Assessing corporate emissions reduction targets against national transition plans

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Abstract

Corporate climate targets are typically assessed against global decarbonisation pathways, overlooking heterogeneous national policy contexts that shape companies' transition risks and opportunities. Analysing 52 countries' electricity sector strategies confirms substantial variation in national decarbonisation trajectories. We evaluate the emissions targets of 65 power companies operating in 19 countries with suitable national and corporate data against three benchmarks: NDC-derived pathways, a global 1.5 °C normative pathway, and national 1.5 °C normative pathways. Unambitious corporate commitments jeopardise the achievement of national plans in 14 countries. If governments implement their strategies, misaligned companies face heightened transition risks. However, because NDCs lack 1.5 °C alignment, using them as benchmarks risks lowering corporate climate ambition. Combining national and global benchmarks, and complementing emissions target assessments with evaluations of implementation plans, can improve their robustness and relevance.

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Introduction

Companies' mitigation efforts play a significant role in meeting country-level commitments under the Paris Agreement [1]. Since 2015, companies have increasingly made commitments to align their operations and actions with the Paris Agreement. However, corporate climate targets have been subject to scrutiny, with companies lacking ambition [2,3], credible implementation plans [4] and accountability mechanisms [5], which undermines their credibility and raises concerns about greenwashing. Weak or poorly designed targets expose companies to growing transition and litigation risks [6]. Assessing whether corporate commitments are aligned with the Paris Agreement has therefore become relevant to policymakers, investors, civil society, and courts.

Methodologies such as the Sectoral Decarbonisation Approach (SDA) [7,8] have been developed to assess a company's Paris alignment. Despite some critiques [9,10], these methodologies remain essential tools to assign responsibilities and track progress [11]. Traditionally, these methods are applied to global normative pathways, modelled through integrated assessment models to achieve temperature goals at least cost. These stylised pathways may not capture context-specific factors that shape the pace of decarbonisation within countries, potentially mischaracterising corporate ambition and transition risks.

Global benchmarks face a second fundamental challenge: equity. Their use could conflict with the principle of Common But Differentiated Responsibilities and Respective Capabilities enshrined in the Paris Agreement, particularly in a context of limited climate finance. Conditioning financial services on climate-related metrics could disproportionately hurt companies in high-emitting emerging and developing countries [12]. Indeed, 90% of the companies with "1.5 °C-aligned" targets validated by the Science-Based Target initiative (SBTi) are in advanced economies [10]. This has prompted growing calls to contextualise corporate target assessments [13–15].

National commitments capture the regulatory environments companies are likely to face. The Paris Agreement is operationalised through countries' Nationally Determined Contributions (NDCs) and Long-Term Strategies (LTSs). These national roadmaps reflect domestic political priorities, economic structures and capacities, and shape the operating environment for companies. Some countries are embedding these roadmaps in legislation, including sector-specific decarbonisation targets (e.g. South African Government, 2024) [17,18]. The Paris Agreement recognises the interdependence between corporate and national action: Article 6, paragraph 8(b), highlights the role of corporate action in achieving NDCs, and reporting standards such as IFRS S2 require companies to explain how national commitments inform their targets. Yet, mainstream corporate target assessment methodologies do not use national decarbonisation strategies. Critical gaps remain. It is unclear whether corporate targets align with the regulatory trajectories in countries where companies operate, how benchmark choice shapes assessments of transition risk, or whether national plans provide a more equitable basis for allocating decarbonisation responsibilities.

We address these gaps by assessing corporate targets against national sectoral plans. Given the power sector is particularly well covered in national plans, with most countries setting mitigation targets and policies [16,17], it is especially suitable for examining corporate-national alignment. We first analyse national decarbonisation strategies for the electricity sector in the 52 countries with the highest absolute emissions from power generation, covering 97% of the world's CO2 emissions from the sector. We identify 19 countries with sufficient data on national decarbonisation strategies and corporate data to enable systemic assessment. We then evaluate the targets of 65 companies operating in these countries, including multinationals, against two national benchmarks and one global benchmark : (1) national real-world pathways derived from sectoral plans, (2) 1.5 °C-aligned national normative pathways (Climate Analytics), (3) a 1.5 °C-aligned global normative pathway (IEA Net Zero by 2050). Although we focus on electricity generation, we also assess seven steel companies in Australia and the United Kingdom to demonstrate the approach's applicability across industrial sectors (Supplementary Tables 5 and 6).

We provide the first systematic assessment of corporate targets against national sectoral plans, revealing how benchmark choice shapes evaluation of corporate emissions targets. We find widespread misalignment: unambitious corporate commitments threaten the achievement of national goals in 14 of 19 countries. Yet because current NDCs lack 1.5 °C alignment, NDC-based assessment risks legitimising insufficient climate ambition. This dual tension highlights that neither global normative pathways nor national plans alone suffice: global pathways may mischaracterise transition risks by ignoring regulatory contexts, while national roadmaps may understate climate urgency. These findings have direct implications for investors, regulators, courts, and standard-setters in evaluating corporate climate performance.

Diverse national decarbonisation trajectories question the relevance of global benchmarks

We analyse the climate strategies and policy documents of 52 countries, identifying 19 with sufficient detail to build GHG emission and production pathways in the power sector (see Supplementary Table 1). These national pathways reveal striking differences in starting points and planned decarbonisation trajectories. Some countries already operate relatively low-carbon electricity systems and plan to reach net zero before 2040 (e.g., the Netherlands), while others start with a high-emissions baseline and plan rapid transitions (e.g., Australia), and others combine high initial carbon intensities with slower decarbonisation plans (e.g., Indonesia). Other countries fall between these profiles, resulting in a wide spectrum of power decarbonisation pathways across jurisdictions (Figure 1).

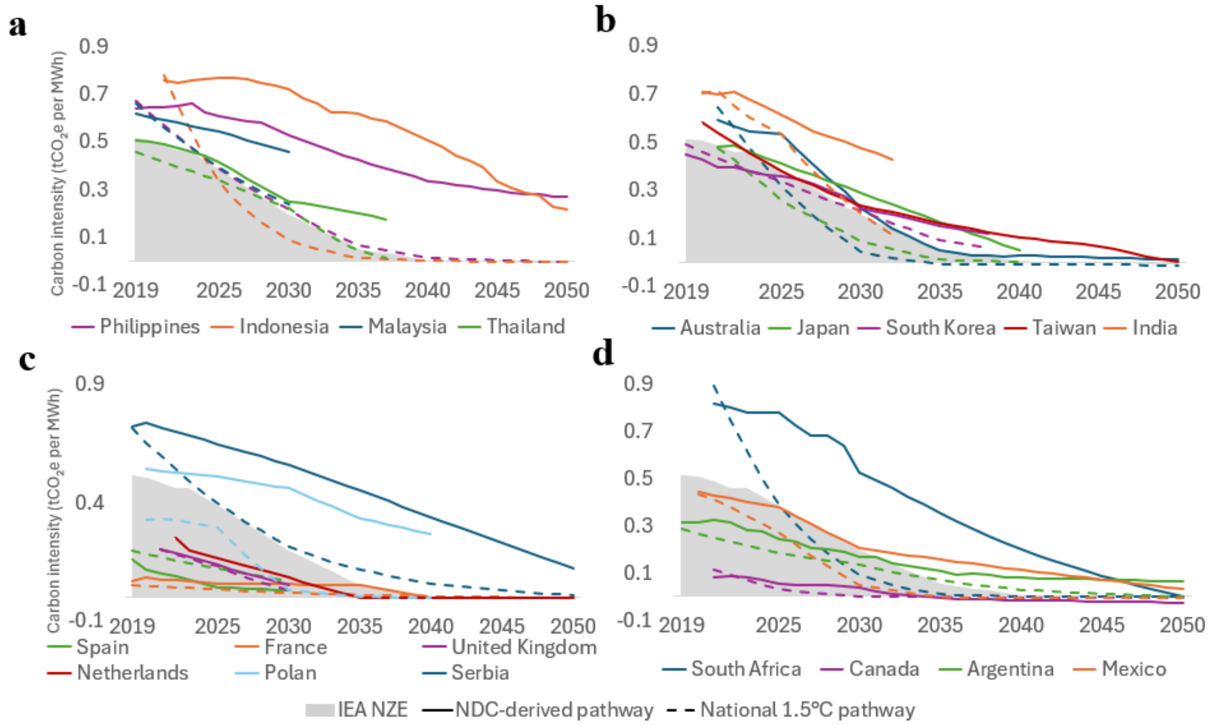

Figure 1. Evolution of the carbon intensity from power generation in 19 countries based on NDC-aligned national sectoral pathways and 1.5 °C-aligned national sectoral pathways. *This figure compares national decarbonisation trajectories under three benchmarks: pathways derived from Nationally Determined Contributions and sectoral plans (solid lines), 1.5 °C-aligned national pathways from Climate Analytics (dashed lines), and the IEA Net Zero by 2050 global pathway (shaded grey). Countries are grouped regionally: Asian countries (set 1) (a), Asian countries (set 2) (b), European countries (c), and the Americas and South Africa (d). Each country is colour-coded, with both national pathway types sharing the same colour for direct comparison. NDC-derived pathways were constructed from official national climate strategies and policy documents (see Methods and Supplementary Table 1 for sources). Climate Analytics pathways are not available for the Netherlands and Taiwan, so only NDC-derived pathways are shown for these countries. The divergence between national pathways and the global benchmark illustrates how national contexts shape decarbonisation trajectories relative to a uniform global standard.*

While NDCs represent the committed implicit allocation of the global carbon budget across countries, their aggregated ambition falls short of the Paris temperature goal [17] as shown by the gap between national plans and national 1.5 °C pathways (Figure 1). NDC alignment is therefore not equivalent to Paris alignment or 1.5°C alignment. If NDCs are used as a benchmark it thus captures a different dimension of alignment: whether companies' planned decarbonisation is consistent with the regulatory and policy trajectory of the countries in which they operate.

Benchmark choice reshapes corporate target assessment

We allocate carbon budgets to companies based on sectoral pathways. These pathways are constructed differently across our three benchmarks. The conventional approach, exemplified by the IEA Net Zero by 2050 scenario, uses sectoral trajectories from a *global* 1.5°C carbon budget. The 1.5°C national pathways from Climate Analytics extend this by downscaling global sectoral trajectories to the country level while maintaining consistency with the global 1.5°C budget. By contrast, our NDC-derived national pathways estimate sectoral budgets directly from nationally determined emissions and production trajectories, fundamentally reversing the direction of allocation: rather than distributing a global budget downward, we construct benchmarks from national commitments themselves.

To allocate sectoral budgets to companies, we use the Sectoral Decarbonisation Approach (SDA), a widely used method in both academic research and practice. The SDA allocates emissions to firms based on their baseline carbon intensity, market share, and the pace of decarbonisation embedded in the pathway. For sensitivity analysis, we also benchmark companies against the sectoral average without company-specific allocation, a method used in the Cumulative Benchmark Divergence approach[18] (see Methods). For each company, we estimate future cumulative emissions based on stated emission targets and calculate the percentage of its allocated carbon budget consumed under each pathway. A value of 100 % indicates full use of the budget, while values above 100 % indicate overshoot. Benchmarks cover different periods, so the period of analysis was harmonised for each country (see Methods and Supplementary Table 1) to ensure comparability of results across benchmarks within each country. Assessing companies from an earlier date holds them accountable for higher historical emissions but also credits early decarbonisation efforts.

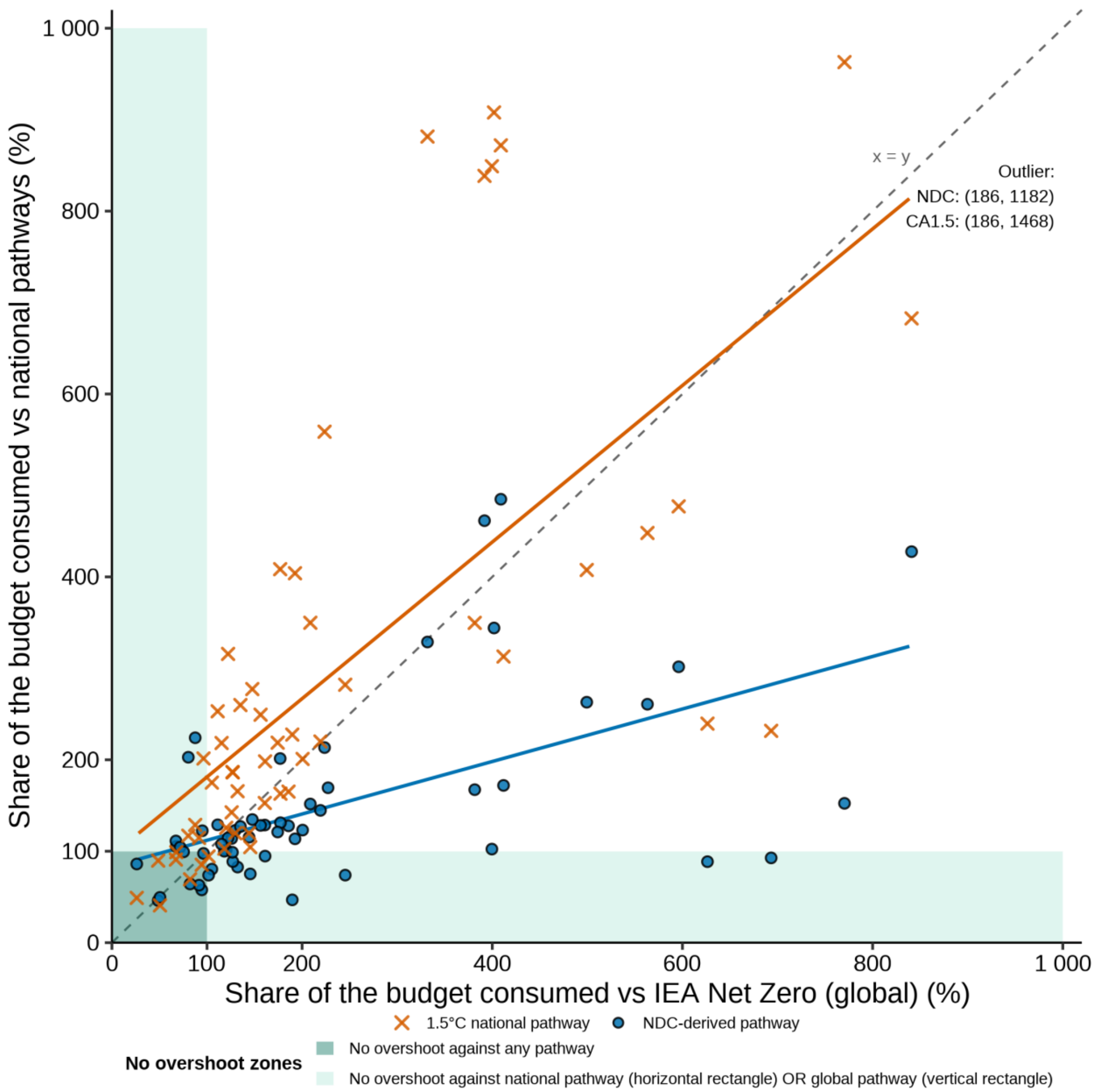

Figure 2. Corporate carbon budget consumption under national and global pathways using the SDA. *This figure compares each company's carbon budget consumption under national pathways (y-axis) against the global IEA Net Zero by 2050 pathway (x-axis). Each company appears twice at the same x-axis position: a blue dot showing budget consumption under the NDC-derived pathway, and an orange cross showing consumption under the 1.5°C national pathway. Lines of best fit are shown for each (blue for NDC-derived, orange for 1.5°C national). The shaded regions indicate alignment status: dark green indicates alignment with both global and national pathways (below 100% on both axes), vertical light green indicates alignment with the global pathway only, and horizontal light green indicates alignment with national pathways only. Points above the y=x diagonal consume more budget under national pathways than global; points below consume less. When a cross sits higher than its corresponding dot, the company performs worse under the 1.5°C national pathway than the NDC-derived pathway. Companies in the Netherlands and Taiwan appear as blue dots only because Climate Analytics does not provide 1.5°C national pathways for these countries.*

Figure 2 reveals that benchmark choice substantially affects corporate assessments. Most companies fall outside the green alignment zones, indicating widespread misalignment with all three benchmarks. The trend lines reveal systematic patterns: NDC-derived pathways (blue) provide generally less stringent assessments than both 1.5°C national pathways (orange) and the global IEA Net Zero pathway. The contrast is stark for some companies. AGL in Australia consumes 109% of its global pathway budget but 127% of its NDC budget and 251% under the 1.5°C national pathway. NTPC in India consumes 131% of its NDC budget but 183% of its global budget and 163% under the 1.5°C national pathway. National transition plans can prove more stringent benchmarks than global pathways in some cases (e.g. the Netherlands). Full results for all companies are reported in Supplementary Table 2.

The allocation methodology interacts with benchmark choice

Our analysis prioritises benchmark choice, though allocation methodology also matters. We use the SDA (Krabbe et al., 2015), an established standard in research and practice, which calculates a company-specific benchmark based on a company's initial carbon intensity and market share relative to the underlying decarbonisation scenario. We also include results benchmarking against the sectoral average without company-specific allocation (Supplementary Table 3). These approaches embed different assumptions about how decarbonisation responsibilities should be distributed.

The SDA applies a convergence logic, requiring all companies to reach the same endpoint intensity but allowing high-intensity companies more time to get there. This grandfathering approach can produce counterintuitive results: companies with initially lower intensities may receive worse assessments than carbon-intensive peers with weaker targets, illustrated by J-Power outperforming Kansai Electric Power under the global benchmark despite maintaining higher emissions intensity throughout the assessment period.

Moreover, while grandfathering is intended to implicitly account for national circumstances despite the use of a global benchmark, the SDA anchors convergence to individual firm characteristics rather than actual country-level contexts. Firm baselines thus serve as imperfect proxies for national circumstances, whereas national benchmarks incorporate these contexts directly. The SDA's treatment of market share further complicates global benchmarking: the formula expects slower intensity reduction from companies with declining market share, potentially favouring companies in mature economies over those in growing markets.

Benchmarking against the sectoral average avoids these issues by accumulating deviations from the benchmark throughout the assessment period. If a company's intensity exceeds the benchmark, it is overshooting regardless of starting position. Our sensitivity analysis shows that methodology choice matters most when a company's carbon intensity diverges substantially from its national average, and that average itself diverges from the global benchmark. The difference can be substantial and change relative company rankings. SaskPower consumes 330% of its NDC budget under the SDA but 14,115% under the sectoral average approach. Whether to allow convergence or hold all companies to the same standard is a normative choice. The sectoral average approach proves problematic under global benchmarks but becomes viable with national benchmarks, reflecting national circumstances more closely and without relying on grandfathering.

Unambitious corporate targets jeopardise the achievement of national transition plans

Aggregating company trajectories provides a picture of how the power sector is expected to decarbonise in each country, and whether this aligns with national transition plans (Table 1). Coverage varies by country, ranging from about 25% of the sector's emissions and generation to near-complete representation, with most countries exceeding 50% coverage. In the 19 countries assessed, corporate targets are aligned with national sectoral pathways in only five countries, partially aligned in eleven (sectoral overshoot of less than a factor of two), and strongly misaligned in Australia, Canada and Argentina (overshoot greater than a factor of two). These patterns are derived using the SDA, but results are similar when benchmarking using the sectoral average (see Supplementary Table 4) because the aggregated corporate intensity tends to approximate the national average.

State-owned utilities contribute significantly to this gap in some countries. Stanwell Group (Australia) and NTPC (India) have targets that would lead to substantial overshoots under their respective national plans. This reveals a significant contradiction: governments are supporting corporate commitments that conflict with their own sectoral strategies.

Company name	% of national power emission (2023)	% of national power generation (2023)	Share of carbon budget consumed		
			NDC & National Plan	CA 1.5 national pathway	IEA Net Zero (global)
British companies	24%	44%	99%	82%	52%
Australian companies	61%	42%	228%	435%	198%
Indian companies	30%	25%	129%	163%	179%
South African companies	111%*	82%	113%	404%	193%
Philippine companies	59%	73%	129%	783%	636%
Malaysian companies	55%	67%	96%	123%	118%
Canadian companies	34%	50%	429%	816%	383%
Polish companies	69%	58%	87%	175%	148%
Mexican companies	76%	79%	143%	328%	195%
Serbian companies	99%	89%	167%	349%	380%
South Korean companies	55%	63%	99%	113%	121%
Thai companies	62%	73%	123%	155%	162%
Argentine companies	49%	47%	233%	358%	447%
Japanese companies	46%	48%	121%	242%	142%
Indonesian companies	101%*	92%	100%	847%	398%
Spanish companies	43%	54%	171%	98%	63%
Dutch companies	32%	33%	104%	NA	74%
French companies	86%	71%	73%	102%	144%

Taiwanese companies	51%	62%	167%	NA	227%
World	14%	13%	NA	NA	172%

Table 1. Corporate carbon budget consumption aggregated at the country level under national and global pathways. *This table reports the share of allocated carbon budget consumed by companies in each country, aggregated across all assessed companies. Coverage columns show the percentage of national emissions and generation represented by the assessed companies. Colour coding indicates budget consumption: green denotes consumption below 100% (no overshoot), yellow denotes consumption between 100% and 200%, and red denotes consumption above 200%. NA indicates no pathway is available. *Values above 100% in coverage columns reflect discrepancies between corporate country-level reporting and country data from Our World in Data. Full methodology and data sources are provided in the Supplementary Information.*

For each country, we estimate the year in which companies exhaust their carbon budget which is defined over the assessment period [3]. In most countries, the sector-level budget is fully consumed well before 2035, highlighting the lack of ambitious intermediate corporate targets (Table 2). Long-term net zero targets reduce total overshoot, but interim misalignment threatens both the achievement of national transition plans and the 1.5 °C goal. Moreover, net zero targets often lack clarity on residual emissions, with limited reporting on the quantity and type of offsets planned.

Company name	% of national power emission (2023)	% of national power generation (2023)	Estimated year in which the company carbon budget will be fully consumed		
			NDC & National Plan	CA 1.5 national pathway	IEA Net Zero (global)
British companies	24%	44%	Aligned	Aligned	Aligned
Australian companies	61%	42%	2032	2026	2033
Indian companies	30%	25%	2030	2028	2027
South African companies	111%*	82%	2041	2026	2032
Philippine companies	59%	73%	2045	2025	2026
Malaysian companies	55%	67%	Aligned	2028	2028
Canadian companies	34%	50%	2027	2024	2031
Polish companies	69%	58%	Aligned	2030	2032
Mexican companies	76%	79%	2037	2026	2031
Serbian companies	99%	89%	2039	2030	2031
South Korean companies	55%	63%	Aligned	2036	2035
Thai companies	62%	73%	2033	2030	2030
Argentine companies	49%	47%	2034	2031	2029
Japanese companies	46%	48%	2035	2027	2032
Indonesian companies	101%*	92%	Aligned	2027	2029
Spanish companies	43%	54%	2024	Aligned	Aligned
Dutch companies	32%	33%	2036	NA	Aligned
French companies	86%	71%	Aligned	2046	2033
Taiwanese companies	51%	62%	2033	NA	2031

World	14%	13%	NA	NA	2031

Table 2. Estimated year in which companies fully consume their carbon budget, aggregated at the country level. *This table shows the percentage of national power sector emissions and generation covered in our sample for each country, alongside the estimated year when aggregated corporate emissions fully consume carbon budgets derived from three different pathways. Light red indicates that companies fully consume their carbon budget by 2035.Carbon budgets are defined over a country-specific time period available in Supplementary Table 1. NA indicates that no pathway is available. *Values above 100% in coverage columns reflect discrepancies between corporate country-level reporting and country data from Our World in Data.*

Our analysis only considers generation activities within the country of interest. Drax, for example, operates across multiple countries and sectors, but only its UK-based generation is assessed. Company-level assessments can be aggregated across sector–country pairs to reconstruct company-wide assessments, as illustrated in Table 3 for the company SSE. Overall, our analysis demonstrates that assessing companies against national pathways is feasible, despite requiring more granular data than global benchmarks, specifically country-level breakdowns of corporate operations and published sectoral pathways from relevant jurisdictions.

	United Kingdom	Ireland	Total
Cumulative scope 1 emissions in MtCO2e	37.45	6.61	44.06
Carbon budget scope 1 emissions in MtCO2e	34.88	6.04	40.93
Overshoot	107%	109%	108%

Table 3. Aggregating country-level assessments for multinational companies, illustrated by SSE. *This table demonstrates how company-level assessments can be reconstructed by aggregating across countries. SSE's cumulative scope 1 emissions and allocated carbon budgets are shown separately for its United Kingdom and Ireland operations, with the total indicating overall company performance against national pathways.*

Discussion

Our findings reveal widespread misalignment between corporate emissions targets and both global and national pathways. We explore two conceptual shifts in benchmarking practice: moving from global to national benchmarks and from normative scenarios to real-world plans. A central question is when and how these different benchmarks should be applied. We discuss the adequacy of different benchmarking approaches across three dimensions; (1) transition risk assessment, (2) equity considerations, and (3) Paris alignment. We argue that national decarbonisation strategies better capture more immediate transition risks for some companies and can better reflect equity principles in certain contexts. However, they do not measure Paris alignment but rather represent a lower bound: alignment with current national commitments is a necessary but insufficient condition for climate adequacy.

National plans capture the regulatory and policy contexts that directly shape firms' operating environments. National plans are therefore relevant benchmarks to evaluate the transition risks that companies are exposed to. Companies that deviate from national trajectories may not face legal non-compliance, since NDC pathways represent averages rather than company-level caps, but they are likely to face greater exposure to carbon pricing, technology phase-outs, and missed opportunities in emerging low-carbon markets.

Whether national plans are a relevant benchmark to assess a company's transition risks depends both on the credibility of these national plans and on the extent to which a company's emissions fall within the scope of policy frameworks. Regarding the first, national plans are more likely to be suitable benchmarks to assess transition risks if they are backed by a stable political commitment, robust policy instruments, and a high institutional capacity. Corporate and national transition plans are interdependent. Companies rely on enabling policies to decarbonise, while governments depend on corporate action to deliver sectoral emissions reductions. Gaps between planned and actual decarbonisation may result from either insufficient corporate action or inadequate policy support. When governments' plans lack credible implementation, transition risks for misaligned firms may remain limited.

The second factor determining if national plans are a useful benchmark for assessing a company's transition risk is the extent to which a company's emissions fall within the scope of policy frameworks. This depends on three elements: (1) the emission scopes, (2) the geography of production and consumption, and (3) companies' ability to diversify.

First, there is overlap between corporate and national GHG inventories. National GHG inventories aggregate scope 1 emissions from all activities within a country, alongside emissions from consumption and government activities [19]. Scope 2 emissions are tied to electricity grids, which usually overlap with national or regional boundaries. Companies with significant scope 1 and 2 emissions are therefore directly exposed to national transition plans aimed at reducing national emissions. Scope 3 emissions can also be indirectly affected when they originate from scope 1 activities of other actors within the same jurisdiction.

Second, beyond domestic national planning, national plans of importing countries can shape transition risks for exporters, as illustrated by the EU Carbon Border Adjustment Mechanism or bans on internal combustion engines. In such cases, considering the policies of consumer markets is essential to assess transition risk.

Third, companies' ability to shift production or diversify markets also affects how strongly national plans constrain their transition risks. Firms with flexible supply chains may partially avoid regulatory stringency in specific jurisdictions, whereas those tied to fixed infrastructure or capital-intensive assets, such as power generation, steel, cement, or mining, face more rigid exposure. By contrast, global pathways may provide a more relevant benchmark for assessing transition risk than national plans for firms operating in globally integrated commodity markets such as oil.

While target assessments provide useful indicators of corporate transition risks, they inadequately capture companies' moral obligations to decarbonise, as they rarely incorporate equity principles at either country (e.g., CBDR-RC) or firm level. National benchmarks engage equity considerations more directly than global pathways by reflecting differentiated national circumstances through NDCs. However, NDCs themselves do not constitute equitable allocations of the global carbon budget [20], and neither NDC-based nor least-cost national normative pathways guarantee equity.

Our approach does not allocate carbon budgets fairly, but it can produce fairer assessments in specific contexts. In high-income countries with high responsibility and capacity to transition, national pathways provide more appropriate benchmarks than global ones when they impose more stringent requirements. For instance, national plans provide a more stringent benchmark in the United Kingdom, a country with high income, responsibility and capacity, and a more lenient one in India.

Overall, none of the approaches provide a target assessment that is perfectly aligned with three key dimensions of the Paris Agreement: (1) an overarching temperature goal, (2) an equity principle, and (3) an operationalisation through NDCs. NDC-alignment better captures transition risks for some companies but it does not satisfy (1) and (2) and normative pathways do not account for (2) and (3).

This study demonstrates the value of using national decarbonisation pathways as benchmarks to assess corporate targets. National sector plans reflect real policy signals as well as sector- and country-specific contexts. This is a key advantage over global normative scenarios in assessing transition risks and feasibility. However, relying on NDCs also carries risks; most NDCs are not (yet) aligned with the Paris temperature goal and national benchmarks can lower overall ambition if used uncritically. Finally, focusing on emissions targets alone is insufficient. Most companies face few binding requirements to deliver on their targets [5], and the overall quality of corporate transition plans remains low [12,21]. Emerging voluntary mechanisms and litigation may improve accountability over time [22,23]. Bridging the implementation gap requires moving beyond target assessments to evaluate the credibility of corporate and national transition plans and their capacity to deliver actual required emissions reductions.

Methods

Allocation methods.

We use two allocation methods. Our first methodology uses the Sectoral Decarbonisation Approach developed by Krabbe et al., (2015) which translates sectoral emissions and production pathways into a corporate carbon budget. Instead of using only a global IEA decarbonisation scenario as the underlying pathway (as in Krabbe et al., (2015)), we compare a company's performance against three pathways: (1) an NDC-derived pathway, (2) a global normative pathway (the IEA Net Zero by 2050), and (3) a 1.5°C-aligned national normative pathway (Climate Analytics). The corporate carbon budget is calculated for each underlying pathway separately, as the sectoral activity and emissions trajectory differs across benchmark. The formula using the SDA methods is as follows:

$$Carbon\ Budget_{SDA,\ b-l} = \sum_{y=b}^{l} intensity_y * CA_y \quad (1)$$

and

$$intensity_{y,} = d * p_y * m_y + SI_l \ (2)$$

where:

$$d = CI_b - SI_l (3)$$

$$p_y = \frac{(SI_y - SI_l)}{(SI_b - SI_l)} \ (4)$$

$$m_y = \frac{(CA_b/SA_b)}{(CA_y/SA_y)} \ (5)$$

CI_y = Carbon intensity of the company in year y

SI_y = Carbon intensity of the sector in year y

CA_y = Physical output of the company in year y

SA_y = Physical output of the sector in year y

l = the last year for which data is available in the underlying pathway

b = the baseline year used in the underlying pathway

d captures the company's distance from the sector's intensity in the final year. It is constant over time and company specific. It is the element in the formula that induces grandfathering: all else equal, companies with higher initial emission intensities have a higher *d* and therefore are allowed to have higher emission intensities over the assessed period compared with companies with lower initial emission intensities. p_y is an index that varies over time and is the same across all companies. It represents the proportion of sectoral decarbonisation remaining at year *y* relative to the base year, effectively capturing the pace of decarbonisation of the pathway.

m_y varies over time and is company specific . It adjusts the allocated intensity based on changes in the company's market share relative to its baseline market share: companies with growing market share receive a less generous intensity allocation, while those with shrinking market share receive a more generous one. Importantly, the SDA only ensures the sectoral carbon budget is preserved if aggregate sectoral activity matches the production trajectory assumed in the underlying pathway; if total market activity exceeds the pathway's projections, the corporate carbon budgets will not add up to the pathway's sectoral budget[7].

We focus on the implications of using different geographical scale (global vs national) and types (normative vs real world) of benchmark, but we also include different allocation methodologies to outline how they can impact our results. In addition to the SDA, we therefore also conduct our analysis using the sectoral intensity average as a benchmark (typically used by the Cumulative Benchmark Divergence) [18]. Using the sectoral average intensity as the benchmark pathway, the carbon budget is calculated as follows:

$$Carbon\ Budget_{sectoral\ intensity\ average,\ \ b-l} = \sum_{y=b}^{l} SI_y * CA_y \ (6)$$

Unlike the SDA, this approach does not adjust for a company's initial intensity or market share. This means all companies are held to the same intensity standard regardless of their baseline position. As with the SDA, the approach does not guarantee preservation of the sectoral carbon budget when realised aggregate sectoral activity deviates from the production trajectory assumed in the underlying pathway. However, the resulting discrepancy between the aggregate of firm-level carbon budgets and the pathway-consistent sectoral budget is larger than under the SDA, as the latter's market-share adjustment partially mitigates this divergence.

Performance Metrics. We use several performance metrics to capture a company's expected performance. The first metric is the share of carbon budget consumed over the assessment period, which measures the projected exceedance of the company's allocated carbon budget (corresponding to Metric 2c in Rekker et al. (2022)[3]). This is defined over a specific time frame using the formula below:

$$Share\ of\ budget\ consumed_{\ b-l} = \frac{Cumulative\ emissions_{b-l}}{Carbon\ Budget_{\ b-l}} \quad (7)$$

The second metric is the estimated year in which the company fully consumes its carbon budget over the entire assessment period, defined as the first year when the cumulative emissions exceed the allocated Carbon budget (corresponding to Metric 2a in Rekker et al. (2022)[3]).

Finally, the benchmark pathways used in this analysis cover different timeframes, making assessments non-comparable across companies: starting from an earlier baseline year penalises firms more for past emissions. We harmonise the assessment window at the country level to ensure consistency across assessments of a company. Because carbon budgets are defined over fixed periods, starting the assessment later than the first year of the period covered in a benchmark would imply not capturing the overshoot happening in that year, leading the assessment to be inconsistent with the carbon budget. Therefore, the period of analysis starts in the earliest start year of the three benchmarks. Historical data (growth rates from Our World in Data for national pathways) is used to make benchmarks start in the same year. The period of analysis ends in the earliest final year of the three benchmarks because this is the last year for which we have data for all three benchmarks. This leads assessment periods to start in 2019 at the earliest and 2022 at the latest, and to end in 2030 at the earliest and 2050 at the latest. Of the 19 countries, 12 are covered for more than 28 years, 4 for 18 to 27 years, and 3 for 9 to 18 years.

Country data, assumptions, and benchmarks

We constructed NDC-derived pathways from national decarbonisation strategies. Our analysis covers the 52 countries with the highest emissions from the power sector, representing 97% of global CO2 emissions from electricity generation (see Supplementary Information). Sources include official submissions to the UNFCCC (Nationally Determined Contributions, Long-Term Strategies, Biennial Reports), economy-wide decarbonisation strategies with sectoral elements, and sector-specific roadmaps published by relevant ministries. 22 countries provide sufficient forward-looking quantitative information on both emissions and production to derive pathways with limited additional assumptions. 19 of these also have companies reporting adequate country-level data to enable the application of the SDA.

Countries report future greenhouse gas emissions and electricity production with varying levels of granularity, ranging from annual data to single end-year targets. When intermediate data points are missing, we use linear interpolation to generate annual time series. If data are only available in graphical form, values are estimated directly from the figures. Historical electricity production gaps are filled using annual growth rates from Our World in Data. Beyond these procedures, no additional modelling of future emissions or generation is undertaken.

Alongside NDC-derived pathways, we use two additional benchmarks to assess corporate targets: 1) the IEA Net Zero by 2050 scenario, and 2) the 1.5 °C National Pathways produced by Climate Analytics, which are obtained by downscaling IPCC scenarios to the national level using regional models and national historical data[24]. For the latter, we average the available 1.5 °C-aligned pathways for each country–sector to create a single reference pathway. For both benchmarks, yearly data are estimated using linear interpolation.

Many national plans focus on end-year targets rather than cumulative emissions, limiting the relevance of carbon budget allocation methodologies for transition risk assessments. Sectoral decarbonisation approaches hinge on cumulative emissions, yet interim trajectories are often poorly defined in both national and corporate strategies. Nevertheless, cumulative emissions remain the most meaningful indicator of climate outcomes[25]. Several countries have already adopted this logic through legally binding carbon budgets (e.g. the United Kingdom, France) or multiple interim milestones, making national pathways increasingly suitable for assessing corporate contributions over time.

Assessing companies' transition risks in relation to national decarbonisation efforts also remains relevant in the countries for which insufficient data preclude deriving national pathways. Although this limitation prevents the direct application of tools such as the SDA or CBD, many of these countries have policies and plans likely to shape corporate decarbonisation trajectories (e.g. the emission trading system in China).

Finally, the 19 countries included in our main analysis may differ from others in important ways, including the role of government in coordinating the transition and institutional capacity to implement climate policies. These differences could influence the relevance of generalising our approach across countries.

Corporate data and assumptions

For each country, we analyse the largest power companies in terms of physical output and scope 1 greenhouse gas (GHG) emissions for which country-level data are available, covering a substantial share of national electricity generation (Supplementary Table 2). Only generation activities within the country of interest are considered. For example, Drax operates across multiple countries and sectors, but only its UK-based generation is assessed. Company-level assessments can be aggregated across sector–country pairs to reconstruct company-wide assessments (see the SSE example in the Results section).

Data on scope 1 emissions from power generation and electricity output were taken from companies' public reporting made (e.g. annual sustainability reports). We do not challenge the reliability of corporate reporting in this paper, though we acknowledge that reported data can be inaccurate. Differences in consolidation methods for emissions and generation can bias carbon intensity estimates, for instance, when generation from joint ventures is included in output figures but not in emissions reporting. Limited assumptions were made to estimate companies' current GHG emissions, electricity generation, and carbon intensity.

Future emissions pathways are derived from company targets. We use absolute or intensity targets, depending on availability. Where company-wide targets lack a country breakdown, we use company-wide targets as a proxy for country-level targets. For example, RWE and SSE's company-wide targets are applied to their UK activities; this has little effect in SSE's case, given its marginal operations abroad. In some cases, targets covering scope 1 + 2 emissions are applied to scope 1 only, which has negligible impact because scope 2 emissions are small for power generators. For Origin Energy, a target covering scopes 1–3 is applied to scope 1 due to the absence of a scope 1-specific target, likely underestimating the speed of its decarbonisation.

Companies rarely report annual targets, so we use linear interpolation between current performance and short- and long-term targets to estimate intermediate values. This likely underestimates cumulative emissions and therefore companies' overshoot, as power companies typically decarbonise through discrete asset retirements, producing a stepwise rather than linear emissions trajectory. An alternative specification assuming a stepwise trajectory, whereby a company's emissions intensity remains constant until the target year, would lead to worse assessments for most firms, with a particularly strong effect for firms without intermediate targets. This adjustment primarily affects firms with net-zero targets but no interim milestones. Net zero is assumed to refer to a carbon intensity of 0 gCO2e/kWh, though companies do not report the quantity or quality of the offsets they plan to use to reach net zero. This means that companies' emissions from power generation are likely to be higher than 0 gCO2e/kWh.

Companies often only set targets on emissions, while a carbon budget derived from the SDA also relies on the associated physical output. To forecast future physical output, we apply the annual growth rates from each benchmark pathway to the company's current output. Since growth rates differ across pathways, the estimated physical output for each company varies by benchmark. This assumes constant firm-level market shares relative to the final year of observed data, an approach commonly used by practitioners and researchers but which results in bias[9]. While precisely forecasting the yearly market share between the baseline and 2050 seems infeasible, it is possible to adjust the assessment over time using the actual market share to verify whether the company is on track to achieve its SDA-derived target [3].

Overall, these assumptions mean our estimates of cumulative emissions are conservative lower bounds in most cases, implying actual overshoots may be larger. More granular and transparent corporate data would enable more accurate assessments. All data are publicly available, with full sources, raw data, and results provided in the Supplementary Information.

Use of generative AI

During the preparation of this manuscript, the authors used large language models (ChatGPT and Claude) to support the search for transition plans published by national and corporate actors, to assist in drafting R code for figure generation, and to proofread and edit the manuscript. All outputs produced by these tools were reviewed, verified, and revised by the authors, who take full responsibility for the final content of the manuscript.

Competing interests

The authors declare the following competing interests: Abhinav Jindal is affiliated with the Power Management Institute in NTPC. NTPC is a large power generation company operating in India and is included in the sample analysed in this study. Abhinav Jindal was not involved in the collection or processing of data relating to NTPC, nor in the analysis or interpretation of results concerning the company. The same methodology was applied consistently across all firms, including NTPC. The remaining authors declare no competing interests.

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Supplementary Information

Supplementary tables for the power sector

Supplementary table 1. Policy documents reviewed and period of analysis per country.

Plan	Country	Period	Increased ambition available	1.5 National Pathways from Climate Analytics available	Period covered in the 1.5 CA pathway	Harmonised period used for the analysis
Clean Power 2030 Action Plan	GBR	2023-2030		Yes	2021-2050	2021-2030
Electricity and Energy Sector Plan	AUS	2025-2050	X	Yes	2021-2050	2021-2050
National Electricity Plan	IND	2020-2032		Yes	2021-2050	2020-2032
Draft sectoral emission targets & Integrated Resource Plan 2023	ZAF	2025-2050		Yes	2021-2050	2021-2050
Energy Plan 2023-2050 Volume 1	PHL	2023-2050	X	Yes	2019-2050	2019-2050
Nationally Determined Contribution Roadmap and Action Plan	MYS	2019-2030	X	Yes	2019-2050	2019-2030
Canada's Energy Future 2023	CAN	2021-2050		Yes	2021-2050	2021-2050
Energy Policy of Poland until 2040 (EPP2040)	POL	2020-2040		Yes	2021-2050	2020-2040
Evaluation of Decarbonization Strategies for the Update of Mexico's National Climate Change Strategy	MEX	2020-2050	X	Yes	2021-2050	2020-2050
Low Carbon Development Strategy for the Period 2023- 2030 with projections until 2050	SRB	2020-2050	X	Yes	2019-2050	2019-2050
11th Basic Plan for Power Supply and Demand (2024-2038)	KOR	2024-2038		Yes	2019-2050	2019-2038
Power Development Plan 2024-2037	THA	2024-2037		Yes	2019-2050	2019-2037
National Energy Plan for the energy transition by 2030 & Guidelines and scenarios for the energy transition by 2050	ARG	2023-2050	X	Yes	2019-2050	2019-2050
Outlook for Energy Supply and Demand in FY2040	JPN	2023-2040		Yes	2021-2050	2021-2040
National Electricity Plan (RUKN) 2025	IDN	2025-2060		Yes	2021-2050	2021-2050
National Energy and Climate Plan	ESP	2023-2030		Yes	2019-2050	2019-2030
National Energy System Plan 2023	NLD	2023-2050		No	NA	2022-2050
National Energy System Plan 2024	FRA	2020-2050		Yes	2019-2050	2019-2050
2050 Net Zero Roadmap	TWN	2020-2050				2020-2050

Plan not suitable to apply the SDA with limited assumptions, or no plan	CHN, USA, IRN, DEU, EGY, SAU, IRQ, KAZ, UZB, ITA, ARE, PAK, BGD, BRA, GBR, DZA, KWT, CHL, ISR, CZE, QAT, BHR, SGP, MAR, HKG, COL, TKM, LBY
Suitable plan but no corporate reporting	VNM, UKR, OMN, NGA

Supplementary table 2. Alignment of corporate emissions reduction targets with different pathways using the SDA.

Companies - Only electricity generation is analysed	Country	% of emissions from electricity (2023)	% of national generation (2023)	Share of carbon budget consumed		
				NDC & National Plan	IEA Net Zero (global)	CA 1.5 national pathway
AGL	AUS	23%	14%	170%	118%	251%
EnergyAustralia	AUS	11%	6%	91%	102%	203%
Origin	AUS	9%	5%	224%	228%	410%
Stanwell	AUS	12%	7%	687%	461%	870%
AlintaEnergy	AUS	2%	4%	251%	281%	558%
CS Energy	AUS	5%	3%	682%	421%	840%
Hydro Tasmania	AUS	0%	3%	Green	Green	Green
SSE - UK	GBR	8%	7%	107%	108%	95%
RWE - UK	GBR	16%	14%	62%	59%	84%
EDF - UK	GBR	0%	19%	Green	Green	Green
Drax	GBR	0%	4%	Green	Green	Green
Tata Power	IND	2%	2%	114%	231%	183%
NTPC	IND	24%	20%	131%	416%	543%
Adani Power	IND	4%	3%	132%	632%	619%
Eskom	ZAF	111%	82%	126%	226%	404%
Meralco	PHL	9%	11%	147%	549%	1468%
San Miguel Corporation	PHL	17%	13%	74%	221%	285%
Aboitiz	PHL	23%	30%	145%	672%	962%
FirstGen	PHL	10%	18%	41%	190%	230%
TNB	MYS	34%	38%	102%	247%	262%
Malakoff	MYS	14%	11%	113%	241%	192%
Sarawak Energy	MYS	6%	18%	56%	281%	250%
Fortis	CAN	8%	2%	114%	154%	315%
Ontario Power Generation	CAN	3%	12%	Green	Green	Green
Hydro-Québec	CAN	0%	28%	Green	Green	Green
Nova Scotia Power	CAN	5%	2%	347%	472%	910%
SaskPower	CAN	13%	4%	330%	549%	883%
Transalta	CAN	5%	2%	88%	549%	239%
PGE	POL	43%	35%	98%	171%	242%
Enea	POL	15%	13%	84%	132%	192%
Tauron	POL	8%	8%	60%	63%	98%
Energa	POL	1%	2%	90%	588%	180%
ZE PAK	POL	2%	1%	120%	244%	328%

CFE	MEX	70%	70%	153%	399%	701%
Naturgy Mexico	MEX	3%	4%	80%	156%	241%
Iberdrola Mexico	MEX	3%	5%	45%	48%	85%
Elektroprivreda Srbije (EPS a.d.)	SRB	99%	89%	167%	481%	349%
KEPCO	KOR	55%	63%	106%	149%	100%
EGAT	THA	33%	36%	127%	231%	235%
Ratch Group	THA	5%	7%	65%	84%	144%
Banpu Power	THA	9%	6%	129%	181%	141%
GULF	THA	11%	17%	117%	465%	528%
GPSC Group	THA	5%	7%	115%	251%	588%
AES Argentina	ARG	3%	4%	61%	83%	68%
Central Puerto	ARG	19%	14%	284%	576%	498%
Pampa Energia	ARG	14%	15%	258%	597%	469%
YPF Luz	ARG	9%	8%	142%	369%	327%
Albanesi	ARG	2%	2%	517%	1121%	715%
EPEC	ARG	2%	2%	289%	544%	424%
Enel Argentina	ARG	0%	2%	0%	11%	39%
JERA	JPN	23%	23%	130%	182%	283%
Kansai Electric Power Group	JPN	4%	10%	96%	171%	220%
Tohoku	JPN	7%	6%	122%	177%	290%
JPower	JPN	7%	5%	129%	142%	243%
Chugoku Electric Power Group	JPN	5%	4%	132%	173%	314%
Hokuriku Electric Power Group	JPN	3%	2%	127%	172%	208%
PLN	IDN	101%	92%	111%	438%	823%
Endesa	ESP	24%	22%	164%	99%	89%
Iberdrola Espana	ESP	8%	23%	67%	63%	36%
Naturgy	ESP	11%	9%	218%	157%	135%
RWE NDL	NLD	17%	13%	104%	75%	NA
Eneco	NLD	4%	12%	108%	98%	NA
Vattenfal	NLD	12%	9%	86%	78%	NA
EDF	FRA	86%	71%	88%	273%	122%
Taiwan Power Company	TWN	51%	62%	167%	245%	NA

Source: Light red implies an overshoot of more than twice the carbon budget, yellow implies an overshoot between once and twice the carbon budget, green implies no overshoot. Companies labelled "Green" already have carbon intensities that are near-zero.

Supplementary table 3. Alignment of corporate emissions reduction targets with different pathways using the Cumulative Benchmark Divergence approach.

Company name	Share of carbon budget consumed under the Cumulative Benchmark Divergence		
	NDC & National Plan	CA 1.5 national pathway	IEA Net Zero (global)
AGL	241%	473%	305%
EnergyAustralia	174%	361%	214%
Origin	284%	576%	362%
Stanwell	777%	1422%	957%
AlintaEnergy	128%	246%	164%
CS Energy	743%	1410%	919%
Hydro Tasmania	18%	37%	24%
SSE - UK	139%	154%	50%
RWE - UK	152%	166%	55%
EDF - UK	3%	3%	1%
Drax	13%	14%	5%
Tata Power	118%	154%	210%
NTPC	142%	206%	255%
Adani Power	147%	218%	269%
Eskom	152%	496%	488%
Meralco	123%	424%	453%
San Miguel Corporation	88%	323%	366%
Aboitiz	121%	442%	469%
FirstGen	32%	107%	121%
TNB	96%	112%	126%
Malakoff	136%	176%	199%
Sarawak Energy	36%	48%	53%
Fortis	4671%	2238%	161%
Ontario Power Generation	300%	144%	10%
Hydro-Québec	65%	31%	3%
Nova Scotia Power	14230%	6652%	537%
SaskPower	14115%	6823%	796%
Transalta	4079%	1743%	850%
PGE	138%	566%	292%
Enea	114%	443%	232%
Tauron	76%	268%	142%
Energa	80%	327%	232%
ZE PAK	205%	785%	405%
CFE	214%	622%	346%
Naturgy Mexico	76%	208%	116%
Iberdrola Mexico	35%	78%	46%
Elektroprivreda Srbije (EPS a.d.)	183%	464%	709%

KEPCO	110%	123%	127%
EGAT	128%	184%	168%
Ratch Group	62%	83%	76%
Banpu Power	174%	235%	215%
GULF	96%	138%	130%
GPSC Group	100%	146%	134%
AES Argentina	70%	107%	68%
Central Puerto	351%	688%	458%
Pampa Energia	260%	508%	337%
YPF Luz	151%	271%	186%
Albanesi	514%	1024%	693%
EPEC	281%	542%	355%
Enel Argentina	55%	75%	44%
JERA	133%	256%	174%
Kansai Electric Power Group	52%	102%	75%
Tohoku	145%	296%	169%
JPower	168%	336%	194%
Chugoku Electric Power Group	148%	297%	177%
Hokuriku Electric Power Group	145%	272%	211%
PLN	103%	1004%	619%
Endesa	229%	117%	40%
Iberdrola Espana	64%	33%	11%
Naturgy	297%	153%	52%
RWE NDL	195%	NA	78%
Eneco	49%	NA	20%
Vattenfal	139%	NA	57%
EDF	75%	167%	18%
Taiwan Power Company	164%	NA	270%

Supplementary table 4. Corporate carbon budget consumption aggregated at the country level under national and global pathways using the SDA and the CBD.

Country	% of national power emission (2023)	% of national power generation (2023)	Share of carbon budget consumed (SDA)			Share of carbon budget consumed (CBD)		
			NDC & National Plan	CA 1.5 national pathway	IEA Net Zero (global)	NDC & National Plan	CA 1.5 national pathway	IEA Net Zero (global)
British companies	24%	44%	99%	82%	52%	74%	75%	25%
Australian companies	61%	42%	228%	435%	198%	341%	648%	419%
Indian companies	30%	25%	129%	163%	179%	141%	203%	253%
South African companies	111%	82%	113%	404%	193%	0%	496%	488%
Philippine companies	59%	73%	129%	783%	636%	95%	334%	362%
Malaysian companies	55%	67%	96%	123%	118%	88%	107%	120%
Canadian companies	34%	50%	429%	816%	383%	2076%	980%	105%
Polish companies	69%	58%	87%	175%	148%	124%	495%	257%
Mexican companies	76%	79%	143%	328%	195%	197%	567%	317%
Serbian companies	99%	89%	167%	349%	380%	183%	464%	709%
South Korean companies	55%	63%	99%	113%	121%	110%	123%	127%
Thai companies	62%	73%	123%	155%	162%	113%	162%	148%
Argentine companies	49%	47%	233%	358%	447%	245%	467%	307%
Japanese companies	46%	48%	121%	242%	142%	124%	244%	156%
Indonesian companies	101%	92%	100%	1039%	398%	103%	1004%	619%
Spanish companies	43%	54%	171%	98%	63%	170%	87%	30%
Dutch companies	32%	33%	104%	NA	74%	131%	NA	53%
French companies	86%	71%	73%	102%	144%	75%	167%	18%
Taiwanese companies	51%	62%	167%	NA	227%	164%	NA	270%
World	14%	13%	NA	NA	172%	NA	NA	254%

Supplementary tables for steel

Supplementary table 5. Alignment of corporate emissions reduction targets with different pathways using the SDA in the steel sector.

Companies	Country	Assessment period	% of national steel output (2024)	Share of budget consumed		
				NDC & National Plan	Third party national pathway	IEA Net Zero (global)
BlueScope	AUS	2024-2050	52%	119%	115%	81%
Liberty Steel	AUS	2024-2050	37%	25%	42%	23%
Total Australia	**AUS**	**2024-2050**	**89%**	**92%**	**85%**	**62%**
Tata Steel Limited	IND	2020-2030	14%	99%	210%	145%
SAIL	IND	2020-2030	13%	106%	163%	120%
JSW Steel	IND	2020-2030	15%	96%	180%	141%
Arcelormittal Nippon Steel India	IND	2020-2030	6%	91%	159%	130%
Total India	**IND**	**2020-2030**	**48%**	**99%**	**179%**	**135%**

Results should not be compared across scenarios, as the scenarios are defined over different activity perimeters.

Supplementary table 6. Pathways used for the analysis of steel companies.

Pathways	Region	Issuer	Plan or scenario	Period
National Steel Strategy	IND	Regulator	Plan	2024-2030
Mission Possible Partnership	IND	Academia	Scenario	2020-2050
Industry Sector Plan	AUS	Australian Treasury	Plan	2025-2050
CSIRO - CCA - 1.5	AUS	Regulator/Academia	Scenario	2025-2050
IEA Net Zero by 2050	World	IEA	Scenario	2024-2050

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