Energy Transition and the Changing Cost of Capital: 2023 Review

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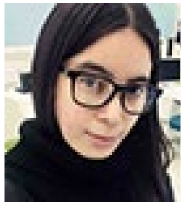

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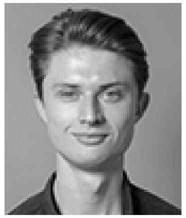

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Executive Summary

We need to accelerate investment in low-carbon energy. The energy crisis created by Russia's war against Ukraine has demonstrated the urgency of weaning the world off fossil fuels. A higher share of low-carbon energy in the mix can reduce exposure to volatile fossil fuel prices and deliver enhanced energy security, while contributing to the realisation of net zero commitments and the avoidance of the worst climate outcomes.

To accelerate the shift, the cost of capital for low-carbon as opposed to high-carbon energy needs to fall, given that it is a key transmission mechanism between the financial system and the real economy, affecting the investment decisions of both financial institutions and corporates. This is crucial, given that most low-carbon energy options are capital expenditure heavy, and that a higher cost of capital impacts low-carbon energy options more than high-carbon equivalents.

The energy crisis created by Russia's war against Ukraine has demonstrated the urgency of weaning the world off fossil fuels

Thus as policymakers guide the economy towards net-zero emission targets, **it is important to track the changes in the cost of capital** by technology, sector, region, and asset class:

1. To identify if current or past interventions have been successful at increasing relative risk premias for high carbon energy and lowering them for low;
2. To assess if the effect of energy transition risks varies geographically and identify the jurisdictions that have and have not decreased financial costs for low carbon energy; and
3. To learn if and how financial institutions respond to energy transition risks differently since they determine a firm's cost of capital by assessing the risk of its cash flows relative to other available investment opportunities.

Transition risks can affect the cost of debt by increasing the spread due to higher credit or default risk and the cost of equity by affecting the variability of future earnings.

As part of the Energy Transition Risk and Cost of Capital Programme (ETRC), **in 2021 we published our first report tracking the cost of debt in the energy sector**. Using loan data over the last twenty years, we found that not only had the cost of capital for solar and wind energy fallen over the last decade but it had also risen for coal mining and coal-fired power generation. We also found that the cost of capital for oil & gas remained consistently stable, albeit with significant variation between regions and types of project (e.g. onshore vs offshore).

Our 2023 report extends the scope of analysis to the cost of equity as well as expanding our analysis of the cost of debt. In this process, we looked at corporate bonds and included data from other sources, including the Platts World Electric Power Plants Database (WEPP) and the Institutional Brokers' Estimate System (IBES). We tracked the cost of capital across the global energy system in both electric utilities (renewable and fossil fuel) and energy production (oil & gas, coal mining, and renewable fuels & technology).

To identify different types of companies and assets, we used the Refinitiv Business Classification (TRBC) sector classification[1]. To differentiate between companies in these sectors, we used Scope 1 and 2 carbon emission intensity as well as the proportion of solar and wind capacity in the energy mix. The measures, definitions, models, and scope — for both cost of equity (CoE) and cost of debt (CoD) — are summarized in the table below. The key idea behind the variety of analysis was to examine not only past performance but also future financial institution expectations. Furthermore, this helped us verify our results from many different perspectives, making them more robust.

[1] TRBC sector classification was originally developed by the Reuters Group and has been owned by Refinitiv since 2018. It is the basis for Refinitiv Indices.

Executive Summary

Cost of capital	Measures	Definitions/ implications	Analysis	Geography	Sample period
CoD in the secondary bond market	Bond spreads (bond yields minus treasury yields)	It reflects the *current* and *future* firm risks perceived by bond investors	TRBC sector analysis Emission intensity analysis Energy mix capacity analysis	US	Jul2002 - Dec2021
CoD in the corporate bond and loan markets (i.e., accounting CoD)	Interest paid divided by total debt outstanding (bonds & loans)	It reflects the *past* risks as interest paid in the present depend on past financial conditions	TRBC sector analysis Emission intensity analysis Energy mix capacity analysis	Global	Jan2000 - Dec2021
CoD in the syndi-cated loan market	Loan spread (loan yields minus LIBOR)	It reflects the *current* and *future* project risks perceived by banks	TRBC sector analysis	Global	Jan2020 - Dec2021
CoE in the equity market	Implied CoE estimated using the IBES earnings forecasts models	It reflects the *future* firm risks perceived by equity investors	TRBC sector analysis Emission intensity analysis Energy mix capacity analysis	Global	Jan2000 - Dec2021

Electric Utilities

Globally, renewable electric utilities continue to have a lower cost of capital than those relying on fossil fuel.

The cost of debt of renewable electric utilities is at 6%, compared to 6.7% for fossil fuel electric utilities (Figures 1 and 2). Similarly, utilities focused on renewables have a cost of equity lower than those relying on fossil fuel (15.2% vs 16.4%).

FIG 1. ACCOUNTING COST OF DEBT, GLOBAL TREND TRBC CLASSIFICATION

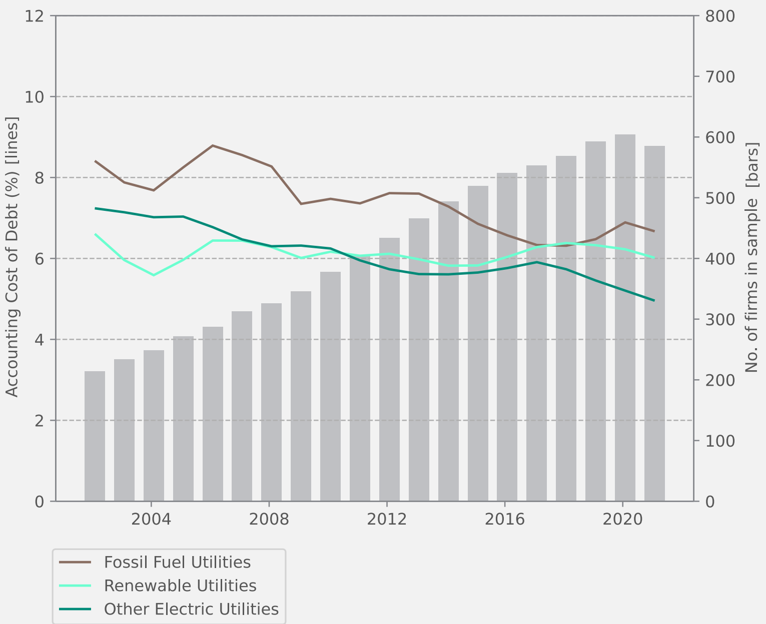
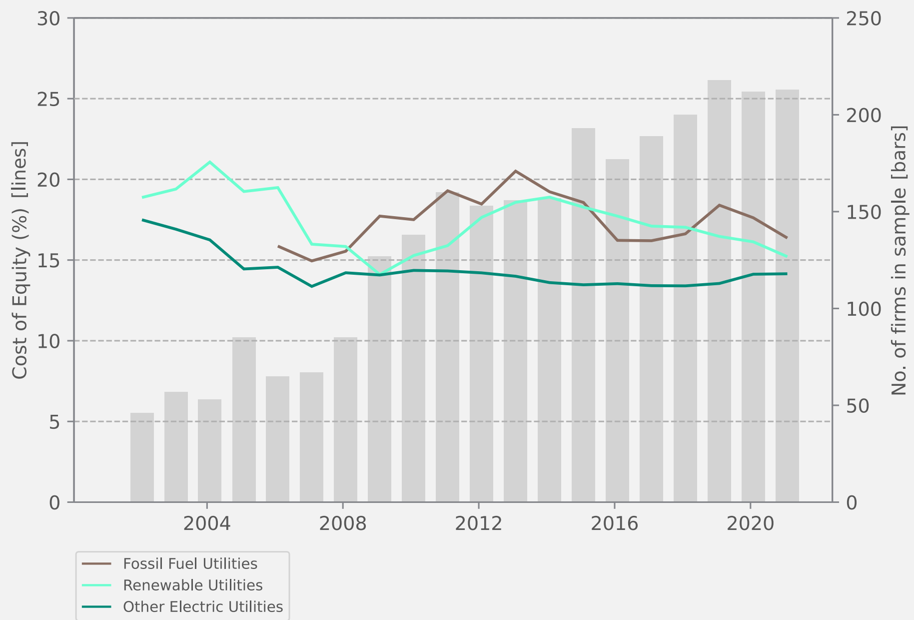


FIG 2. COST OF EQUITY, GLOBAL TREND TRBC CLASSIFICATION



There is significant variation in these trends across regions. **In Europe, low-carbon electric utilities have a lower cost of capital than their high-carbon peers.**

This trend is consistent across types of capital (i.e., debt vs equity) as well as the basis of comparison (i.e., emission intensity vs share of renewables). Based on emission intensity (Figures 3 and 4), by 2020, the gap between high and low emitters has fallen to 0.2%pts for cost of debt and grown to 5.4%pts for cost of equity. This could be because transition risk has been priced more over time for equity, whereas the impact on debt is harder to ascertain.

Similarly, based on the share of solar and wind in the energy mix (Figures 5 & 6), by 2021, while the gap between high and low share companies has been persistent, it has fallen to 0.85% for cost of debt, and grown to 4.3% for cost of equity. When using a broader low-carbon energy mix – including nuclear, geothermal, hydro, and biomass beyond solar and wind – consistent results are observed, with a gap of 0.5% for cost of debt and 3.1% for cost of equity.

In North America the cost of capital of low-carbon electric utilities is no lower than high-carbon peers. (This continues a similar trend observed in our 2021 report.)

Based on emissions intensity (Figures 7 & 8), the cost of capital of the top and bottom 50% of emitters is effectively equal. While the cost of equity of lower emitters fell marginally below highest emitters in 2014, this gap closed in 2020. In our 2021 report, we found a similar trend in North America: the loan spreads for solar and wind power plants, ranging between 2.2%pts to 2.9%pts, were comparable to those of gas power plants.

FIG 3. ACCOUNTING COST OF DEBT, EUROPE
SCOPE 1 & 2 EMISSION INTENSITY

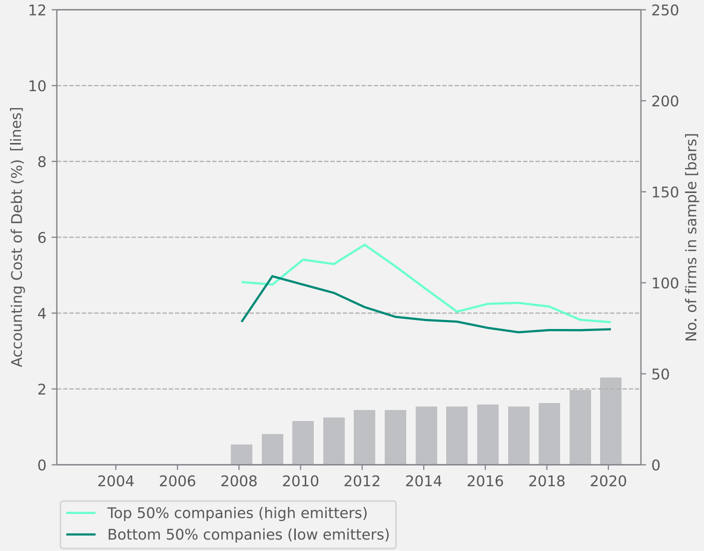


FIG 4. COST OF EQUITY, EUROPE
SCOPE 1 & 2 EMISSION INTENSITY

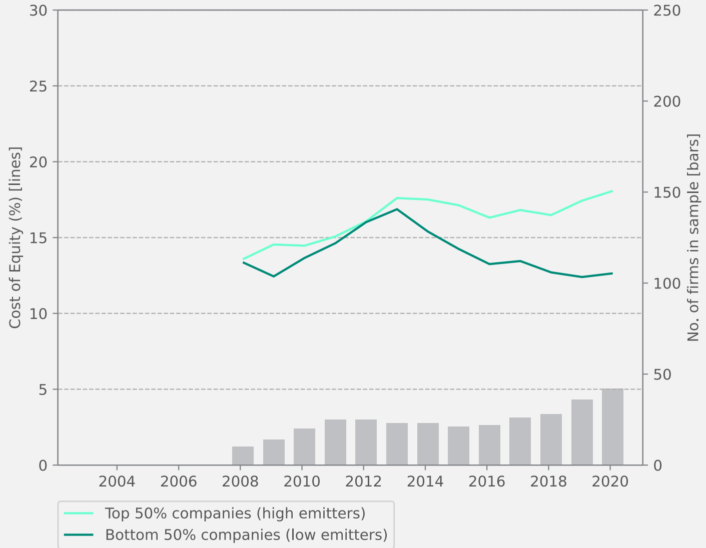


FIG 5. ACCOUNTING COST OF DEBT, EUROPE SOLAR & WIND % IN ENERGY MIX

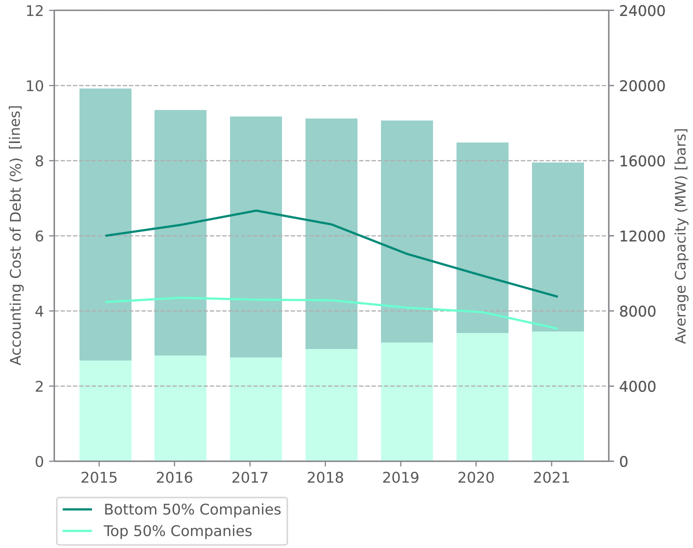


FIG 6. COST OF EQUITY, EUROPE SOLAR & WIND % IN ENERGY MIX

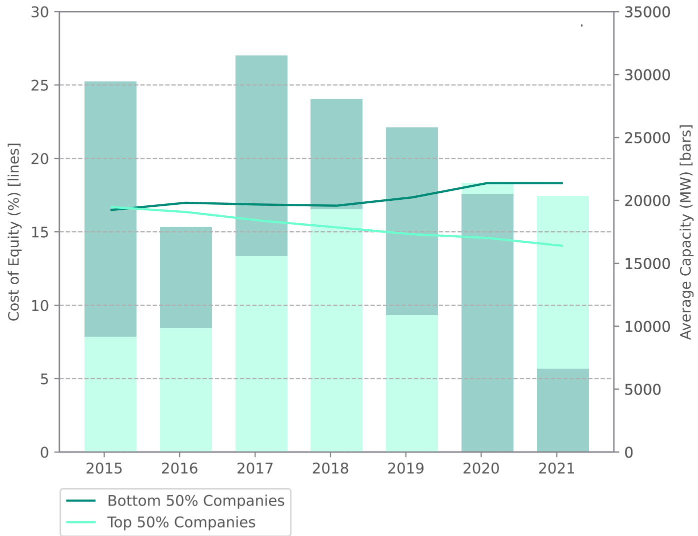


FIG 7. COST OF EQUITY, NORTH AMERICA SCOPE 1 & 2 EMISSION INTENSITY

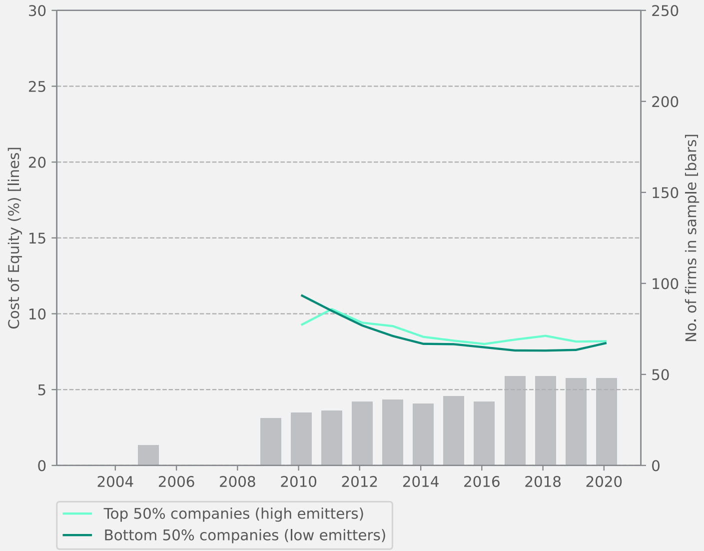
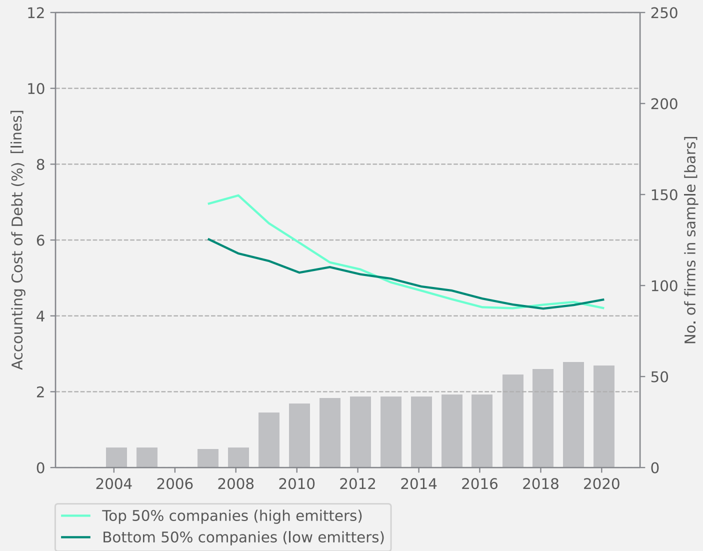


FIG 8. ACCOUNTING COST OF DEBT, NORTH AMERICA SCOPE 1 & 2 EMISSION INTENSITY



Based on the share of solar and wind in the energy mix, the cost of capital of the top and bottom 50% companies is similar. Companies with a greater allocation to solar and wind in the energy mix have had a marginally lower cost of debt since 2015, with a gap of 0.4% in 2021 (Figure 9). This gap is even lower —close to zero — for bond spreads. Based on a broader low-carbon energy mix — including nuclear, geothermal, hydro, and biomass — consistent results are observed, with gaps of 0.4% and 0.1%. For cost of equity, companies with a greater allocation to solar and wind in the energy mix have a marginally higher cost of capital, with this gap shrinking to nearly zero in 2021 (Figure 10). When using a broader low-carbon energy mix, this gap is again close to zero.

In China, a new finding is that low-carbon utilities have a higher cost of capital than high-carbon peers.

Renewable electric utilities have a higher cost of debt than fossil fuel and other electric utilities, as well as a higher cost of equity (Figures 11 & 12). Companies with a higher allocation to solar and wind in the energy mix have a higher cost of debt since 2019 (Figures 13 & 14), with the gap increasing to 0.7% in 2021. For cost of equity, this gap has grown to 4% in 2021. When using a broader low-carbon (including nuclear, geothermal, hydro, and biomass) energy mix, there is an 0.9% gap in 2021 for cost of debt, but close to zero for cost of equity.

Some implications of these findings are as follows. **First, there is significant variation in these trends across regions.** European trends probably dominate globally and are the most positive from a climate perspective. On the other hand, there are no discernible trends in North America and the trends in China are reversed. Furthermore, other emerging markets, such as LATAM and ASEAN, show signs that the renewable focused utilities have a higher cost of capital.

FIG 9. ACCOUNTING COST OF DEBT, NORTH AMERICA SOLAR & WIND % IN ENERGY MIX

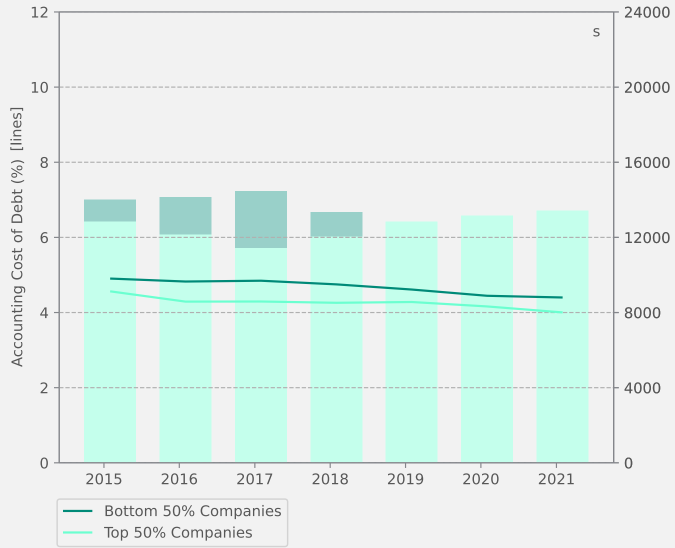


FIG 10. COST OF EQUITY, NORTH AMERICA SOLAR & WIND % IN ENERGY MIX

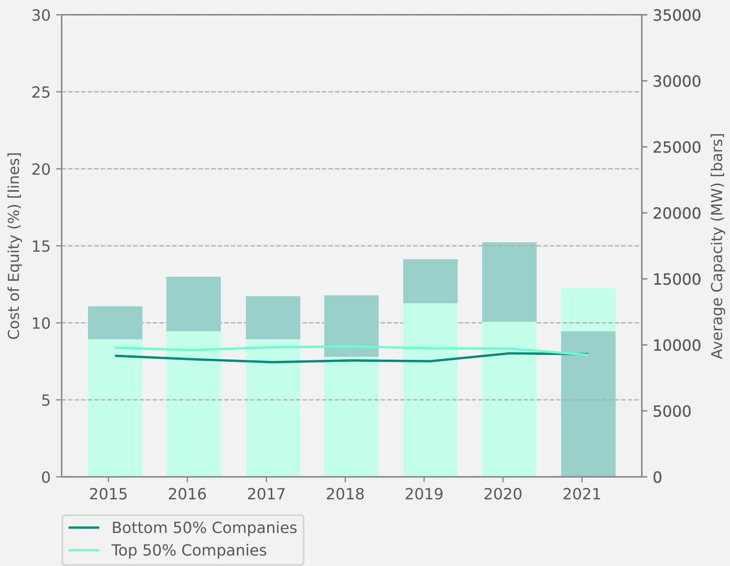


FIG 11. ACCOUNTING COST OF DEBT, CHINA TRBC CLASSIFICATION

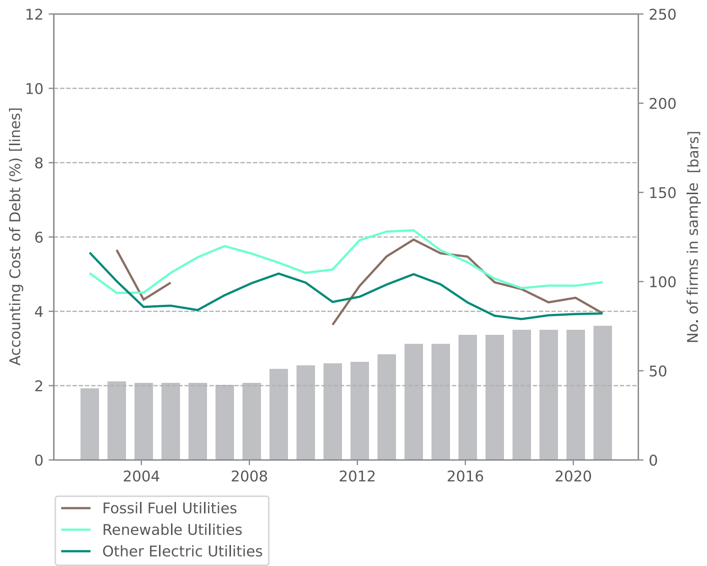


FIG 12. COST OF EQUITY, CHINA TRBC CLASSIFICATION

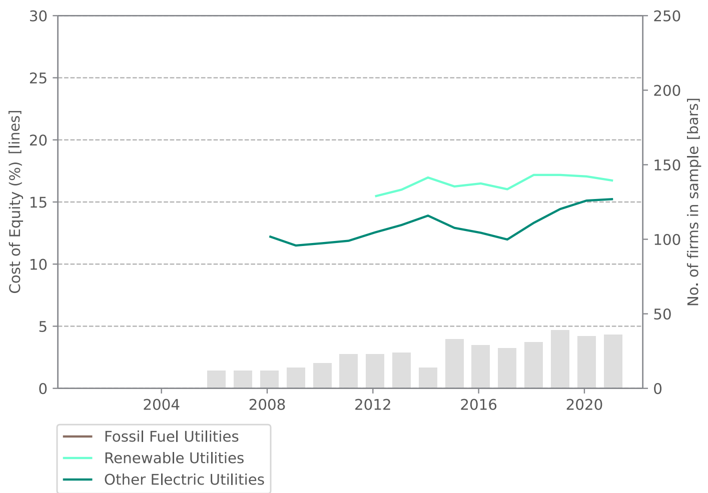


FIG 13. ACCOUNTING COST OF DEBT, CHINA SOLAR & WIND % IN ENERGY MIX

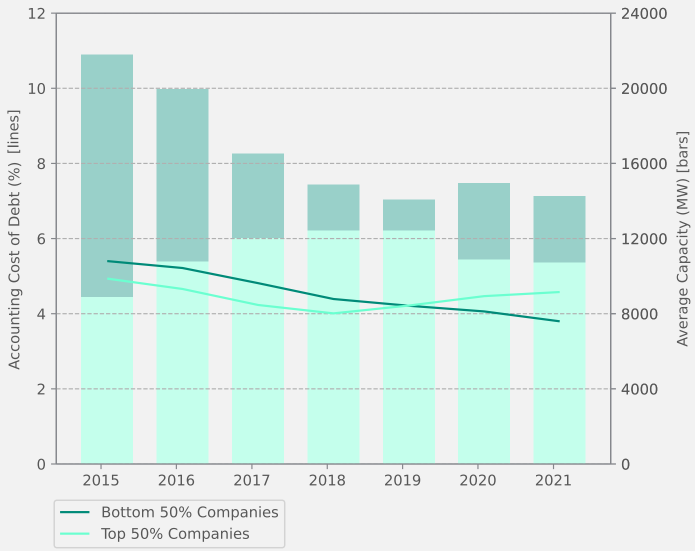
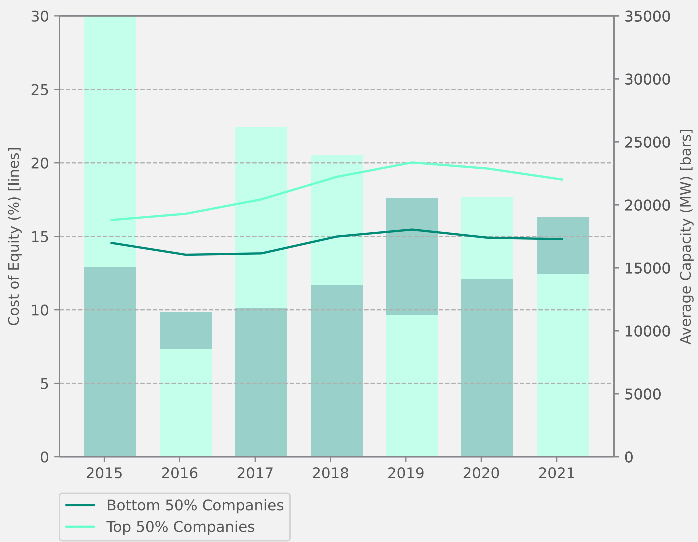


FIG 14. COST OF EQUITY, CHINA SOLAR & WIND % IN ENERGY MIX



Second, policies matter in influencing the cost of capital. In Europe, low-carbon electric utilities consistently have a lower cost of capital. This would imply climate change friendly actions (e.g., policies) have been successful at decreasing risk for low-carbon generation and increasing it for high-carbon peers. However, similar trends are not present in other regions where climate action has been less consistent (e.g., in North America), or where fossil fuel power has continued to grow (e.g., China). We are investigating the effect of climate change policy and other factors on the pricing of energy transition risk in a separate study that is a work in progress. Our preliminary findings support the implication that stronger climate change policy reduces the cost of capital for renewable firms. We also separately assess the impact of changes in the cost of capital on the ability of companies to transition from high-carbon to low-carbon assets in the power sector. This study is also forthcoming. These reports are planned to publish in 2023.

Third, other factors (e.g., firm size) may be at play. While in this report we do not conduct nuanced analysis to explain factors behind these trends, the differences in the cost of capital may be due to diversification by large firms into low-carbon energy, which itself could be driven by climate action at country and regional levels. In Europe, companies most diversified into renewables are also the largest firms, which we would expect to have lower risk to begin with due to the size advantage. Within the context of the European energy crisis sparked by the Russian invasion of Ukraine, this suggests those companies able to obtain the cheapest capital to replace Russian energy, through additional renewable generation, are those already most invested in renewables.

Our preliminary findings support the implication that a stronger climate change policy reduces the cost of capital for renewable firms

Energy Production

Globally, coal mining has the highest cost capital within the energy sector.

The cost of debt of coal mining has increased to 7.9% in 2021, while the cost of equity has increased to 18.2% (Figures 15 & 16). Since the Paris Agreement was signed in 2015, this increase is significant. Furthermore, while renewable fuels & technology has a cost of capital below oil & gas production and coal mining, it is above oil & gas services.[2] This also implies oil & gas production has a higher cost of capital than oil & gas services, which is true for the cost of debt since 2006, whereas for the cost of equity the divergence has occurred since 2016. This could show that transition risks are being reflected in the cost of capital for coal mining but are not as pervasively reflected in the cost of capital for oil & gas.

FIG 15. ACCOUNTING COST OF DEBT, GLOBAL TREND TRBC CLASSIFICATION

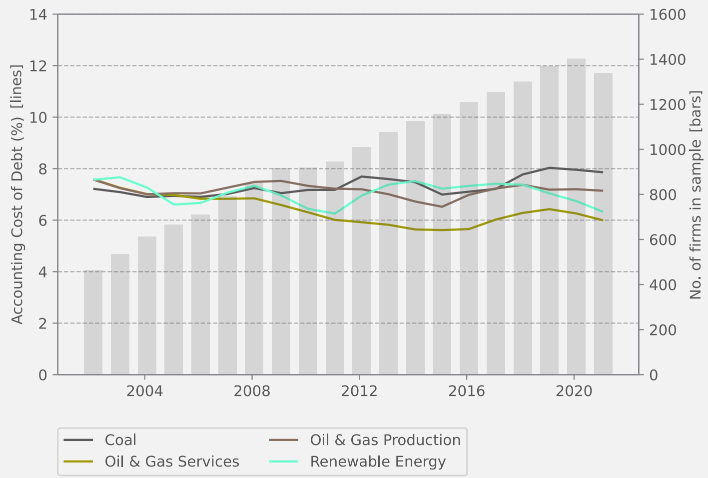
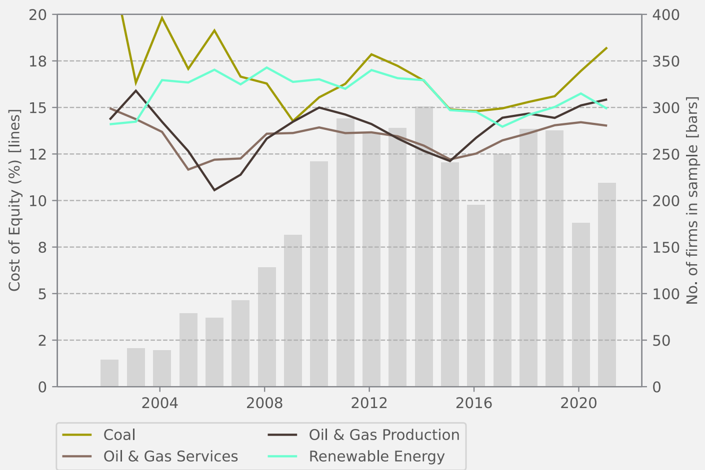


FIG 16. COST OF EQUITY, GLOBAL TREND TRBC CLASSIFICATION



[2] Oil & gas production encompasses exploration & production, refining & marketing, and integrated oil & gas. Oil & gas services encompasses oil & gas drilling, equipment & services, and transportation. Renewable fuels & technology encompasses biodiesel, biomass & biogas fuels, ethanol fuels, geothermal equipment, hydropower equipment, stationary fuel cells and renewable energy equipment & services. We use the term renewable energy in the charts for simplicity.

In Europe, similar trends are observed. In addition, higher emitters face a higher cost of capital.

Coal mining and oil & gas production have the highest cost of capital compared to renewable fuels & technology and oil & gas services (Figures 17 & 18). All oil & gas activities except exploration & production have seen decreasing costs of debt between 2002 and 2021. As a result, there is a significant gap between upstream exploration & production (8%), midstream transportation (4.1%) and downstream refining & marketing (5.1%). Similarly, since 2016, the cost of equity of exploration & production also increased relative to the rest of the sector.

Oil & gas producers with more carbon-intensive operations have a higher cost of debt. That of the top 50% of emitters rose above the lowest 50% in 2016, with a gap of 1% in 2020 (Figure 19). For the cost of equity, there is a similar persistent gap over the past decade, with a slight decline in recent times (Figure 20). This indicates that the transition risks may be being priced into the cost of debt as well as equity.

FIG 17. **ACCOUNTING COST OF DEBT, EUROPE, TRBC CLASSIFICATION**

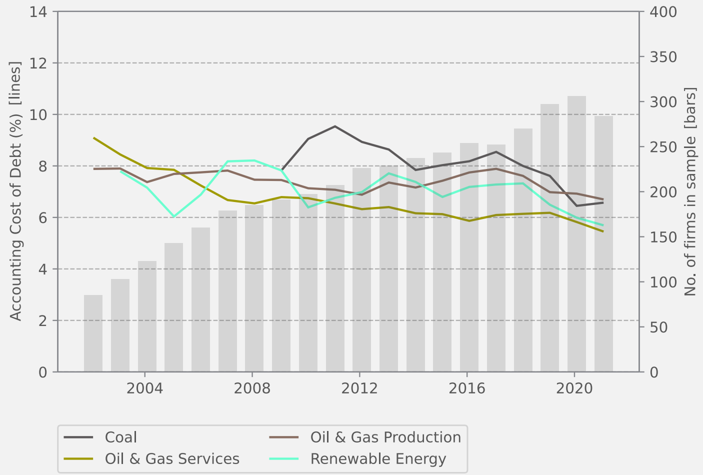


FIG 18. **COST OF EQUITY, EUROPE TRBC CLASSIFICATION**

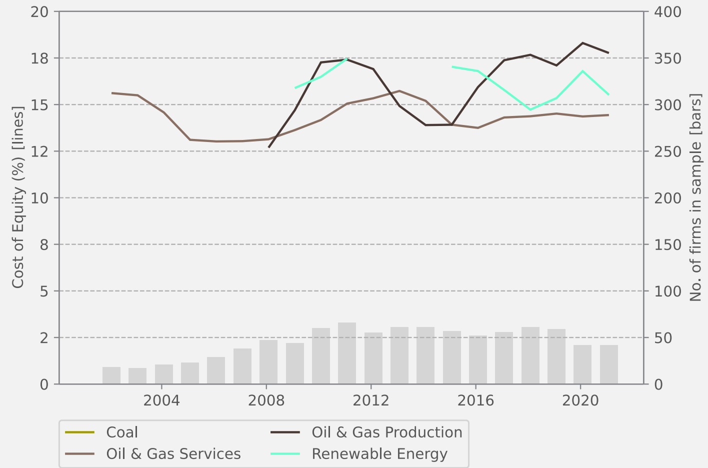


FIG 19. **ACCOUNTING COST OF DEBT, EUROPE, SCOPE 1 & 2 EMISSION INTENSITY ANALYSIS**

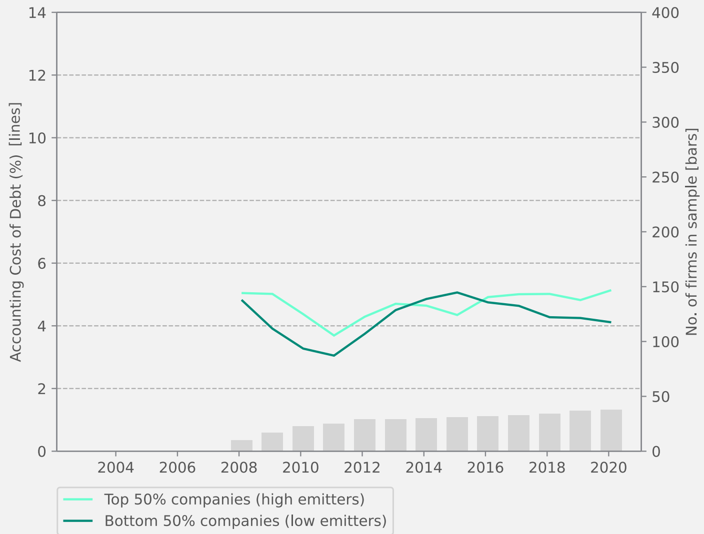
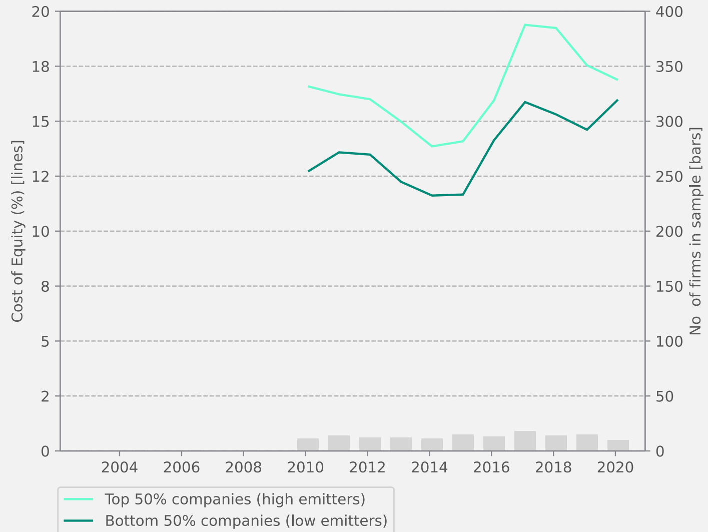


FIG 20. **COST OF EQUITY, EUROPE SCOPE 1 & 2 EMISSION INTENSITY ANALYSIS**



In North America, similar trends are observed except that renewable fuels & technology have the highest cost of capital, plus the cost of equity does not appear to reflect transition risk for higher emitters.

Coal mining and renewable fuels & technology have the highest cost of debt at 10% in 2021 (Figures 21 & 22). Furthermore, both sectors show significant volatility relative to oil & gas production and services, sectors with much lower cost of debt at 8.7% and 6.7%, respectively. For cost of equity, while there is not enough data for coal mining or renewable fuels & technology; consistent with the cost of debt, we observe a persistent gap between oil & gas production and services, with cost of equity for both increasing sharply since 2016.

FIG 21. ACCOUNTING COST OF DEBT, NORTH AMERICA TRBC CLASSIFICATION

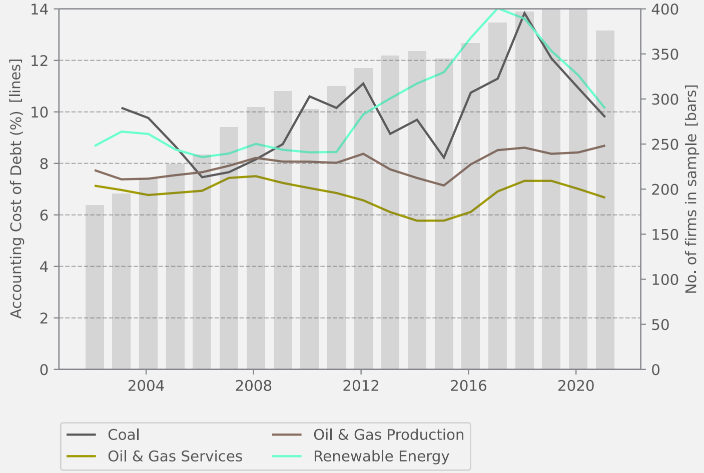
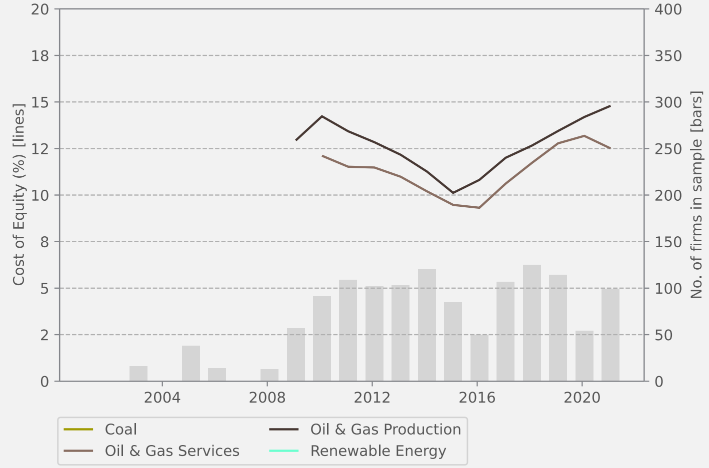


FIG 22. COST OF EQUITY, NORTH AMERICA TRBC CLASSIFICATION



Within oil & gas, there is divergence between exploration & production and drilling with respect to midstream transportation and downstream refining. Since 2015, exploration & production has observed the highest cost of debt, rising to 9.3% in 2021, while oil & gas drilling rose to 8.2%. With regard to cost of equity in 2021, there has been a steady rise since 2016, with exploration & production and refining being in 2021 the highest subsectors at 14.7% and 15.1%, respectively.

Like Europe, oil & gas producers with more carbon-intensive operations have a higher cost of debt (Figure 23). That of the top 50% of emitters has been consistently above the lowest 50% since 2008, with a gap of 0.9% in 2020. However, unlike Europe, the cost of equity for the top and bottom 50% is effectively equal (Figure 24), highlighting that the higher transition risks may have been factored into cost of debt but not into cost of equity.

Like Europe, oil & gas producers with more carbon-intensive operations have a higher cost of debt

FIG 23. ACCOUNTING COST OF DEBT, NORTH AMERICA SCOPE 1 & 2 EMISSION INTENSITY ANALYSIS

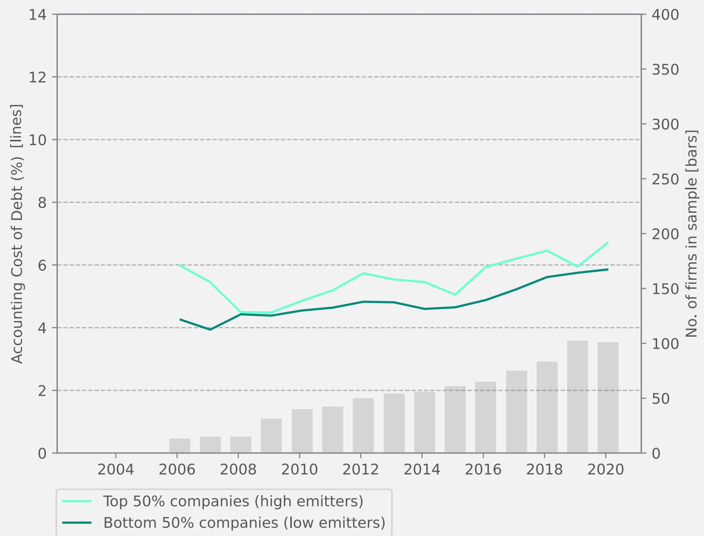
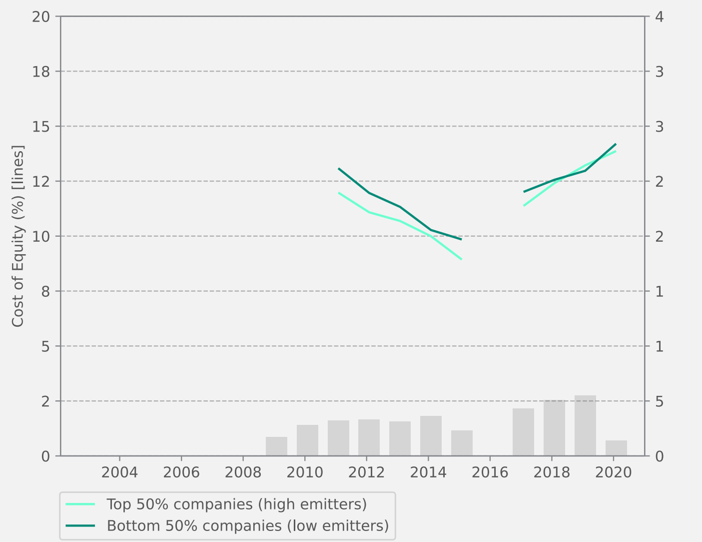


FIG 24. COST OF EQUITY, NORTH AMERICA SCOPE 1 & 2 EMISSION INTENSITY ANALYSIS



In China, the cost of capital for low-carbon firms is not lower than for high-carbon peers.

The cost of debt for coal mining has remained stable over the past decade. In fact since 2017 it has fallen below that of oil & gas production (Figures 25 & 26). Also, since 2017, the cost of equity for coal mining has been similar to that for oil & gas services. This is to be expected, given the significant role coal plays within China. For renewable fuels & technology, analyses of both the cost of debt and equity show similar trends, with the cost of debt of renewable fuels & technology equal to that of oil & gas services. The cost of equity, however, is consistently higher.

The cost of debt for coal mining has remained stable over the past decade.

FIG 25. **ACCOUNTING COST OF DEBT, NORTH AMERICA TRBC CLASSIFICATION**

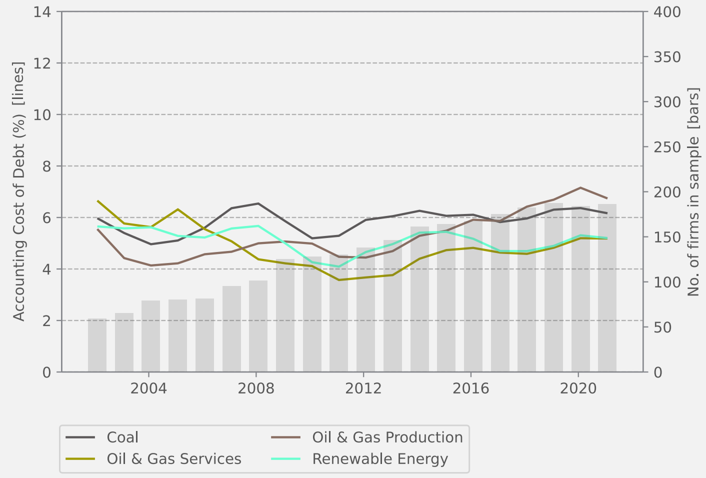
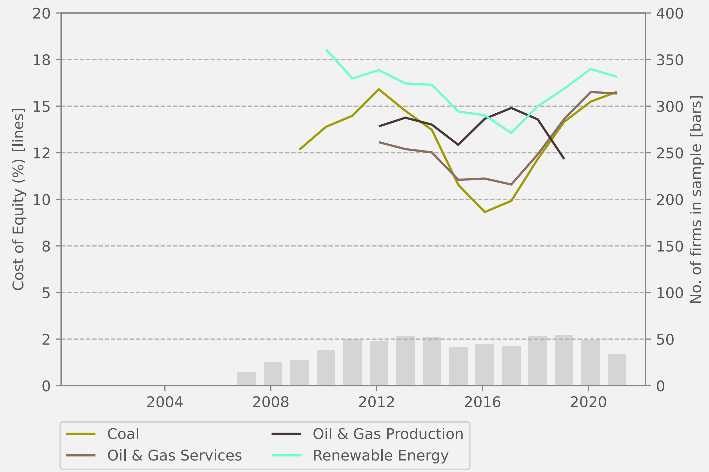


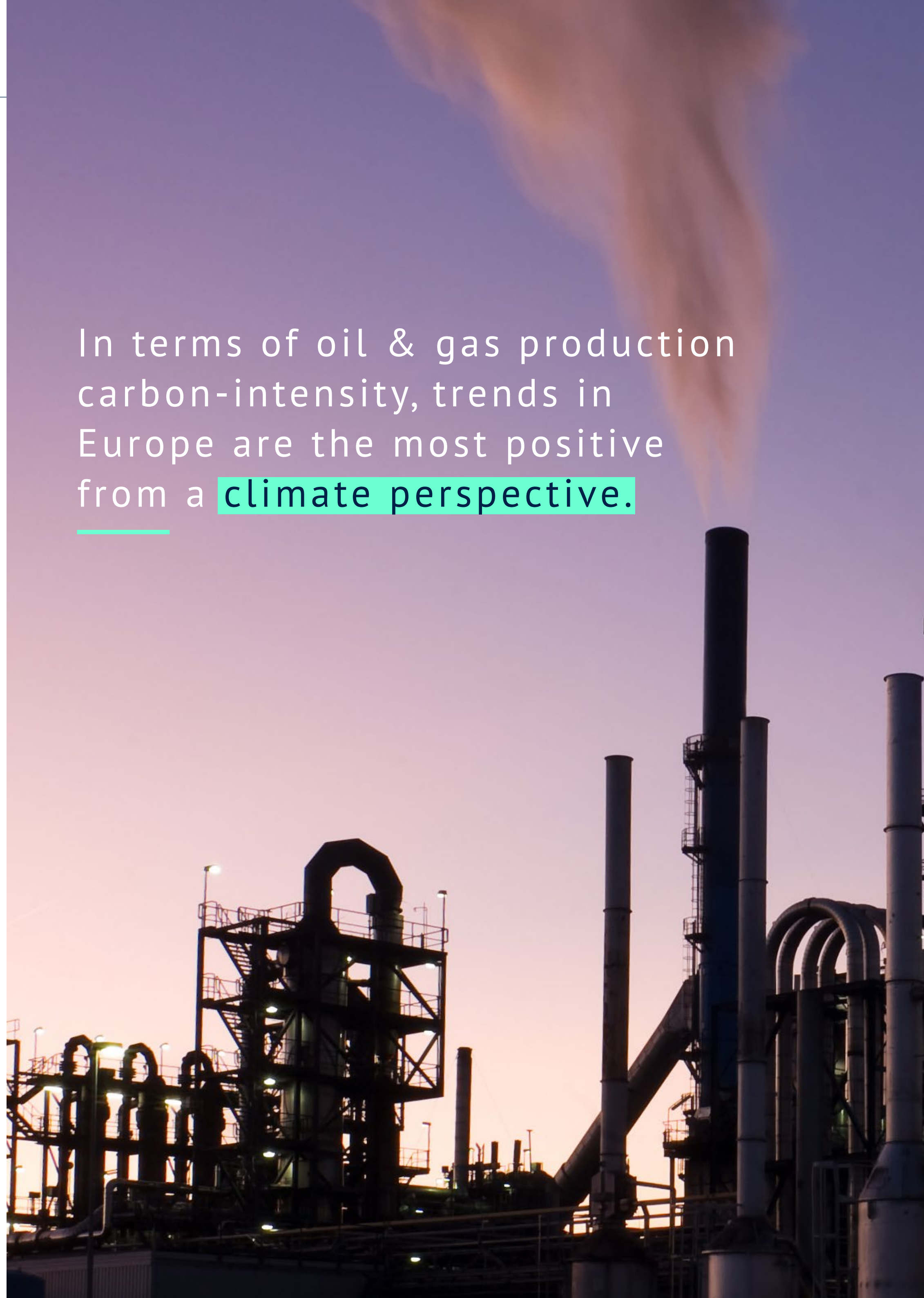
FIG 26. **COST OF EQUITY, NORTH AMERICA TRBC CLASSIFICATION**



Some implications of these findings are as follows. **First, at the sector level, while there is some regional variation, in line with electric utilities, there are common themes.** In terms of oil & gas production carbon-intensity, trends in Europe are the most positive from a climate perspective. There is, however, a consistent spread between oil & gas production and services across regions and a high cost of capital for coal mining. Furthermore, in most regions, the cost of capital for renewable fuels & technology is either above or equal to that for oil & gas. This suggests that lower transition risk does not compensate for other forms of investment risk, such as those associated with emerging technologies.

Second, it is becoming increasingly risky to invest in carbon-intensive operations. The growing gap in the cost of capital between the highest and lowest emitters suggests that companies with less efficient operations, or those investing in carbon-intensive unconventional oil & gas, are being perceived as higher risk.

Third, it is becoming increasingly risky to invest in capital intensive upstream activities in the oil & gas industry. There is a consistent gap between exploration & production and other parts of the industry which has widened over the past decade in Europe and North America, with increases seen across all regions in the past five years. While the pricing of stranded asset risks may have influenced this change, the oil price crash of 2014/2015 is likely to have played a significant role. This difference in the cost of capital is expected given the higher risk (capital-intensive) nature of exploration & production relative to midstream and downstream activities, making financing of the development of further oil & gas reserves more costly. This is key in the context of 1.5C scenarios, such as the IEA Net Zero by 2050, which states that from 2021 the development of new oil & gas reserves is no longer required to meet demand.



Contents

1 Introduction

The Russian war against Ukraine has driven oil & gas prices to their highest levels in a decade, motivating economies to wean themselves from fossil fuels and shift capital flows to clean energy. To accelerate this transition, investment flows must be directed from high to low carbon energy. In this context, the cost of capital is a key transmission mechanism between the financial system and the real economy, affecting the investment decisions of both financial institutions and corporates, thereby requiring a fall in the cost of capital for low-carbon energy and an increase in its cost for high-carbon energy.

Financial institutions play a key role in shaping climate actions and the energy transition (Bolton and Kacperczyk, 2021). Investors determine a firm's cost of capital by assessing the risk of its cash flows relative to other available investment opportunities. Broadly speaking, firms are financed through debt or equity capital: the former can come from issuing debt securities including bonds and loans; the latter is the return investors require from investing/holding a public firm's shares.

Investors determine a firm's cost of capital by assessing the risk of its cash flows relative to other available investment opportunities.

How is the cost of capital changing for low-carbon compared to high-carbon investments across asset classes? Knowing this is essential to, for instance, identify transformational interventions and understand whether current or past interventions (e.g., campaigns and policies) have been successful at increasing risks for high carbon emission activities, and lowering risks for low carbon equivalents. Regulatory and reputational risks of energy transition among others determine the cost of capital and access to capital (van Benthem et al., 2022). Oil and gas firms and fossil fuel-based power generators are a major source of carbon emissions and are thus directly exposed to transition risks as policymakers guide the economy towards net-zero emission targets. In contrast, renewable energy firms stand to benefit from such carbon regulations as feed-in tariffs.

Transition risks can affect the cost of debt by increasing the spread due to higher credit or default risk (Umar et al., 2021; Bolton and Kacperczyk, 2021; Palea and Drogo, 2020). Transition risks are likely to impact the cost of equity by affecting the variability of future earnings ((Bolton and Kacperczyk, 2021; Kim, An, and Kim, 2015; Bui, Moses, and Houqe, 2020; Gupta, 2018). Further, Campiglio, Monnin, and Jagow (2019) reviewed the empirical evidence on the link between transition risks and financial asset prices and suggested that they could increase default probabilities and decrease equity return for some firms. The increased focus on climate-related considerations differs across financial institutions; and the impact of climate risks on the cost of capital may vary across asset classes (van Benthem et al., 2022). For example, Kling et al. (2021) document that climate-related vulnerability increases the cost of debt directly and indirectly through its impact on restricting access to finance; however, its effect on the cost of equity is limited.

In this report, following up from our 2021 ETRC report, we expand the scope of the cost of capital tracking to equities, corporate bonds, and accounting data in electric utilities and energy production sectors globally. Furthermore, in addition to using sector classification, we use carbon-intensity and energy mix to differentiate between companies. Expanding the scope of the analysis to additional asset classes and methods improves the robustness of our findings, and enables us to shed light on how the cost of capital differs depending on sector, region, and company characteristics. This could provide insights on the impacts of climate policy, how financial institutions respond to energy transition risks, and whether such responses vary across asset classes.

In this report, following up from our 2021 ETRC report, we expand the scope of the cost of capital tracking to equities, corporate bonds, and accounting data in electric utilities and energy production sectors globally.

2 Methods and Data

In contrast to the 2021 ETRC report's focus on loan spreads only, here four different approaches to measuring and tracking the cost of capital in the energy sector are used: accounting cost of debt, secondary market bond spreads, syndicated loan transactions, and implied cost of equity. By using multiple types of analysis, we aim to improve the robustness of results, improve coverage, and provide additional insights. Details of these methods are provided below.

2.1 ACCOUNTING COST OF DEBT

This method uses accounting data provided by Refinitiv's Eikon to calculate the corporate cost of debt, denoted "accounting cost of debt." As in (Polzin et al., 2021), for company in year this is defined as:

$$\text{ACCOUNTING COST OF DEBT}_{i,t} = \frac{\text{INTEREST EXPENSE}_{i,t}}{\text{OUTSTANDING DEBT}_{i,t}}$$

The sample is based on all publicly listed companies within the energy and electric utilities sector in Refinitiv's Eikon as of March 2022, according to The Refinitiv Business Classification (TRBC) sector classification. This is assessed on an organization's primary business activity. Where organisations have multiple business segments, the classification is selected according to the largest revenue contribution. Out of these approximately 3,000 companies, accounting data between 2000 and 2021 is available for 2,573, as displayed in Table 1. Due to large variations in the data, we bound the accounting cost of debt between 0 and 1 and winsorize the data at 5% and 95% levels, respectively.

In the 2021 ETRC report, only loan transactions were used to calculate the cost of debt; we encountered issues such as low coverage in emerging markets and high variability in companies issuing loans year-on-year. The advantage of using the accounting cost of debt is that it encompasses both bonds and loans, allowing a firm-level time series to be constructed which provides a more stable sample over time, and has greater global coverage. Tackling such issues improved the robustness of our findings.

However, the accounting cost of debt is not without drawbacks. Each year, it reflects current and past conditions, as interest expenses paid depend on past financing conditions when loans or bonds were arranged. Therefore, changes in the perception of firm-level risks are reflected only when companies raise new debt, resulting in a potential lag regarding the impact of changes in risk perception.

TABLE 1

ACCOUNTING COST OF DEBT SAMPLE

Unique Companies								
TRBC industry group	**Africa**	**Asia**	**Europe**	**Latin America**	**Middle East**	**Northern America**	**Oceania**	**All Regions**
Coal Mining	6	122	15	1	0	21	25	**190**
Renewable Fuels and Technology	0	115	73	2	9	89	0	**288**
Oil & Gas Production	22	245	170	31	41	387	67	**963**
Oil & Gas Related Equipment and Services	3	145	100	5	15	187	6	**461**
Other Electric Utilities	6	115	135	67	24	73	7	**427**
Fossil Fuel Electric Utilities	1	30	0	4	2	0	0	**37**
Renewable Electric Utilities	1	115	73	11	14	20	10	**207**
Total	**39**	**866**	**504**	**120**	**98**	**762**	**113**	**2573**

2.2 SECONDARY MARKET BOND SPREADS

In line with existing literature (Borisova and Megginson, 2011; Chen and King, 2014; Kabir, Li, and Veld-Merkoulova, 2013; Qi, Roth, and Wald, 2010), we proxy secondary market cost of debt based on bond spreads. Bond spreads change in the secondary bond market as market participants price the perceived credit risks associated with issuers. The advantage to using secondary market trade data is that – unlike the accounting cost of debt, which is backwards looking – it reflects current changes in perceived risks by debt investors, acting as an effective measure of the marginal cost of debt, i.e., how expensive it is to take on new debt at a given moment. Therefore, bond spreads may provide a more accurate picture of how the cost of capital is changing in different sectors, allowing us to supplement the more backward-looking measure of accounting cost of debt, thus improving the robustness of our findings. However, the major limitation is the availability of secondary market bond data in regions outside of the US, resulting in our analysis being restricted to bonds traded in the US.

For this, we use the Trade Reporting and Compliance Engine (TRACE) database, a US mandatory reporting vehicle for over-the-counter transactions of fixed-income securities implemented by the Financial Industry Regulatory Authority (FINRA). We filter all reported trades in TRACE for non-discontinued, non-closed and non-exchanged bonds issued by either electric utilities or energy producers using The Refinitiv Business Classification (TRBC). We take the yields from TRACE and subtract time-to-maturity-matched, interpolated, US treasury yields to obtain bond spreads. Using Refinitiv's Eikon database we assign each bond in our sample to its risk-bearing organisation, usually, the issuer of the bond.[3] We winsorize bond spreads at 1% and 99% to exclude negative spreads and eliminate errors, and resample the data based on the last observation per quarter[4] to obtain a time series for each bond. Further details of the methods used are provided in Annex 1. Table 2 presents the sample of US companies whose bonds were traded in the US between July 2002 and December 2021.

TABLE 2

US SECONDARY MARKET BOND SPREADS SAMPLE BY TRBC INDUSTRY GROUP

TRBC industry group	Unique US bonds	Unique US companies
Coal Mining	15	9
Renewable Fuels and Technology	35	9
Oil & Gas Production	671	120
Oil & Gas Related Equipment and Services	671	109
Other Electric Utilities	2364	195
Renewable Electric Utilities	0	0
Fossil Fuel Electric Utilities	1	1
Total	**3757**	**443**

[3] However, if we find a separate guarantor of the bond that is not the issuer, we take the guarantor instead. We make an exception to ensure bonds are not assigned to large financial institutions; if the guarantor does not operate in the electric utility or energy production sector, we assign the issuing company instead.

[4] Results are similar when using quarterly averages instead of last trade resampling.

2.3 SYNDICATED LOAN TRANSACTIONS

In this analysis, which is similar to our 2021 ETRC report, we extend the sample by two years. To outline key trends in the cost of debt in the loan markets, syndicated bank loan data is taken from LPC DealScan. The loan spread represents the loan yield over and above a floating rate, such as the LIBOR. The basic unit of observation in DealScan is a loan facility or a tranche grouped into deals. The sample from LPC DealScan includes loan pricing information on 1,286 loan tranches and 898 loan deals between Jan 2020 and Jan 2022, involving 635 borrowers across 46 countries in the energy and electric utilities sectors identified by (TRBC) sector identification. We then breakdown each category by loan issuer's business activities. Table 3 presents the details of sector and business activities classifications. Loan spreads data are winsorized at 1% and 99% to handle outliers.

Consistent with the 2021 ETRC report, we focus on the four industry groups within energy production: renewable energy (biofuels and renewable energy services), oil & gas production, oil & gas related equipment and services, and coal mining. Since the historical developments of loan spreads within the sector were already explored in last year's report, this year's focuses solely on the period from 2020 to 2021.The advantage of analysing loan transactions, in addition to the accounting cost of debt and bond spreads, is that we can identify loans for specific technologies.

Consistent with the 2021 ETRC report, we focus on the four industry groups within energy production

TABLE 3

DISTRIBUTION OF BORROWERS BY TRBC BUSINESS ACTIVITY

TRBC sector	TRBC industry group	Business activity	No. of deals	No. of borrowers
Power generation & other Electric Utilities	Renewables	Offshore wind	12	12
	Renewables	Onshore wind	20	16
	Renewables	Solar PV	40	37
	Renewables	Solar equipment	12	11
	Renewables	Wind equipment	1	1
	Renewables	Biopower	4	3
	Renewables	Hydropower	7	7
	Fossil fuel	Coal power plant	9	8
	Fossil fuel	Gas power plant	25	21
	Other electric utilities	Mixed powers	24	18
	Other electric utilities	Electric generation and services	149	103
	Total		**303**	**237**
Energy production	Renewable Fuels and Technology	Biofuels	3	3
	Renewable Fuels and Technology	Renewable energy equipment and services	3	3
	Oil & Gas Production	Oil Exploration & Production - Onshore	131	111
	Oil & Gas Production	Oil Exploration & Production - Offshore	1	1
	Oil & Gas Production	Natural Gas Exploration & Production - Onshore	9	7
	Oil & Gas Production	Oil & gas refining	109	78
	Oil & Gas Equipment and Services	Oil & Gas Drilling	12	10
	Oil & Gas Equipment and Services	Oil Pipeline Transportation	16	13
	Oil & Gas Equipment and Services	Natural Gas Pipeline Transportation	26	19
	Coal mining	Coal mining	20	18
	Others		94	27
	Total		**424**	**290**

Notes: The majority electric utilities borrowers are “Electric and gas utilities” and “Electric utility services” firms classified as “Other electric utilities.” We present only the trend in the loan spread with five or more deals within regions.

2.4 COST OF EQUITY

Finance literature defines the cost of equity (CoE) as the expected return on a company's stock. There are two methods of estimating the cost of equity: one is based on realised stock returns (i.e., the ex-post approach), the other on analysts'forecasts (i.e., the ex-ante approach).

The ex-post approach is used under the assumption that the average realized returns should be an unbiased estimator of the unobservable expected returns in an efficient market. However, estimates derived from average realized returns (i.e., CAPM and three-factor models) have been problematic due to the weak correlation between expected and realised returns (Elton, 1999) and the inaccuracy of estimates of factor loading and factor risk premia (Fama and French, 1997). To verify this claim, we used the CAPM model to estimate CoE and found these estimations very noisy and biased toward market return fluctuations, especially in less developed markets.

Due to these issues with the ex-post approach, we use the ex-ante equity valuation model to estimate the cost of equity implied in the current stock prices, future cash flows, and analysts' earnings forecast. An advantage of this approach is that it is inherently forward looking, so it should reflect investor expectations regarding future transition, as well as other, investment risks.

Following (Hail and Leuz, 2009; Cao et al., 2015; Dhaliwal et al., 2011), we use four models: an approach following Gebhardt, Lee and Swaminathan (2001) – r_{GLS} an approach based on the Easton (2004) implementation of Ohlson and Juettner (Ohlson and Juettner-Nauroth, 2005) model – r_{PEG}; an approach based on Ohlson and Juettner-Nauroth, 2005 – r_{GLT}; and an approach following Claus and Thomas (2001) – r_{CT}. We use the mean value of the above four measures of the implied CoE as our estimate of the cost of equity capital. Employing the average cost of equity estimates derived from four models decreases the likelihood of spurious results arising from the use of a particular model.

We collect analyst earnings forecasts and stock prices used to calculate the implied cost of equity from the Institutional Brokers' Estimate System (I/B/E/S) and obtain the equity book value (BV) and dividend per share from the Worldscope Database. Merging the I/B/E/S data with the Worldscope data, we document 582 listed firms in the energy sector and 361 in the electric utilities sector, resulting in a sample of 51,254 firm-year observations from Jan 2000 to Jan 2022. Table 4 presents the number of listed firms by TRBC business activity. The definitions of the above estimated cost of equity are presented in Annex 1.

TABLE 4

DISTRIBUTION OF LISTED FIRMS BY TRBC INDUSTRY GROUP

TRBC sectors	TRBC industry group	No. of listed firms
Energy Production	Oil & Gas Production	247
	Oil & Gas-Related Equipment and Services	246
	Renewable Fuels and Technology	89
	Coal Mining	77
Electric Utilities	Fossil Fuel Electric Utilities	48
	Renewable Electric Utilities	79
	Other Electric Utilities	234

2.5 ANALYSIS

TRBC Classification

In this report, three types of analysis are conducted. First, using TRBC classification, companies in different sectors are identified. To ensure an adequate sample size, a country is shown only if data is present for at least ten observations and a sector only if there are at least five observations. The cost of capital for a sector is obtained by averaging the cost of capital of companies within scope. Following this, a three-year moving average is taken.

Emissions Intensity

To differentiate between companies in each sector, emission intensity is used. This is calculated by dividing total Scope 1 and 2 CO2 equivalent emissions by revenue[5], with data taken from Eikon. To ensure an adequate sample size, at least ten data points must be present each year in each country or region. Companies are then split into the top and bottom 50% by emissions intensity in each year, and the average cost of capital of each group is then calculated. A 50% cut off was used to maximise the sample size available: this was required for the emerging market analysis due to paucity of data. Following this, a three-year moving average is taken. As we can identify loans transactions for specific technologies, emission intensity classification is not applied for loan analysis.

WEPP Energy Mix

Within the electric utilities sector, most companies are TRBC classified as "Other Electric Utilities," as many companies do not operate in one specific energy type, meaning one cannot clearly separate fossil fuel and renewable utilities companies. To differentiate between these, in addition to using emissions intensity, the World Electric Power Plants (WEPP) data provided by S&P Global Platts (now S&P Global Commodity Insights) is used to calculate the company-level energy mix between 2011 and 2021. This enables us to extract the percentage of operating capacity in wind and solar, or in low-carbon energy more broadly (i.e., nuclear, hydroelectric, geothermal, and biomass, in addition to solar and wind). In this analysis, we limited our sample to those companies with over 100MW in overall capacity. To ensure an adequate sample size, at least ten data points must be present each year in each country or region. Companies are then split into the top and bottom 50% by energy mix, and the average cost of capital of each group is then calculated. Following this, a three-year moving average is taken. As we can identify loans transactions for specific technologies, WEPP Energy Mix is not applied for loan analysis.

[5] Results are similar when using other emission intensity metrics, most notably emissions/total assets as well as emissions/operating assets.

3 Results

This section summarises key findings. Due to limited and inconsistent data coverage in emerging markets, the analysis is primarily focused on Europe, North America, and China. First, we present findings in electric utilities, followed by energy production. Within both, we show trends in the cost of debt (i.e., accounting cost of debt, bond spreads, and loan spreads) and cost of equity, both globally and by key regions. In Annex 2, we show charts for all regions.

3.1 Electric Utilities

3.1.1 GLOBAL
Accounting Cost of Debt

Globally, renewable electric utilities have a lower accounting cost of debt than fossil fuel focused peers in 2021, but one higher than "other" electric utilities with a diversified asset base. This trend is consistent with the finding of loan spreads in the 2021 report.

Using TRBC classification, we observe that the accounting cost of debt for fossil fuel electric utilities as well as other electric utilities has decreased over the sample period to 2018, changing by 2.1%pts and 1.5%pts (Figure 1). In the same period, the accounting cost of debt for renewable utilities has remained stable at around 6.5%. This has resulted in a convergence between classifications. Since 2018, the gap between classifications has widened, with non-classifiable other electric utilities falling to 5%, renewables falling to 6%, and fossil fuel electric utilities rising to 6.7%. As most electric utilities are classified as "other," due to their diversified asset base, emissions and energy mix are used to differentiate between firms.

Globally, over past 10 years, electric utilities that are more carbon-intensive have had a lower cost of debt.

As shown by Figure 2, the lowest 50% of electric utilities by emissions intensity have had a cost of debt above the highest 50%. However, in 2020 this gap has narrowed to just 0.2%pts. This historical difference between higher and lower emitters is driven by the LATAM region, where the cost of debt fell sharply for higher emitters and rose sharply for lower emitters, as shown in Annex 2. If this region is removed, the cost of debt is effectively equal globally between the top and bottom 50%.

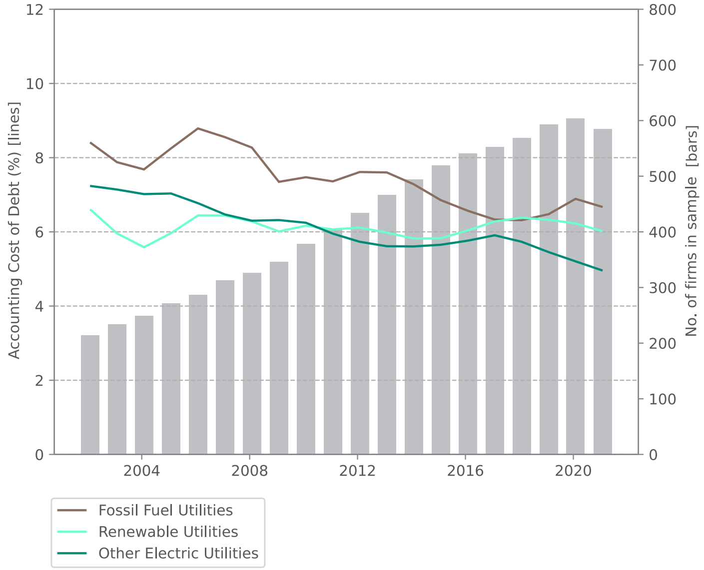
At the global level, companies with a greater allocation to renewables (solar/wind) have lower costs of debt over the past decade.

As shown by Figure 3, the gap between the top (at 4.7%) and bottom 50% (at 5.2%) has shrunk over the past five years to 0.5%pts in 2021. This holds when including other forms of low-carbon energy, such as nuclear, geothermal, and hydro as shown by Figure 4. Based on global averages, this difference could arise because larger companies tend to invest more in renewables. As these companies are more diversified and of greater scale, their cost of capital may be lower to begin with. This suggests that larger utilities already exposed to renewables may be able more easily to raise capital to invest in low-carbon energy.

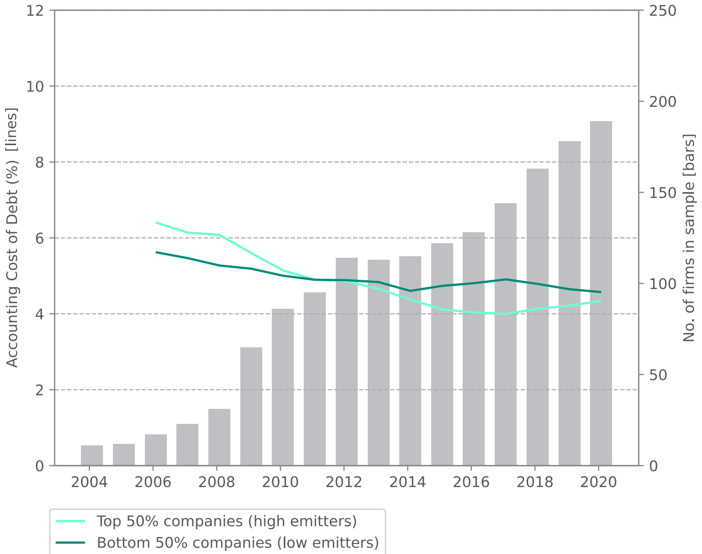
There is significant variation in the cost of debt across regions.

Breaking the cost of debt down into regions, we see that the cost of debt is lowest in Europe and China. There is a clear divide in the cost of capital in developed vs developing countries, with an average 2021 cost of debt for OECD countries of 3.9% vs 4.7% for non-OECD.

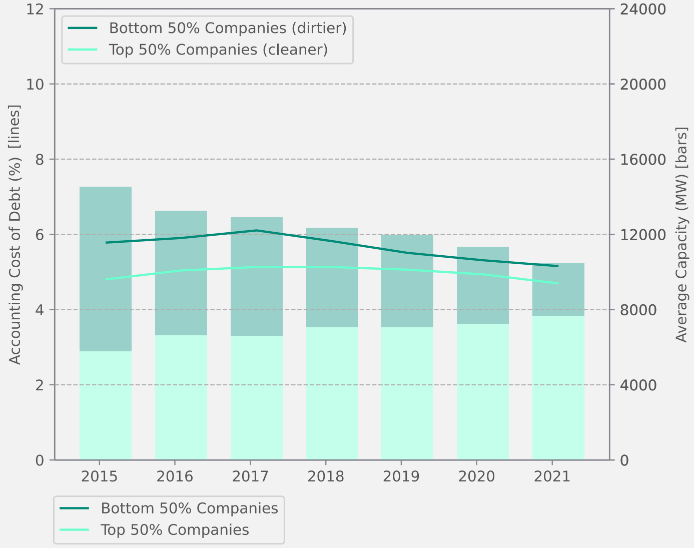
F1. GLOBAL ELECTRIC UTILITIES ACC COD, TRBC CLASSIFICATION



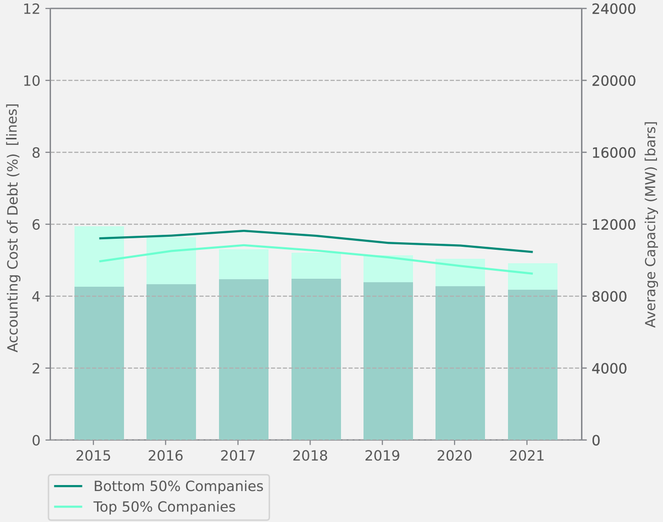
F2. GLOBAL ELECTRIC UTILITIES ACC COD, SCOPE 1 & 2 EMISSION INTENSITY



F3. GLOBAL ELECTRIC UTILITIES ACC COD, SOLAR/WIND ENERGY MIX

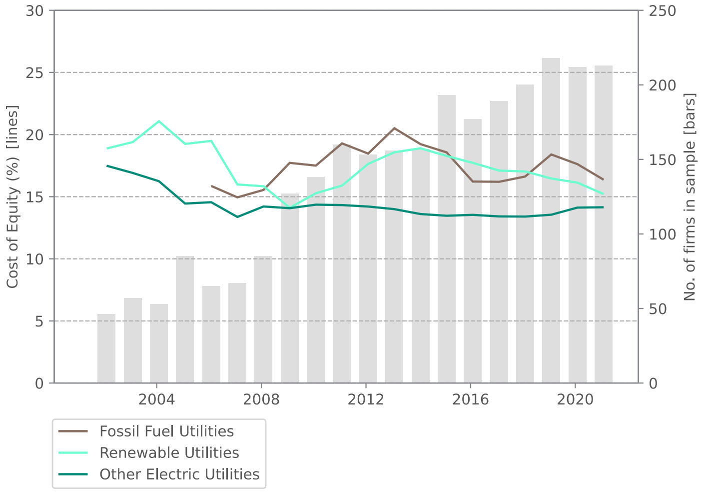


F4. GLOBAL ELECTRIC UTILITIES ACC COD, LOW-CARBON ENERGY MIX

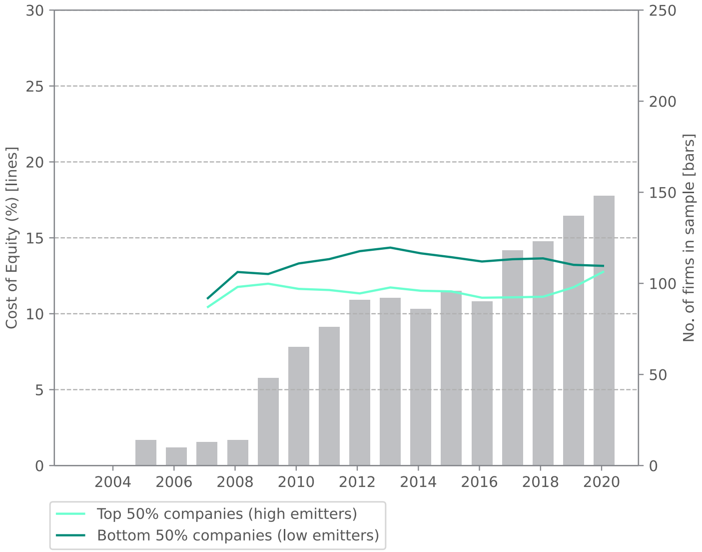


Cost of Equity

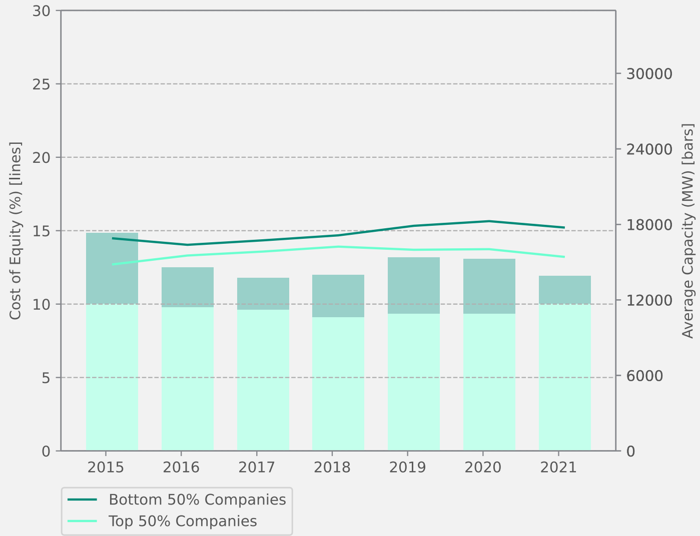
F5. GLOBAL ELECTRIC UTILITIES COE, TRBC CLASSIFICATION



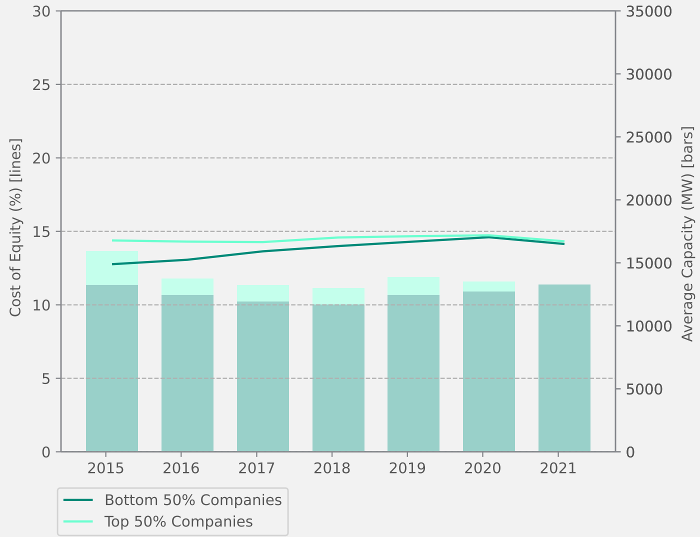
F6. GLOBAL ELECTRIC UTILITIES COE, SCOPE 1 & 2 EMISSION INTENSITY



F7. GLOBAL ELECTRIC UTILITIES COE, SOLAR/WIND ENERGY MIX



F8. GLOBAL ELECTRIC UTILITIES COE, LOW-CARBON ENERGY MIX



Globally, renewable electric utilities have a cost of equity lower than fossil fuel, but above "other", electric utilities.

In line with accounting cost of debt, in 2021, utilities focused on renewables by TRBC classification have a cost of equity lower than fossil fuel focused peers (15.2% vs 16.4%), but higher than diversified electric utilities (14.1%), as shown by Figure 5.

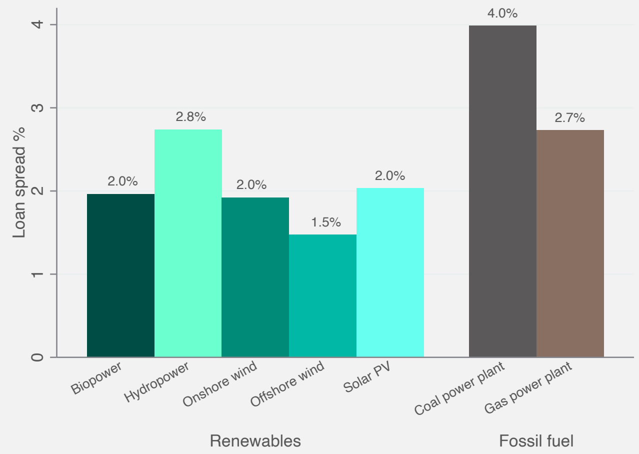
Over the past 10 years, lower emission intensity utilities have shown higher costs of equity.

In line with accounting cost of debt, the gap between low and high emitters has fallen in recent years, to 0.3%pts in 2020, as shown by Figure 6. We need to be cautious in explaining the global trends based on carbon intensity, however. Bolton and Kacperczyk (2021) document that carbon return premium is not significantly related to emission intensity, suggesting that carbon intensity is likely to be a noisier measure of climate risk exposure and requires a more nuanced analysis by country and subsector.

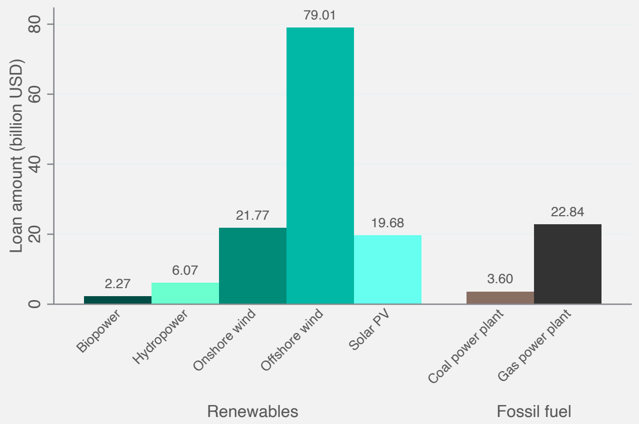
At the global level, companies with a greater allocation to renewables (solar/wind) have lower costs of equity over the past decade, in line with accounting cost of debt. Using solar/wind energy mix to differentiate between companies shows that those with a greater allocation have a lower cost of debt in 2021, at 13.2% vs 15.2%, as shown by Figure 7. However, this does not hold when including other forms of low-carbon energy, such as nuclear, geothermal, and hydro, with the cost of debt effectively equal between the top and bottom 50% of companies – 14.3% vs 14.1% in 2021, as shown by Figure 8.

Loan spreads (2020-2021)

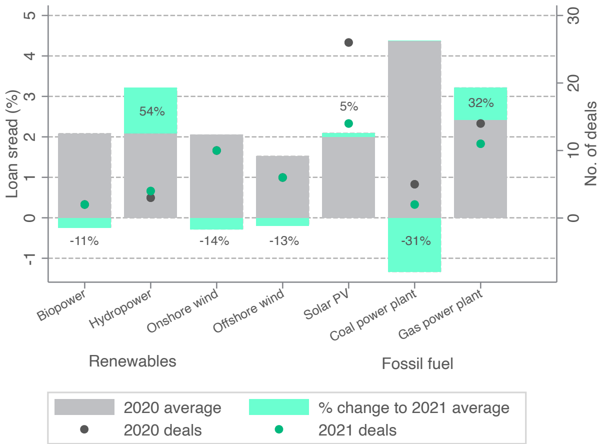
F9. GLOBAL ELECTRIC UTILITIES, LOAN SPREAD BY TECHNOLOGY, 2020-2021



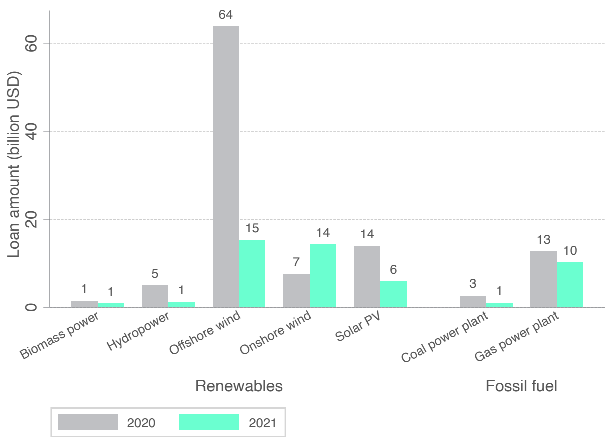
F10. GLOBAL ELECTRIC UTILITIES, LOAN VOLUME BY TECHNOLOGY, 2020-2021



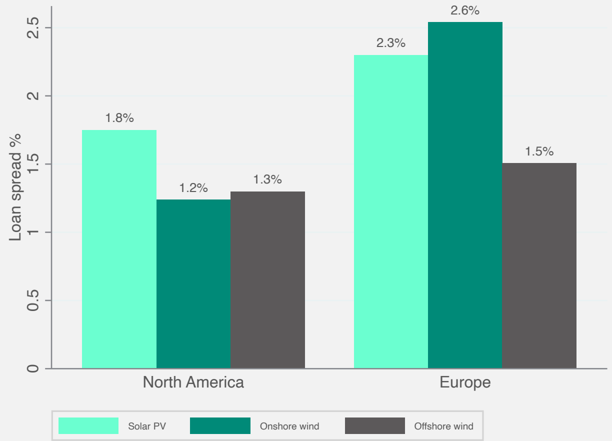
F11. GLOBAL ELECTRIC UTILITIES LOAN SPREAD, 2020 VS 2021



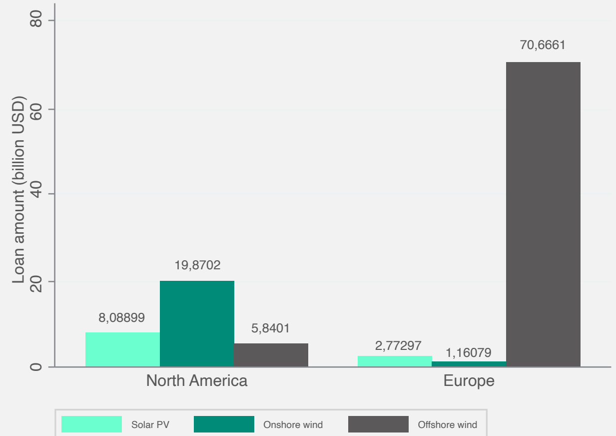
F12. GLOBAL ELECTRIC UTILITIES LOAN VOLUME, 2020 VS 2021



F13. SOLAR & WIND LOAN SPREAD BY REGION, 2020-2021



F14. SOLAR & WIND LOAN VOLUME BY REGION, 2020-2021



Globally, we see that renewable focused electric utilities have a lower loan spread than fossil fuel electric utilities, consistent with the accounting costs of debt and equity.

As shown by Figure 9, this is reflected by the difference between the average loan spreads of fossil fuel power plants (coal-fired and gas-fired) at 0.34%pts, compared to renewable power generation (solar, wind, and biomass power) at 0.2%pts.

In the past two years, loan spreads for renewables have remained stable, but have decreased for fossil fuels.

Comparing the average loan spread in 2020 with 2021, it has remained relatively stable for solar, wind and biomass power generation technologies. Within fossil fuels, coal experienced the largest decrease of 31%, whereas the loan spreads for gas power have increased by 32%, as shown by Figure 11.

Due to data availability constraints, only North America and Europe are shown separately. As shown by Figure 14, North America received the most loans in onshore wind ($8bn) and solar PV ($8.1billion), while Europe received the most loan investments for offshore wind ($70.7billion). However, it is important to note that this not a true reflection of loan volumes, as only transactions where the loan spread data is available are shown.

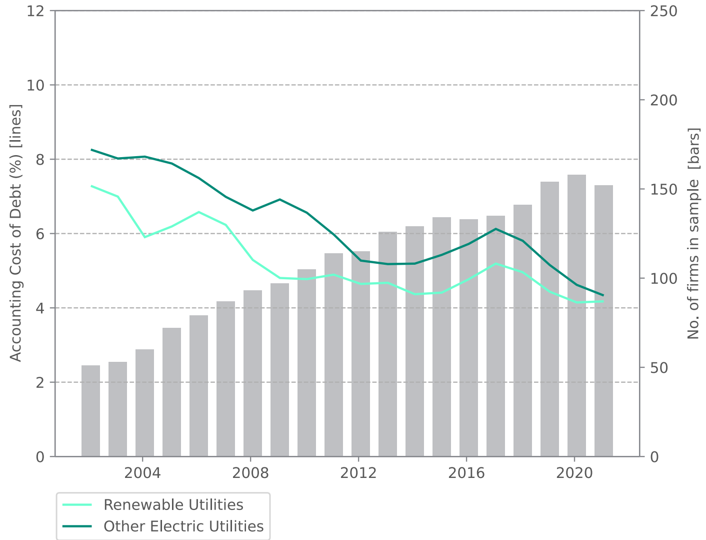
There is variation in the cost of debt across and within regions

As shown by Figure 13, North America has lower loan spreads for solar PV, onshore and offshore winds at 1.8%pts, 1.2%pts, and 1.3%pts, compared to Europe. Within Europe, there is clear difference in recent loan spreads between solar PV and onshore wind relative to offshore wind at 1.5%pts. Given the substantial proportion of transactions that occur within offshore wind, this suggests learning by doing within Europe has helped to drive down the cost of capital relative to other technologies.

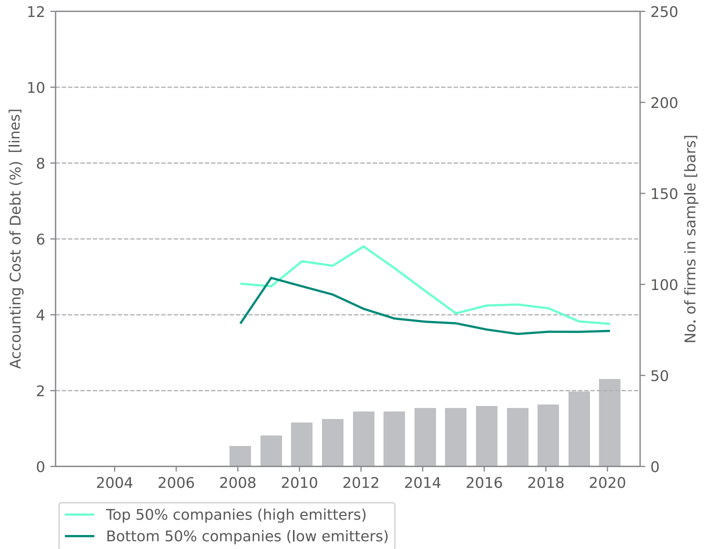
3.1.2 EUROPE

Accounting Cost of Debt

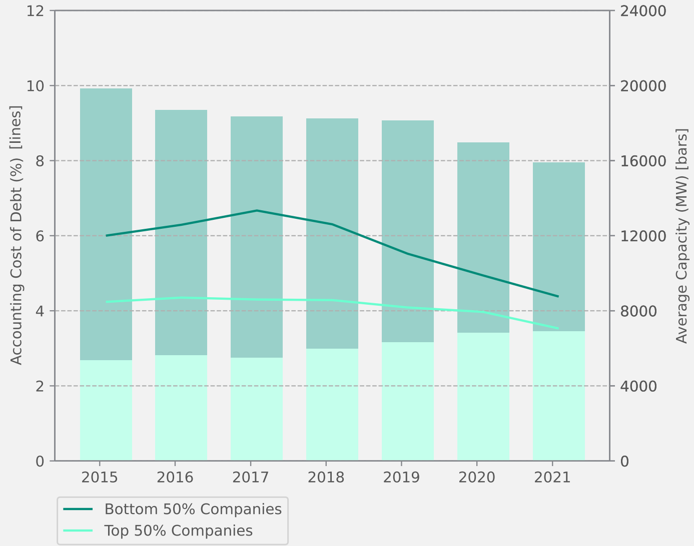
F15. EUROPE ELECTRIC UTILITIES ACC COD, TRBC CLASSIFICATION



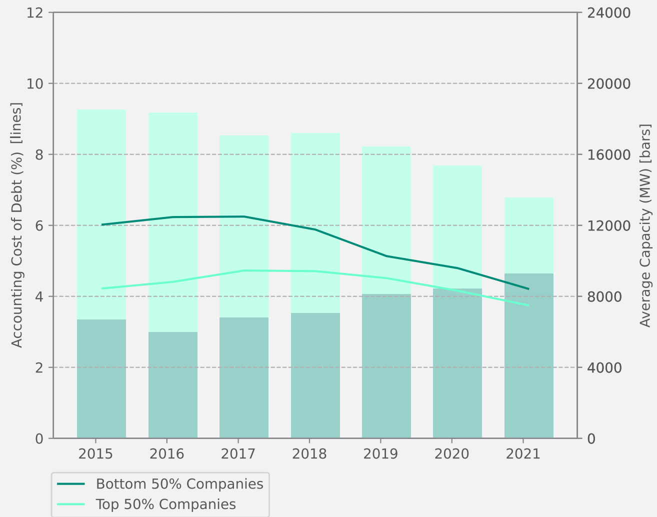
F16. EUROPE ELECTRIC UTILITIES ACC COD, SCOPE 1 & 2 EMISSION INTENSITY



F17. EUROPE ELECTRIC UTILITIES ACC COD, SOLAR/WIND ENERGY MIX



F18. EUROPE ELECTRIC UTILITIES ACC COD, LOW-CARBON ENERGY MIX



In Europe, lower-carbon electric utilities have a lower cost of debt than their higher-carbon peers. However, this gap appears to be decreasing over time.

- Using TRBC classification, utilities focused on renewables have historically had a cost of debt lower than diversified peers, (There are not enough fossil fuel electric utilities to be plotted). However, this gap has effectively closed over the past 5 years to 0.2%pts in 2021, as shown by Figure 15.

- In line with this trend, electric utilities with lower carbon-intensity emissions had consistently lower costs of debt over the past decade, as shown by Figure 16. This gap has fallen over time to just 0.2%pts in 2020.

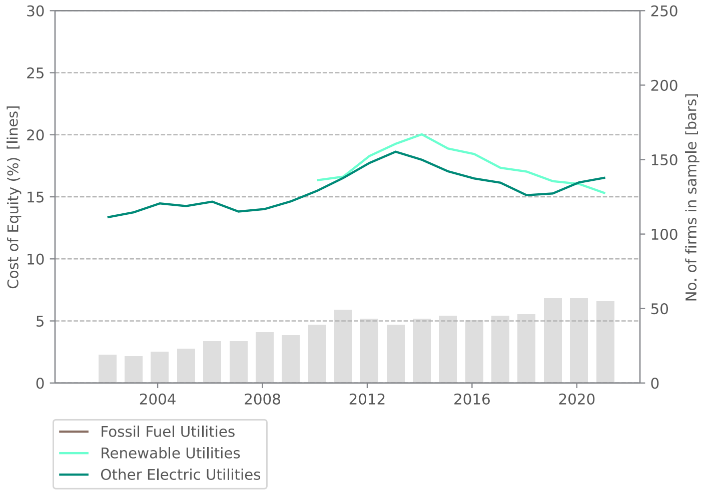
- A similar story is shown by the WEPP analysis, with companies with a higher proportion of solar/wind or low carbon in their energy mix having a consistently lower cost of debt, but with this gap falling over time. In 2021, this gap was 0.85%pts based on solar/wind and 0.5%pts for low-carbon energy, as shown by Figure 17 and 18.

- This could be because historically utilities with more renewable and low-carbon energy were significantly larger in terms of average MW capacity, and we would therefore expect them to have a lower cost of debt. Over time, as the gap in average capacity has fallen, so has the difference in the cost of debt, perhaps because it is smaller new entrants (such as independent power producers) rather than larger incumbent utilities that are driving growth in renewables.

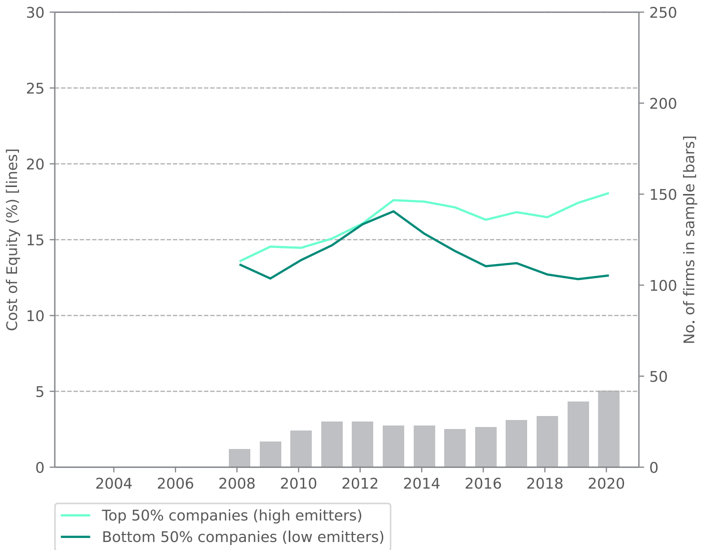
Electric utilities with lower carbon-intensity emissions had consistently lower costs of debt over the past decade

Cost of Equity

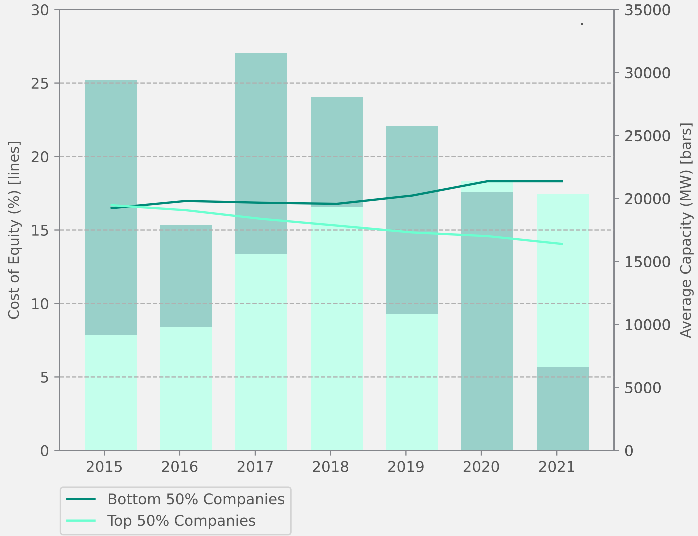
F19. EUROPE ELECTRIC UTILITIES COE, TRBC CLASSIFICATION



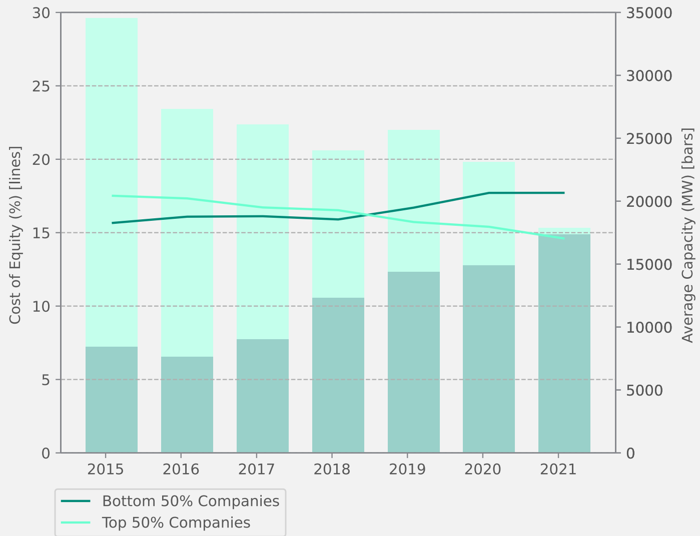
F20. EUROPE ELECTRIC UTILITIES COE, SCOPE 1 & 2 EMISSION INTENSITY



F21. EUROPE ELECTRIC UTILITIES COE, SOLAR/WIND ENERGY MIX



F22. EUROPE ELECTRIC UTILITIES COE, LOW-CARBON ENERGY MIX

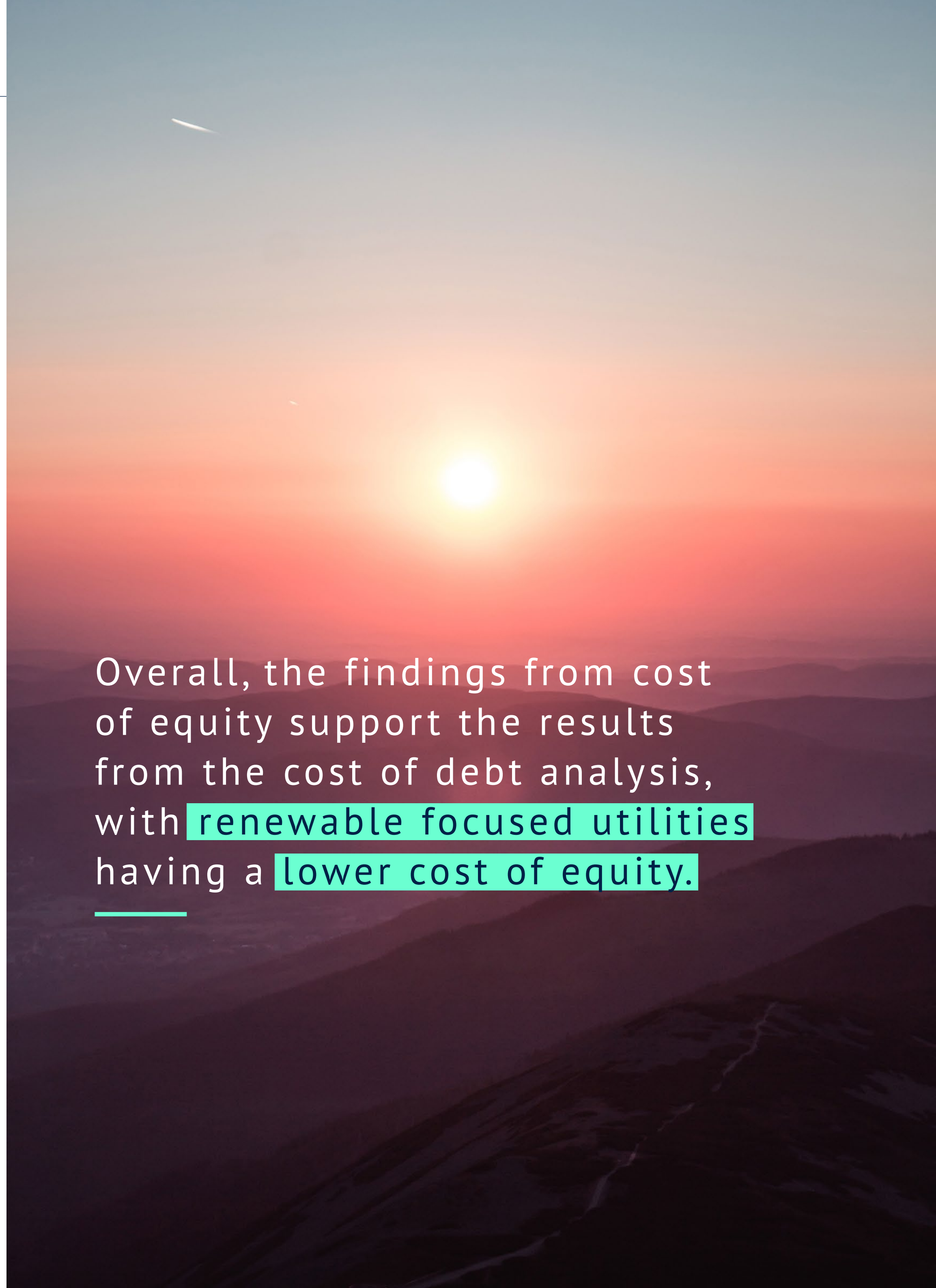


In Europe, lower-carbon electric utilities have lower cost of equity than their higher-carbon peers, with this gap increasing over time.

- According to TRBC classification, renewable utilities have historically had a cost of equity higher than diversified peers. (There are not enough fossil fuel electric utilities to be plotted.) However, this reversed from 2020, as shown by Figure 19.

- Similarly, electric utilities with a lower carbon-intensity have a lower cost of equity. As shown by Figure 20, lower carbon-intensity utilities have diverged from peers over the past decade as their cost of equity has fallen, with a difference of 5.4%pts shown in 2020. Using solar/wind energy mix, we observe a similar trend, with the cost of equity between the two groups diverging since 2015, with a gap of 4.3%pts in 2021 as shown by Figure 21. More recently, using low-carbon energy mix, this divergence occurred from 2019, with a gap of 3.1%pts in 2021 as shown by Figure 22.

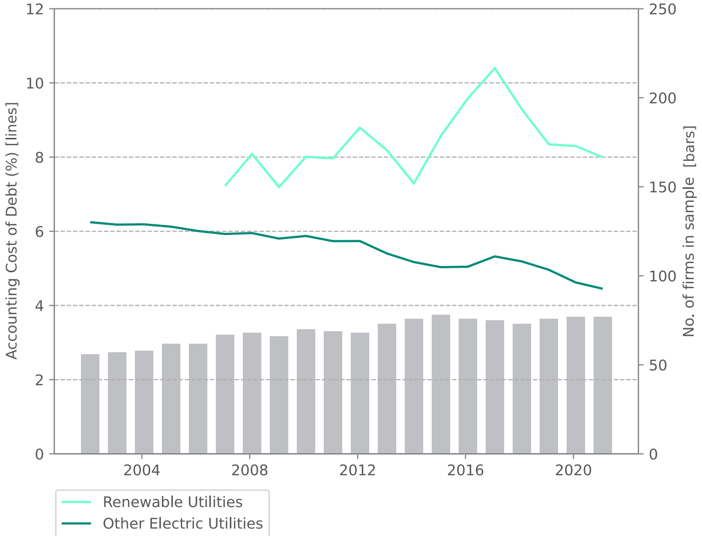
- Overall, the findings from cost of equity support the results from the cost of debt analysis, with renewable focused utilities having a lower cost of equity. However, unlike cost of debt, this gap is growing over time rather than shrinking. This may imply that the more forward-looking equity investors in Europe foresee that transition risks embedded in fossil fuels will increase soon.



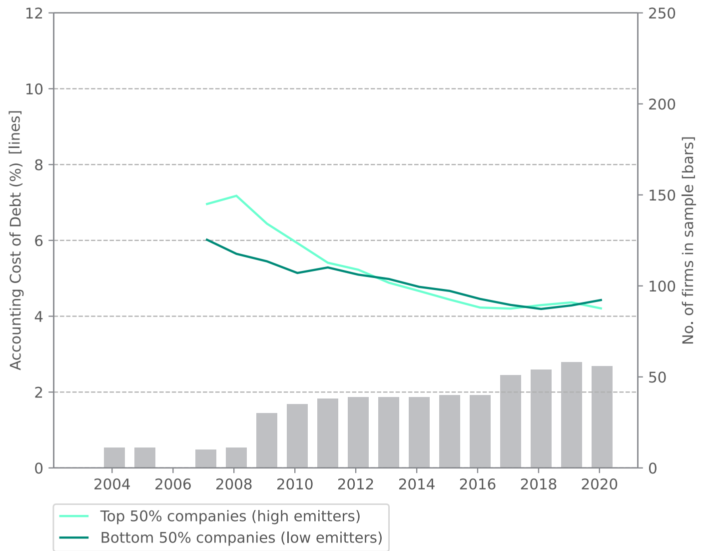
3.1.3 NORTH AMERICA

Accounting Cost of Debt

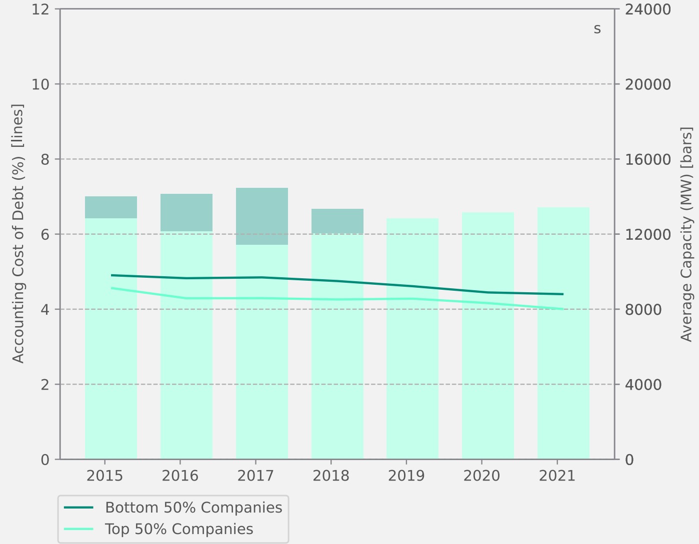
F23. NORTH AMERICA ELECTRIC UTILITIES ACC COD, TRBC CLASSIFICATION



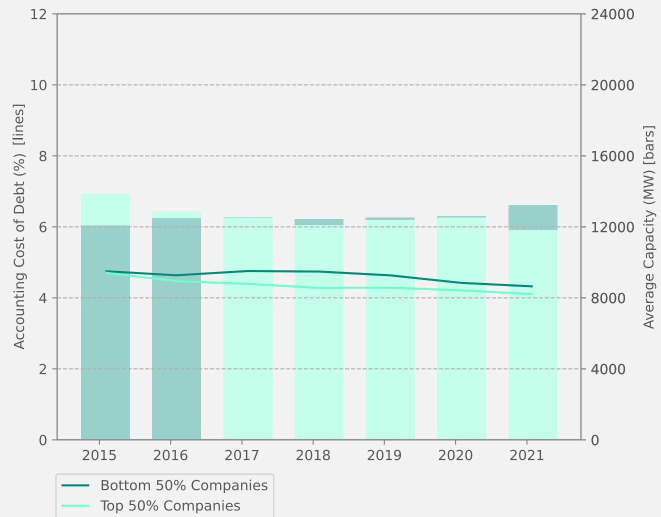
F24. NORTH AMERICA ELECTRIC UTILITIES ACC COD, SCOPE 1 & 2 EMISSION INTENSITY



F25. NORTH AMERICA ELECTRIC UTILITIES ACC COD, SOLAR/WIND ENERGY MIX



F26. NORTH AMERICA ELECTRIC UTILITIES ACC COD, LOW-CARBON ENERGY MIX



In North America, the cost of debt of low-carbon electric utilities is comparable to high-carbon peers, with no clear trend across different types of analysis.

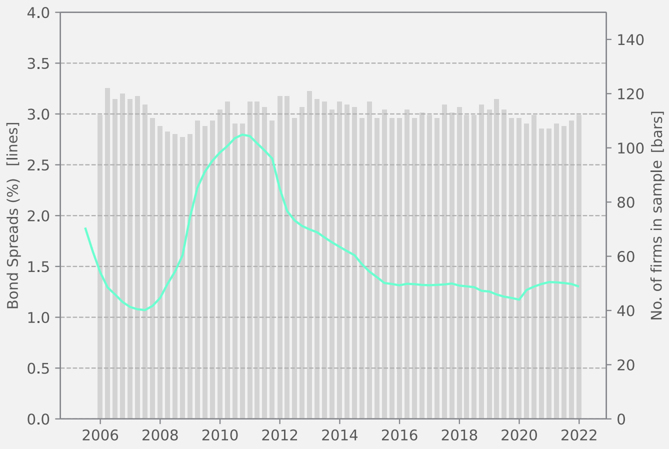
- Using TRBC classification, renewables utilities have historically had a significantly higher cost of debt than diversified peers. (There are not enough fossil fuel electric utilities to be shown). This gap has grown over the past decade to 3.5%pts in 2021, as shown by Figure 23.

- However, when using emission intensity and energy mix to distinguish between companies in the "other" category, we find mixed results. As shown by Figure 24, analysis based on carbon-intensity shows that over the past decade higher and lower carbon-intensity emitting utilities have effectively had an identical cost of debt,.

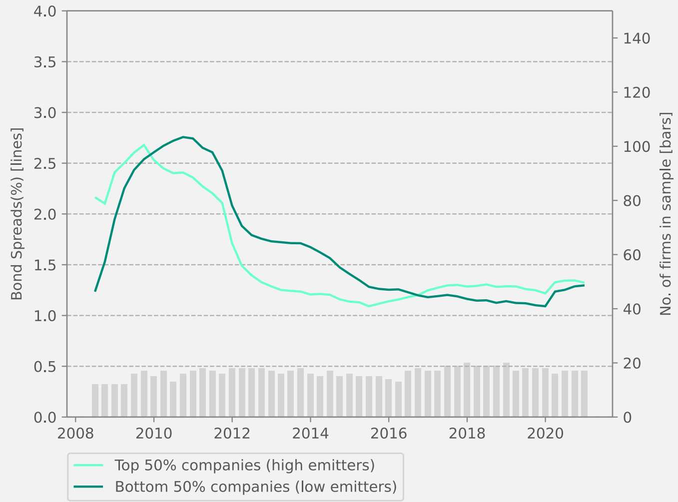
- Yet, when using solar/wind and low-carbon energy mix, results show that companies with a higher proportion of these technologies in their energy mix had a lower cost of debt over the past decade, though not significantly so. In 2021, the difference was 0.4%pts for solar/wind and 0.2%pts for low-carbon energy, as shown by Figures 25 and 26.

Secondary Market Bond Spreads

F27. US ELECTRIC UTILITIES BOND SPREADS, TRBC CLASSIFICATION



F28. US ELECTRIC UTILITIES BOND SPREADS, SCOPE 1 & 2 EMISSION INTENSITY



In the US, the bond spreads for low-carbon electric utilities are comparable to high-carbon peers in line with the accounting cost of debt, with evidence of marginally lower financing costs in recent years.

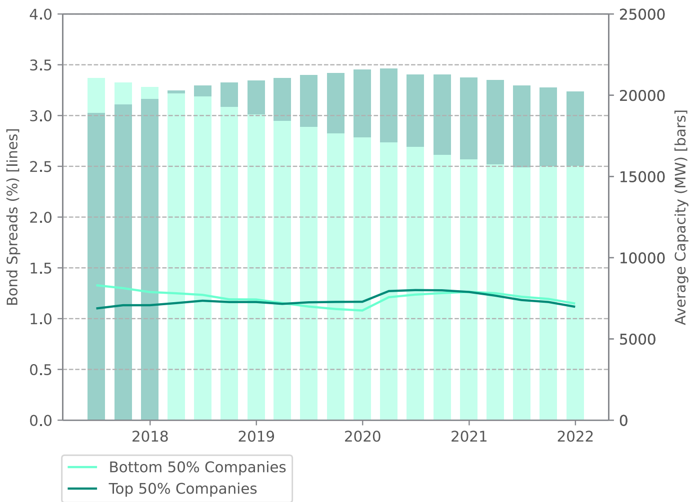
- Due to a lack of companies classified as renewable or fossil fuel electric utilities in the sample, only the TRBC "Other Electric Utilities" classification is plotted, showing a drop in bond spreads from almost 3%pts in 2011 to approximately 1.25%pts in 2021 (Figure 27).

- In contrast to the accounting cost of debt, electric utilities with low carbon-intensity have had lower bond spreads than peers since 2016. However, this gap has been small, and closed in 2021, when spreads for the top and bottom 50% became equal (Figure 28).

- Similarly, when using solar/wind energy mix to differentiate between companies, we see that the top and bottom 50% have equal bond spreads (Figure 29). When using low-carbon energy mix, we observe that the top 50% have marginally lower bond spreads, at just 0.1%pts (Figure 30).

- In summary, in both the accounting cost of debt and bond spread analysis, the financing costs of high and low-carbon companies are closely aligned, making it hard to draw clear conclusions. This may be since the average MW capacity of both groups is effectively equal, unlike in Europe. The implication is that carbon-intensive utilities can raise capital at effectively the same cost as the less carbon-intensive. This could support continued investment in carbon-intensive power production.

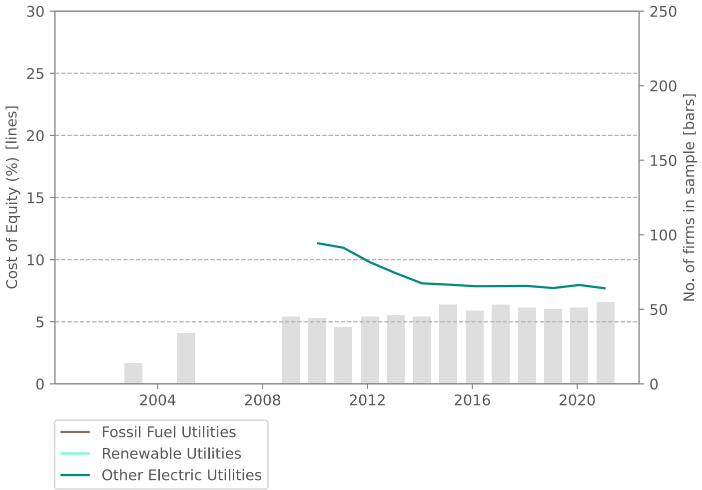
F29. US ELECTRIC UTILITIES BOND SPREADS, SOLAR/WIND ENERGY MIX



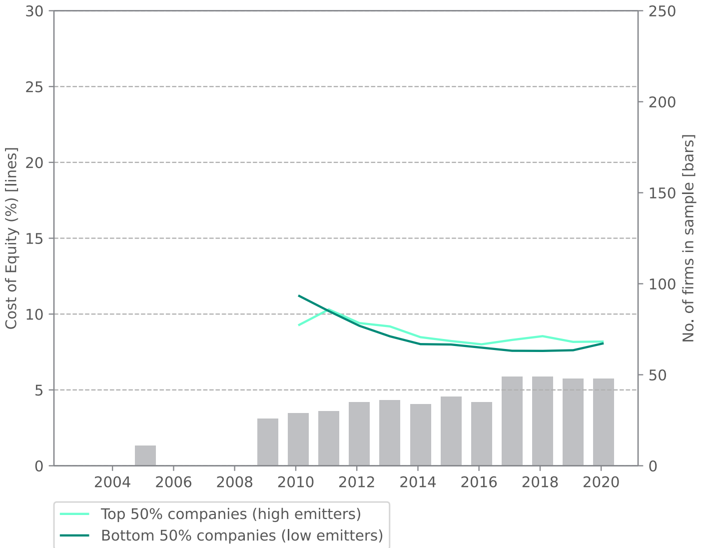
F30. US ELECTRIC UTILITIES BOND SPREADS, LOW-CARBON ENERGY MIX

Cost of Equity

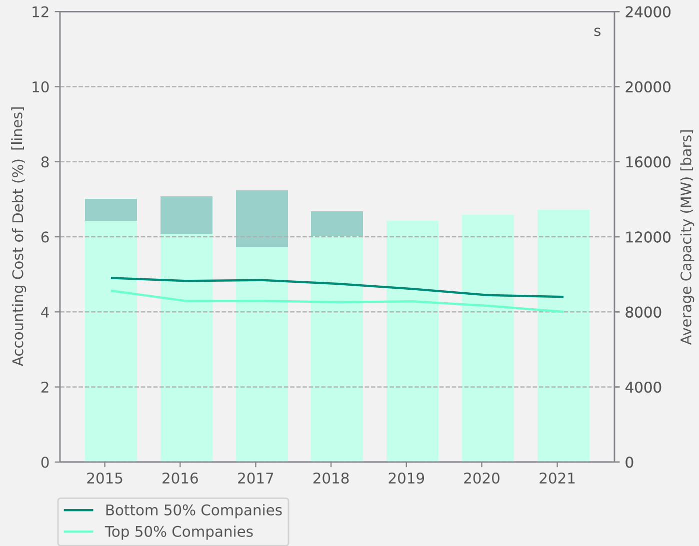
F31. NORTH AMERICA ELECTRIC UTILITIES COE, TRBC CLASSIFICATION



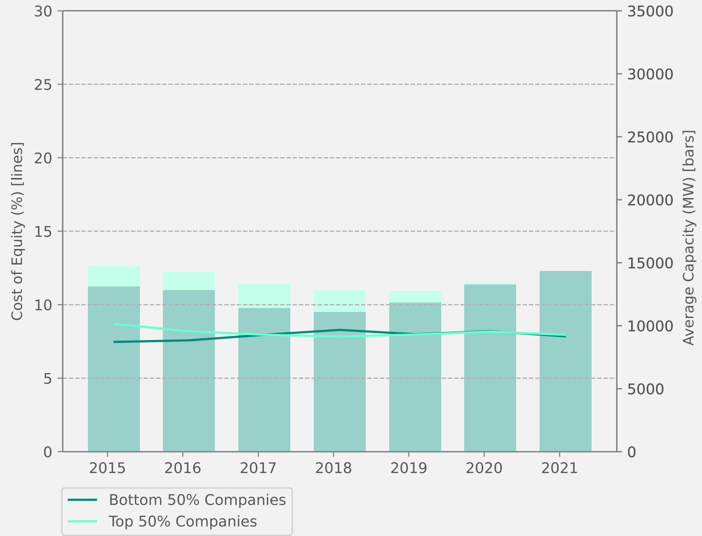
F32. NORTH AMERICA ELECTRIC UTILITIES COE, SCOPE 1 & 2 EMISSION INTENSITY



F33. NORTH AMERICA ELECTRIC UTILITIES COE, SOLAR/WIND ENERGY MIX



F34. NORTH AMERICA ELECTRIC UTILITIES COE, LOW-CARBON ENERGY MIX



In North America, the cost of equity for low-carbon electric utilities is comparable to high-carbon peers in line with the cost of debt, with no clear trend across different types of analysis.

- Due to a lack of companies classified as renewable or fossil fuel electric utilities in the sample, only the TRBC "Other Electric Utilities" classification is plotted. This shows a stable cost of equity since 2014 (Figure 31).

- When using carbon-intensity to differentiate between companies, there is no clear separation between high and low emitters. As shown by Figure 32, the top and bottom 50% of emitters have similar levels and trends in the cost of equity, with the two equal in 2020.

- When using the proportion of solar/wind in the energy mix to differentiate between companies, those in the top 50% with a higher allocation to these technologies had a higher cost of equity until 2021, when this gap closed (Figure 33). Regarding low-carbon energy mix, the top and bottom 50% have effectively had the same cost of equity since 2017 (Figure 34).

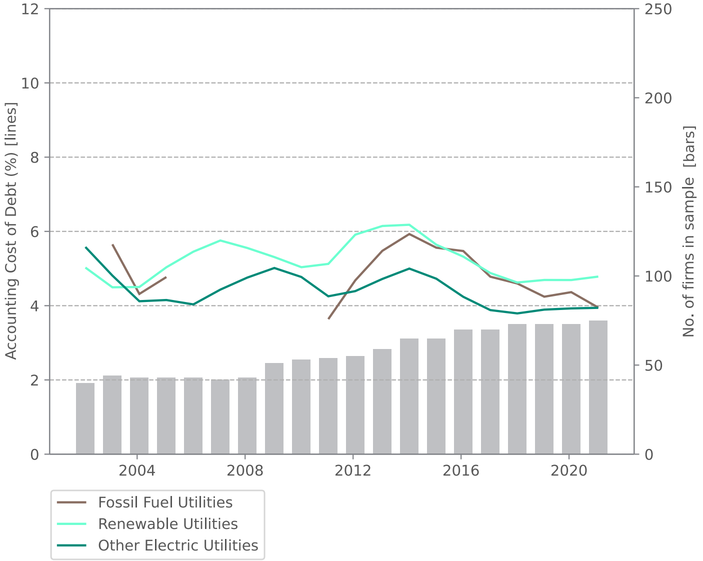
- In summary, we observe that, in North America, the costs of raising equity capital for both high and low carbon-intensity companies are closely aligned, consistent with the accounting cost of debt and bond spread.

In summary, we observe that, in North America, the costs of raising equity capital for both high and low carbon-intensity companies are closely aligned

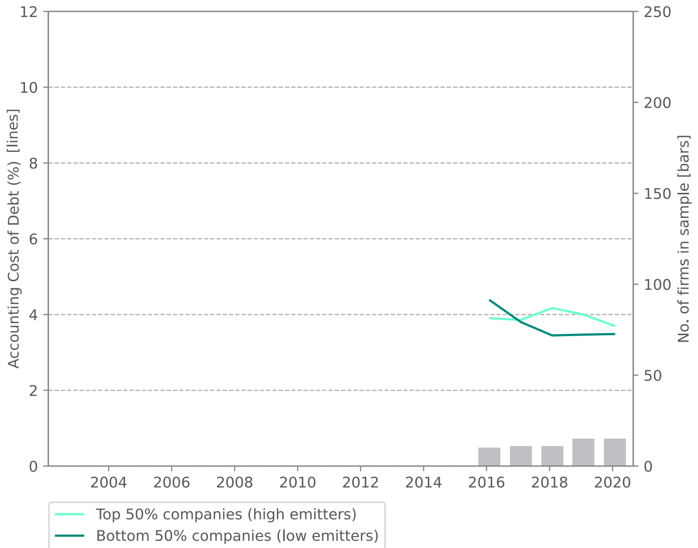
3.1.4 CHINA

Accounting Cost of Debt

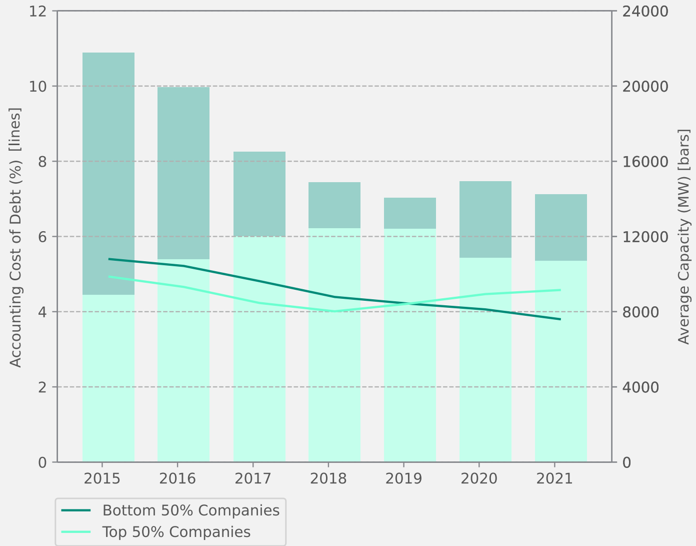
F35. CHINA ELECTRIC UTILITIES ACC COD, TRBC CLASSIFICATION



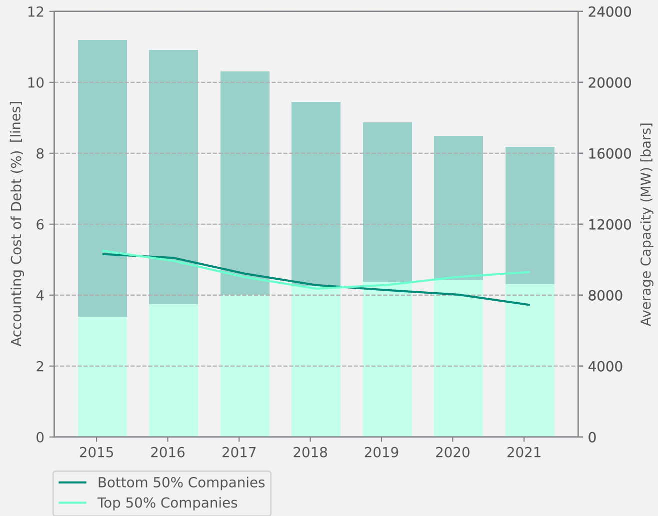
F36. CHINA ELECTRIC UTILITIES ACC COD, SCOPE 1 & 2 EMISSION INTENSITY



F37. CHINA ELECTRIC UTILITIES ACC COD, SOLAR/WIND ENERGY MIX



F38. CHINA ELECTRIC UTILITIES ACC COD, LOW-CARBON ENERGY MIX

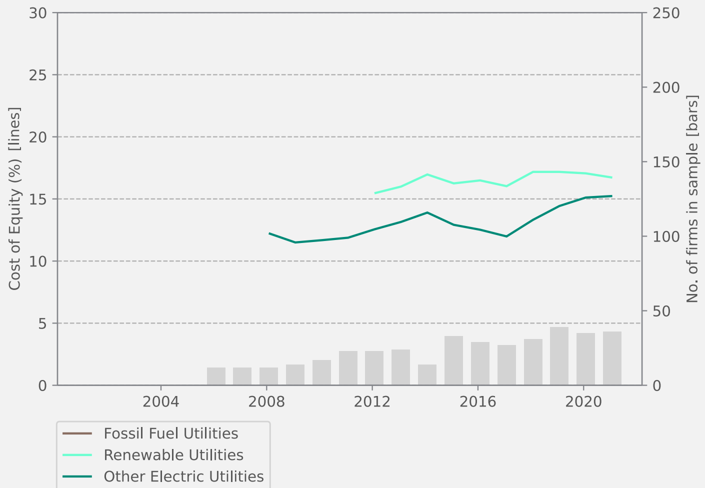


In China, there is evidence that low-carbon electric utilities have a higher cost of debt than high-carbon peers since 2018.

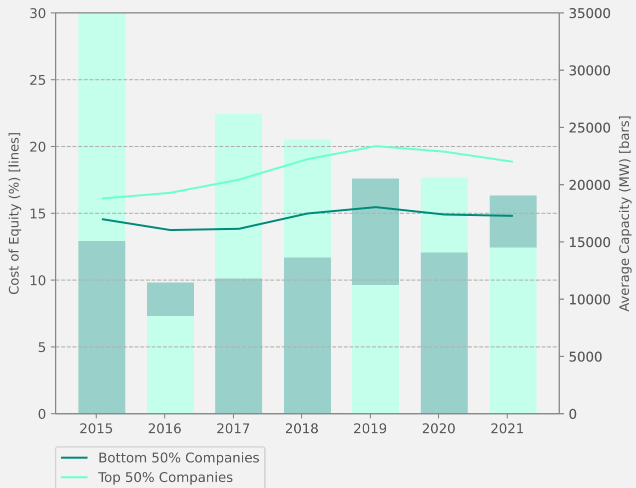
- Utilities focused on renewables have historically had a cost of debt higher than diversified peers, and, since 2018, had a higher cost of debt than fossil fuel electric utilities (Figure 35).
- There is limited historical data on emissions. However, since 2017, the cost of debt of the top 50% of emitters has risen marginally risen above that of the bottom 50%.
- However, in line with the TRBC analysis, we see that companies more heavily invested in renewable technologies as a proportion of their energy mix have had a higher cost of debt since 2019. Similarly, the cost of debt of companies with a greater focus on low-carbon energy have had a higher cost of debt since 2018. Figures 37 and 38 show the difference between the top and bottom 50% in 2021 at 0.8%pts and 0.9%pts respectively, for solar/wind vs broader low-carbon mix.
- This recent reversal suggests that rapid growth in renewable energy in China has not translated into lower financing costs relative to high-carbon electric utilities.

Cost of Equity

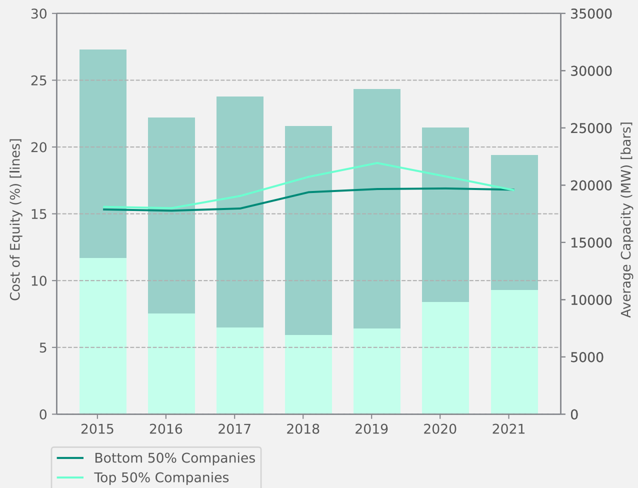
F39. CHINA ELECTRIC UTILITIES COE, TRBC CLASSIFICATION



F40. CHINA ELECTRIC UTILITIES COE, SOLAR/WIND ENERGY MIX



F41. CHINA ELECTRIC UTILITIES COE, LOW-CARBON ENERGY MIX



In China, there is evidence that low-carbon electric utilities have a higher cost of equity than high-carbon peers, in line with the cost of debt analysis.

- In line with the cost of debt analysis, Figure 39 shows that renewable utilities have historically had a cost of equity higher than diversified peers according to TRBC classification. (There are not enough fossil fuel electric utilities to be plotted.)

- There is not enough data to separate companies by emissions intensity.

- In China, companies with a higher proportion of capacity allocated to solar and wind have a significantly higher cost of equity. As shown in Figure 40, in 2021, using solar/wind energy mix, the top 50% of companies have a cost of debt 4%pts higher than the bottom 50%. When including other forms of low-carbon energy, such as nuclear, hydro, and geothermal, while the top 50% of companies have a higher cost of equity historically, this gap closed in 2021.

In summary, in China, this analysis suggests that high-carbon utilities can raise capital — both debt and equity — at a lower cost, which could support continued investment in carbon-intensive power production. This difference could be due to the carbon-intensive nature of state-owned enterprises with low credit risk, which play a significant role in coal power.

3.1.5 OTHER REGIONS

Below, the key trends are summarised in other regions where data is available. All charts are shown in Annex 2.

Developing Countries/Regions

ASEAN: In the ASEAN region, based on TRBC sector classification, renewable electric utilities have a higher cost of debt and equity than fossil fuel and diversified peers. For example, in 2021, the cost of debt of renewable utilities was 7.3%, compared to around 5.3% for fossil fuel and diversified electric utilities. However, when using energy mix to differentiate between companies, there is no clear trend. Companies more exposed to solar/wind have a higher cost of debt, while those more exposed to low-carbon energy have historically had lower. Yet, for the cost of equity, these trends are reversed.

LATAM: In the LATAM region, based on TRBC sector classification, the cost of debt of renewable utilities has risen above that of other diversified peers since 2017. In 2021, the difference between the two was 1.9%pts. Based on emissions intensity, lower emitters have historically had a higher cost of debt and equity, but this gap has closed over time. Furthermore, when using the solar/wind and low-carbon energy mix to differentiate between companies, we observe that electric utilities most invested in these technologies have a higher cost of debt and equity.

India: In India, according to TRBC sector classification, while renewable electric utilities and diversified utilities have had an effectively equal cost of debt over the past decade, the cost of debt of renewables has risen marginally higher since 2019, with a difference of 0.3%pts in 2021. This finding is supported by energy mix analysis, which shows those utilities with a greater allocation to solar/wind seeing a higher cost of capital since 2020, with a difference of 0.8%pts in 2021. However, utilities with a higher exposure to low-carbon energy more broadly have a lower cost of debt since 2016, with a difference of 1.1%pts in 2021.

MENA: In MENA, we observe that companies with a higher exposure to solar/wind and low-carbon energy have a significantly higher cost of debt, with a difference of 4.2%pts and 3.8%pts, respectively, in 2021.

Developed Countries/Regions

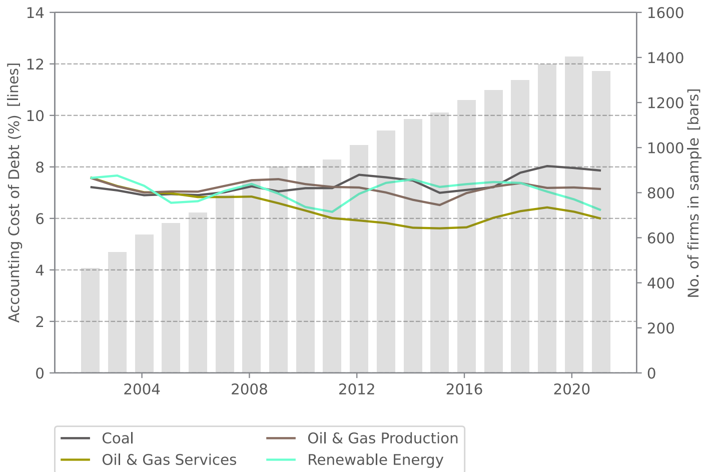
Australia: In Australia, historically renewable-focused utilities have had a cost of debt higher than diversified peers. However, this trend has shrunk over time, reaching zero in 2021.

Japan/Korea: In Japan and South Korea, we observe that companies with a higher exposure to solar/wind have a higher cost of debt, with a difference of 0.4%pts in 2021. However, when using low-carbon energy mix, this gap has shrunk over time, hitting zero in 2021.

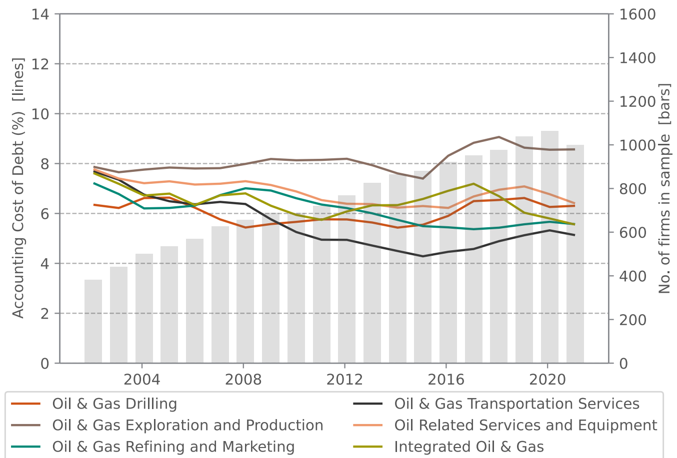
3.2 Energy Production

3.2.1 GLOBAL Accounting Cost of Debt

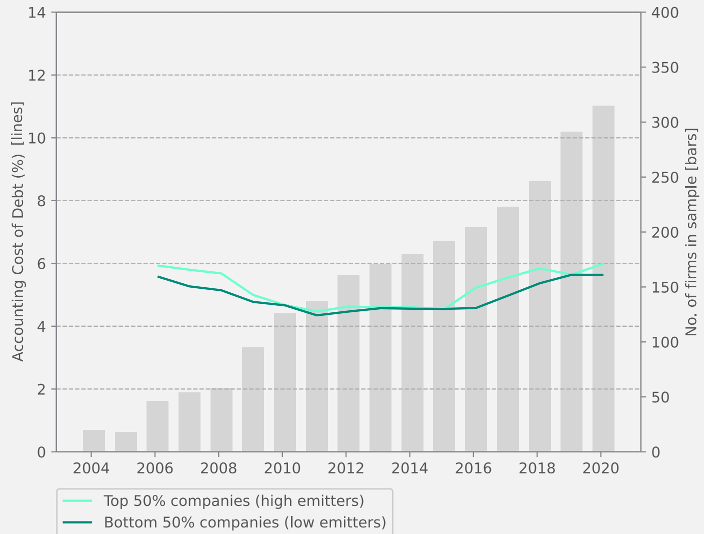
F42. GLOBAL ENERGY PRODUCTION ACC COD, TRBC CLASSIFICATION



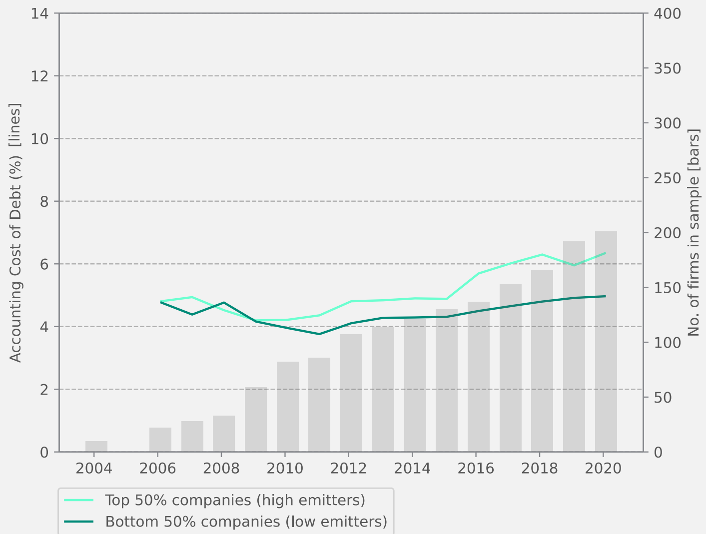
F43. GLOBAL OIL & GAS ACC COD, TRBC SUBSECTOR CLASSIFICATION



F44. GLOBAL OIL & GAS ACC COD, SCOPE 1 & 2 EMISSION INTENSITY



F45. OIL & GAS PRODUCTION ACC COD, SCOPE 1 & 2 EMISSION INTENSITY



Globally, coal mining has the highest cost of debt within the energy sector; however, renewables fuels & technology does not have the lowest cost capital.

Since 2016 the cost of debt of renewable fuels & technology has been on a downward trend, while that of coal mining has risen (Figure 42). As of 2021, the accounting cost of debt was highest for coal mining at 7.9%, followed by oil & gas production at 7.1%, renewable fuels & technology at 6.3%, and oil & gas services at 6%. We observed a similar trend for loan spreads in the 2021 report.

Within oil & gas, production and upstream activities have a higher cost of debt.

Splitting out by TRBC sector shows persistent spread between oil & gas production and services, while splitting out by TRBC subsector shows a clear difference between upstream oil & gas production, with a cost of debt of 8.6% in 2021, and the rest of the oil & gas industry (Figure 43). Within the context of the low-carbon transition this is significant, as it is upstream activities that expand fossil fuel reserves, where the risk of stranded assets and carbon lock-in is significant. All oil & gas sub sectors experienced falls in the cost of debt between 2002 and 2015, with the sharpest occurring in transportation services, while exploration & production remained almost stable. Following the oil price crash of 2014-2016, cost of debt rose in all sectors.

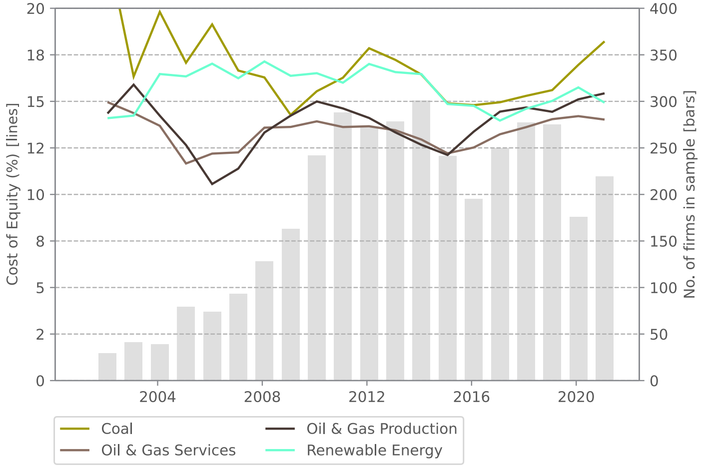
Within oil & gas, more carbon-intensive companies have a higher cost of debt.

Using Scope 1 & 2 emissions intensity to evaluate firms in the oil & gas industry shows that there is no clear difference between the top and bottom 50% of emitters (Figure 44). However, when limiting the scope of analysis to oil & gas production (encompassing "Integrated Oil & Gas", "Oil & Gas Exploration and Production", and "Oil & Gas Refining and Marketing"), the cost of debt of the highest emitters is significantly higher, with the gap expanding over time to 1.4%pts in 2020 (Figure 45). NB, the exclusion of Scope 3 emissions means that these results should be interpreted with caution.

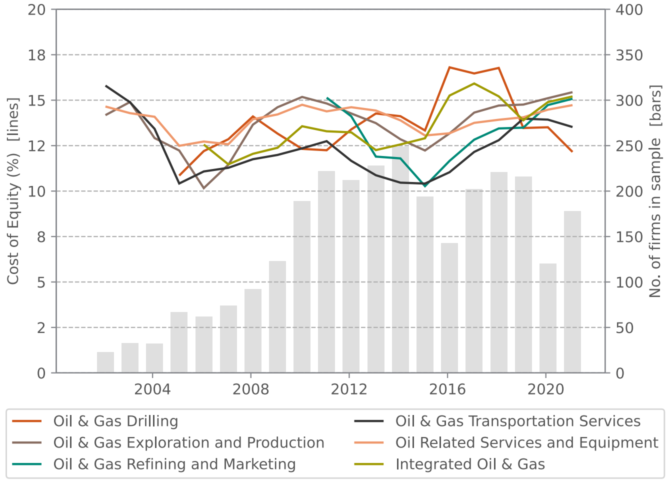
Since 2016 the cost of debt of renewable fuels & technology has been on a downward trend, while that of coal mining has risen

Cost of Equity

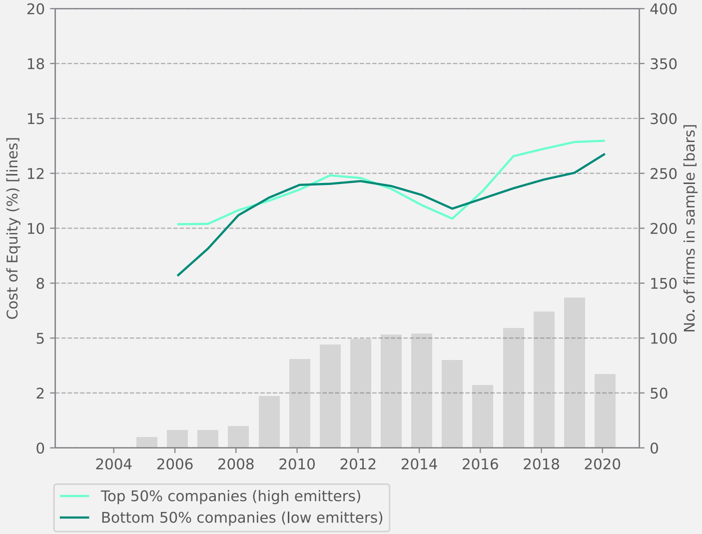
F46. GLOBAL ENERGY PRODUCTION COE, TRBC CLASSIFICATION



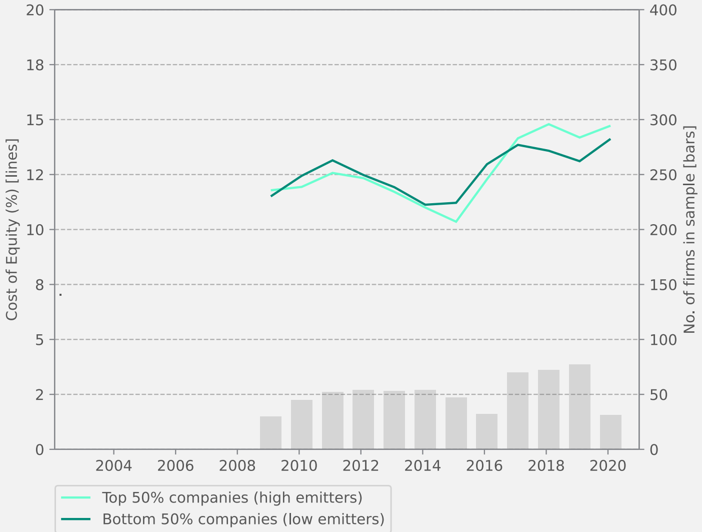
F47. GLOBAL OIL & GAS COE, TRBC SUBSECTOR CLASSIFICATION



F48. GLOBAL OIL & GAS COE, SCOPE 1 & 2 EMISSION INTENSITY



F49. GLOBAL OIL & GAS PRODUCTION COE, SCOPE 1 & 2 EMISSION INTENSITY



Globally, coal mining has the highest cost of equity within the energy sector; however, renewables fuel & technology does not have the lowest cost capital.

In line with accounting cost of debt, the cost of equity of coal mining, oil & gas production, and services has risen since 2016 by 18.2%, 15.4%, and 14.0% respectively (Figure 46). During this time, the cost of equity of renewable fuels & technology has remained effectively constant at around 15%.

Within oil & gas, production and upstream activities have a higher cost of equity.

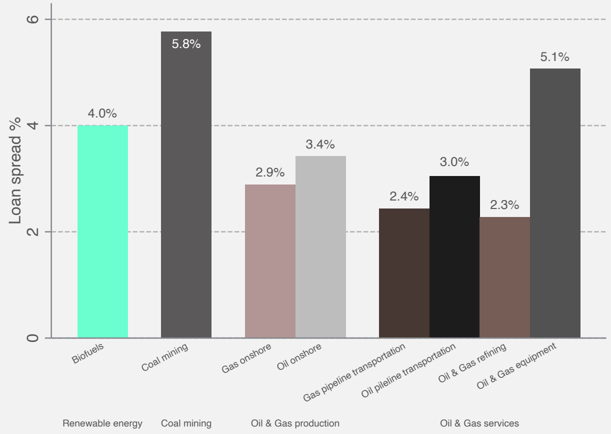
Splitting out by TRBC sector shows the gap between oil & gas production and services grow since 2016 to 15.4% vs 14% in 2021 (Figure 46). When splitting out by TRBC subsector, upstream oil & gas production has the highest cost of equity at 15.4% (Figure 47), in line with the accounting cost of debt. All oil & gas sub subsectors apart from drilling show a rise in the cost of equity since 2016, following the oil price crash of 2014-2016.

Within oil & gas, more carbon-intensive companies have a marginally higher cost of equity.

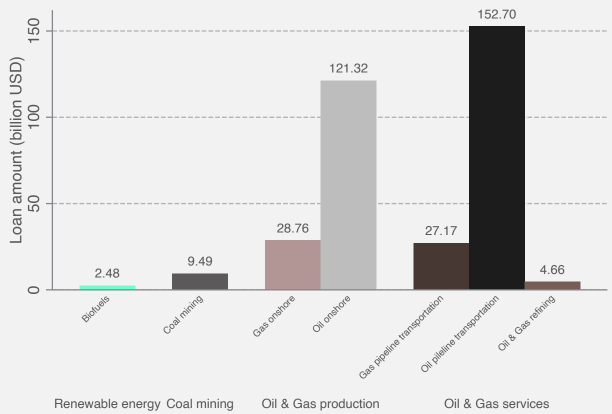
Using Scope 1 & 2 emissions intensity to evaluate firms in the oil & gas industry shows that since 2015 there is a small difference emerging between the top and bottom 50% of emitters in line with the accounting cost of debt, with a gap of 0.6%pts in 2020 (Figure 48). This gap also exists when limiting the scope of analysis to oil & gas production, at 0.6%pts in 2020 (Figure 49). However, this gap is smaller than for the accounting cost of debt.

Loan Spreads

F50. GLOBAL OIL & GAS, LOAN SPREAD, 2020-2021



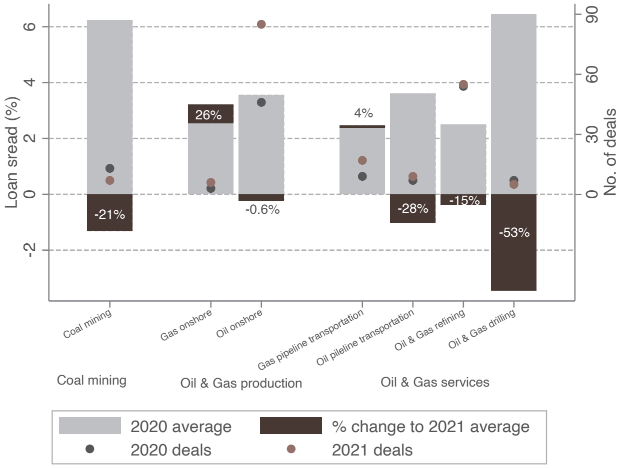
F51. GLOBAL OIL & GAS, LOAN VOLUME, 2020-2021



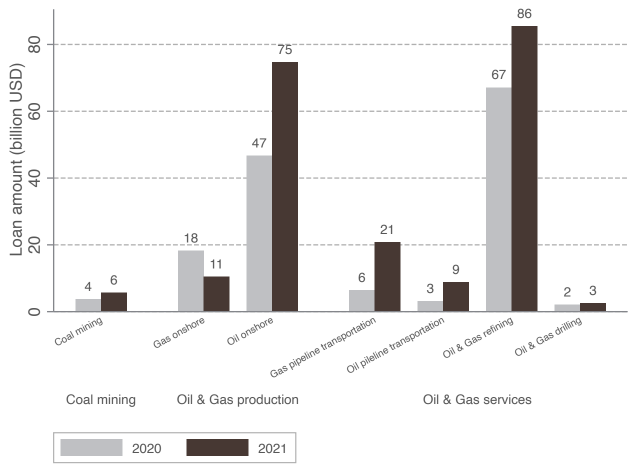
OXFORD SUSTAINABLE FINANCE GROUP

UNIVERSITY OF OXFORD

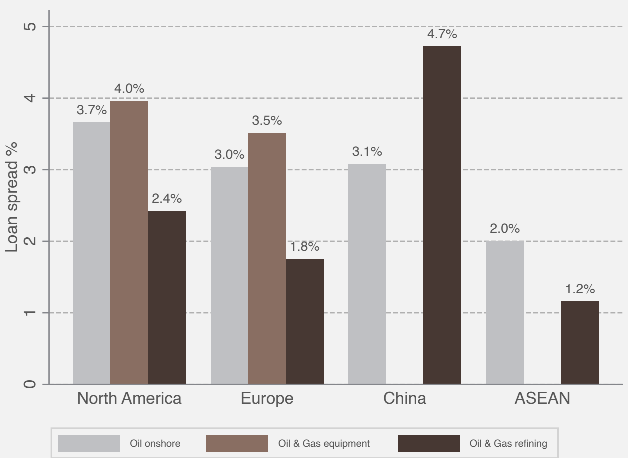
F52. GLOBAL OIL & GAS, LOAN SPREAD, 2020 VS 2021



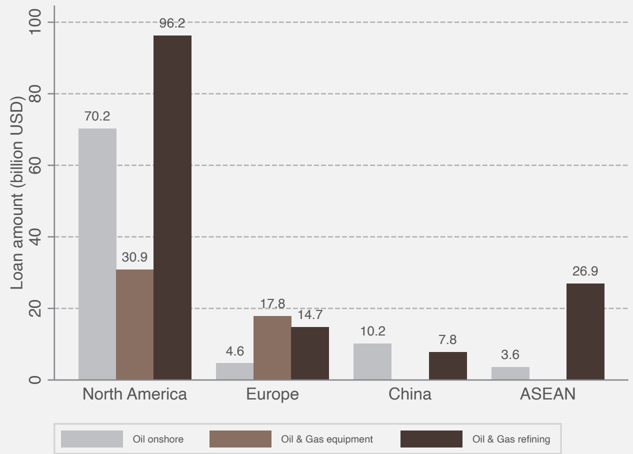
F53. GLOBAL OIL & GAS, LOAN VOLUME, 2020 VS 2021



F54. OIL & GAS BY REGION, LOAN SPREAD 2020-2021



F55. OIL & GAS BY REGION, LOAN VOLUME, 2020-2021



Globally, in line with the accounting cost of debt and equity, coal mining companies have the highest loan spreads in the energy sector.

- Over the past two years, coal mining, on average, had the highest loan spread of 5.8%pts compared to other energy types (Figure 50). However, comparing the 2020 and 2021 average, the average loan spreads for coal mining have decreased by 21%, from 6.2%pts to 4.9%pts (Figure 52). The decrease in the loan spread for coal mining occurred during the second year of the Covid-19 pandemic period.

- The average loan spreads for onshore gas and onshore oil are 2.9%pts and 3.4%pts, lower than that for biofuel of 4.0%pts between 2020 and 2021 (Figure 50). However, the changes in loan spreads vary across energy types. Comparing the 2020 and 2021 average, loan spreads in oil onshore production have remained largely stable, decreasing less than 1%, however, loan spreads in gas onshore have increased by 26%, from 2.5%pts to 3.2%pts (Figure 52).

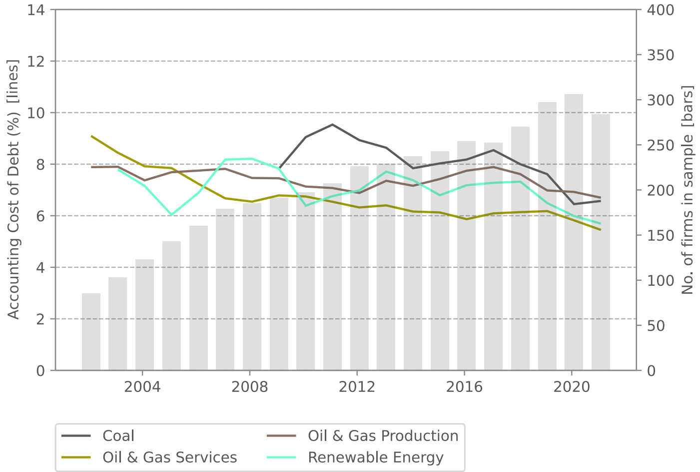
- During the same period, the loan spreads for oil & gas services generally show a downward trend from 2020 to 2021. For example, while the average loan spreads for gas pipeline transportation slightly increased by 4%, it has decreased by 28% and 15% for oil pipeline transportation and oil & gas refining, respectively (Figure 52).

- North America has received most loan investments for onshore oil production, oil & gas equipment and oil & gas refining compared to other regions (Figure 55). It has slightly higher loan spreads for those subsectors than Europe (Figure 54).

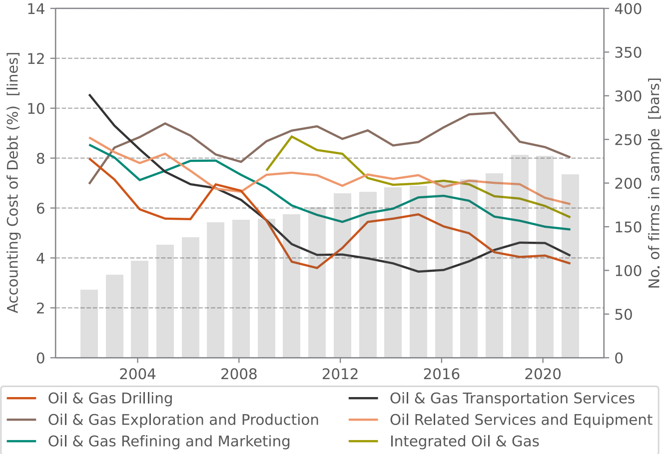
3.2.2 EUROPE

Accounting Cost of Debt

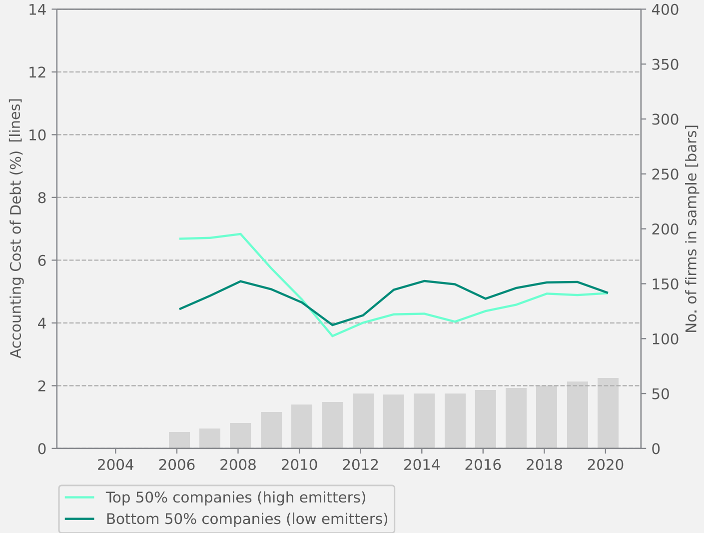
F56. EUROPE ENERGY PRODUCTION ACC COD, TRBC CLASSIFICATION



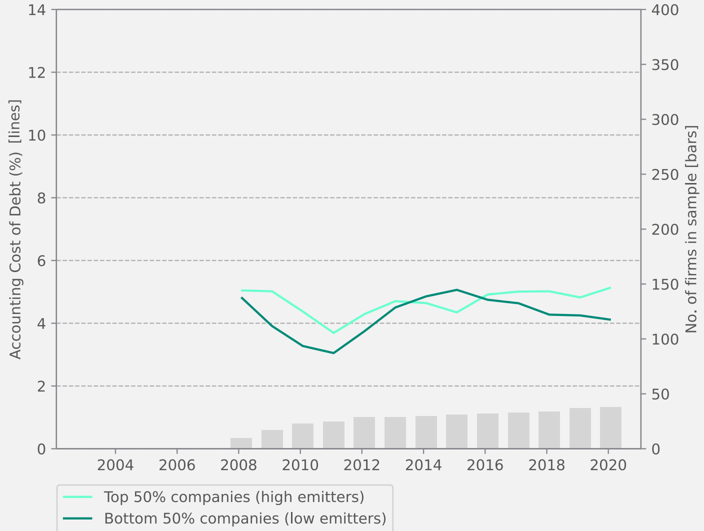
F57. EUROPE OIL & GAS ACC COD, TRBC SUBSECTOR CLASSIFICATION



F58. EUROPE OIL & GAS ACC COD, SCOPE 1 & 2 EMISSION INTENSITY



F59. EUROPE OIL & GAS PRODUCTION ACC COD, SCOPE 1 & 2 EMISSION INTENSITY



In Europe, coal mining and oil & gas production have the highest cost of debt, relative to oil & gas services and renewable fuels & technology. Within oil & gas production, companies with higher carbon-intensity have had a higher cost of debt since 2016.

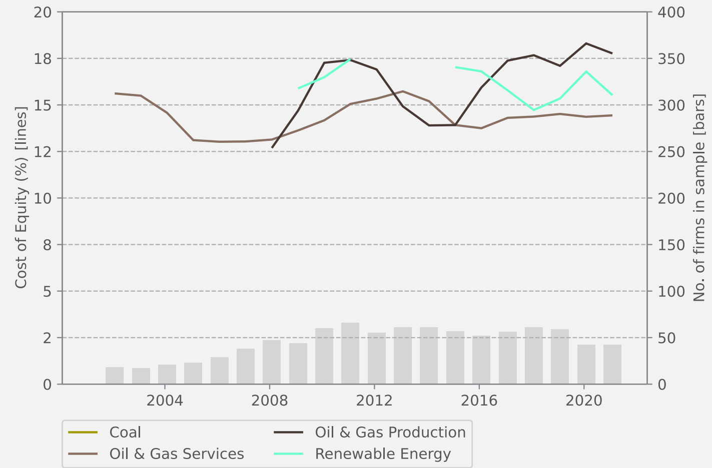
- In Europe, we see a consistent gap in the cost of debt between oil & gas production and oil & gas services (6.7% vs 5.5% in 2021). While coal mining as a cost of debt comparable to oil & gas production, renewable fuels and technology have a cost of debt comparable to lower risk oil & gas services (Figure 56).

- There is also a clear separation in the cost of debt between exploration & production and the rest of the sector, making the financing of the development of new reserves more costly in relative terms. All oil & gas activities other than exploration & production have seen decreasing costs of debt between 2002 and 2021, which remained more stable (Figure 57). As a result, as with 2021, there is a significant gap between upstream exploration & production (8%), midstream transportation (4.1%) and downstream refining & marketing (5.1%).

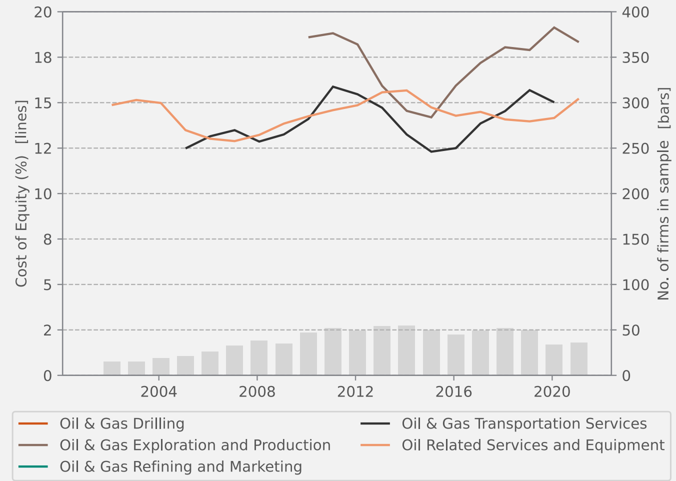
- Within the oil & gas sector, since 2011, the cost of debt of firms with high carbon-intensity was lower than those with low. However, over the past five years this gap has shrunk, with the two converging in 2020 (Figure 58). If limited to oil and production, this trend is accelerated, with lower emitters' cost of debt falling below that of higher emitters from 2016, with a gap of 1%pt in 2020 (Figure 59).

Cost of Equity

F60. EUROPE ENERGY PRODUCTION COE, TRBC CLASSIFICATION



F61. EUROPE OIL & GAS COE, TRBC SUBSECTOR CLASSIFICATION

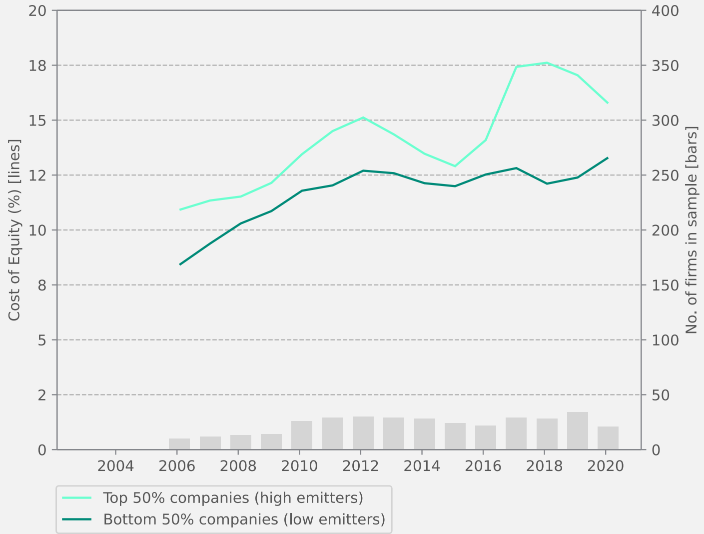


In Europe, oil & gas production has the highest cost of equity, while within oil & gas, companies with a higher carbon-intensity have the higher cost.

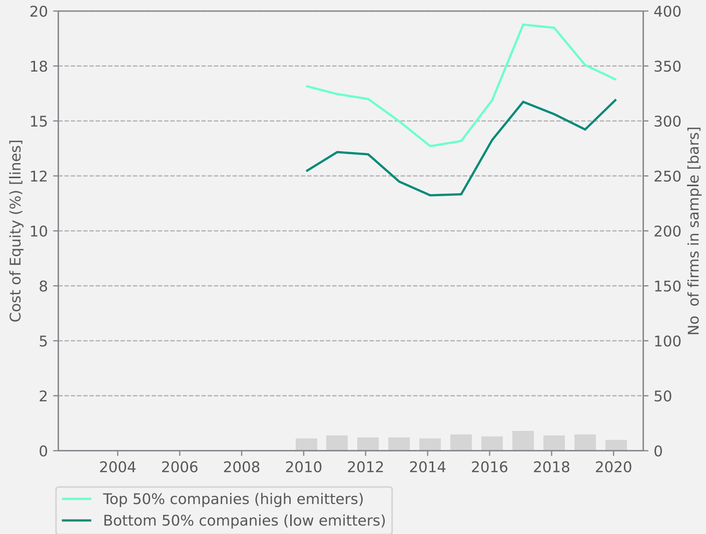
- In Europe, we see since 2015 a growing gap in the cost of equity between oil & gas production and oil & gas services as shown in Figure 60 (17.8% vs 14.4% in 2021). Similarly, using TRBC subsector classification, we see since 2016 an increasing cost of equity for exploration & production (Figure 61), consistent with the accounting cost of debt.

- Within the oil & gas sector, we observe a consistent gap between the cost of equity of the highest and lowest emitters since the start of the dataset, unlike the accounting cost of debt. This gap has fallen in recent years to 2.5%pts in the oil & gas industry and 0.9%pts in oil & gas production in 2020 (Figures 62 and 63).

F62. EUROPE OIL & GAS COE, SCOPE 1 & 2 EMISSION INTENSITY



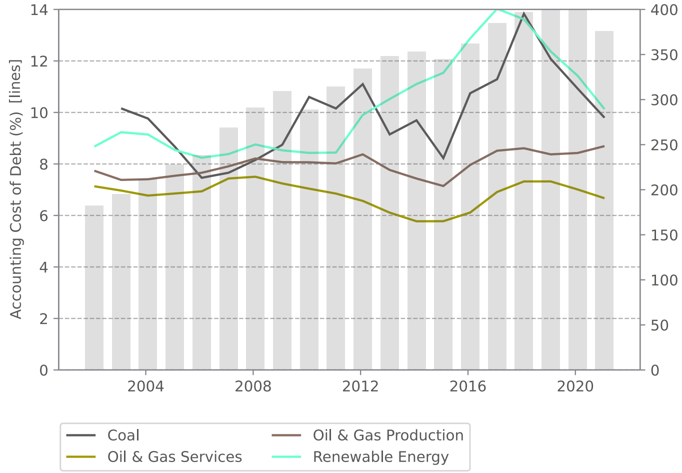
F63. EUROPE OIL & GAS PRODUCTION COE, SCOPE 1 & 2 EMISSION INTENSITY



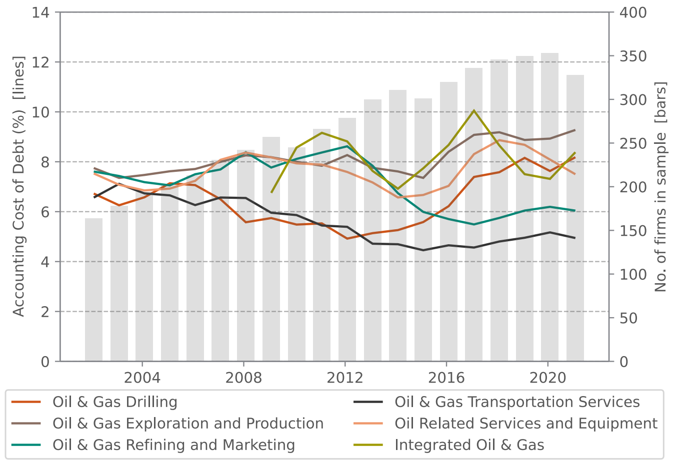
3.2.3 NORTH AMERICA

Accounting Cost of Debt

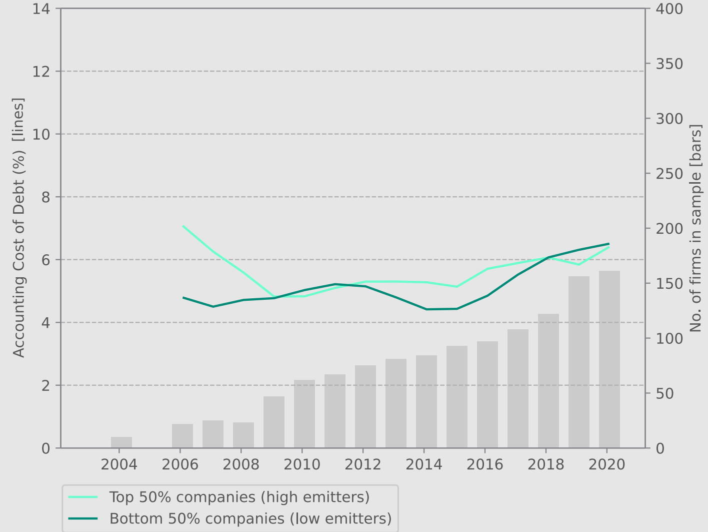
F64. NORTH AMERICA ENERGY PRODUCTION ACC COD, TRBC CLASSIFICATION



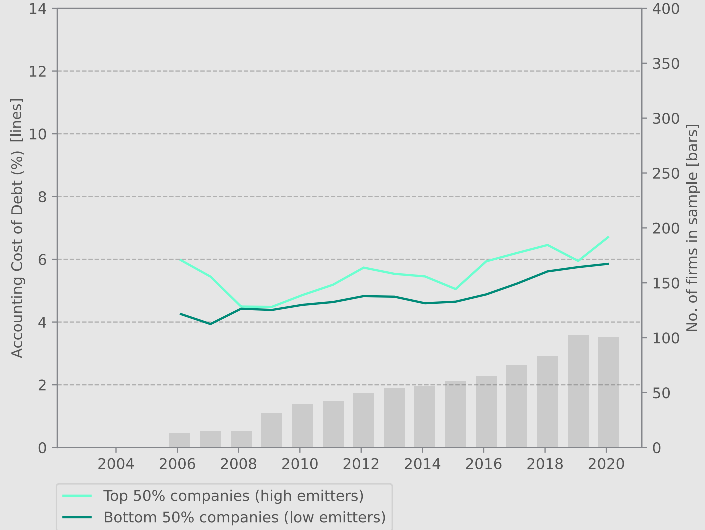
F65. NORTH AMERICA OIL & GAS ACC COD, TRBC SUBSECTOR CLASSIFICATION



F66. NORTH AMERICA OIL & GAS ACC COD, SCOPE 1 & 2 EMISSION INTENSITY



F67. NORTH AMERICA OIL & GAS PRODUCTION ACC COD, SCOPE 1 & 2 EMISSION INTENSITY



In North America, within the energy sector, companies engaged in coal mining and renewable fuels & technology have the highest cost of debt. However, within oil & gas, upstream companies and carbon-intensive producers have higher costs.

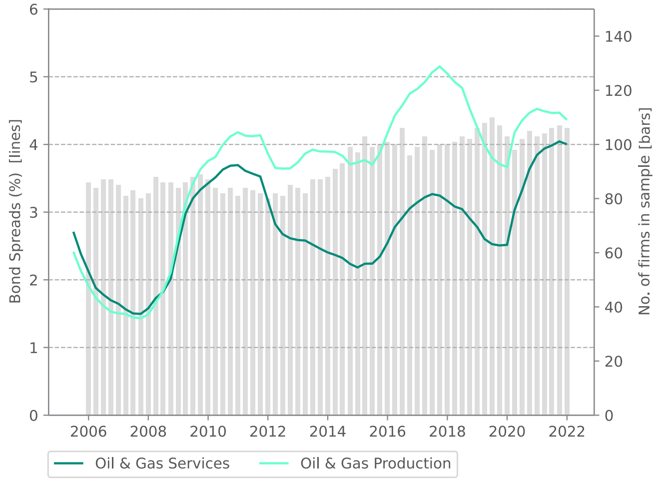
- Using TRBC sector classification, we see a consistent gap between oil & gas production and oil & gas services (8.7% vs 6.7% in 2021). Unlike Europe, in North America the cost of debt of renewable energy and fuels is comparable to that of coal mining, with both close to 10% in 2021 (Figure 64).

- When using TRBC subsector, we see exploration & production has the highest cost of debt, making the financing of the development of new reserves more costly in relative terms (Figure 65). Like Europe, North America has seen a rising cost of debt for exploration & production to 2021 (9.3%), while midstream transportation (4.9%) and downstream refining & marketing (6%) have fallen. In North America, there has also been a sharp increase in the risk of oil & gas drilling to 8.2%. In contrast to Europe, in North America the cost of debt of renewable energy and fuels is comparable to that of coal mining.

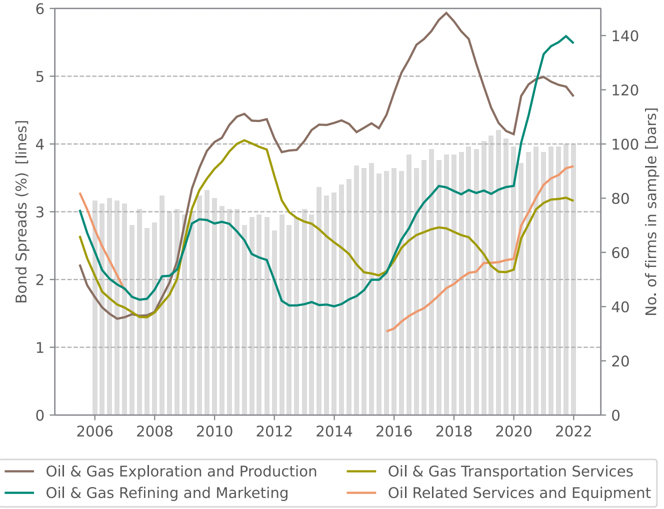
- In North America, oil & gas companies with lower carbon-intensity have had a marginally higher cost of debt since 2018 (Figure 66). However, when the analysis is limited in scope to oil & gas production, more carbon-intensive companies have had a consistently higher cost of debt, with this gap reaching 0.9%pts in 2020.

Secondary Market Bond Spreads

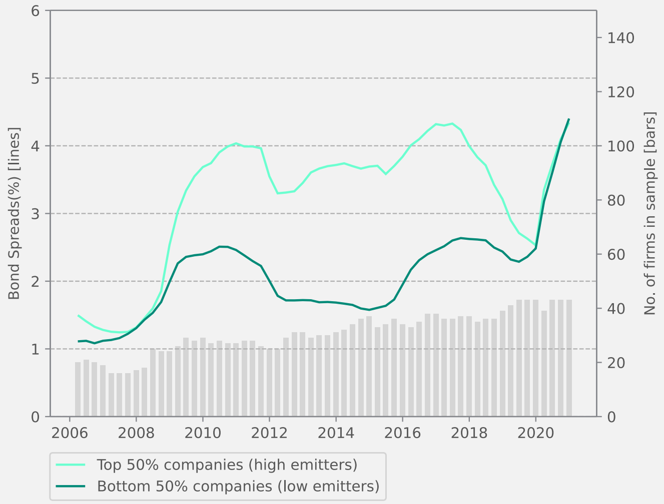
F68. US ENERGY PRODUCTION BOND SPREADS, TRBC CLASSIFICATION



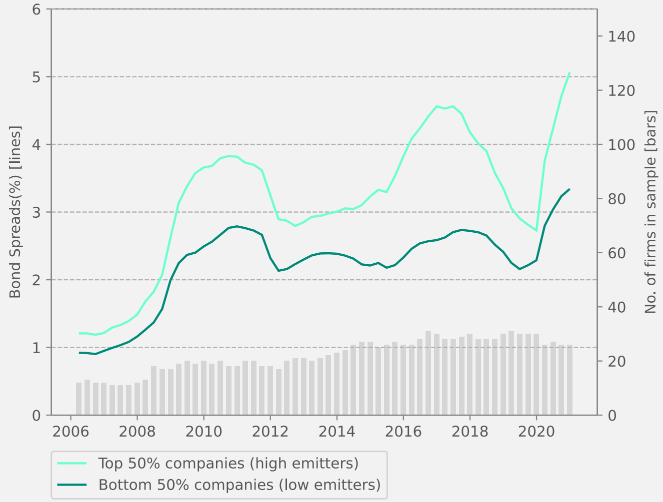
F69. US OIL & GAS BOND SPREADS, TRBC SUBSECTOR CLASSIFICATION



F70. US OIL & GAS BOND SPREADS, SCOPE 1 & 2 EMISSION INTENSITY



F71. US OIL & GAS PRODUCTION BOND SPREADS, SCOPE 1 & 2 EMISSION INTENSITY



In the US, in line with the accounting cost of debt, upstream oil & gas companies have higher bond spreads than mid and downstream companies, while within oil & gas production, companies that are more carbon-intensive producers have higher bond spreads.

- After the Global Financial Crisis (GFC), a significant gap in the spreads between US oil & gas services and oil & gas production emerged (Figure 68). At its peak in 2017, the spreads for oil & gas producers were around 2%pts higher than for oil & gas service companies. This gap has since gradually shrunk, especially during the COVID-19 crisis, with spreads rising rapidly for services. TRBC subsector analysis shows a similar trend (Figure 69). Even though the gap between upstream exploration & production and midstream transportation and downstream refining fell in recent years, the gap remains significant at over 1%pts (Figure 68).

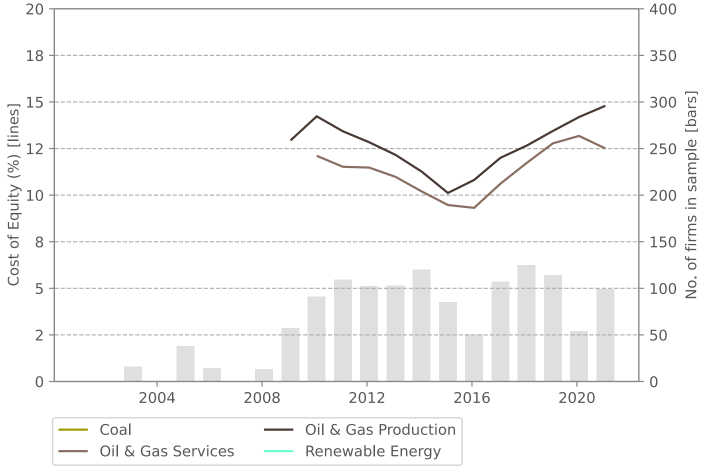
- Comparing secondary market bond spreads with accounting cost of debt reveals that for oil & gas subsectors has remained more stable in absolute levels since the year 2000, whereas secondary market bond spreads showed a significant absolute increase after the GFC. This difference is probably due to the responsive nature of secondary markets to macroeconomic conditions and interest rates compared to backward-looking accounting measures that take longer to adjust.

- Historically, higher emitting US oil & gas companies have had significantly higher spreads than lower emitting peers (Figure 70). However, in 2020, the two converged, due to the sharp increase in bond spreads observed in oil & gas services relative to higher carbon-intensity exploration & production and refining & marketing. In 2020, oil & gas transportation and exploration & production had the highest average scope 1 and 2 carbon-intensity at 4,063 $CO_2t/\$m$ and 826 $CO_2t/\$m$ respectively, followed by refining and marketing at 477 $CO_2t/\$m$ and oil related services at 108 $CO_2t/\$m$. Limiting the scope of the emission intensity analysis to oil & gas production, we see that higher emitters have had bond spreads consistently above lower emitters, in line with the accounting cost of debt (Figure 71).

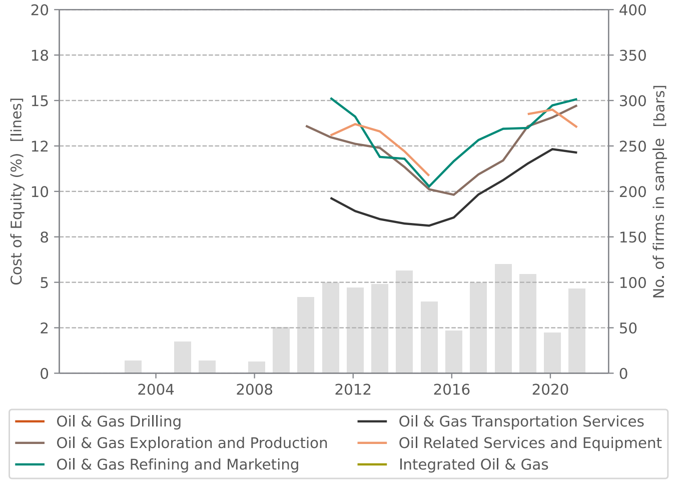
After the Global Financial Crisis (GFC), a significant gap in the spreads between US oil & gas services and oil & gas production emerged

Cost of Equity

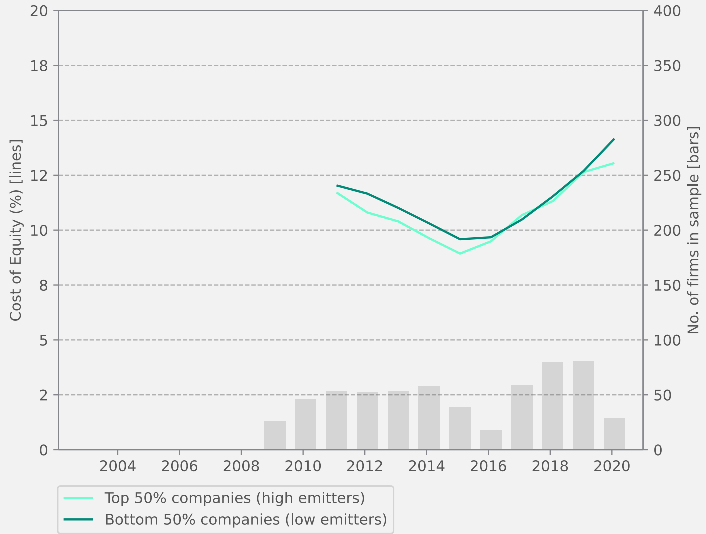
F72. NORTH AMERICA ENERGY PRODUCTION COE, TRBC CLASSIFICATION



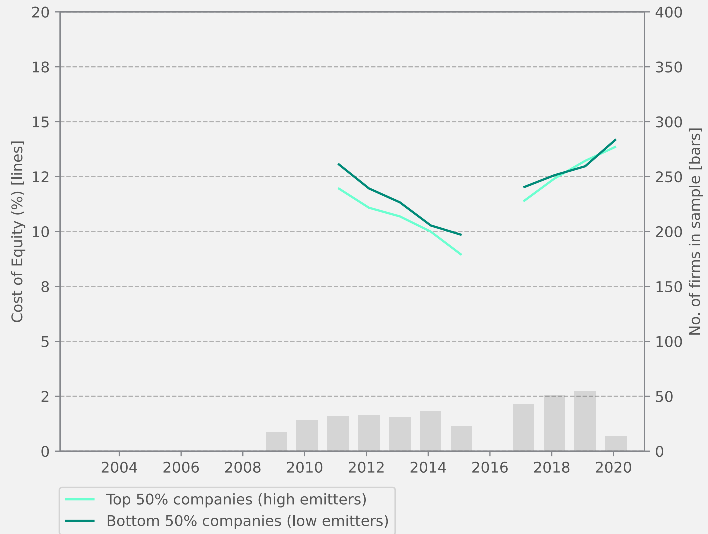
F73. NORTH AMERICA OIL & GAS COE, TRBC SUBSECTOR CLASSIFICATION



F74. NORTH AMERICA OIL & GAS COE, SCOPE 1 & 2 EMISSION INTENSITY



F75. NORTH AMERICA OIL & GAS PRODUCTION COE, SCOPE 1 & 2 EMISSION INTENSITY



In North America, while companies in oil & gas production have a higher cost of equity than those in services, companies with carbon-intensive operations have effectively the same cost of equity as lower-emitting peers.

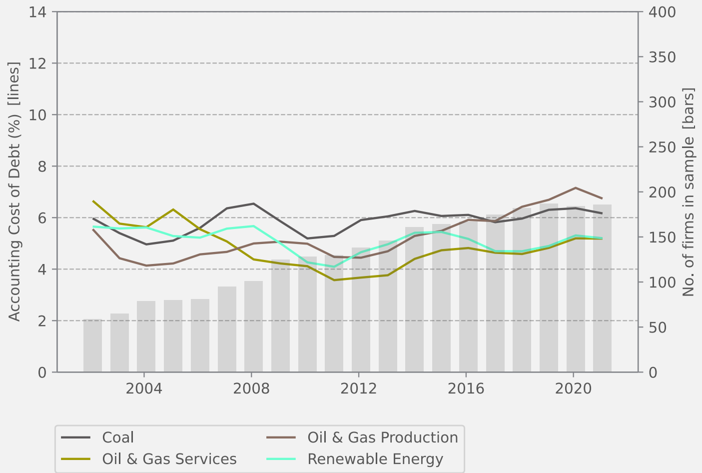
- In North America, there is a consistent gap between oil & gas production and oil & gas services as shown by Figure 72 (14.8% vs 12.5% in 2021), in line with the cost of debt and bond spreads analysis. However, by subsector, we observe that the cost of equity of exploration & production is comparable to that of refining & marketing, at around 15% (Figure 73).

- Unlike the cost of debt and bond spread analysis, we observe that the highest and lowest emitters have a comparable cost of equity, both within the oil & gas sector overall and when limited to oil & gas production (Figures 74 & 75).

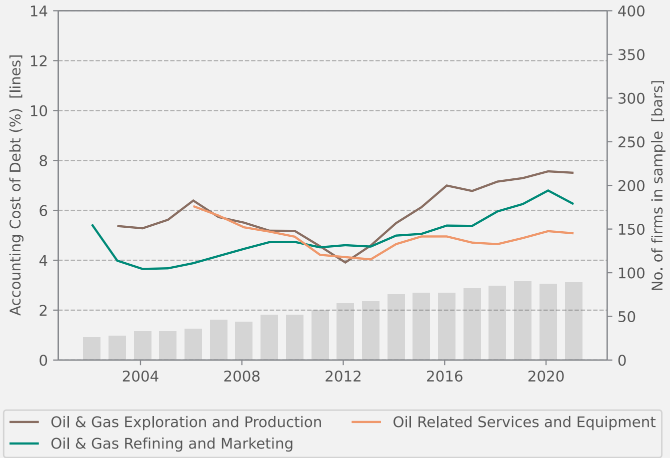
4.2.4 CHINA

Accounting Cost of Debt

F76. CHINA OIL & GAS ACC COD, TRBC SUBSECTOR CLASSIFICATION



F77. CHINA OIL & GAS ACC COD, SCOPE 1 & 2 EMISSION INTENSITY



In China, within the energy sector oil & gas production has the highest cost of debt, rising above coal mining in 2017, while renewable fuels & technology are perceived as lower risk.

- Within energy production in China, oil & gas production has the highest cost of debt at present. This is shown by Figure 75, with a cost of debt of 6.7% in 2021, following a sharp increase since 2014. This is above coal mining at 6.2%, oil & gas services at 5.2%, and renewable fuels & technology at 5.2%.

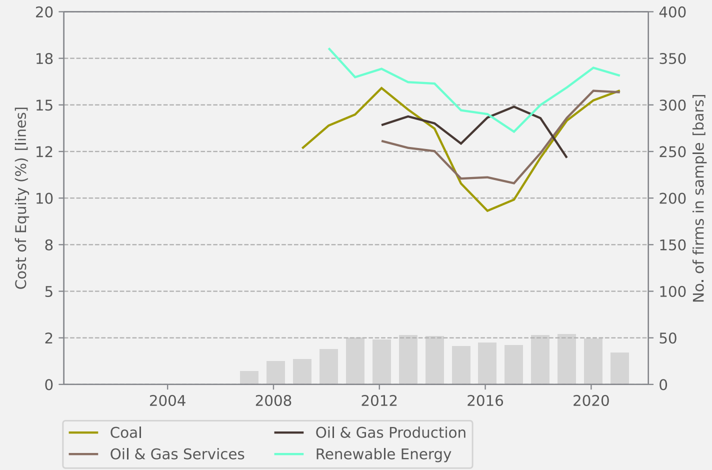
- Since 2012, when focused on the oil & gas only, we observe a sharp growth in the cost of debt of exploration & production, making financing the development of new oil & gas reserves increasingly costly. This is shown in the TRBC subsector in Figure 76, with the cost of debt in 2021 of upstream production at 7.5%, compared to 6.3% for downstream refining & marketing.

- Due to a lack of data, emission intensity analysis limited to oil & gas is not shown.

Within energy production in China, oil & gas production has the highest cost of debt at present.

Cost of Equity

F78. CHINA ENERGY PRODUCTION COE, TRBC CLASSIFICATION



In contrast to the cost of debt, in China, renewable fuels & technology have the highest cost of equity.

- Within energy production in China, oil & gas production had the highest cost of equity in 2021 at 6.7%, following a sharp increase from 2014. This was above coal mining at 6.2%, and oil & gas services and renewable fuels & technology at 5.2% (Figure 78).

- The different performance between the cost of debt and cost of equity for renewable fuel & technology in China may suggest that other factors such as size or net profits may be at play in the equity earnings forecast.

3.1.5 OTHER REGIONS

Below, the key trends are summarised in other regions where less data is available. All charts are shown in Annex 2.

Developing Countries/Regions:

ASEAN: In the ASEAN region, the cost of debt of coal mining is significantly above that of oil & gas production and services, as well as renewable fuels & technology. Consistent with trends observed in other regions, since 2016 all sectors have experienced a rising cost of debt. In 2021, it was 8% for coal mining, 7.2% for renewable fuels & technology, and 5.7% for oil & gas production and services.

India: In India, unlike all other regions, we observe that the cost of debt of oil & gas production is significantly below oil & gas services, while renewable fuels & technology is above both. In keeping with global trends, all sectors have had a rising cost of debt since 2015/2016. In 2021, it was 8.8% for renewable fuels & technology, 7.6% for oil & gas services, and 5.8% for oil & gas production.

Developed Countries/Regions:

Australia: In Australia, coal mining has a marginally higher cost of debt than oil & gas production, at 9.5% and 9% in 2021 respectively. Consistent with trends observed in other regions, both sectors have experienced a sharp increase in the cost of debt since 2015.

Japan/Korea: In Japan and South Korea, the cost of debt for renewable fuels & technology has been consistently above that of oil & gas production and coal. In 2021, for example, the cost of debt of renewable fuels & technology reached 3.7% as opposed to 2.3% for oil & gas production. (No coal mining data was available in 2021).

4 Conclusion

In our second report as part of the Energy Transition Risk and Cost of Capital Programme (ETRC), we a) expanded on Phase 1 by tracking the cost of capital to equities, corporate bonds, and accounting data in addition to syndicated loans, b) extended trend analysis based on TRBC sector classification to emission intensity and energy mix. This large-scale and robust approach allowed us to provide a broader vision of changes in the global energy system's cost of capital and to inform practitioners and policy makers about changing market sentiments and risk preferences by region and asset class in the carbon intensive industries.

In electric utilities, we find that, globally, renewable electric utilities with a higher share of solar and wind power capacities have a lower cost of equity and debt than fossil fuel focused peers. This finding is consistent with the previous report for the syndicated loan markets, which showed that loan spreads for renewables fell below fossil fuel power generations in the past decade. In addition, there are significant variations across regions: renewable electric utilities have shown clear evidence of a lower cost of capital in Europe, a higher cost in China, and mixed trends in North America. These variations imply that during the energy transition to a low carbon economy, financial institutions seem to respond to climate risks according to the geographical context, including the stringency of local environmental policy.

For energy production, globally, the cost of capital is highest for coal mining, followed by oil & gas production and renewable fuels. Europe has demonstrated similar trends in the changes in the cost of capital based on TRBC sector analysis, emission intensity analysis and energy mix analysis. However, the findings in North America are not as consistent as in Europe and vary by asset class. Sector analysis shows that the cost of debt for coal mining and renewable fuels is higher and more volatile than in oil & gas production and services over the past ten years. Emission-intensive analysis indicates that, while the cost of debt of higher emitters has been consistently above the lower since 2008, this performance difference is not the case for the cost of equity. In China, the cost of capital for low-carbon firms is not lower than for high-carbon peers. The divergence in the cost of capital across major markets reinforces our observation that environmental policies matter in asset pricing. The gap in the cost of capital between coal mining and others has widened since the 2015 Paris Agreement, suggesting that international regulative efforts could play a role in combating climate change. These findings are of relevance to policymakers looking to accelerate the financing of low-carbon transition.

This study comes with two limitations. First, the descriptive trend analysis does not take into account other firm-level characteristics that are likely to contribute to the financing costs, as the purpose of this study is to show the changes or shocks in the cost of capital by country/region and energy source, and draw policymakers' and researchers' attention to the need for further risk analysis for any specific region or asset class. Second, due to the limitations in the availability and consistency of data in emerging markets, we can provide useful insights only for major markets. We are looking to work with other partners to collect qualitative data such as surveys to complete studies for regions lacking quantitative data.

5 Annexes

ANNEX 1: DETAILED METHODS

Accounting Cost of Debt

For this, we use the Trade Reporting and Compliance Engine (TRACE) database, a US mandatory reporting vehicle for over-the-counter transactions of fixed-income securities implemented by the Financial Industry Regulatory Authority (FINRA). We filter all reported trades in TRACE for non-discontinued, non-closed and non-exchanged bonds issued by either electric utilities or energy producers using The Refinitiv Business Classification (TRBC). We take the yields from TRACE and subtract time-to-maturity-matched, interpolated, US treasury yields to obtain bond spreads.

To ensure that the reported prices on TRACE are close to fair value we exclude retail trades, as their higher bid-ask spreads introduce noise to prices (Bessembinder et al., 2009; Dick-Nielsen, 2009). Hence, we exclude trades with volumes below 100,000 USD (as in Becker and Ivashina 2015; Duan, Li, and Wen, 2020). We also discard trades of bonds with maturities under six months (as in Bai, Bali, and Wen, 2019; Dick-Nielsen, Feldhütter, and Lando, 2012), as securities with shorter maturities are often excluded from bond-indices and therefore less frequently traded by financial institutions.

For the remaining trades we take the yields from TRACE and subtract time-to-maturity-matched, interpolated, US treasury yields to obtain bond spreads. Treasury yields are extracted from the Federal Reserve Economic Data (FRED) database and linearly interpolated to match the time-to-maturities of bonds. With this linear method, our interpolation errors increase for bonds with larger time-to-maturity. Furthermore, if time-to-maturity exceeds 30 years (less than 2% of observations), which is the maximum time-to-maturity for a US treasury bond, we match the bond yield with the 30-year treasury yield. We winsorize bond spreads at 1% and 99% to exclude negative spreads and eliminate errors, and resample the data based on the last observation per quarter[6] to obtain a time series for each bond.

[6] Results are similar when using quarterly averages instead of last trade resampling.

Using Refinitiv's Eikon database we assign each bond in our sample to its risk-bearing organisation. Usually, this is the issuer of the bond.[7] To limit the impact of country risk on our analysis, we continue with companies headquartered in the US, which make up approximately 80% of the full sample. The value-weighted average of bond spreads by market value for each organization is our final measure of secondary market cost of debt (Anderson, Mansi, and Reeb, 2004; Bessembinder et al., 2009; Li and Richie, 2016).

Implied Cost of Equity

Our first measure, based on Gebhardt, Lee, and Swaminathan (2001) (r_{GLS}) is estimated from the following model:

(1)

$$P_t = BV_t + \frac{ROE_{t+1} - r_{GLS}}{1 + r_{GLS}} \times BV_t \frac{ROE_{t+2} - r_{GLS}}{1 + r_{GLS}} \times BV_t \times BV_{t+1} + \sum_{i=3}^{11} \frac{ROE_{t+1} - r_{GLS}}{(1 + r_{GLS})^i} \times BV_{t+1-i} \frac{ROE_{t+11} - r_{GLS}}{r_{GLS} \times (1 + r_{GLS})^{11}} \times BV_{t+11}$$

Where P_t is the price per share at the end of year t; BV_t is the book value per share at the end of year t; *ROE* is the forecasted return on equity, where for the first three years, ROE_{t+i} is computed as $FEPS_{t+i} / BV_{t+i}$, where $FEPS_{t+i}$ is the median forecasted EPS for year t+i from I/B/E/S database, and, beyond the third year, we estimate the ROE using a linear interpolation to the Fama-French industry mean ROE in line with Gebhardt et al. (2001).

Our second measure, based on (Claus and Thomas 2001) (r_{CT}), is specified as follows:

(2)

$$P_t = BV_t + \frac{eps_{t+1}}{1 + r_{CT}} + \frac{eps_{t+2}}{(1 + r_{CT})^2} + \frac{eps_{t+3}}{(1 + r_{CT})^3} + \frac{eps_{t+4}}{(1 + r_{CT})^4} + \frac{eps_{t+5}}{(1 + r_{CT})^5} + \frac{eps_{t+5} \times (1 + g_{eps})}{(r_{CT} - g_{eps}) \times (1 + r_{CT})^5}$$

Where $EPS_{i,}$ is the abnormal EPS in the year i, measured as $FEPS_{t+i}\ xBA_{t+i-1}$ $x\ r_{CT}$; g_{eps} is the growth rate of abnormal earnings beyond year t+5, and it is set to r_f where r_f is the interest rate on a 10-year treasury bill measured in June of the given year.

[7] However, if we find a separate guarantor of the bond that is not the issuer, we take the guarantor instead. We make an exception to ensure bonds are not assigned to large financial institutions; if the guarantor does not operate in the electric utility or energy production sector, we assign the issuing company instead.

(3)

$$r_{OJ} = A + \sqrt{A^2 + \frac{eps_{t+1}}{P_t} \times \left(\frac{eps_{t+2} - eps_{t+1}}{eps_{t+1}}\right) - (g-1)}$$

$$A = \frac{1}{2}(g-1) + \frac{dps_{t+1}}{P_t}$$

Our third measure is based on the Ohlson and Juettner-Nauroth (2005) model (r_{OJ}) and we specify the equation following Gode and Mohanram (2003).

Where dps_{t+1} is the expected dividend per share for year t+1, proxied by *dps; g* represents economic growth and is set to r_f is the interest rate on a 10-year treasury bill measured in June of the given year.

Our fourth measure is based on Easton (2004) (r_{PEG}) and we construct the estimation as follows:

(4)

$$r_{PEG} = \sqrt{\frac{eps_{t+2} - eps_{t+1}}{P_t}}$$

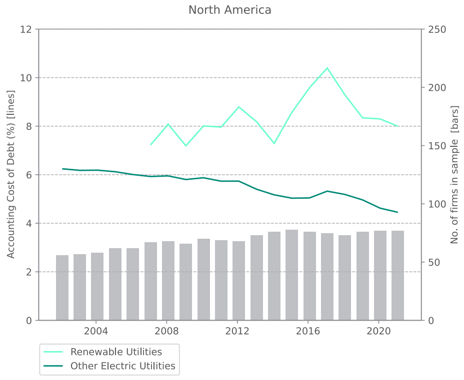
where eps_{t+1} is the expected accounting earnings in the next period, eps_{t+2} is the expected accounting earnings at two-periods-ahead of the current date, and P_t is the price per share at the current date.

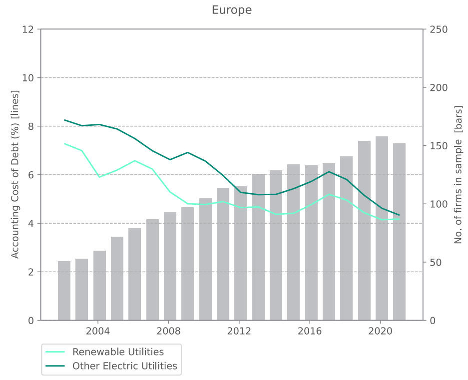
TABLE 5 DEFINITIONS OF THE APPROACHES EMPLOYED TO ESTIMATE THE COST OF EQUITY CAPITAL

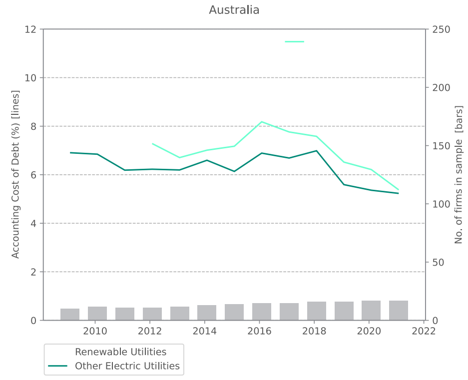
Cost of Equity	Definitions
CoE	The cost of equity capital (CoE), measured as the mean value of four different measures of the implied cost of equity: *rGLS, rCT, rOJ, and rPEG.*
r_{GLS}	The estimate of cost of equity following Gebhardt et al. (2001).
r_{CT}	The cost of equity estimated based on Claus and Thomas (2001).
r_{OJ}	The cost of equity following Gode and Mohanram (2003) and Easton and Monahan (2005),which is based on the model in Ohlson and Juettner-Nauroth (2005).
r_{PEG}	The measure of the cost of equity as in Easton (2004).

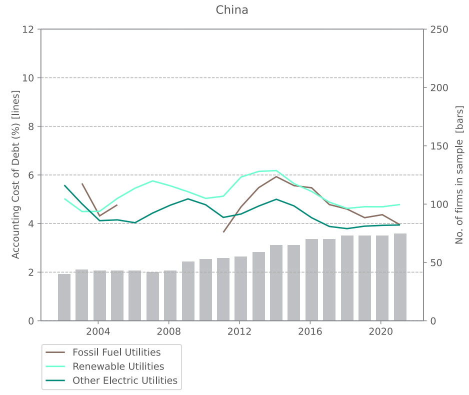
ANNEX 2: CHARTS OF ALL REGIONS

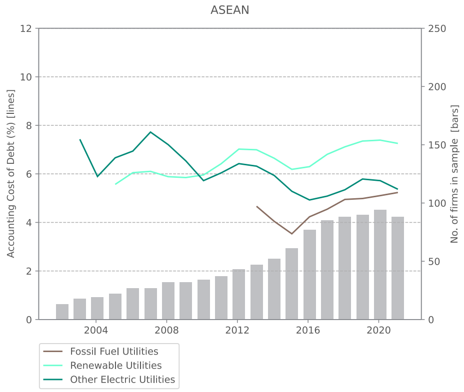
Electric Utilities 3-YEAR MOVING AVERAGE ACCOUNTING COST OF DEBT FOR ELECTRIC UTILITIES, BY TRBC CLASSIFICATION

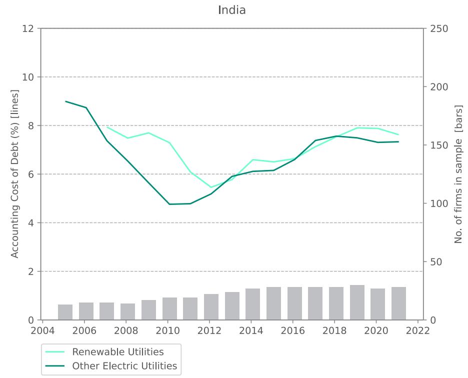


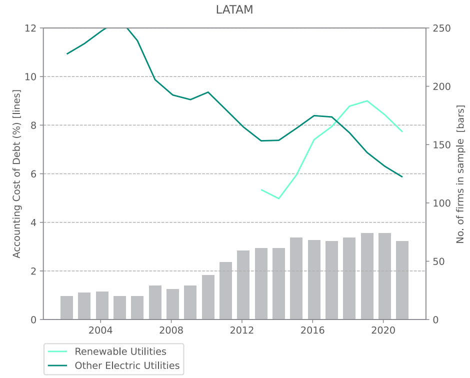


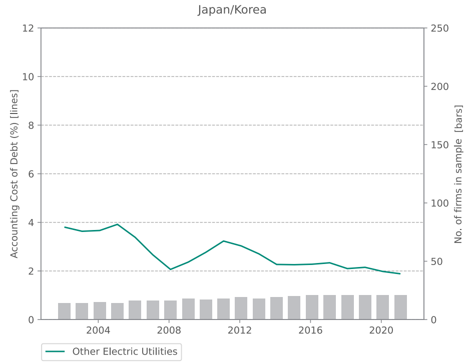


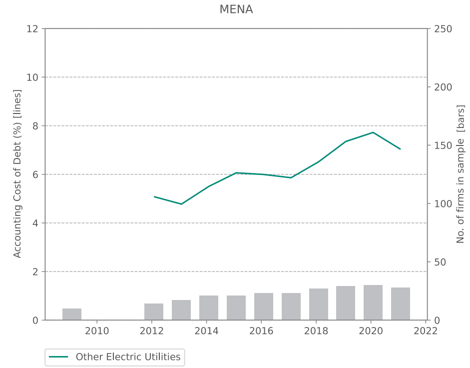


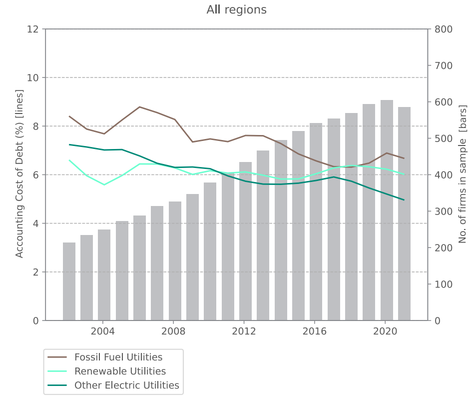




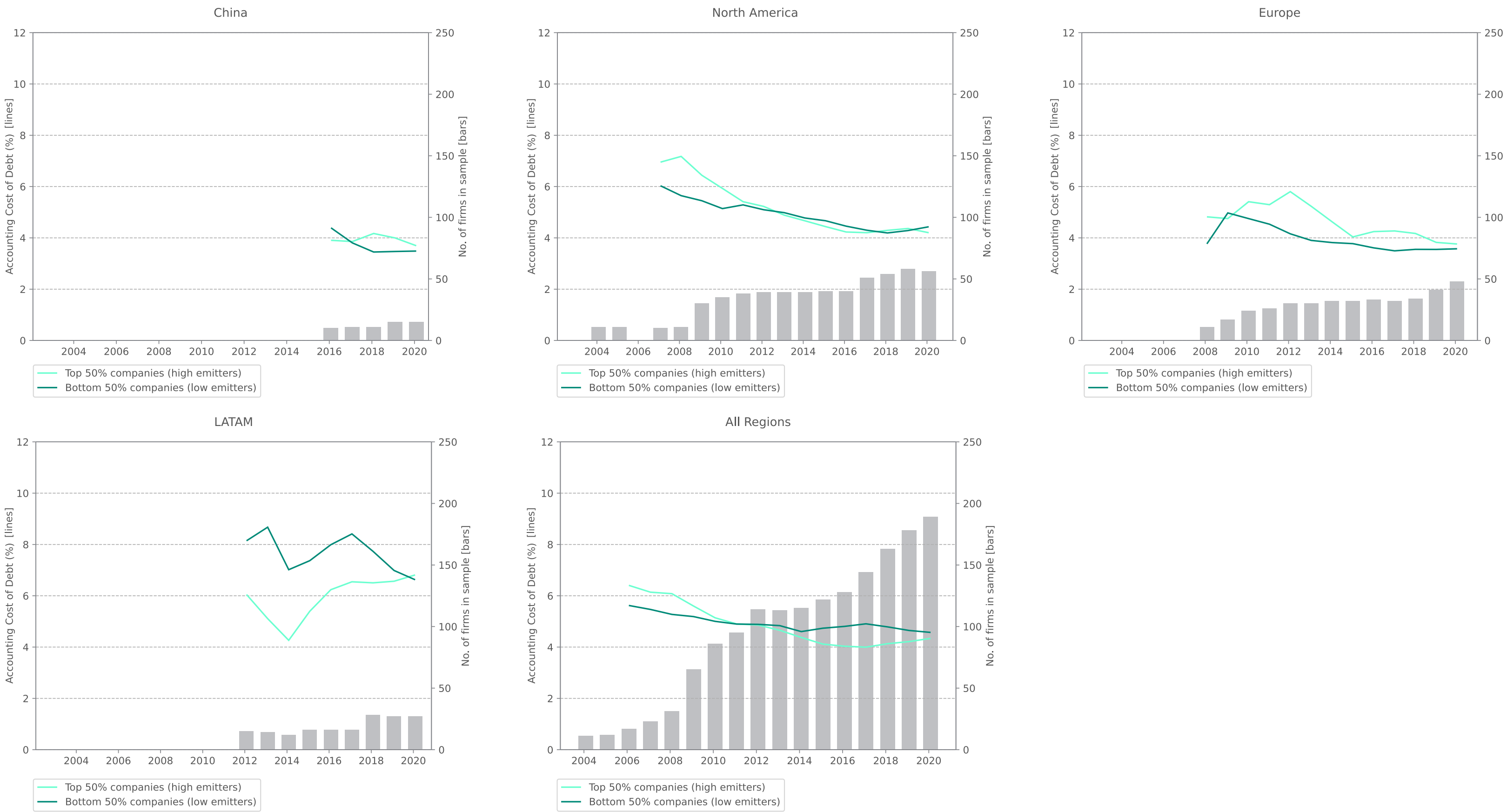








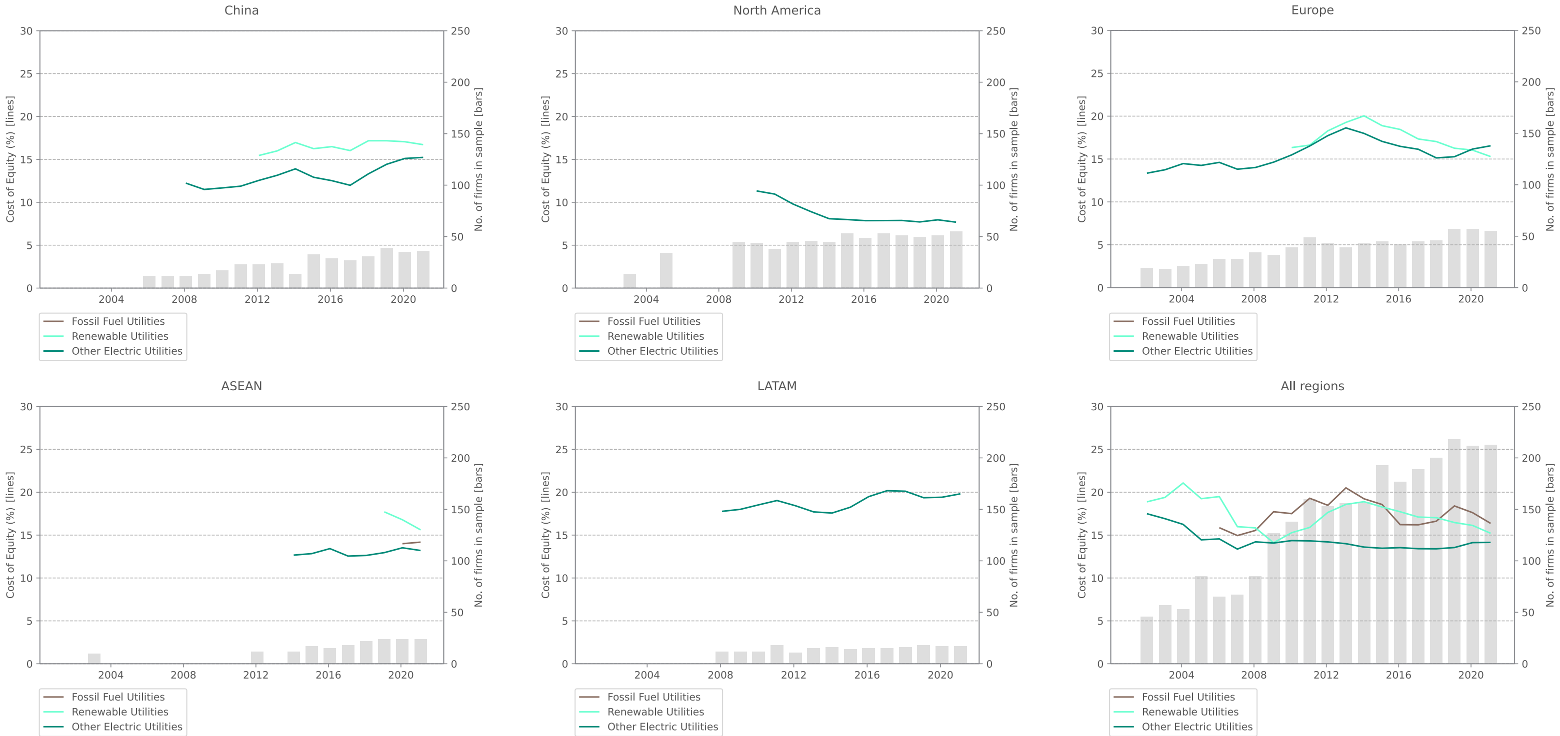
3-YEAR MOVING AVERAGE ACCOUNTING COST OF DEBT FOR ELECTRIC UTILITIES, BY EMISSION INTENSITY



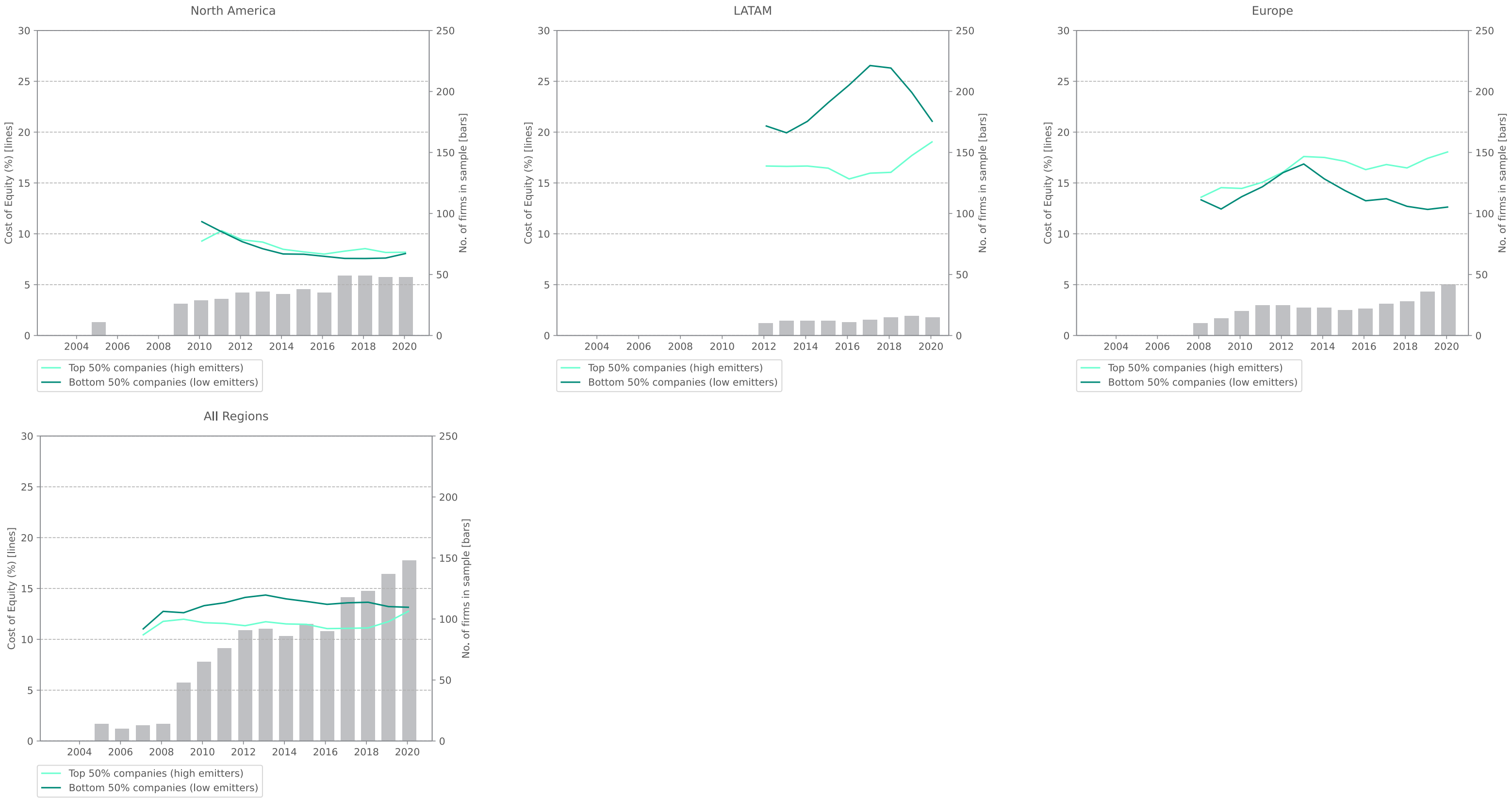
3-YEAR MOVING AVERAGE ACCOUNTING COST OF DEBT FOR ELECTRIC UTILITIES, BY SOLAR/WIND ENERGY MIX

3-YEAR MOVING AVERAGE ACCOUNTING COST OF DEBT FOR ELECTRIC UTILITIES, BY LOW-CARBON ENERGY MIX

3-YEAR MOVING AVERAGE COST OF EQUITY FOR ELECTRIC UTILITIES, BY TRBC CLASSIFICATION



3-YEAR MOVING AVERAGE ACCOUNTING COST OF EQUITY FOR ELECTRIC UTILITIES, BY EMISSIONS INTENSITY



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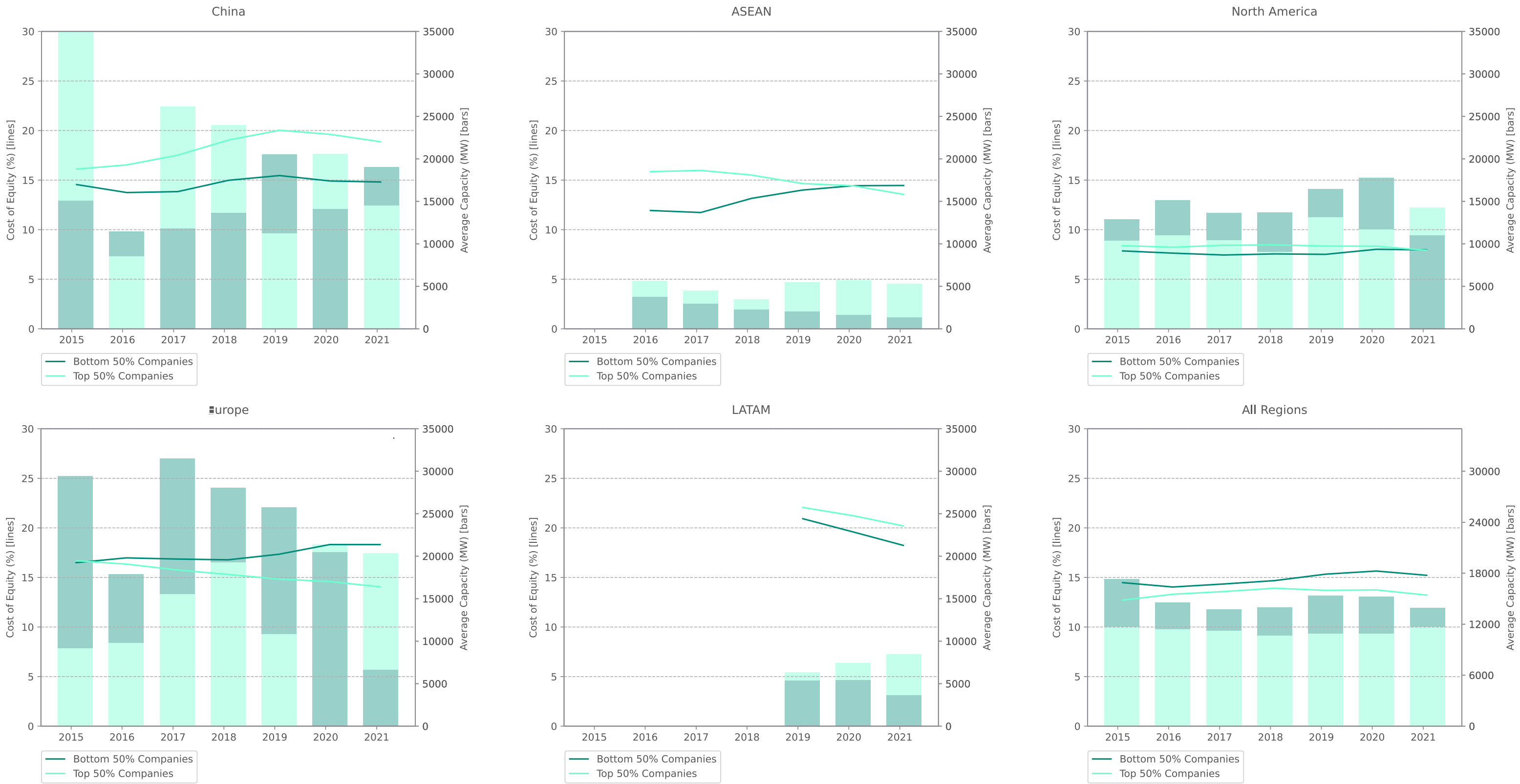
3-YEAR MOVING AVERAGE ACCOUNTING COST OF EQUITY FOR ELECTRIC UTILITIES, BY SOLAR/WIND ENERGY MIX



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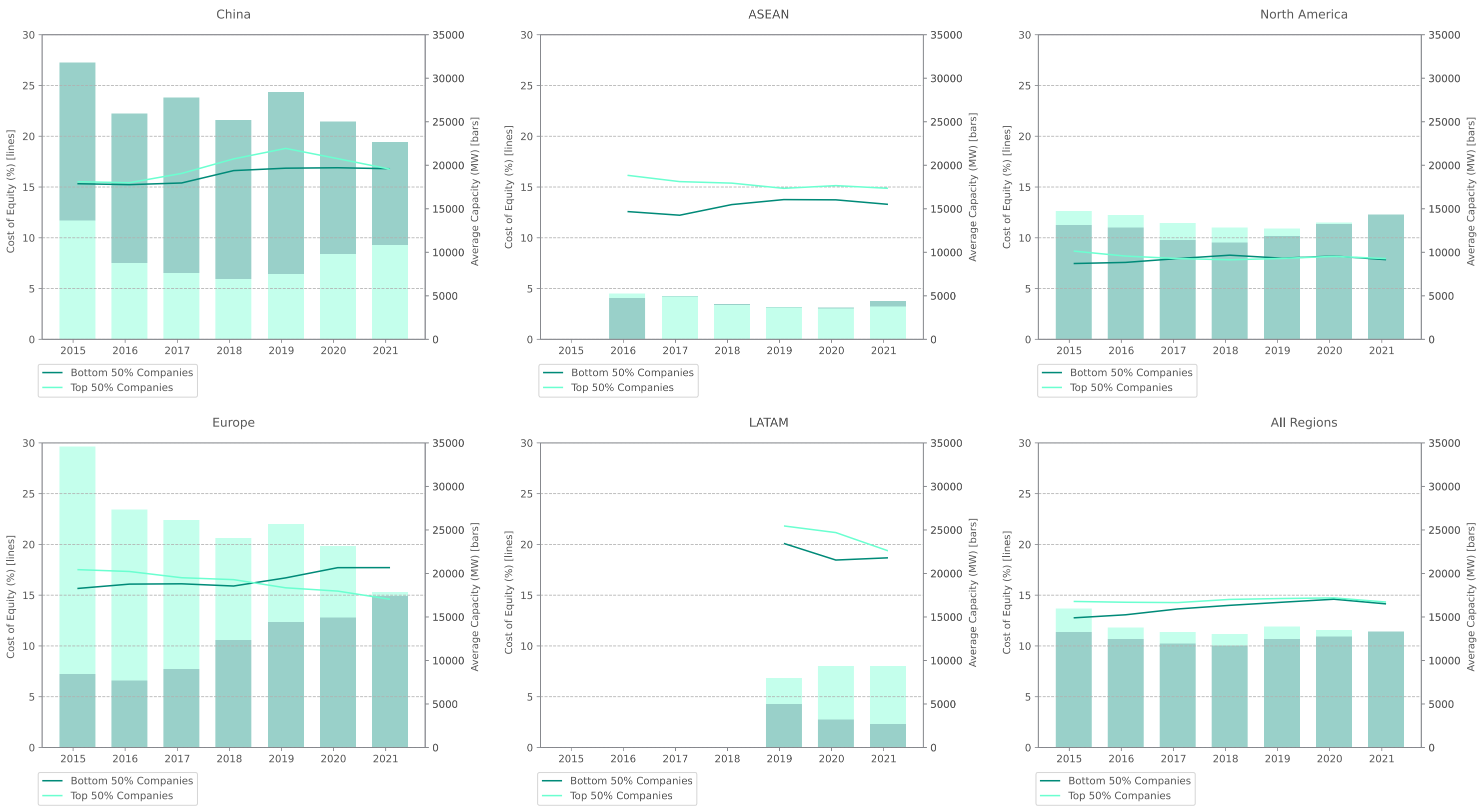
3-YEAR MOVING AVERAGE ACCOUNTING COST OF EQUITY FOR ELECTRIC UTILITIES, BY LOW-CARBON ENERGY MIX



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ENERGY PRODUCTION 3-YEAR MOVING AVERAGE ACCOUNTING COST OF DEBT FOR ENERGY PRODUCERS, BY TRBC CLASSIFICATION

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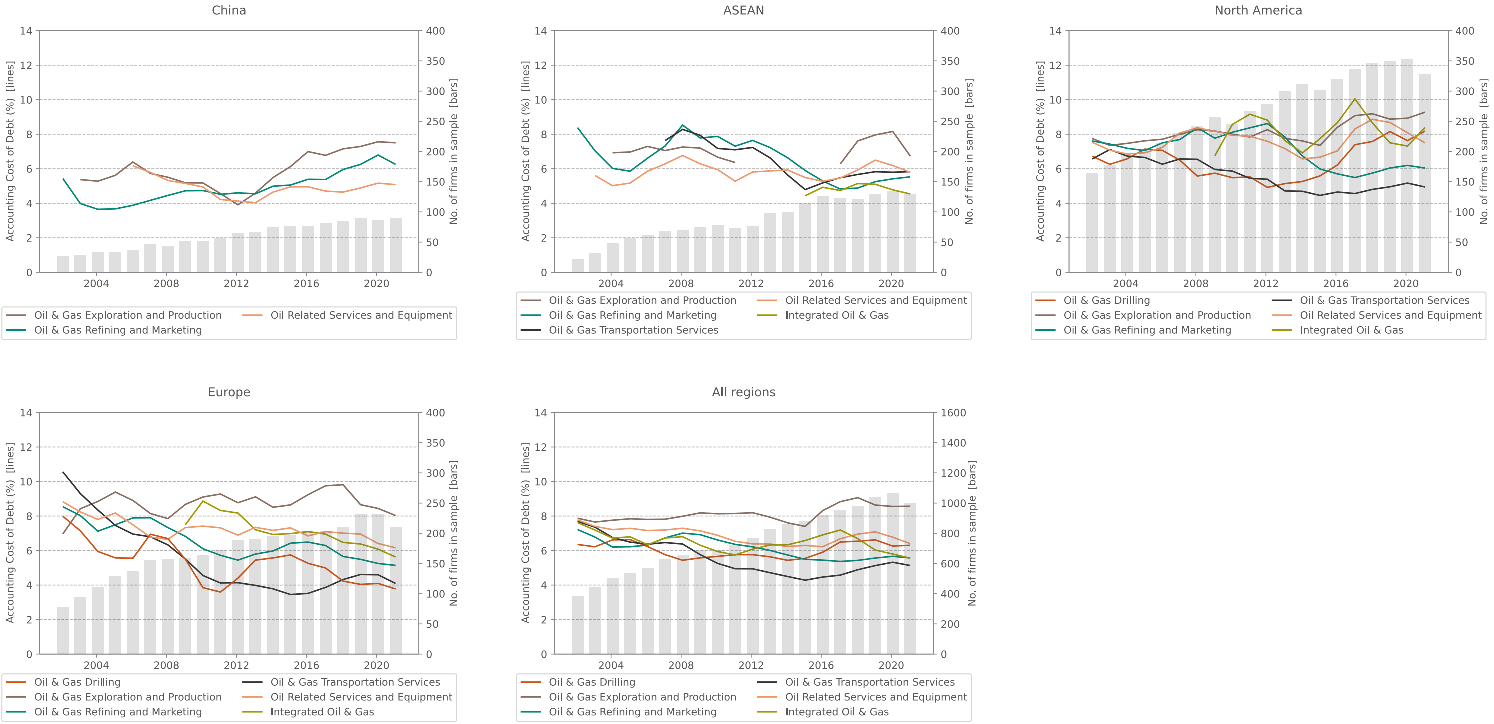
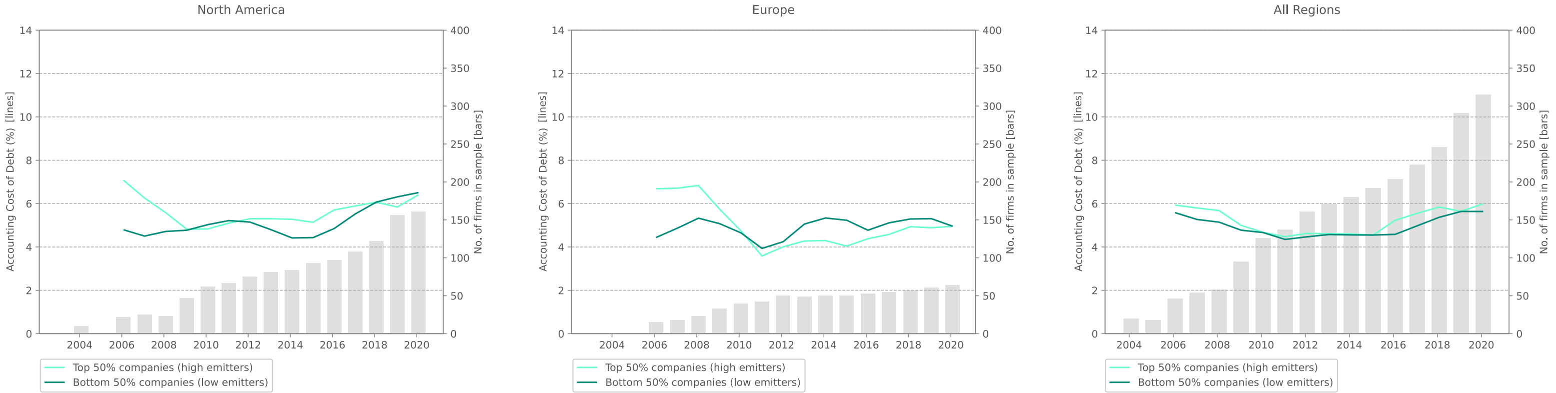
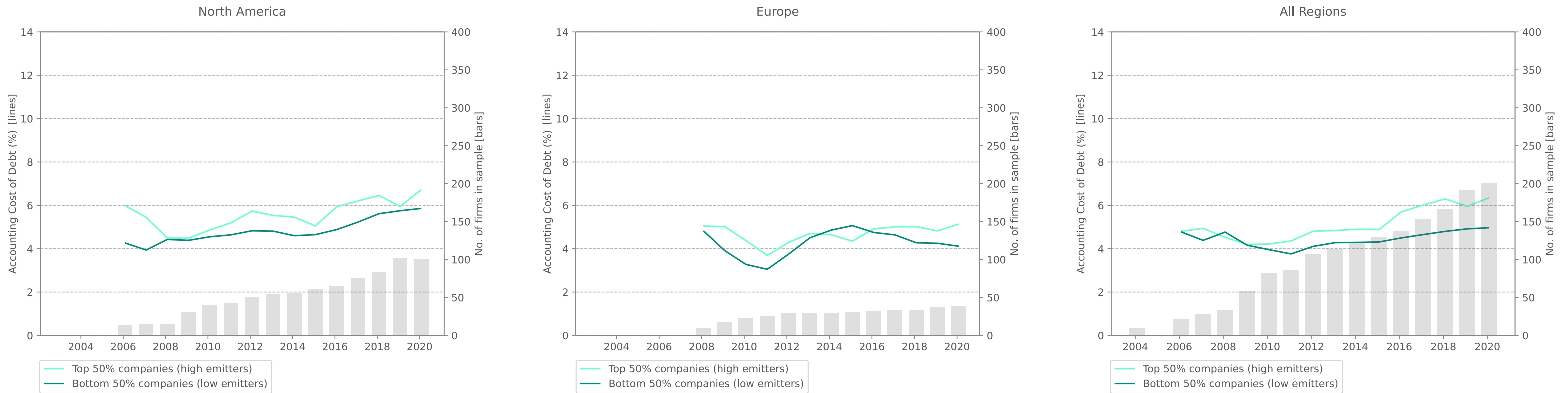
3-YEAR MOVING AVERAGE ACCOUNTING COST OF DEBT FOR OIL & GAS, BY TRBC SUBSECTOR CLASSIFICATION



3-YEAR MOVING AVERAGE ACCOUNTING COST OF DEBT FOR OIL & GAS, BY EMISSION INTENSITY



3-YEAR MOVING AVERAGE ACCOUNTING COST OF DEBT FOR OIL & GAS PRODUCTION, BY EMISSION INTENSITY



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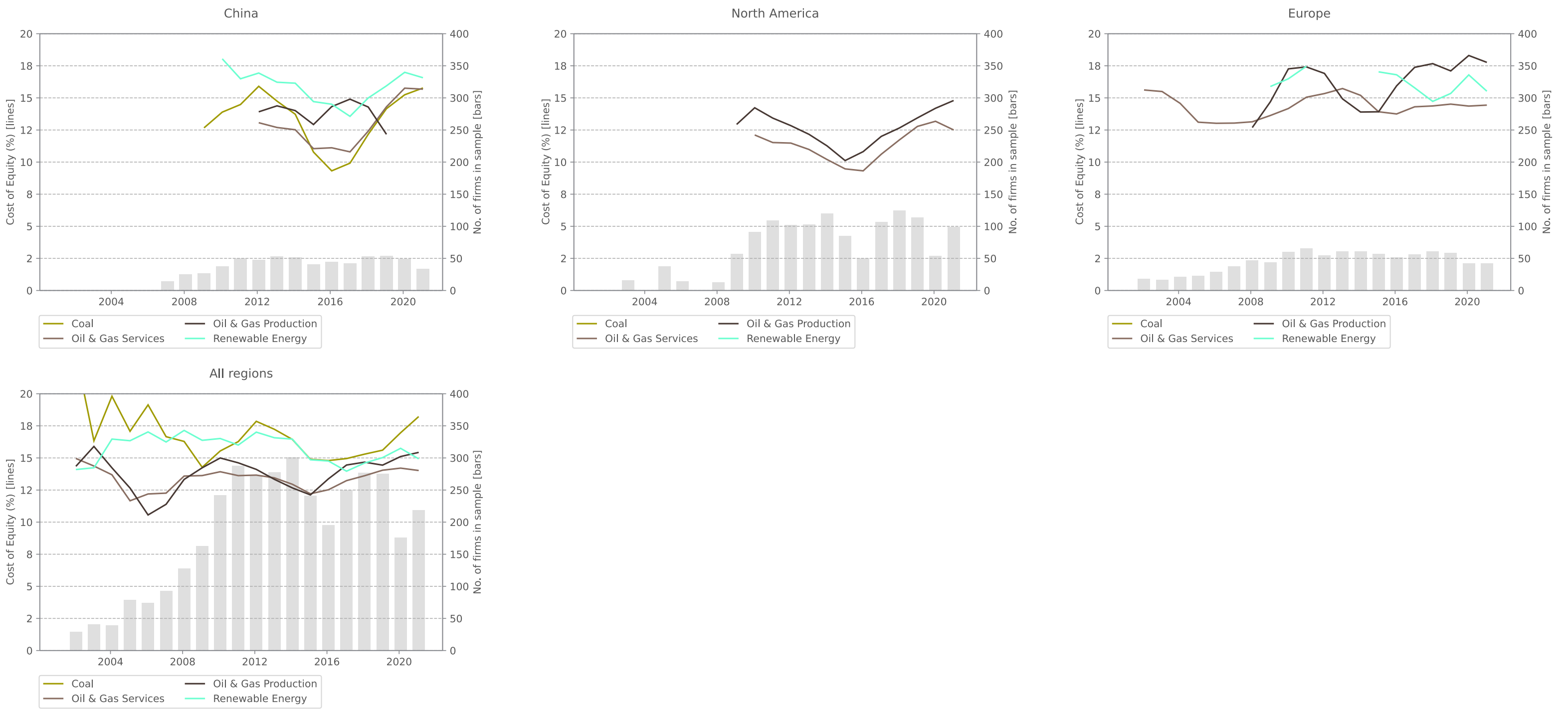
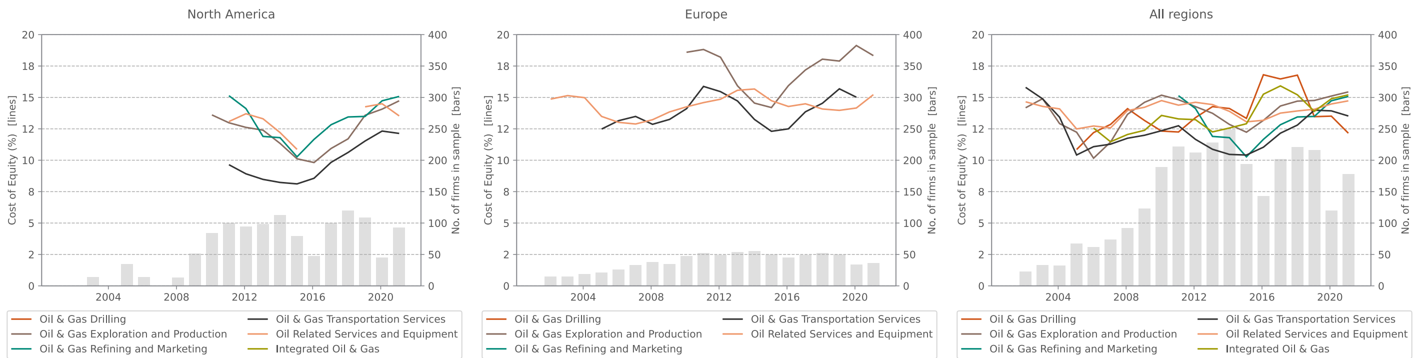
3-YEAR MOVING AVERAGE ACCOUNTING COST OF EQUITY FOR ENERGY PRODUCTION, BY TRBC CLASSIFICATION



3-YEAR MOVING AVERAGE COST OF EQUITY FOR OIL & GAS, BY TRBC SUBSECTOR CLASSIFICATION



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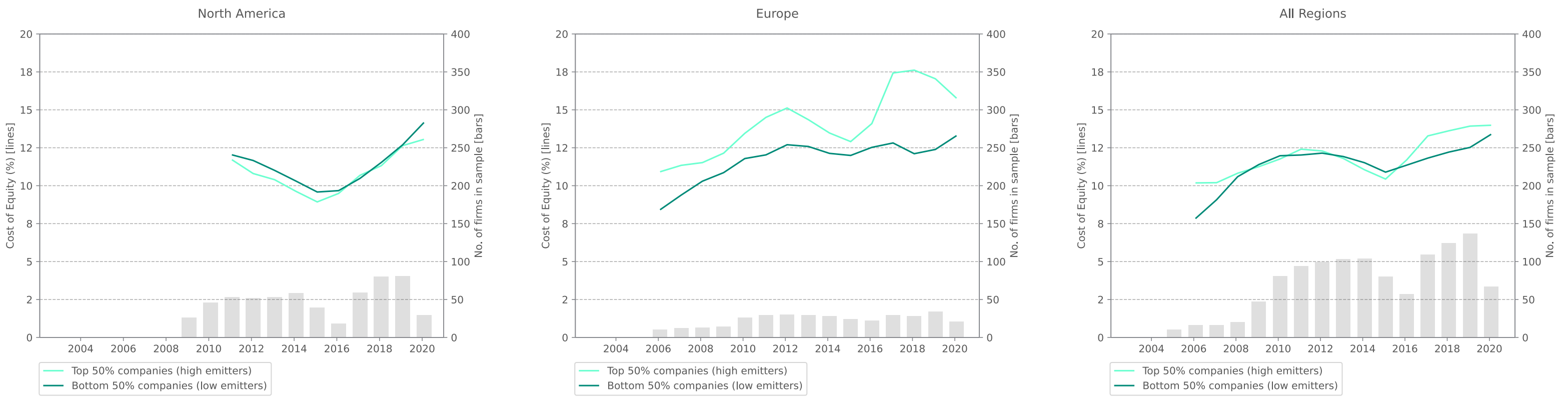
3-YEAR MOVING AVERAGE COST OF EQUITY FOR OIL & GAS, BY EMISSION INTENSITY



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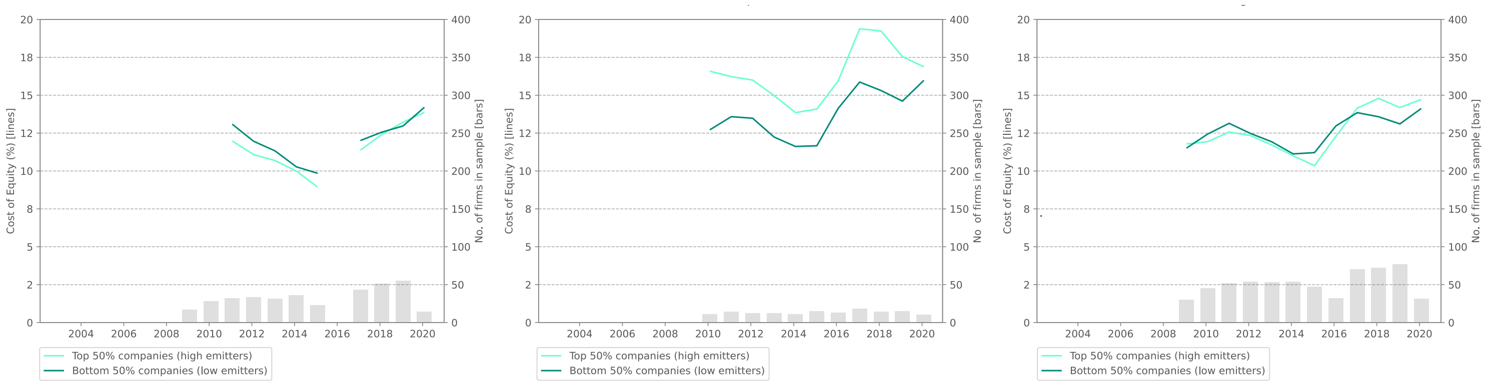

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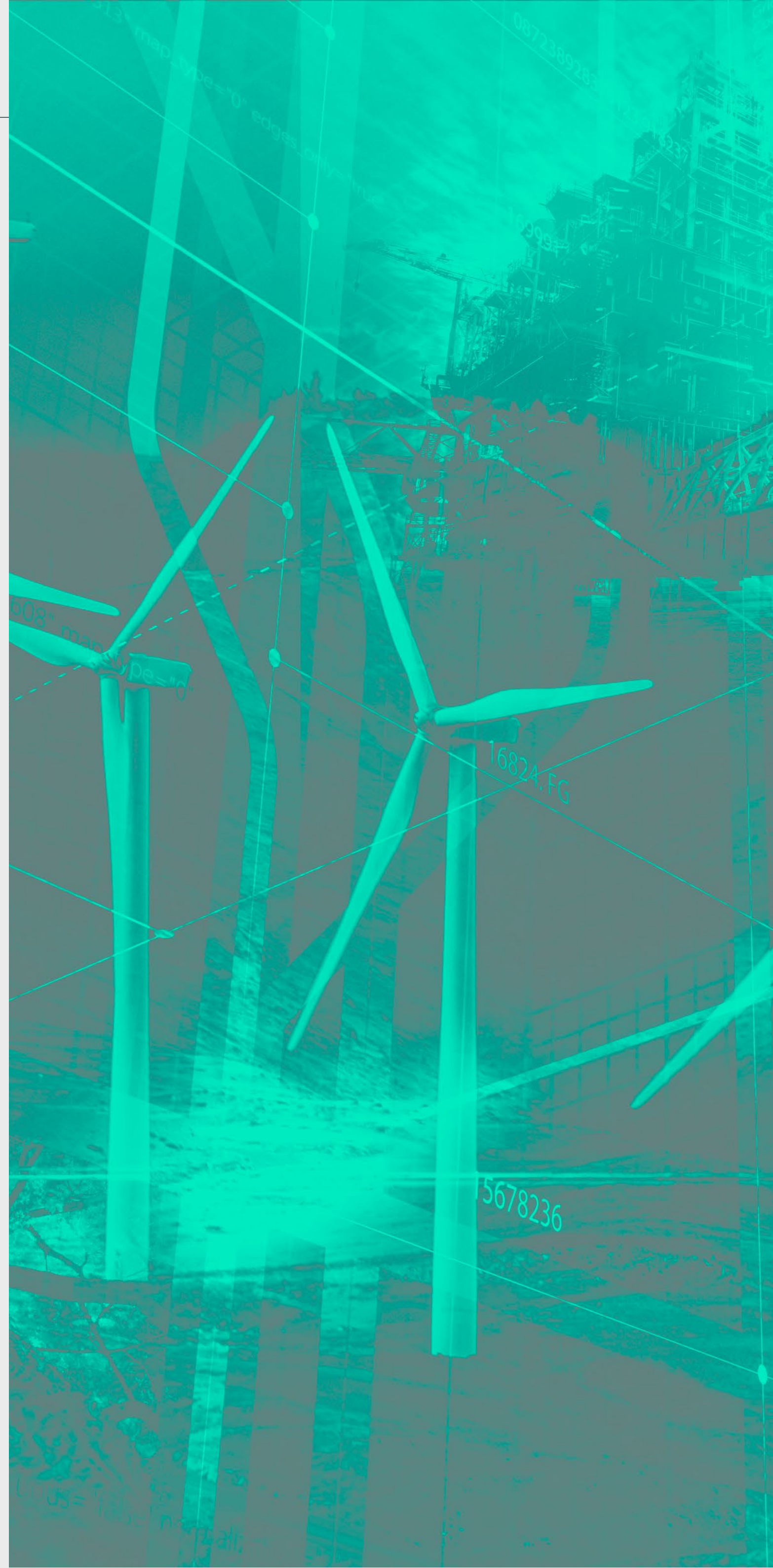

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