bank releases it publicly.

METHOD DETAILS

Overview

We assemble a new database of climate-relevant infrastructure projects in emerging and developing economies and analyze those projects across a number of climate-relevant dimensions. The database uses project-level data collected by the World Bank and that we have extensively checked, strengthened, and refined. It includes information specific to each infrastructure project about the identity of the financing entities, the financial instruments they are using, the location and size of the project, and the level — which we have estimated — of CO_2 emissions from each project. The data is broader and deeper than that previously available. To that data we have applied a methodology to impute project-level carbon emissions.

Our analysis includes three elements:

- The carbon intensity of the electricity generated from an individual project or from a portfolio of projects. Carbon intensity of generation is defined as the quantity of emitted carbon divided by the quantity of generated electricity. This metric makes possible comparing the carbon footprints of different financiers' infrastructure investments.
- The carbon intensity of investment in an individual project or in a portfolio of projects. Carbon intensity of investment is defined as the quantity of emitted carbon per million dollars invested in the project or

the portfolio. This facilitates a second comparison of financiers and of recipient countries in terms of the carbon intensity of their infrastructure activities in emerging and developing economies.

- Whether an individual project or a portfolio of projects is, in its expected carbon emissions profile, consistent — or ''aligned'' — with the goals set out in the 2015 Paris Climate Accord.

Although in this analysis we apply the methodology only to electricity-generation projects, in the future the methodology could be used to assess climate-relevant financing flows for other types of infrastructure both in the energy sector and beyond it.

Data sources

The database uses data collected by the World Bank and included in two World Bank sources. Both sources comprise projects across the full gamut of infrastructure types: energy, transport, water, communication technology, and more. They include projects throughout the developing world.

- The World Bank's Private Participation in Infrastructure (PPI) data set, which for years has been publicly available. (World Bank Group, 2021)
- The World Bank's State Participation in Infrastructure (SPI) data set, which the World Bank has created for three years — 2018, 2019, and 2020 — was made available to us; and is planned to make publicly available by summer 2022.

Understanding each of the two data sets is important because they are structured based on World Bank definitions some of which do not comport with generally understood terms.

The PPI dataset captures infrastructure projects in which entities that the World Bank labels as ''public'' have invested less than 80% of the project's value. Put differently, the PPI includes projects in which entities that the World Bank calls ''private'' have invested at least 20% of the project's value. However, the World Bank's definition of a ''private'' entity is idiosyncratic. Included in that definition are public entities — including state-owned enterprises (SOEs) — in cases when those entities are operating not in their home countries but in foreign countries. The PPI data set also captures projects that are strategically supported but not owned by these public institutions.

The SPI data set, by contrast, captures projects with more than 80% equity financing invested by treasuries and ministries or by SOEs when the SOEs are investing in projects in their home countries.

Taken together, the PPI and SPI data sets represent a comprehensive compendium of financing of infrastructure projects in emerging and developing economies.

Other databases

Each of these databases focuses, by design, on a specific slice of international infrastructure finance rather than on the whole universe of it. (See STAR Methods section for further details about each database's focus.)

- China's Global Energy Finance, a database from Boston University's Global Development Policy Center, focuses on lending by two major Chinese banks, the China Development Bank and the Export-Import Bank of China. (Gallagher, 2017)
- Johns Hopkins' Chinese Africa Research Initiative hosts a database of financial information on lending by Chinese policy banks to infrastructure projects in Africa. (Johns Hopkins University, 2021)
- Agence Française de Développement's Development Banks Database includes information about financing by international development banks. (Agence Française Développement, 2021)
- Decarbonizing the Belt and Road, a data collection from Tsinghua University and Vivid Economics, provides aggregated estimated emissions forecasts from a set of Chinese-affiliated energy-infrastructure projects in a select group of countries that are part of China's massive international infrastructure finance effort, the Belt and Road Initiative. (Jun and Zadek, 2019)

- The American Enterprise Institute's China Global Investment Tracker provides a list of Chinese investments reflecting corporate and project investments across infrastructure and non-infrastructure sectors; it considers nominal deal value. (American Enterprise Institute, 2021)
- Refinitiv's BRI Connect, a subscription-based data platform, provides financial and operational data on projects that have Chinese involvement as determined through official identification by the Chinese government or where projects have obtained relevant approval with BRI regulators.
- A database from Sichuan University compiles operational and financial information on projects financed through Chinese overseas foreign direct investment, largely from information in the subscription-based Wind Economic Database. (Liu et al., 2020)

Scope of inquiry

Our analysis, using the World Bank's PPI and SPI databases, considers just new electricity-generation projects and, more specifically, just those that the World Bank deems to have been "executed" in 2018, 2019, or 2020. For the vast majority of those projects, the World Bank considers the date of execution to be the date of financial close. The World Bank deems financial close to be the date on which:

a) equity holders and/or debt financiers reach legal agreement to provide or mobilize financing for the full cost of the project; or
b) the conditions for financing have been met and the first tranche of financing is mobilized. If the World Bank cannot find this information, it uses the date of the start of construction as a proxy for the date of execution.

We focus on the electricity-generation sector because it is the main contributor to climate change, accounting for more than one-third of the global greenhouse-gas emissions. (World Resources Institute, 2021) For each electricity-generation project, our database records operational metrics (e.g., fuel, power capacity, and location), financial metrics (e.g., total investment, total debt, and total equity), and CO_2-emissions metrics (e.g., annual emissions, emission factors, and capacity factors).

Estimating a project's annual emissions from fuel combustion

We base our estimate for each project on two numbers. One is the project's estimated annual electricity generation, which we estimate using country- and fuel-specific capacity factors. The other is the project's CO_2-emission factor, or the amount of CO_2 it emits for every unit of electricity it produces, a metric that is specific both to the country in which the project sits and to the fuel it uses.

Equation 1. Estimated annual emissions from fuel combustion per project

$$CO_2\ emissions\ (million\ tons\ of\ CO_2) = CO_2\text{-}emission\ factor\ (t\,/\,MWh) * annual\ plant\ generation\ (MWh) * 1e^{-3} \quad \text{(Equation 1)}$$

In equation 1:

- CO_2 emissions (million tons of CO_2) are the project's annual estimated CO_2 emissions. The CO_2-emission factor (kg/MWh) is defined as the amount of CO_2 emitted per megawatt-hour (MWh) of electricity generated. Each emission factor is specific to the generation technology used in the project. We used technology-specific CO_2-emission factors calculated by the IEA as published in the IEA CO_2 Emissions from Fuel Combustion Statistics Database. (International Energy Agency, 2020) The IEA factors are based on the methodology laid out by the IPCC in the 2006 IPCC Guidelines for National Greenhouse Inventories. (Eggelston et al., 2006) Emission-factor estimates for combined-cycle natural-gas-fired power plants are unavailable in the IEA database; therefore, we use standard factors from the U.S. Environmental Protection Agency for these plants. (Spath and Mann, 2000)
- Annualized plant generation (MWh) is the estimated amount of electricity generated by the project per year. This metric is calculated using the plant's installed capacity (MW), which is provided by the World Bank data and recorded in our database, and the plant's estimated capacity factor (expressed as a percentage). The capacity factor is the percentage of time in a year during which

the plant is generating power. A plant with a capacity factor of 100% is generating power 365 days a year and 24 hours a day, for a total of 8,640 hours per year.

Equation 2. Estimated annualized plant generation and capacity factors

$$\textit{Annualized plant generation}\ (MWh) = \textit{plant installed capacity}\ (MW) * \textit{capacity factor}\ (\%) * 8,640\ \textit{hours/year} \quad \text{(Equation 2)}$$

where:

$$\textit{Capacity factor}\ (\%) = \frac{\textit{estimated annual generation}\ (MWh)}{\textit{installed capacity}\ (MW) * 8,640\ \textit{hours/year}}$$

Capacity factors vary by generation technology and by country. In other words, a natural-gas–fired power plant in Pakistan, a coal-fired power plant in Pakistan, a natural-gas–fired power plant in Malaysia, and a coal-fired power plant in Malaysia each will have a different capacity factor.

Nevertheless, many studies apply the same capacity factor — 60% — to projects regardless of a project's generation technology or of the country in which it sits. These studies use this blanket estimation methodology for simplicity. But the estimation lacks depth and nuance. In particular, it tends to overestimate generation in certain plants.

To improve the robustness of our results, we attempted to tailor capacity factors to generation technologies and to countries. We did so using estimated annual-generation figures and installed-capacity data from the World Resources Institute's (WRI's) Global Power Plant Database. (World Resources Institute, 2020)

A lack of certain data in the World Bank's PPI and SPI databases limits the specificity of our analysis. In particular, in calculating CO_2-emission factors and capacity factors, we are limited in our ability to distinguish among projects whose underlying technologies differ in certain nuanced ways. For example:

- We cannot calculate different capacity or emission factors for coal-fired power plants of different technologies, such as subcritical, supercritical, and ultra-supercritical, or for those using different types of coal, such as bituminous or mixed coal.
- We cannot calculate different emission factors for hydropower projects of different generation capacities, even though hydropower dams of varying sizes differ in their capacity factors. Because data on actual generation (MWh) and installed capacity (MW) for non-conventional fuels such as biomass, waste, and biogas are sparse and vary greatly from project to project, we did not calculate emission or capacity factors for these fuels. They are excluded from our analysis.
- Plants with no fuel input of their own (e.g., those that produce steam or heat but that receive their energy inputs from other plants) were also removed from the database because no emissions can be estimated without understanding the materials burned to generate energy.
- For countries for which the WRI Global Power Plant Database does not include data that allows us to calculate country-specific capacity factors, we used the WRI database's global averages instead.

Calculating carbon intensity per unit of electricity generated for a project and for a portfolio of projects

The carbon intensity per unit of electricity generated is measured in million tons per megawatt-hour (MWh). This metric allows us to compare projects by their CO_2 emissions. By aggregating the projects of a financing institution or in a country, we can compare the carbon impacts of the financier's or the country's activities.

Equation 3. Carbon intensity, per unit of electricity generated, for a project

$$\textit{carbon intensity}\ (Mt\ /\ MWh) = \frac{\textit{estimated annual } CO_2 \textit{ emissions}\ (\textit{Million tons of } CO_2)}{\textit{estimated annual generation}\ (MWh)} \quad \text{(Equation 3)}$$

Calculating the carbon intensity per dollar invested for a project and for a portfolio of projects

As our analysis focuses on identifying investment trends, we also calculated the carbon intensity per dollar invested for a project and for a financier's portfolio of projects.

Equation 4. Carbon intensity, per dollar invested, for a project

$$\text{carbon intensity of financing}\left(Mt \middle/ MWh\right) = \frac{\text{estimated annual } CO_2 \text{ emissions } (\text{Million tons of } CO_2)}{\text{total investment in project } (MWh)} \quad \text{(Equation 4)}$$

Determining the Paris alignment of each project

Assessing the climate implications of infrastructure investment requires comparing the carbon impacts of projects and of portfolios of projects not just to one another but also to the global thresholds that international climate-science bodies have promulgated. We compute whether each project in our database is consistent (''aligned'') with, or inconsistent (''misaligned'') with, two thresholds of increased average global temperature, beyond that of pre-industrial times, that the IPCC has identified as important. One threshold is an increase in global average temperature of 2°C beyond pre-industrial levels. The other threshold is an increase of 1.5°C.

To do this, we adapt, and enter our data into, a model suggested by the Climate Policy Initiative (CPI), a San Francisco-based climate-analysis firm that operates internationally. The CPI's Proposed Method for Measuring Paris Alignment of New Investment outlines a way to determine whether the carbon intensity of an infrastructure project, of a portfolio of projects financed by an institution, or of a portfolio of projects located in a country is or is not aligned with each of those IPCC temperature thresholds. (Micale et al., 2020) The CPI methodology computes a threshold carbon intensity for each temperature level. If the carbon intensity of a project or of a portfolio of projects is below that threshold, the project is considered aligned; if the carbon intensity is above that threshold, the project is considered misaligned.

To calculate the carbon intensities that define whether a project or a portfolio of projects is aligned or misaligned with the Paris thresholds, we apply the following formula:

Equation 5. Carbon intensities to determine whether a project is aligned or misaligned

Broadly,

$$\text{carbon-intensity benchmark} = \frac{\text{Available carbon below warming target}}{\text{New generation needed to meet future demand}} \quad \text{(Equation 5)}$$

Specifically,

$$\text{carbon-intensity benchmark} = \frac{\text{Carbon budget}_{2018-2040} - \text{Locked-in } CO_2 \text{emissions}_{2018-2040}}{\text{Total future electricity generation}_{2018-2040} - \text{Locked-in generation from existing assets}_{2018-2040}}$$

Our methodology uses as inputs a number of economy-wide variables. Because we consider not the whole economy but just the electricity-generation sector, we apply a scaling factor to trim the economy-wide variable to the power-generation sector. So, for instance, we take the IPCC's calculated carbon budget for the world and, using a scaling factor, in this case the portion of global emissions produced by the power sector, we obtain the equivalent of a power-sector carbon budget.

The components of this model are as follows:

1. Carbon budget

The carbon budget (Gt) is the maximum cumulative amount of CO_2 that may be emitted from 2018 through 2040 in order to ensure that by 2040 average global temperatures remain below a particular temperature threshold (either 2°C or 1.5°C above pre-industrial levels). For each of the two temperature thresholds, there are three scenarios: one with a 33% chance of remaining below the temperature threshold, one with a 50% chance, and one with a 67% chance. Each of those scenarios has its own carbon budget. Given that there are two temperature thresholds and three scenarios per threshold, there are six carbon budgets. These budgets are taken from the IPCC's Global Warming of 1.5°C (Table 2.2). (Masson-Delmotte et al., 2018) The scenarios are as follows:

a) 33% chance of staying below 1.5°C
b) 50% chance of staying below 1.5°C
c) 67% chance of staying below 1.5°C
d) 33% chance of staying below 2°C
e) 50% chance of staying below 2°C
f) 67% chance of staying below 2°C

For each of these six scenarios, the IPCC provides a carbon budget that comprises all economic activity. As explained above, we must adapt each of these six budgets because our analysis considers not all economic activity but only a subset of it: electricity generation. To do so, we compute the ratio between projected electricity-sector emissions and projected economy-wide emissions — for 2018, 2019, 2025, 2030, and 2040 — from one of the global-emissions scenarios articulated by the IEA, the IEA's Stated Policies Scenario (SPS). The SPS assumes the implementation of specific announced policies and measures in the relevant parts of the energy sector. See Table 6 for our results.

Table 6. Global carbon budget

Temperature target		
Percentile	1.5° C	2.0° C
Unadjusted IPCC global carbon budget (Gt)		
33%	840	2030
50%	580	1500
67%	420	1170
Adjusted IPCC global carbon budget (Gt)		
33%	333	804
50%	230	594
67%	166	464

2. Locked-in emissions

Locked-in emissions (Gt) are projected cumulative emissions from the quantity of generation that the IEA calculates will, according to its SPS, be needed to meet global demand in 2040. Starting with the total power-sector carbon emissions estimated by the IEA in its SPS, we apply a regression model to calculate locked-in emissions. Thus, we account for the expected increase in emissions from 2018 through 2040 rather than assuming locked-in emissions will remain flat.

3. Future electricity generation

Future electricity generation (TWh) is what the IEA's SPS projects as the amount of electricity generation the world will need in 2040. We start with the total electricity generation estimated by the IEA in its SPS, and then we apply a linear regression to calculate future electricity needs. We opted to use electricity generation rather than power-sector demand for this part of our model so that we would measure the related emissions on a gross-power-production basis — the metric that is relevant to emissions. (Power-sector demand is equivalent to net electricity generation; that is, it includes losses.) At this stage, we also apply a "decommissioning factor" calculated from IEA-SPS data to account for plant retirements each year.

4. Locked-in generation from existing assets

Locked-in generation (TWh) from existing assets is the amount of electricity that was generated in 2018 by production facilities expected still to be operating in 2040. We projected 2040 generation from these assets by extrapolating from the IEA's 2018 figures.

Carbon intensity thresholds to determine Paris alignment of new electricity-generation assets

The foregoing process produces, for each of the six warming thresholds described above, the following maximum carbon intensities that a project or a portfolio of projects can reach and remain aligned with the Paris climate goals.

The negative carbon intensities for two of the six scenarios described in Table 7 indicate that, to meet that threshold, a project or a portfolio of projects must not only not increase emissions but, in effect, actually reduce them. A project or portfolio could do this either by replacing existing generation or by integrating what is known as ''negative-emission technology'' — systems that result in the project's consuming more carbon than it produces.

Table 7. Calculated carbon intensity thresholds for project's Paris alignment

Temperature target		
Percentile	1.5°C	2.0°C
Carbon intensity thresholds for project's Paris alignment (MT CO_2/MWh)		
33%	0.0000004	0.000005
50%	(0.0000005)	0.000003
67%	(0.0000011)	0.000002

We calculate each financier's and each country's proportion of misaligned electricity generation, generating capacity, and investment. This approach is preferable to calculating each financier's and each country's percentage of misaligned projects. A project-based metric would be skewed by a myriad of small projects.

Our model likely underestimates both the carbon intensity and the actual emissions of a project and of a portfolio of projects. It does so for several reasons:

- We consider emissions from only fuel combustion, not taking into account emissions from other processes.
- We consider only CO_2 emissions, not emissions of other greenhouse gases that are, pound for pound, more dangerous than CO_2 to the climate. This approach minimizes the calculated climate impact of, for instance, natural-gas–fired power plants because it disregards emissions from the production of the natural gas, particularly methane leakage from natural-gas pipelines.
- We maintain 2018 and 2040 as the temporal bounds of our model even though our data encompasses projects on which execution took place in 2019 or 2020 or will be decided in 2021 or beyond. In reality, each year's crop of projects locks in marginally more emissions, thus reducing the total carbon budget that remains through 2040. In theory, it would have been ideal for our model to have taken into account this continuous annual diminution in the total carbon budget. In practice, we found that doing so yielded results little different from using 2018 as the base year. Its major effect, indeed, would have been to increase the uncertainty in our model.