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15th January 2021

**INET Oxford Working Paper No. 2021-03**

# The Paris-compliant company: Measuring transition performance using a strict science-based approach

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**Abstract**

To meet climate goals, it is necessary for companies to become Paris-compliant. Two recent initiatives, the Transition Pathway Initiative (TPI) and Assessing low-Carbon Transitions (ACT) initiative, have proposed methodologies to benchmark companies' performances against science-based emission reduction levels. However, these initiatives have several limitations, including a shifting baseline, and a focus on carbon-intensities. Here, we propose a methodology that overcomes these limitations by ensuring each company strictly adheres to the Paris carbon budget. Applying our metrics to the ten highest emitting companies in the Australian electricity sector, we find that none are currently Paris-compliant, with every year of delayed action increasing their required rate of decarbonisation and hence the exposure of billions in assets to transition risk. We demonstrate that even using the more prescriptive ACT guidelines allows these companies to exceed their carbon budgets up to 235% by mid-century. Applying our proposed method ensures accurate tracking of progress, which is imperative for companies and stakeholders to align their decision-making with the Paris Agreement.

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## Introduction

There is international accord that to avoid the worst effects of climate change, global temperature increases must be limited to 'well below 2°C above pre-industrial levels' [1]. Stabilising global temperatures in line with this primary objective of the Paris Agreement requires net emissions of greenhouse gases to decline rapidly and reach net zero by around 2050[2]. Companies have an important role to play in achieving these goals [3]. They contribute to greenhouse gas emissions directly, through their operations (Scope 1 or 2 emissions), and indirectly, through upstream and downstream emissions (Scope 3), such as those associated with the use of their products [4, 5]. Business strategy, investments, innovation, and lobbying practices may also affect emissions [6]. Despite evidence of increasing commitment to strengthen global action, most businesses globally are failing to significantly reduce their greenhouse gas emissions [7], an issue exacerbated by a lack of emission regulations in many countries, such as a price on carbon. Continued business inaction on emissions reductions will render the goals of the Paris Agreement unachievable. Consequences of allowing climate change to continue include considerable economic and financial risk for most companies [8], while evoking ethical concerns for the resulting impacts to the lives of global communities disconnected in space and time from the emission source [9-11].

Addressing climate change requires an awareness of executives of the risks it entails, the support of regulators, investors, and other stakeholders to ensure firms can remain profitable through the transition [12], and a sense of shared responsibility for firms to reduce their emissions [13]. We define here the concept of a Paris-Compliant company as one that has aligned its recent and future emissions reductions to a Paris-Compliant Pathway (PCP) [14] and hence the goals of the Paris Agreement. Pressure for companies to take account of their greenhouse gas emissions and associated climate risk has been growing over the last few decades [15-17]. However, to be effective, businesses need a means by which their performance on their climate responsibilities and climate risks can be measured within a consistent and defensible framework [18]. This includes the construction of science-based, company-specific greenhouse-gas emission targets and metrics that assess a firms' alignment to their agreed climate targets.

The level of ambition and capability required by a company will vary between firms depending on their sectoral and geographic footprint. A number of methodologies for converting global climate targets to company-specific emissions trajectories have been developed [13, 19, 20], of which the Sectoral Decarbonisation Approach (SDA) is the most widely adopted. This approach allocates a global carbon budget to sectors using the International Energy Agency's (IEA) decarbonisation pathways[21], which is then divided between companies in each sector based on their initial emission intensity, i.e. emissions ($CO_2$) per activity (such as kWh of electricity, or tonnes of steel), and their projected market share. It has several advantages over other approaches in that it can be applied to any sector; it has been updated to use a "Paris-compliant" scenario [22] limiting temperature rise to *well below* 2°C; and it includes some equity principles (market share and initial carbon intensities).

The SDA method is now commonly used to set "science-based" targets by companies through the Science Based Targets initiative, making it increasingly common for large firms to publicly report against and commit to them [23, 24]. Until recently, it was uncommon for science-based methodologies to be used by sustainability rating agencies to measure a firm's climate performance [20]. In recent years, two initiatives have sought to fill this gap by developing science-based climate ratings, which assess a company's performance using the SDA as their benchmark: 1) The Transition Pathway Initiative (TPI) [25]; and 2) Assessing low-Carbon Transitions (ACT) [26].

This paper first assesses the conditions under which the SDA provides an adequate benchmark to assess a companies' Paris-compliance, and conversely, the conditions under which the TPI and ACT metrics might prove inaccurate or misleading in this regard, either due to a misapplication of the SDA benchmark by the SBTi, or by the TPI or ACT. We then present a novel methodology, the Paris-Compliant Pathways (PCPs), that overcomes these shortcomings and can be applied by companies and stakeholders to accurately track company performance against the Paris climate goals. Finally, we apply our PCP approach to the Australian electricity sector, which has billions of dollars of assets potentially at risk of stranding [27], to demonstrate its use on the assessment of an existing industry.

## A strict methodology for assessing companies' Paris compliance

The SDA operates according to three key conditions for quantifying climate-safe emission pathways for companies. First, the pathway must be consistent with the Paris agreement. The SDA has accordingly been updated to use the IEA Beyond 2°C Scenario (IEA B2DS) instead of the IEA 2°C Scenario (IEA 2DS) [23]. The IEA B2DS is indicative of a 50% chance of limiting global average temperature rise to 1.75°C above pre-industrial levels, consistent with the "well-below 2°C" goal of the Paris Agreement [1]. Second, the SDA methodology downscales the carbon budget concept using IEA scenarios so that the carbon budget remaining from the year the B2DS scenario begins (2014) can be allocated across time, location, sectors, and then to companies. By doing so, this approach aims to reflect the differing challenges faced by different sectors undergoing decarbonisation, and for companies to have different emissions intensity starting points. Third, the SDA requires that carbon intensity trajectories use a common base year (2014, when using IEA B2DS) for *all* entities, and that emissions intensity pathways are adjusted over time to account for deviations from the original target trajectory through either inaction or unforeseen changes in market share. Finally, given that intensity metrics can be gamed, the SDA states that both intensity and absolute emission targets are defined and reported [13]. Ultimately, the absolute cumulative emissions determine whether Paris goals are met.

Our proposed PCP approach holds true to each of these requirements, including a common base year and a clear and consistent approach to ensuring that any shortfall in emissions intensity reductions since 2014 is subsequently compensated for by accelerating the remaining decarbonisation. Put simply, a given company is given a "base" PCP founded on the SDA principles using the company's initial emissions intensity and projected market (PM) share, or actual market (AM) share where available, from the common base year (2014). This sets the company's "base" Paris-Compliant Pathway for each firm which has an associated Company Carbon Budget (CCB). If a company deviates from its "base" PCP, a "revised" PCP is calculated that ensures the company stays within its CCB. In assessing a company's progress, we present the PCP using carbon intensity, $PCP_i$, as well as using cumulative emissions, $PCP_e$. They both represent the exact same pathways using a different measure.

Our PCP approach deviates from way the SBTi operationalises the SDA method in several key areas. Firstly, the SBTi allows for flexibility in setting the base year, and thus does not account for the emissions of all companies from a common base year. Second, the SBTi does not require a revision of the target when the company has not met its target or has deviated from its projected market share. The need to account for the "action deficit" this might cause is acknowledged in principle by the updated SBTi, with companies that are not on track required to "explain why and the strategy for addressing these deficits in the future" [28]. However, the SBTi still allows companies to set a base year beyond 2014, and even if a company sets a target in 2014, there is no clarity on how to accurately include any past deficits, or account for changes in their actual vs projected market share, in their target recalculation.

The TPI and ACT both inherit similar shortcoming to those of the SBTi when using the SDA as a benchmark, with additional issues of their own, summarized in Table 1, and demonstrated in Figure 1a and b for an anonymous Australian electric utility company. The TPI, established in 2017, uses the IEA sectoral intensity pathway ($SI_y$), rather than firm-specific carbon intensity ($CI_y$) proposed by the SDA (Figure 1a). This contrasts clearly with the SDA methodology which uses initial company intensity and projected market share to derive company-specific emissions-intensity trajectories [13]. Further, a limitation of the TPI is that it does not provide a revised company-specific decarbonisation trajectory against which its future progress can be tracked.

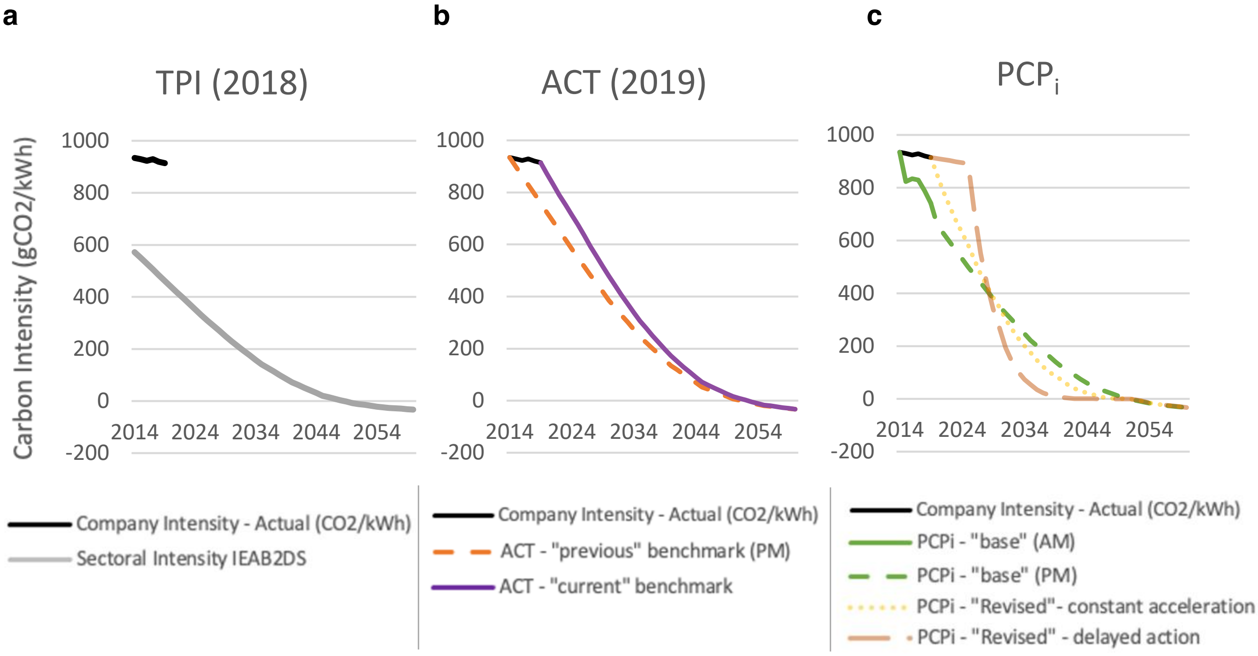


**Fig. 1 | Comparison of the different benchmarking approaches using the SDA method by TPI, ACT and PCP's to evaluate transition performance.** All panels include the companies' actual carbon intensity since 2014 (black line). Panel a) shows that the Transition Pathway Initiative [29] maps a company's carbon intensity against the sectoral intensity as set out by the IEA B2DS. Panel b) shows that the Assessing low-Carbon Transitions (ACT) initiative uses the SDA to set a "previous" benchmark pathway (dashed orange line), set 5 years prior using projected market (PM) share, and a "current" benchmark pathway (purple line) based on current (2019) carbon intensity and projected market share. Panel c) illustrates our methodology showing an "original" Paris-Compliant intensity Pathway ($PCP_i$) that uses the SDA based on a company's initial intensity (2014) and actual market share (green line) and projected market share (dashed green line). It also shows two possible "revised" PCPi's a company could follow to stay within its carbon budget: a PCPi featuring a constant "accelerated" decarbonisation rate which commences immediately (dotted orange line); and a PCPi which follows a Reference Emissions Trajectory (minimum action) for the next 5 years (long dashed orange line), followed by an even more accelerated decarbonisation rate (short dashed orange line).

| | TPI | ACT | PCP |
|---|---|---|---|
| Uses a company-specific pathway to benchmark performance against | × | ✔ | ✔ |
| Defines benchmark and evaluates performance from a common base year | ✔ | × | ✔ |
| Revised pathway included | × | ✔ | ✔ |
| Revised pathway adjusted for changes in actual vs projected market share since base year | × | × | ✔ |
| Revised pathway adjusted for action deficit since base year | × | × | ✔ |

**Table 1. Summary of different approaches to benchmarking transition performance.** This table shows the different approaches by the TPI, ACT and PCP of defining benchmarks.

The ACT methodology, developed in 2019, defines benchmarks based on a company's carbon intensity and market share, but does not redefine the benchmark over time based on 1) deviations in projected vs. actual market share, and 2) any emissions performance deficits incurred since the common base year. The ACT defines a "previous" benchmark (set at the reporting year less five years) and a "current" benchmark (reporting year), but by doing so does not account for performance outside of the scope of this 5-year interval. The ACT also strays from the most recent SDA approach in using the IEA 2DS pathway instead of the IEA B2DS pathway. Even if the ACT were to evaluate all companies' performance since 2014 using IEA B2DS (as illustrated for the company in Figure 1b), their "previous" benchmark does not adjust for discrepancies between the actual and projected market share. Finally, as the "current" benchmark is not adjusted to account for failure to follow a previously defined emissions-intensity pathway, a company's original allocated carbon budget would be exceeded if this new benchmark were followed by the company. In the Supplementary Materials[1] we provide a more detailed analysis of the limitations of these alternative approaches.

Figure 1c presents several new emissions intensity pathways for an individual company experiencing a deviation from their PCP, both of which address the shortcomings of the TPI (Figure 1a) and ACT (Figure 1b), as outlined above. The base year of the PCP is 2014 as this reflects the inception of the IEA B2DS. Our "base" PCP is defined using the company's actual market share for the years to date (2014-2019) and projected market share (here, beyond 2019), instead of only using projected market share as used by ACT. This allows us to account for discrepancies between realised emissions and those that would have been produced if following the base PCP since 2014. Given the company has deviated from its PCP set in 2014, we illustrate two potential "revised" PCPs in Figure 1c that the company could follow to compensate for the lack of progress since 2014 and stay within its CCB. Through this example we show that decarbonisation rates in the next 5 years have a significant effect on the decarbonisation rates required between 2025 and 2050 if the company is to remain "Paris-compliant".

## New metrics for gauging companies' transition performance

We propose three new metrics, mostly focused on absolute emissions (PCPe), for evaluating the climate performance of companies against the Paris goals. Metric 1 measures current performance since the base year, Metric 2 provides indicators for the implications of continuing business as usual, and Metric 3 gives the re-alignment factor required for the company to return to a climate-safe pathway. For measuring Metric 1 we compare a company's cumulative emissions to date against its PCPe, where PCPe's are defined as the cumulative emissions that would have been emitted since 2014 had it followed its "base" PCPe. For Metric 2 we estimate a reference emission pathway based on both "minimum" and "maximum" action, and estimate three sub-metrics: 2a) the "Estimated Year to Finish" (EYF), the year the company carbon budget would be exceeded, 2b) their projected production capacity in the EYF that produces a greater than zero emission intensity, and 2c) the exceedance of the company carbon budget (CCB) as a multiple in the year the company's PCP must become net-zero (around 2050 for the electric utilities sector). The CCB is defined as the total emissions a company can emit before it must achieve net-negative carbon intensities (the IEA B2DS allows for temporary overshoot). For Metric 3 we quantify two re-alignment options (as shown in Figure 1) that provide a measure of how much faster a company will need to decarbonise relative to the rate in its original PCPi.

Both the TPI and ACT also provide metrics to enable companies to gauge their progress towards their long-term goals. The TPI is designed to require only publicly available data [25] and hence uses a simple binary carbon performance metric (aligned/not aligned) without quantifying the level of (mis-) alignment. There is no stipulation of what the company needs to do to re-align its trajectory to compensate for any deficits to date. The ACT uses a set of quantitative performance indicators to compare the company's actual and future carbon intensity pathway to their benchmark trajectory. We provide a comparison of our metrics with the TPI and ACT metrics in the Supplementary Materials.

[1] Supplementary materials are available on request from the corresponding author

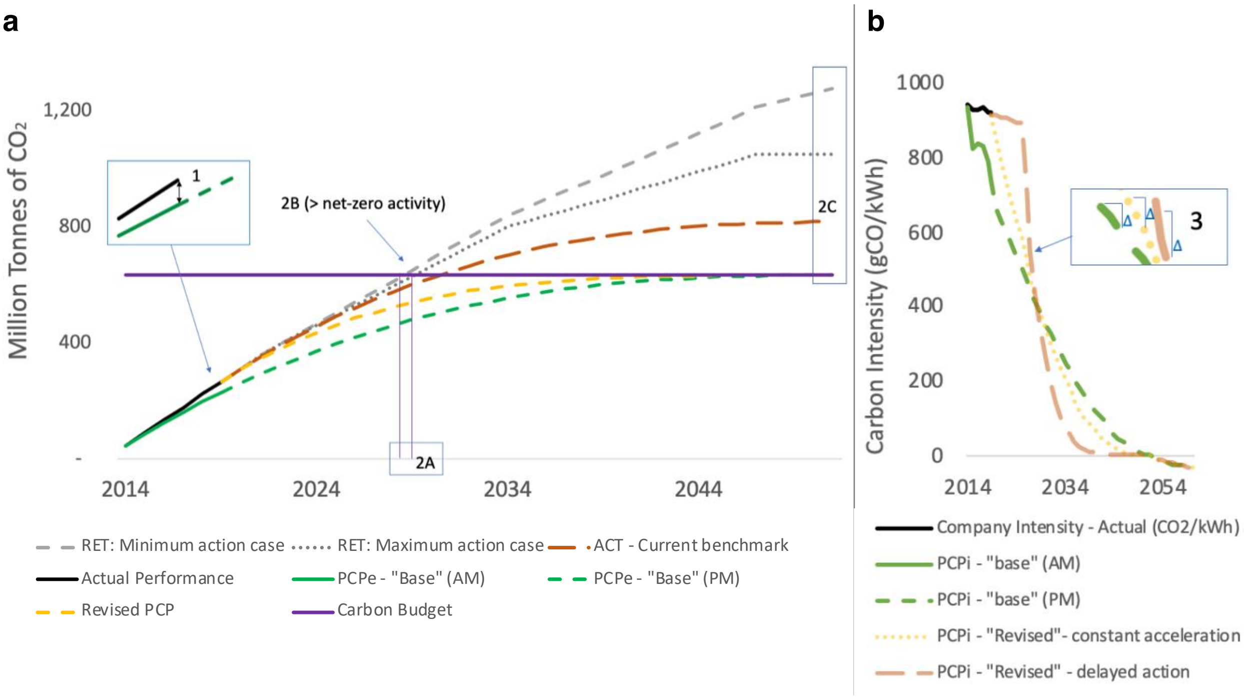


**Fig. 2 | Transition performance metrics for an anonymous electric utility company. Panel a** shows Metric 1 and metric 2. Metric 1 measures the performance since the base year (cumulative emissions since the base year 2014 relative to the Climate-safe Emissions Pathway). Metric 2 is composed of three sub-metrics; 2A is the estimated year that the company carbon budget will be fully emitted based on two reference emission trajectories (RETs) of future cumulative emission projections, all assuming constant market-share, 1) continuing operation of assets until closure date + minimum action (long dash) and 2) continuing operation of assets until closure date + maximum action (short dash); 2B is the amount of activity in place under both RETs at the EYF with a positive emission intensity; 2C is the emissions under both RETs in 2050 compared to the carbon budget; we also show the emissions that had occurred if the company had followed the ACTs "current benchmark" going forward (orange long dash), **Panel b** illustrates Metric 3 which measures the difference in decarbonisation rates between the "base" PCPi and the "revised" PCPi's.

Figure 2 demonstrates our three metrics for an anonymous Australian electricity provider. The actual $CO_2$ emissions (black line) of the company since 2014 exceeded their Climate-safe Emission Pathway (green line) by a factor of 1.12 in 2019. If the company were to continue to operate its assets until the expected closure date and replace their assets with a lower carbon alternative, 50% gas and 50% renewables (referred to as "minimum action case"), or with a zero-carbon alternative ("maximum action case"), then the company would exceed their carbon budget in about a decade (2029 to 2030) (metric 2a), whilst still producing 34.2 million MWh under the maximum action scenario, and 44.1 million MWh under the minimum action scenario. Thus, the company would need to retire this non net-zero production capacity if it wants to remain within its CCB. If either of the projected pathways are followed, emissions will be 166%-199% of the CCB by 2050 (Metric 2c). We further calculate metric C for the case in which the company followed the carbon intensity pathway proposed by the ACTs current benchmark (Figure 1b), which is shown to be 126% times the CCB in 2050. This demonstrates the inadequacy of using the ACT as a methodology to analyse how compliant a company is with a Paris-aligned carbon budget.

If the company takes immediate action to realign its trajectory to stay within its carbon budget to 2050, it will need to decarbonise its operations 1.46 times more rapidly than had it followed its PCP since 2014 (Table 2). If the company delays realignment and continues its current decarbonisation pathway until 2025, it will need to decarbonise 3.15 times more rapidly post-2025 than if it had followed its "base" PCP since 2014. This increased pace of change will be highly disruptive forcing the company to accelerate the retirement of carbon-intensive assets and more rapidly mobilize capital for low-carbon assets. Earlier emission reductions would allow for a slightly more gradual decarbonisation (Fig. 1c). These results are summarised in Table 2.

| Metric | Value for company | |
|---|---|---|
| 1: Cumulative Emissions emitted since base year relative to emissions allowed under the Climate-safe Emission Pathway (%/absolute)) | 117%/38Mt$CO_2$ | |
| 2: The potential for stranding of existing assets | | |
| A: Estimated Year to Finish (EYF) Carbon Budget: | | |
| i) if continue operation of assets until closure date + minimum action after | 2029 | |
| ii) if continue operation of assets until closure date + maximum action after | 2031 | |
| B: Production Activity with greater than net-zero emission intensity in EYF | | |
| i) if continue operation of assets until closure date + minimum action after | 34.2 million MWh | |
| ii) if continue operation of assets until closure date + maximum action after | 39.1 million MWh | |
| C: The level of exceedance of the CCB by 2050 (percentage of CCB) | | |
| i) if continue operation of assets until closure date + minimum action after | 166% | |
| ii) if continue operation of assets until closure date + maximum action after | 200% | |
| iii) if continue operation of assets according to ACTs current benchmark | 126% | |
| 3: Adjusted decarbonisation rate required to be climate-safe (compared to rate if followed "base" PCPi) | **2020-2025** | **2025 - 2051** |
| i) constant extra decarbonisation through to 2051 | 1.46x | 1.46x |
| ii) RET (maximum action) in next 5 years | 0.08x | 3.15x |

**Table 2: Calculated transition performance metrics for anonymous company in Figure 2.**

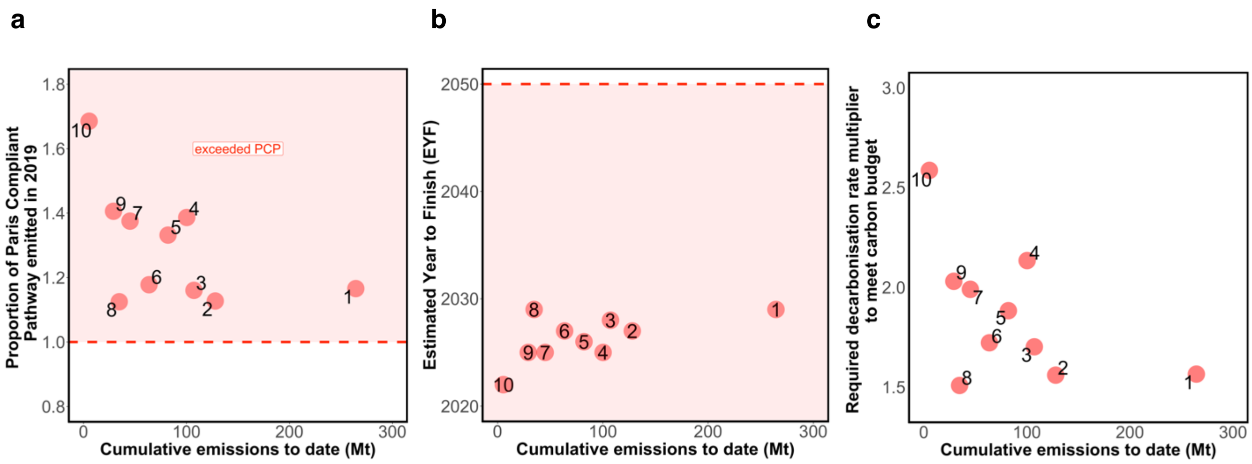


**Figure 3 | Transition performance metrics for the ten largest producing energy generators in Australia, for metric 1, 2a and 3. Panel a** shows Metric 1 - the proportion of the Paris-Compliant Pathway (PCP) (in absolute emissions, PCPe) actually emitted in 2019 since the base year 2014, **Panel b** shows Metric 2A- the Estimated Year to Finish the carbon budget if carbon intensity is decarbonised at Reference Emission Trajectory – minimum action, **Panel c** shows Metric 3 - the multiplier on decarbonisation rates required (compared to if it had followed its PCP (in carbon intensity, PCPi) since 2014) to be Paris-Compliant. Additional metrics are shown in Extended Data Figure 1 and 2. 1 = AGL, 2 = Energy Australia, 3 = Origin Energy, 4 = Stanwell, 5= CS Energy, 6= Alinta Energy, 7= Delta, 8=Millmerran, 9=Callide and 10= Pelican Point.

Figure 3 demonstrates the application of the metrics to the 10 largest Australian electricity utilities, showing the scale of the decarbonisation challenge. All companies currently exceed their PCP (Fig 3a), and if the companies followed a "minimum action case" all companies are expected to exceed their total carbon budget before 2030 (Fig 3b) and exceed their carbon budget by between 2 and 4 times in the year 2050 (Extended Data Figure 1). Overall results are very similar to if companies followed a "maximum action case" but can be quite different for individual companies (Extended Data Figure 2). If companies followed the "current benchmark" by the ACT, i.e. a revised carbon intensity decarbonisation pathway, the carbon budget would be exceeded by 1.14 to 2.35 times in the year 2050.

As a result of their failure to follow their PCP, the companies face a requirement to increase the rate of decarbonisation between 1.46 and 2.5 times faster than required had they followed their base PCP (Metric 3; Fig 3c). This metric is a measure of the extent to which a firm's present decarbonisation trajectory is misaligned with the Paris Agreement, as defined by the PCP. Any further exceedance of the PCP beyond 2019 will increase this rate even further.

The PCP approach provides companies with a means of accurately ensuring their efforts are aligned with the goals of the Paris Agreement. The additional metrics provided can thus be used by companies, investors, and other stakeholders to evaluate the company's *transition performance*. A company's transition performance is related to their exposure to *transition risk* [27, 30, 31, 32] which manifests primarily as assets stranded due to a reduction in demand for their services, or from regulatory and fiscal measures to reduce emissions [30, 33]. The more a company exceeds their PCP, the larger the company's misalignment with meeting the Paris goals, and the more likely they will be exposed to such transition risks. However, it should be noted that the concept of transition risk is much broader than stranded assets and can manifest as a loss of market share (market risk), as a disadvantage through ownership of inferior technologies (technology risk), exposure to litigation (legal risk), and erosion of investor or consumer confidence (reputation risk) [32]. As some of these risks involve historic emissions and actions (e.g. legal and reputation risk) they are not fully covered by the PCP metrics.

## Conclusions

We have presented here a new methodology providing companies with science-based Paris-Compliant Pathways that will ensure their consistency with a "well-below 2C" (i.e. IEA B2DS) transition to net zero emissions. We have also provided three new metrics for evaluating a company's performance against their pathways and demonstrated how such metrics can be used to evaluate companies within a sector. When applied to major companies in the Australian electric utility sector our metric showed they are clearly not on track to meeting the goals of the Paris Agreement, and corporate decarbonisation efforts will need to be ramped up significantly. The shortfalls in decarbonisation progress also indicate the increasing exposure of such companies to transition risks.

Our metrics use the SDA method to set the benchmark, but other science-based methods could be employed, provided they are adjusted accordingly to be consistent with the Paris goals (well-below 2C). It should be noted that the SDA method itself also has limitations in its foundations, such as allowing companies with a higher initial intensity to have a greater share of the remaining global carbon budget and ignoring other historic emissions. In addition, the IEA B2DS pathway relies on significant amounts of carbon capture and storage and negative emissions technologies which are currently not being deployed at anywhere near the rate required by this scenario [21, 34].

Nobel Laureate Milton Friedman once famously wrote that the social responsibility of business was to increase its profits [35]. However, society is now putting much loftier demands on companies, and the many stakeholders now have much more influence on corporate behaviour - shareholders most obviously through the exclusion or inclusion of companies' debt or equity in their portfolios [36-38], and increasingly regulators, central banks, and banks, through lending restrictions and disclosure requirements [39], and customers, suppliers, employees, politicians, academics, and communities through purchasing decisions, employment preferences, publications, policies, and various forms of activism [40-44]. The failure to accurately monitor, verify and benchmark corporations' GHG emissions reductions obscures the perceived risks for these stakeholders [45] and limits their capacity to make decisions aligned with the Paris Agreement. If companies are able to claim compliance while exceeding their carbon budgets, then Paris-compliance will not be achieved and investors will have been misled. Our metrics overcome identified shortcomings in the SBTi, TPI and ACT approaches and provide a sound basis for comparing company's Paris-compliance and transition performance. Regulators, investors, and other stakeholders must also play their part in ensuring that firms that do correctly report their climate performance can also remain profitable through their transition [12].

**Acknowledgements**
We would like to thank Rupert Stuart-Smith for his valuable comments on earlier versions of the manuscript.

**Author Contributions**
S.R., B.W. and C.G. designed the study; S.R. and L.W. collected, verified, processed and analysed the data; S.R. and M.I. wrote the paper; B.W. and C.G. edited the paper. All authors contributed to the methods and interpretation of the results.

**Competing Interest**
All authors declare no competing interests.

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## Methods

**Paris-Compliant Pathway (PCP)**

We use the Sectoral Decarbonisation Approach (SDA) initially published by Krabbe et al. (2015) [13] and updated by the Science-Based Targets initiative (2019) to determine a companies' Paris-Compliant Pathway (PCP). The SDA methodology sets carbon intensity targets based on a company's initial carbon intensity, the IEA B2DS' sectoral decarbonization pathway and their projected market share. The IEA B2DS' pathway is consistent with a 50% chance of limiting average future temperature increases to 1.75°C. The PCPe is a pathway of cumulative emissions that would be consistent with an IEA B2DS pathway provided all companies stay on or below their PCP.

The PCPe is calculated as follows:

**Paris-Compliant Pathway (PCPe) for a company in year y (base year 2014):**

$$PCPe_y = \sum_{y=2014}^{t} PCPi_{y,SDA} * CA_y$$

**Where the "base" PCPi in year y is calculated using the SDA methodology:**

$$PCPi_{\ y,SDA} = dp_y m_y + SI_{2060}$$

Where

$$d = CI_b - SI_{2060},$$

$$p_y = \frac{(SI_y - SI_{2060})}{(SI_b - SI_{2060})},$$

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

$$CI_b = Carbon\ intensity\ in\ the\ base\ year\ (2014)\ set\ by\ IEA\ B2DS$$

$$SI_y = Sectoral\ Intensity\ in\ year\ y\ set\ by\ IEA\ B2DS$$

$$SI_b = Sectoral\ Intensity\ in\ base\ year\ (2014)\ set\ by\ IEA\ B2DS$$

$$SI_{2060} = Sectoral\ Intensity\ in\ 2060\ set\ by\ IEA\ B2DS$$

$$CA_b = Company\ Activity\ in\ base\ year\ (2014)$$

$$CA_y = Company\ Activity\ in\ year\ y$$

$$SA_b = Sectoral\ Activity\ in\ base\ year\ (2014)$$

$$CA_y = Sectoral\ Activity\ in\ year\ y$$

Sectoral activity (SA) is set by the IEAB2DS pathway, and we use the activity for the region the company produces (so we use IEA B2DS-consistent activity for the OECD for Australia).

We distinguish between a) a "base" PCPi calculated using actual market share (AM) where available, thus in 2019 the PCPi is based on actual market share 2014-2019, and b) a "base" PCPi calculated using projected market share (PM) for future years, assuming the company had followed their "base" PCPi to date.

Whilst a company can set targets for their PCP using their projected market share, the PCP can only be finalized once the activity, and thus market share, of a company is known (usually at the end of the year). Therefore, the PCP needs to be continuously revised when new market share data becomes available. We can therefore distinguish between two PCPs: actual and projected. For the actual PCP, $m_y$ and $CA_y$ is known, for the projected PCP, $m_y$ and $CA_y$ is projected keeping market share constant according to regional sectoral activity projections. For the year 2020, this results in:

$$Actual\ PCPe_{2014-2019} = \sum_{y=2014}^{2019} PCPi_{y,SDA} * CA_y$$

$$Projected\ PCPe_{2020-2060} = Actual\ PCPe_{2014-2019} + \sum_{y=2020}^{2060} PCPi_{y,SDA} * CA_y$$

**Metric 1.** To measure performance to date, we compare their actual cumulative emissions to date, i.e. their actual "Emission Pathway", to the Actual PCP and calculate the percentage of PCP emitted to date. We calculate the actual EP as the company's actual carbon intensity multiplied by the company's actual activity.

$$Actual\ EP_{y,2014-2019} = \sum_{y=2014}^{2019} CI_y * CA_y$$

We can then calculate the Corporate Climate Performance to date:

$$Corporate\ Climate\ Performance\ to\ date = \frac{Actual\ EP_{y,2014-2019}}{Actual\ PCPe_{y,2014-2019}}$$

If > 1, the company has emitted more than their PCPe (not consistent with Paris goals)
If ≤ 1, the company has emitted the same or less than their PCPe (consistent with Paris goals)

It is important to note that we use PCPe and not PCPi here. The PCPi simply captures what the intensity should be in a certain year, but gives us no indication on whether a company has exceeded its PCPi to date, and by how many tons of emissions. This is captured by PCPe.

**Metric 2.** To understand the implications of a company's performance to date and their projected emissions, we use three sub-indicators (metric 2a, 2b and 2c). We project emissions forward using the following Reference Emissions Trajectories (RET):
**- RET - Minimum action case:** The company produces until closure date and replaces plant with lower energy intensity (50% lower carbon (gas) + 50% net-zero carbon)
**- RET - Maximum action case:** The company produces until closure date and replaces plant solely with net-zero carbon (e.g. renewables, nuclear or gas + CCS)

Metric 2a. The first submetric follows Rekker et al. (2018) [20] by using the "Estimated Year to Finish", which is the year the company is estimated to have emitted their full Company Carbon Budget (CCB). We define the CCB as the total amount of carbon the company can emit to operate consistently with the chosen climate pathway (e.g. IEA B2DS) in the respective timeframe (e.g. 2014-2060 for IEA B2DS). Under the IEA B2DS however, there is a temporary overshoot allowed, given the Sector Intensity goes negative from about 2050 to 2060. Therefore, we define the CCB of a company at the year that the PCPe is at its highest level:

$$Company\ Carbon\ Budget = max\ (PCP_y)$$

*This is subject to the company generating negative emissions after the year t that satisfies* $max\ (PCP_{y,t})$ *such that it reaches* $PCP_{y,2060}$ *in the year 2060.*

Note that the CCB is not fixed, it depends highly on the projected company activity (captured under *Projected PCPe)*. It should be updated and refined on a yearly basis. Assuming the company has not yet exceeded its CCB in 2019, the remaining CCB in year "EYF" can be calculated by subtracting the emissions to date from the Carbon Budget:

$$Remaining\ Carbon\ Budget_y = Company\ Carbon\ Budget - Actual\ EP_y$$

The firm is estimated to finish its remaining carbon budget in the year "EYF" that satisfies:

$$Actual\ EP_{EYF} = \ Company\ Carbon\ Budget$$

Note that because the EYF is based on a lenient Company Carbon Budget (the company will have to generate negative emissions after), the EYF is also a lenient measure.

Metric 2b. This metric measures the capacity ($CA_y$) that is estimated to be still in place when the company reaches its EYF (metric 2a). This is a measure of how much energy generation capacity will need to be retired at the EYF if the company is to continue with its projected outputs but stay within its CCB. The metric is observed from the difference in the RET in the EYF and the RET the year prior.

Metric 2c. This metric evaluates how many times the CCB will be exceeded if the company continues along their RETs when their PCPi should reach zero, which is around 2050 (but depends on the individual company). It is calculated as the RET in the year the PCPi should reach zero, divided by the CCB.

**Metric 3**. To stay within the carbon budget consistent with the IEA B2DS' pathway, companies that have emitted more than their fair share (i.e. their total PCPe), will have to compensate for this in the future. This is closely aligned with transition risk– the companies that have decarbonized the least to date are the most vulnerable to a transition to a world that meets the Paris goals.

To understand the pathway a company should follow to re-align its emissions, we calculate a "re-alignment factor". This factor captures how much faster the company must decarbonize in order to maintain its projected outputs and stay within its carbon budget, compared to when it had followed the PCPe from the start.

To calculate this re-alignment factor, we first calculate the speed of decarbonisation required if the company had followed its PCPe since 2014. We derive this 'speed' by calculating the "base" PCPi for the firm, and then inferring the required (annual) decarbonisation rates to adhere to this pathway. As the IEA B2DS uses 5-year intervals, we construct our decarbonisation rates such that it ensures the pathway is built on the known data points (while interpolating the pathway between these years using geometric growth rates).

As such, the required decarbonisation rate is constant between the (IEA-specified) time intervals, but not across the whole period. We use the time-intervals (beginning year and ending year) for the geometric growth rates in accordance with the IEA B2DS' timeline. For example, the IEA B2DS reports forecasts for the years 2014, 2025, 2030, 2035, and every 5 years after that until 2060.

As such, the decarbonisation rate (where t is between 2014 and 2025) is calculated as follows:

$$d_t = \left[ \left( \frac{CI_{2025}}{CI_{2014}} \right)^{1/(2025-2014)} - 1 \right]$$

where $d_t$ is the decarbonisation required at time t (given the firm is aligned to date).

With the acquired decarbonisation rates, we can computationally solve the following equation simultaneously to compute the (constant) z value. If the firm is aligned to date, the z score is 1.

$$(1) \quad CI_{t+1} = CI_t \times (1 + z \times d_t)$$

$$(2) \quad \sum_{n=2020}^{2050} CI_t \times CA_t = Remaining\ Carbon\ Budget$$

# Data

To select our sample, we sourced the activity data for all Australian electric utility companies on a disaggregated level (generator-by-generator activity from NEM dispatch data provided by the AEMO) and aggregated the data to a firm-level. We used the NEMReview6 software [46] and sorted each generator by owner, then calculated the total activity for each firm by summing the generators' activity for a given time interval. We did this for the years 2014 - 2019. For robustness, we cross-checked the activity values generated from this method with the activity data for AGL and Origin, which are the only two public companies and have activity data available through the Bloomberg database (code "Total Power Generated") [47]. Our activity values were found to be consistent with the Bloomberg metrics.

We ranked the firms by their activity in 2014 and selected the 10 largest producing firms for our sample. However, due to the nature of some of the corporate entities, certain firms had to be excluded. Two firms, Hazelwood Power and Flinders Power, were excluded from the analysis as their (sole) plants, Hazelwood Power Station and Flinders Power Station, respectively, were decommissioned by the time of analysis. Two other firms, Hydro-Electric Corporation and Snowy Hydro Limited, were excluded from the analysis as these firms were renewable energy generators. Due to the hydro power resulting in much lower carbon intensities [48], their inclusion would have complicated the method to construct a Carbon Budget, and result in these firms having a negative carbon budget (i.e. the method expects these firms to withdraw emissions from the atmosphere that are not related to their own production). For that reason, it was determined that this was outside of the scope of our analysis, and so we chose to exclude the firms that experience this abnormality.

To source company-specific emission data, we first considered the National Greenhouse and Energy Reporting (NGER) database published by the Clean Energy Regulator (CER). Since 2007, Australian corporations have been required by law to report their greenhouse gas emissions to CER each year. Although this may seem the most logical (and most accurate) dataset for company-specific emissions, this data source was not fit for our analysis for the following reasons: i) The data is reported in financial years, whereas the SDA method uses constructed in calendar years. As the NGER data is published as an aggregate, there was/is no possibility of transforming the data from financial years to calendar years, ii) In the earlier reporting years, certain firms chose to publish emissions by holding company (e.g. Loy Yang, Tarong) rather than consolidating it under the 'final' owner (e.g. AGL). To avoid this complexity, we use the same method as we used for the activity data, and thus sourced disaggregated emissions data by generator (using the NEMReview 6 software) and aggregate it to a company level. The same robustness check was conducted using AGL and Origins emission data in Bloomberg (code "GHG_SCOPE_1") and were found to be consistent with our calculations. As a final confirmation of the accurateness of our data, we compared the emission intensity produced from the disaggregated method's results (Emission Intensity $= \frac{Emissions}{Activity}$) against the corresponding Bloomberg value (using the code 'GHG_SCOPE_1_INTENS_PER_PWR_GEN'). Again, these values were in line with one another, further confirming the accuracy of our dataset.

## References Method and Data


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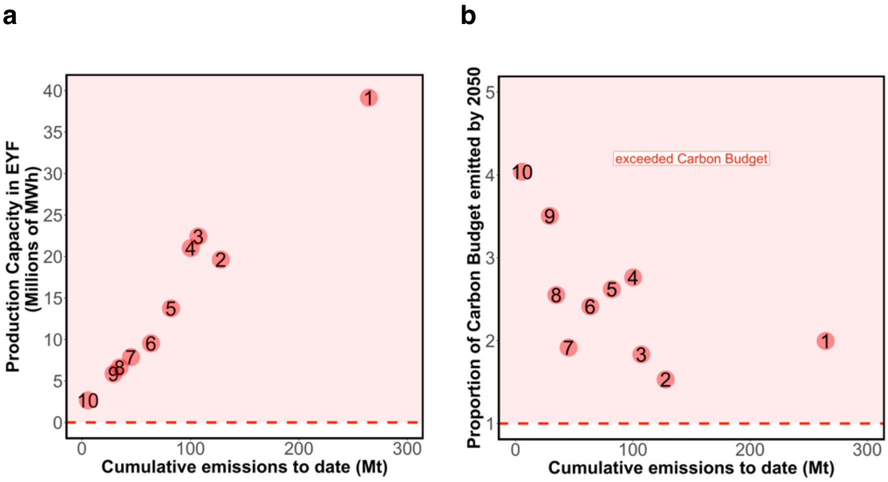
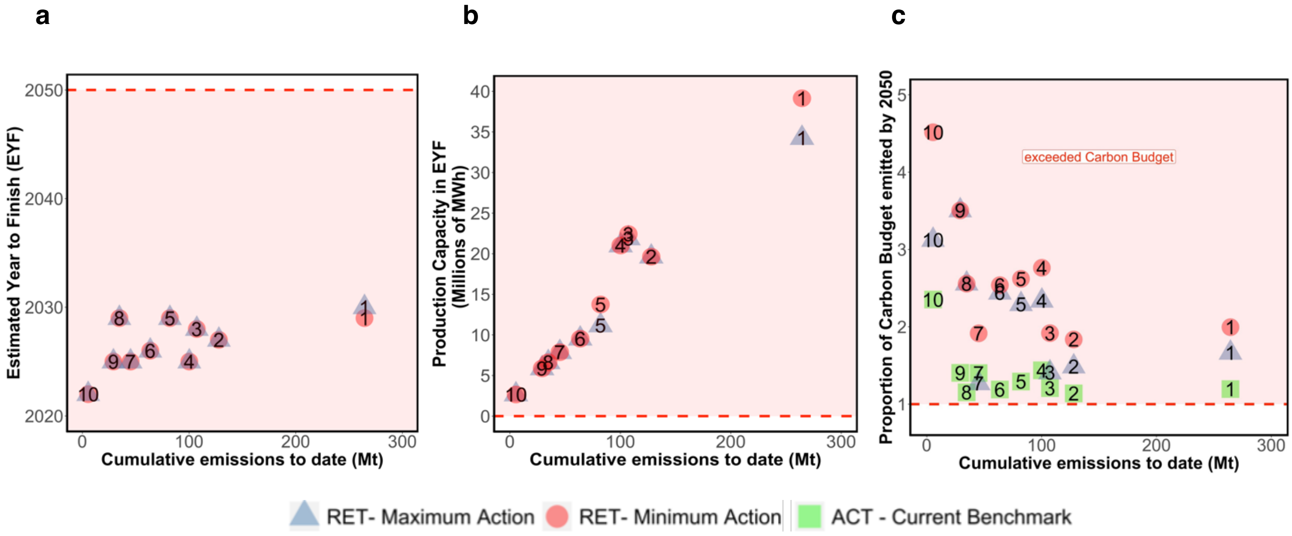



**Extended Data Fig 1 | Transition performance metrics for the ten largest producing energy generators in Australia, for metric 2b and 2c. Panel a)** shows the projected production capacity in the EYF that produces a greater than zero emission intensity, **b)** proportion of the company carbon budget (CCB) emitted in the year the company's PCPi must become net-zero (around 2050 for the electric utilities sector). Projected activity and emissions are based on a Reference Emission Trajectory – minimum action scenario.




**Extended Data Fig 2 | Transition performance metrics for the ten largest producing energy generators in Australia, for metric 2a, 2b and 2c under a "maximum action case" and "minimum action case", and for 2c also a case in which the generators follow a pathway eligible under the ACT. Panel a)** shows metric 2a, **b)** shows metric 2b, and **c)** shows metric 2c. For a description for the metrics see Fig. 2 and Extended Data Fig 1.