ENVIRONMENTAL RESEARCH
LETTERS

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Finance-based accounting of coal emissions

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Keywords: coal-fired power plants, financing, (non-)Annex I countries, energy policy, finance-based emission accounting

Supplementary material for this article is available online

OPEN ACCESS

RECEIVED
2 September 2020

REVISED
27 December 2020

ACCEPTED FOR PUBLICATION
7 January 2021

PUBLISHED
24 March 2021

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Abstract

Most new coal-fired power plants are currently being constructed in Asia. These plants are financed by banks and investors, which in many instances reside elsewhere. This paper examines the international dimension of coal financing from commercial banks and institutional investors based on a newly constructed dataset. We analyse domestic as well as cross-border financial flows and propose a methodology to calculate 'finance-based emissions' associated with the construction of coal-fired power plants. Our results indicate that financial institutions from the United States, Europe and Japan play a major role in financing coal plants globally, especially in terms of loans, bonds and equity investment. From a finance-based perspective some countries account for a substantially larger share of coal emissions than under the commonly used territorial approach that assigns emissions to the country where they are released.

Over the past 40 years coal consumption has almost continuously increased [1, 2], turning coal into the largest single source of greenhouse gas emissions [3]. Phasing out coal is hence inevitable to achieve the international climate targets of the Paris Agreement [4, 5]. Yet, in addition to the committed emissions of already existing coal plants [2, 6], about 500 GW of new coal-fired power plants are in the 'pipeline' (i.e. planned or already under construction), foremost in Asia [7].

Recent research on investment patterns emphasizes that a closer analysis of cross-border finance from commercial banks can improve our understanding of the ongoing construction of coal plants. Global direct investment in coal power projects was around US$ 60–80 billion per year from 2014 to 2018 with a decreasing tendency over the last 3 years [8, 9]. The recent literature has discussed the particular role of Chinese public foreign direct investment for the development of coal and links the financing to Chinese exports of domestic technology [10–12]. Other studies show the tendency of Chinese developers to develop plants abroad [13] or Japanese companies to export coal plants [14]. Steffen and Schmidt [15] quantify the role of multilateral development banks in financing conventional and renewable energy. Chen and Schmidt [16] show how G20 governments' public finance institutions invest in coal. Different dimensions of coal financing have also been investigated by several NGOs [17–19]. To the best of our knowledge, no paper has analysed financing from commercial banks, institutional investors and the development of coal plants together. Other contributions that focus on financial aspects of coal foremost analyse how to de-risk low-carbon investment [20–24]. Policy instruments that explicitly tackle capital flows for coal plants could encourage financial institutions to withdraw from coal and shift to renewables instead and hence might constitute a promising entry point into effective climate policy [25].

Yet, despite the Paris Agreement's call to make 'finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development' [4] and a lively public discussion, financing of carbon-intensive activities and policy implications thereof receives only scant attention in the academic discussion. To move the debate on policies addressing capital flows forward, the analysis presented in this paper provides a comprehensive perspective of who invests in new coal-fired power plants around the globe, highlighting the role of Annex I members to the United Nations Framework Convention on Climate Change as they are supposed to take the lead

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in the response to climate change [26] (for a list of Annex I members see supplementary list 1 (available online at stacks.iop.org/ERL/16/044028/mmedia)). To do so we extend and merge existing data into a new and comprehensive dataset which ultimately enables us to establish and employ a novel finance-based emission accounting scheme (see section 1 for details). Unlike commonly used territorial accounting schemes, which assign emissions to the country where they are released, finance-based accounting allocates emissions that can be expected to occur over the lifetime of a coal plant ('committed emissions') to the country providing the associated financial support, based on the Greenhouse Gas Protocol [27] methodology.

We hence extend the scope of prior research by analysing capital flows of (a) development of coal plants (shown in red throughout the paper), (b) loans and underwriting from commercial banks (green), and (c) bond- and shareholding by institutional investors (blue). We first analyse each of these dimensions of coal finance individually. We then link financial flows to committed emissions to assess finance-based emissions. Finally, we discuss the policy implications of our findings.

1. Data and methods

In order to assess capital flows for coal plants we analyse the development of plants by project developers, which in turn can activate equity and bonds as well as loans and underwriting (see figure 1). The coloured ovals highlight the three financing dimensions we analyse in this paper. The developers are the key actors and organize all other companies to develop the plants. The development can follow many different schemes, such as 'Build Operate Transfer' or 'Engineering Procurement, and Construction' [13]. In this paper we do not discuss the question of ownership in detail. The developers can use balance sheet or project finance [9]. The global banking sector provides and mobilizes financing through loans—mostly corporate—and underwriting [28], which constitutes the biggest share of capital for coal plants [29]. Investment implies purchase of shares and bonds of the developers [16], which are mostly held by global asset management corporations and pension funds [18].

The analysis mainly relies on two datasets, first the 'Global Coal Plant Tracker' from January 2020 [7], which we use to address the development of plants. It dates back to 1927 and covers all units built, under construction and planned, as well as shelved projects. For every unit it contains, among others, information about capacity, status, site, developer and lifetime (committed) CO_2 emissions. The second dataset is provided annually by urgewald e.V. [30]. It originates from a common research by several NGOs compiled by profundo [31] and includes financing for more than 250 developers. It is split into two lists, one covering financing by banks, the other one covering bond- and shareholding by investors. The first includes data of every credit activity taking place between commercial banks and few international financial institutions and the coal developers. It contains the type of financing, the financer and the developer together with their respective countries and the volume of every transaction. The second list includes the shares and bonds that institutional investors hold in the coal developers as of October 2019. It further provides information about the developers and the investors, e.g. their respective countries. The research relies on financial databases provided by Bloomberg, Thomson Reuters and IJGlobal [31]. For the financing dataset we do not assume comprehensive but representative data [18].

Before beginning with the analysis we have to edit the available data frames. We reduce the development data to plants with a year of commissioning from 2015 onwards that are or will likely be developed. The year 2015 was chosen because the financing dataset covers transactions starting from 2012. Steffen and Schmidt [15] assume a lag of 2 years between financing from multilateral development banks and commissioning. For commercial banks we assume at least 3 years [32, 33]. Thus the developers can employ capital received in 2012 for plants with year of commissioning from 2015 onwards. Some units are developed by multiple companies. In this case we assume equal shares of all companies and allocate the split capacity accordingly. The development dataset does not include developers' countries. We determine these by matching with the financing dataset, using Google API and manual research. We merge the most recent update of the financing data with an older version [34] in order to get a more comprehensive dataset which covers transactions from January 2012 to September 2019. From the financing dataset we remove (multilateral) development banks and Export-Import Banks. This leaves us with commercial banks that can be allocated to single countries using their respective headquarters. Finally we convert monetary values to real (2019) US$ using the United States' Consumer Price Index [35].

We calculate the finance-based emissions by expanding the standard for accounting for credit activities published by the Greenhouse Gas Protocol [27] coordinated by the World Resources Institute and the World Business Council for Sustainable Development as an accounting and reporting standard for companies and financial institutions. In 'Scope 3 Emissions, Category 15: Investment' it provides technical guidance for financial institutions to calculate emissions, both for equity investment based on the investee and for project finance based on the project's expected lifetime emissions as it 'reflects the longer term nature of these forms of investment' [27]. Committed emissions are common in the

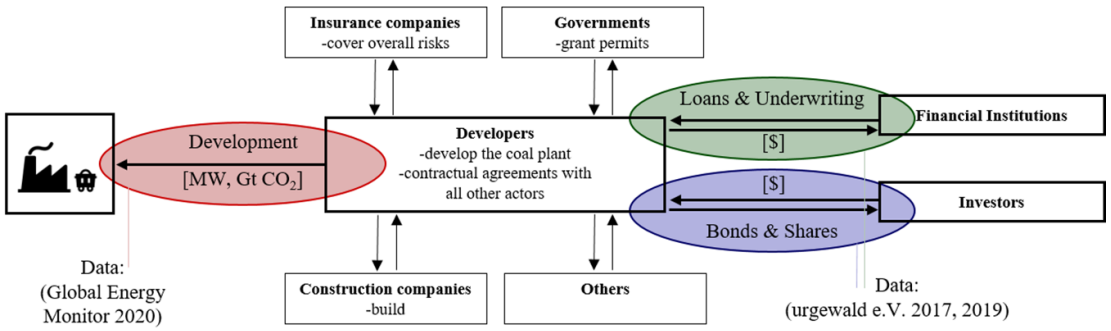

Figure 1. Actors and capital flows for coal-fired power plants. The developers receive financial support from financial institutions and investors to develop coal plants in collaboration with many other actors.

literature [36] and stated in the development data by the Global Energy Monitor [7] for each plant. For the sake of comparability we handle loans, underwriting, bond- and shareholding as project finance and assume that financial transactions are used for individual projects and thus can be attributed to those. We calculate the lifetime emissions for loans, underwriting, bonds and equity individually and, additionally, the total financing (which comprises the other four). More detailed data would allow to directly link financing to the respective project and emissions. As this is not available we have to aggregate development and financing. To do so we link each financing dimension to the development dataset by using the developers as the interface which leaves us with developers that received financing only. Let $\tilde{E}$ denote the committed emissions from the development of all coal units k and F denote financing in developers. We calculate the ratio e of emissions from all units in all countries by all developers k to the total volume of financing granted by all financial institutions j from all countries i:

$$e = \frac{\sum_{k=0}^{K} \tilde{E}_k}{\sum_{i=0}^{I} \sum_{j_i=0}^{J_i} F_{j,i}}. \quad (1)$$

Next we calculate the total volume of financing for each country i granted by all financial institutions j_i from the respective country:

$$F_i = \sum_{j_i=0}^{J_i} F_{j,i}. \quad (2)$$

Finally we multiply the total volume of financing for each dimension by the respective country with the ratio from (1) to get the finance-based emissions E for each country:

$$E_i = F_i \times e. \quad (3)$$

The number of unique developers after merging the datasets ranges from 70 developers for bonds to 161 for total financing. This implies that 70 developers issued bonds and developed plants in the considered period. The finance-based emissions from loans, underwriting, bonds and shares do not add up to the total financing, because some developers received e.g. loans and equity investment and are therefore included in both dimensions. The 161 developers for total financing developed around half of the total capacity in the considered period. We find finance inflows of US$ 2775 per kW for total financing.

The interpretation of the results requires to consider specific data limitations. Our analysis focuses on commercial banks and institutional investors. The literature states that commercial banks provide around half of the total project finance for coal plants in 2017 [9]. However, as the data suggest [30], the total financing of commercial banks is multiple times higher and mostly conducted through corporate finance. The financing and the development dataset do not allow for an exact allocation of financing to capacity and thus emissions. Our methodology aggregates the total financing volume and all emissions in order to calculate a country's finance-based emissions. We rely on estimates conducted by Global Energy Monitor [7] for each unit's emissions that are averaged over global capacity factors, heat rate and emission factors and should therefore be taken as an approximation in line with previous literature [2, 6].

We compare the finance-based emissions from loans, underwriting, bonds and equity investment separately as well as those from total financing, which comprises all four dimensions of financing. The underlying assumption is that all financial flows that are received by specific developers are also channelled into new coal units. While this is straight-forward for loans which can be project related, underwriting and bond- and shareholding on the other hand are almost exclusively corporate [31, 37]. However, as we only analyse developers that were previous identified to develop coal by urgewald e.V. [17], we consider it to be likely that financial flows are actually used to develop coal capacity. As a robustness check it is notable that the construction costs implied by loans,

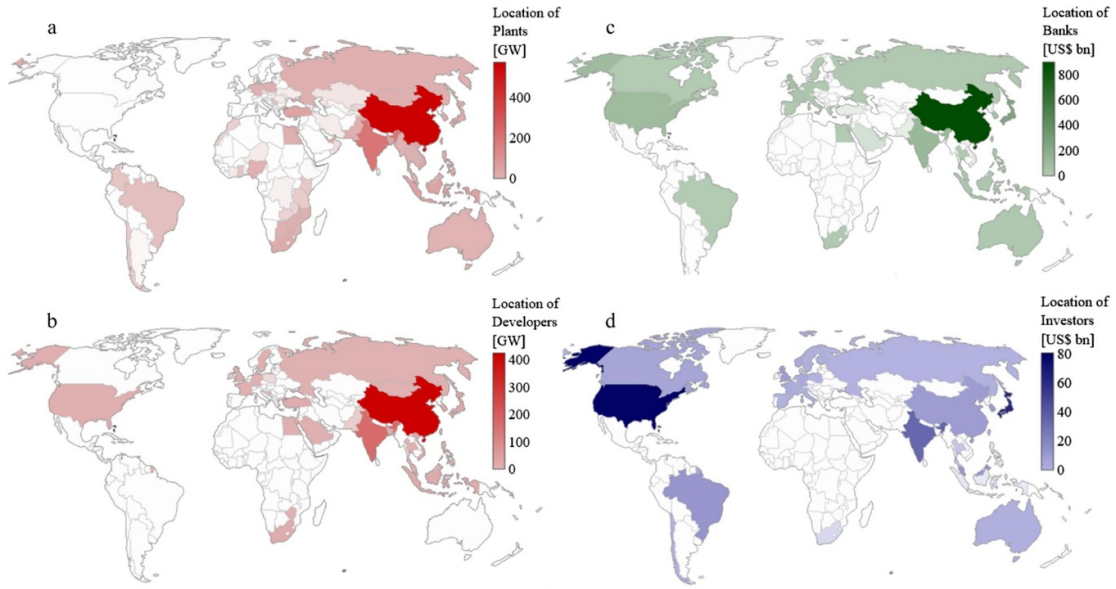

Figure 2. Dimensions of international coal financing. Countries are shaded in proportion to each panel's respective variable. (a), (b) Capacity of coal plants with a year of commissioning from 2015 onwards grouped by country using data from the Global Energy Monitor [7]. The difference in the total capacity for the two panels is due to the fact that the developer (and the associated country) is often still unknown in the planning stage and therefore missing in the data. (c), (d) Location of banks and investors that finance coal developers using data provided by urgewald e.V. [30, 34].

underwriting, bonds and equity investment are all well below the overnight costs of coal plants reported in different studies [38, 39]. However, the resulting total financing inflows of US$ 2775 per kW on average in our sample are in the range of findings from the literature.

2. Results

2.1. Financial flows for coal plants

For coal-fired power plants that were commissioned after 2015 or are currently in the pipeline, the origin of the capital flows and the site of construction are in stark contrast. Figure 2 shows locations of plants (a), project developers (b), banks (c) and investors (d). Coal plants are almost exclusively built in Non-Annex I countries, foremost in Asia, but also in Sub-Saharan Africa and South America. Developers are majorly located in Asia. By contrast headquarters of the financial institutions spread across the globe, with investors being mainly located in North America, Asia and several European countries. Whereas financial institutions from both Annex I and Non-Annex I countries provide financing, coal plants are largely constructed in Non-Annex I countries.

We compare the location of developers to those of banks and investors (figure 3). The development of the total capacity of 1182 GW is dominated by China and India followed by other Asian countries, including South Korea, Vietnam and Japan (light red bars in figure 3(a)). Not surprisingly, in terms of plants developed in each country, China and India rank top, followed by Vietnam, Indonesia and Turkey (dark red bars in figure 3(a)). For the 817 GW for which the developers are known (see also table 1) the share of cross-border development, i.e. capacity that is developed overseas, is 15%. Developers that realize projects overseas are mostly from China, Hong Kong and Japan. In some countries, e.g. Vietnam, South Africa and Bangladesh, more than a third (for Bangladesh even 70%) of the installed capacity is developed by foreign companies (shown by 'foreign share' in figure 3(a)). Generally, the foreign share is higher for plants where construction has not yet started (16%, as compared to around 11% for plants that are finalized or under construction). Two-thirds of all cross-border development activities are conducted by developers from Non-Annex I parties, almost exclusively in Non-Annex I countries (see figure 3(d) for a detailed regional breakdown of the cross-border flows).

Next we analyse where commercial banks that grant loans and underwriting to developers are located (figure 3(b)). From January 2012 to September 2019 banks provided coal developers with US$ 1790 billion. Around US$ 1321 billion were provided through underwriting and loans amounted to US$ 469 billion. Chinese banks disbursed around US$ 896 billion, foremost through underwriting, followed by financial institutions from Japan, India and the United States, who provided US$ 265 billion, US$ 122 billion and US$ 99 billion in financing, respectively. European and American actors are more prominently involved than in the perspective focusing on developers. Developers from China received most financing, followed by developers from

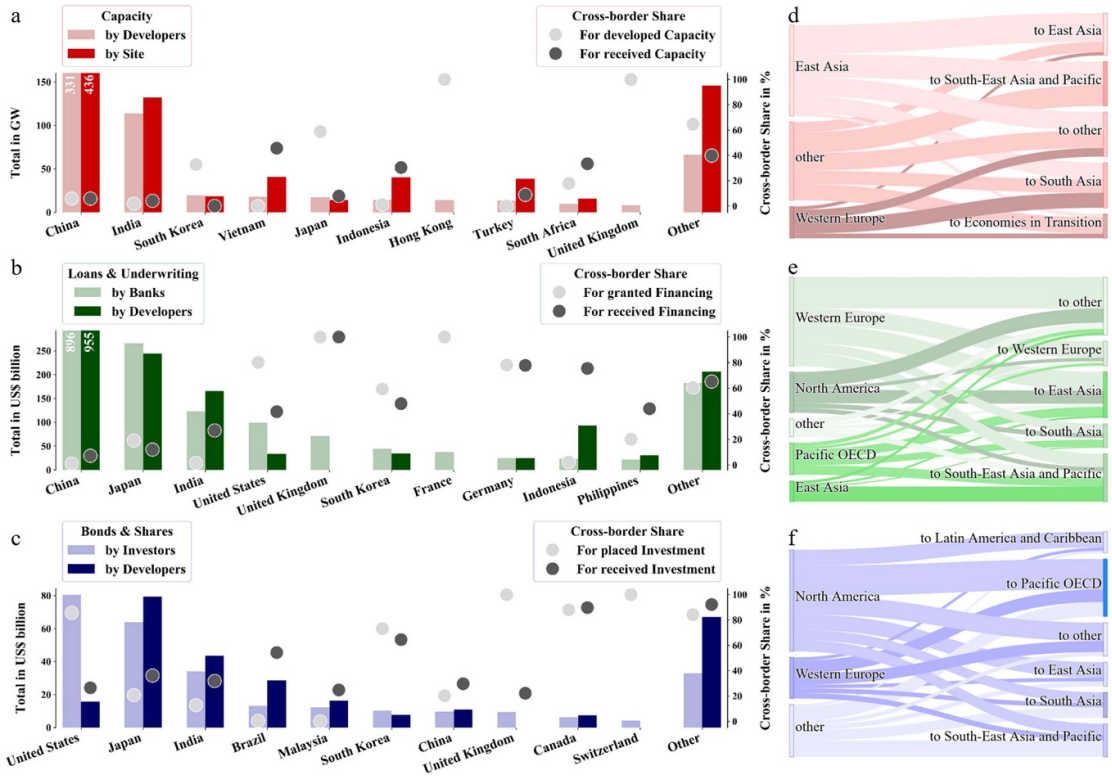

Figure 3. Finance flows by country and region. (a)–(c) Largest ten countries for each finance dimension comprising domestic and foreign flows. (a) Capacity of coal plants with year of commissioning from 2015 onwards that developers from the respective countries developed (light) and that is developed in the respective country (dark) [7]. The share of capacity developed overseas and by foreign companies is depicted on the right *y*-axis. (b) Volume of loans and underwriting that have been granted by banks from the respective country (light) and received by developers from the respective country (dark) together with the foreign share. The data cover the years 2012–2019 [30, 34]. (c) Volume of bonds and shares held in coal developers. Data are split into the placed investment by investors from the respective country (light) and the received investment by developers from the respective country (dark) and the foreign share. The applied data refer to 2019 [30]. (d)–(f) Breakdown of cross-border flows into regions. The flow charts use the same data source as their respective bar graph counterparts but focus on cross-border flows only. Regional sets entail North America, Western Europe, Pacific OECD, Economies in Transition, Latin America and Caribbean, Sub Saharan Africa, Middle East and North Africa, East Asia, South Asia, South-East Asia and Pacific following the IPCC RC10 ([40], see supplementary list 2). (See supplementary figures 1–4 for more detailed graphs.)

Japan, India and Indonesia. A total volume of US$ 413 billion was granted to foreign developers, which equals 23% of the total financing volume. The foreign share of financing from commercial banks from China and India is low, on average they granted more than 98% domestically. Data from the Global Development Policy Center [42] suggest that the Chinese Development Bank and the Export-Import Bank of China, which are both not included in our analysis, provided loans for coal plants overseas in the range of US$ 35 billion since 2012. Commercial banks from some Annex I countries—such as the United Kingdom, France and Switzerland—exclusively financed foreign developers. Thus, when we consider cross-border flows only, around 81% come from banks from Annex I countries foremost from Western Europe and North America (see figure 3(e)), mostly targeted at Non-Annex I countries.

The investment in coal developers amounts to US$ 277 billion as of October 2019 (figure 3(c)). Shareholding represents the majority with US$ 239 billion while bondholding constitutes the remaining US$ 38 billion. Institutional investors from the US account for US$ 80 billion, out of which 86% was invested abroad. Next are investors from Japan and India with placed capital of US$ 64 billion and US$ 34 billion, respectively, which was, to a large extent, invested domestically. The tendency to invest domestically can also be observed for investors from India, Brazil and Malaysia. On the other hand, investors from Europe and Canada mainly finance foreign developers, e.g. from Japan and India, which in total attracted most financing. Around 52% of the total volume was invested overseas. The data suggest a similar pattern as for loans and underwriting: financial institutions from the United States and Europe tend to invest overseas while investors from East and South Asia place capital both internationally and domestically (see figure 3(f)). The cross-border flows therefore show a share of investors from Annex I parties of 83%, out of which around half was placed in Non-Annex I countries (see supplementary information for detailed tables).

Table 1. Overview of financial flows and underlying data. For each dimension the total volume, the foreign investment and the share of flows from Annex I to Non-Annex I countries of the foreign investment are shown together with the respective largest companies and their countries. The foreign share of the development is calculated based on the capacity, where developers are known. The data stems from the Global Energy Monitor [7]. Loans and Underwriting from commercial banks and investment from institutional investors use data from urgewald e.V. [30, 34].

	Development	Loans and underwriting	Bonds and shares
Time span	From 2015 onwards	2012–2019	As of October 2019
Total volume	The Developer country is known for 817 GW (total: 1182 GW)	US$ 1790 billion; US$ 1321 billion underwriting and US$ 469 billion loans	US$ 277 billion; US$ 239 billion shareholding and US$ 38 billion bondholding
Largest companies	National Energy Investment Group, China Datang (both China), National Thermal Power Corporation (India)	Mizuho Financial (Japan), Industrial and Commercial Bank of China (China), Mitsubishi UFJ Financial (Japan)	Blackrock (United States), Government Pension Investment Fund (Japan), Vanguard (United States)
Share of foreign investment	15% (123 GW)	23% (US$ 413 billion)	52% (US$ 143 billion)
Largest companies operating overseas	China Resources (Hong Kong), PowerChina (China), GCM Resources (United Kingdom)	Citigroup (United States), HSBC, Standard Chartered (both United Kingdom)	BlackRock, Vanguard, Capital Group (all United States)
Share of Annex I members of foreign investment	33% (40 GW)	81% (US$ 336 billion)	83% (US$ 119 billion)
Share of foreign investment flows from Annex I to Non-Annex I	23% (29 GW)	50% (US$ 206 billion)	41% (US$ 59 billion)

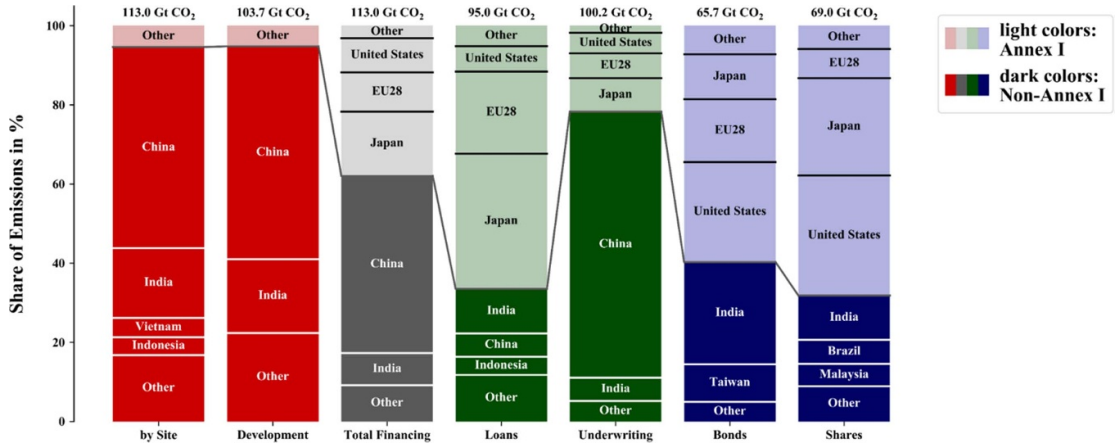

Figure 4. Expected territorial and finance-based emissions from coal plants for different categories. Bars show the share of emissions for the largest countries, grouped by Annex I (light colours) and Non-Annex I (dark colours) [26]. The total emissions for each dimension are shown on top. The country of developers is sometimes unknown, hence the difference in emissions between 'by Site' and 'Development'. Numbers are calculated based on Global Energy Monitor [7] and urgewald e.V. [30, 34] (for more detailed information see section 1). We consider coal plants constructed since 2015 or currently in the pipeline. Loans and underwriting cover a time span of 2012–2019, bonds and shares are as of October 2019. The 28 countries of the European Union as of January 2020 are grouped to 'EU28', ([41], for a list of countries see supplementary list 3). Note that the emissions that are allocated to the respective financial volumes of 'Loans', 'Underwriting', 'Bonds' and 'Shares' do not sum up to the total emissions of coal-fired power plants. (See supplementary figure 5 for a more detailed graph.)

2.2. Finance-based emissions

Figure 4 shows the expected future lifetime emissions of coal-fired power plants related to the different dimensions of financing analysed above. We assign emissions to individual countries as described in the section 1. The first bar assigns emissions by the site of coal plants in the spirit of territorial emission accounting. From this perspective, Non-Annex I countries, such as China and India, account for almost all emissions related to coal-fired power plants. A similar picture is drawn by the second bar, which allocates emissions by the developers' origin. By contrast, a substantially different picture emerges if emissions are allocated to the country from which coal plants are financed. From the perspective of overall financial flows, Annex I countries account for a substantial share of about 40% of total emissions due to their high share (about two thirds) in loans and equity investment. The relatively high share of Non-Annex I countries in 'total financing' is almost

Table 2. Expected territorial and finance-based emissions from coal plants by country. The table shows the allocation of the 113 Gt CO_2 according to territorial and finance-based emission accounting. For the first 15 countries the table is sorted by finance-based emissions. To also show countries with high territorial and low finance-based emissions the residual countries are sorted by territorial emissions and the top five countries are shown. The difference highlights the change in emissions when using finance-based instead of territorial accounting in absolute terms and relative to the territorial emissions. Countries shaded in light red show negative values, countries in light grey positive ones. We calculate the numbers merging data from the Global Energy Monitor [7] and urgewald e.V. [30, 34] (see section 1 for more information).

	Territorial (by site)		Finance-based (by country of financial institutions)		Difference (finance-based relative to territorial)	
	Emissions in Gt CO_2	Capacity in GW	Emissions in Gt CO_2	Financing in US$ bn	Total in Gt CO_2	Relative in %
China	57.4	360.3	50.6	861.0	−6.8	−11.9
Japan	1.6	10.1	18.3	312.2	16.7	1012.7
United States	0	0	9.8	166.6	9.8	—
India	19.9	119.7	9.1	155.6	−10.7	−54.0
United Kingdom	0	0	4.5	76.3	4.5	—
France	0	0	2.1	36.0	2.1	—
Malaysia	0.7	4.6	1.9	32.2	1.2	163.1
Germany	0.2	1.3	1.6	27.3	1.4	668.2
Indonesia	5.1	28.9	1.4	23.4	−3.7	−73.1
Switzerland	0	0	1.2	21.0	1.2	—
Taiwan	0.9	5.8	1.2	20.7	0.3	36.0
Philippines	2.0	11.3	1.2	19.7	−0.9	−42.9
Brazil	0.2	1.0	1.0	17.5	0.8	467.4
Australia	0.3	2.0	1.0	16.4	0.6	176.6
Singapore	0	0	0.8	13.4	0.8	—
Vietnam	5.5	33.2	0.1	1.1	−5.4	−98.8
South Africa	2.8	16.9	0.5	9.1	−2.2	−80.6
South Korea	2.5	16.3	0.8	13.5	−1.7	−68.8
Bangladesh	2.3	13.9	0	0	−2.3	−99.9
Egypt	1.4	8.6	0.4	6.5	−1.0	−73.2

entirely explained by domestic underwriting from Chinese banks.

Many countries show considerable emissions from the financial support of coal plants. The total financing (comprising loans, underwriting, bonds and equity investment) that we were able to allocate to individual countries adds up to 113 Gt CO_2 (see section 1 for details). This value is greater than the committed emissions from plants in the pipeline of 85 Gt CO_2 and around half of the expected emissions from all currently operating plants of 214 Gt CO_2 [7]. We find 14 countries with lifetime finance-based emissions of at least 1 Gt CO_2. Table 2 allows to compare territorial emissions of a plant by its site to the finance-based emissions. On both accounts, China dominates the picture and shows similar emissions for both accounting schemes. All other countries can be classified into two distinct groups: (a) many Asian Non-Annex I countries such as India, Indonesia, Vietnam and Bangladesh have significant larger territorial than finance-based emissions. For instance, under a territorial perspective coal plants built in Vietnam amount to lifetime emissions of about 5.5 Gt CO_2. But as these plants are mainly financed from abroad, finance-based emissions assigned to Vietnam are 0.1 Gt CO_2; (b) countries that account for substantial finance-based emissions but have close to zero expected territorial emissions from the operation of plants. This group almost exclusively consists of Annex I countries, such as Japan, the United States, the United Kingdom and France. Financial institutions from these four countries financed coal-fired power plants abroad with expected lifetime emissions of 18.3 Gt CO_2, 9.8 Gt CO_2, 4.5 Gt CO_2 and 2.1 Gt CO_2, respectively (see supplementary table 24). The differences ('emission transfers') between finance-based and territorial emission accounting add up to 43 Gt CO_2.

3. Discussion and conclusion

Reducing global coal consumption, particularly in the power sector, constitutes one of the most important entry points for ambitious mitigation pathways [2, 5]. Yet, continued financial support for coal plants undermines ambitious climate policy [43]. The analysis shows that this support to a large extent stems from actors based in Annex I countries to the United Nations Framework Convention on Climate Change [26].

Despite the complexity and the dynamics of the financial system one can draw important insights from this paper. Our approach to account for finance-based emissions serves as an illustration that a sizable quantity of emissions falls under the jurisdiction of

governments outside the territory where these emissions occur. In particular, some Annex I parties that have substantially reduced their emissions from coal and are members of the Powering Past Coal Alliance [44] nevertheless host financial institutions that keep financing the construction of new coal-fired power plants abroad. Arguably, investors and ownership structures might change over time, for example as shares in developers are tradable. However, it is unlikely that this general picture will change dramatically in the short to medium term.

Understanding the international dimension of financial support for coal raises important questions of how governments could incentivize banks and investors to favour climate-friendly investments. Standards and risk management frameworks are solutions that also benefit commercial banks [45, 46]. Systematic accounting for emissions can help financial institutions to better evaluate the risk of climate change (and future climate policies) in their portfolios [47]. Already today, many financial institutions have stopped funding highly carbon intensive projects [48] or introduced emissions standards. Several networks evolved to enhance voluntary contributions and commitment [49–51]. Introducing harmonized and binding reporting standards for emissions embedded in financing activities, as for instance outlined by the G20 Task Force on Climate-Related Financial Disclosure [52], could hence be an important first step to inform financial markets about the actual finance-based emissions.

Yet, accounting and reporting might, by itself, not affect financial support for coal-fired power plants. Effective policies should be introduced timely [53, 54]. While in theory a global carbon price would be the optimal instrument for climate change mitigation [55, 56], it is not likely to be implemented anytime soon. Some alternatives are discussed in the literature that could tackle international financial flows for coal-fired power plants specifically, including investment taxes [57]. De-risking alternatives [25], such as renewable energies, investments into the electricity grid and storage facilities [58], emission standards or bans on new coal power plants [59], as well as feebate programs and mandates for new plants [60] might be further alternatives.

Understanding how specific policy instruments, such as taxes on financial flows, mandatory shadow prices on investments or even moratoria could effectively address the internationality of capital flows for coal plants might be a fruitful area of future research. Future studies could further try to broaden the data base and thus draw a more comprehensive picture of the capital flows and assess different policy options. For example, including development banks might give a more adequate picture. More detailed company level information would allow for a more precise allocation of financing to projects and thus emissions. The finance-based accounting approach presented in this paper could then be an even more useful tool to assess the climate implications of investments in coal-fired power plants.

Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors with permission of urgewald e.V. and the Global Energy Monitor.

Acknowledgments

The authors would like to thank urgewald and the Global Energy Monitor for providing the underlying data. The authors acknowledge funding from the German Federal Ministry of Education and Research (BMBF), funding code 01LA1826A (PEGASOS). The authors would like to thank the participants of the following events for their valuable feedback: 7th International Symposium on Environment and Energy Finance Issues in Paris 2019; General Conference of the European Consortium for Political Research in Wroclaw 2019; Expert Workshop on Financial markets, financial sector and climate finance 2020 as part of the Dialogue on the Economics of Climate Change initiated by the BMBF. NM gratefully acknowledges the support of the Heinrich Böll Foundation.

Authors contributions

All authors conceived and planned the project. NM developed the code and carried out the analyses. All authors wrote the paper.

Conflict of interest

The authors declare no competing interests.

Code availability

We developed scripts for Python 3.7 that are publicly available on GitHub: https://github.com/niccoloMG/financed-based_coal_emissions

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