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Designing temperature alignment metrics to invest in net zero: an empirical illustration of best practices

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At a glance

- The private sector is increasingly aware of the physical and transitional risks and opportunities associated with climate change. Implied temperature rise (ITR) metrics provide an effective means of quantifying this challenge.
- The Paris Agreement's overarching objective is to keep "the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels". However, Earth is currently on track for a 3.2°C warming by 2100, with further temperature increase thereafter.
- Consequently, financial institutions – both private and public – are rapidly rethinking how they assess risks and rewards and are working towards developing innovative ways of pricing what we term Climate Value Impact (CVI).
- CVI provides a quantified notion of whether companies are likely to be positively or negatively exposed to the physical as well as the political-economic effects of the climate transition.
- CVI encompasses transitional, physical and liability risks. Arguably, transitional risks are, as of today, the most material to investment decision-making because of the ongoing acceleration of climate mitigation responses.
- Implied temperature rise (ITR) metrics, a critical building block of CVI, are now rapidly gaining traction in the investment community.
- ITR metrics allow investors to assess their investment(s)' climate performance – be it that of individual securities or of entire portfolios – against a reference benchmark. This metric brings a forward-looking perspective to carbon footprinting metrics, which assess historical emissions.

Translating carbon budgets into benchmarks

p.4

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Whereas carbon footprints provide a historical insight into the scale of a company's emissions, ITR metrics seek to determine their expected trajectory.

1. Introduction

The Paris Agreement's overarching objective is to keep "the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels" (UNFCCC, 2015). In stark contrast to those ambitions, the UNEP's 2020 *Emissions Gap Report* found that Nationally Determined Contributions (NDCs – signatory countries' carbon budget) put Earth on track for a 3.2°C warming by 2100, with further temperature increase thereafter. In 2018, the Intergovernmental Panel on Climate Change (IPCC) also found that to contain global warming to 1.5°C, our remaining carbon budget sat at around 420GtCO_2 (for a two-thirds chance of success). In the three years spanning 2018 to 2020, we have collectively spent nearly a quarter of that budget (IEA, 2020).

This alarming and conclusive scientific evidence has pushed the private sector to become increasingly aware of the risks and opportunities associated with climate change. As the real economy comes to grips with this new reality, financial institutions – both private and public – are rapidly rethinking how they assess risks and rewards and are working towards developing innovative ways of pricing what we coin Climate Value Impact (CVI). In essence, CVI provides a quantified notion of whether companies are likely to be positively or negatively exposed to the physical as well as the political-economic effects of the climate transition. CVI encompasses transitional, physical and liability risks. Arguably, transitional risks are, as of today, the most material to investment decision-making because of the ongoing acceleration of climate mitigation responses. These transition risks include, inter alia, the impact of regulation that may cause some businesses to lose their license to operate; rising capital expenditures and increased operating costs linked to the abatement of emissions through decarbonisation technologies; rising expenditures linked to carbon prices and taxes; and demand destruction as consumers and businesses move away from selected products or services such as fossil fuels, air travel, combustion engines and meat.

We can distinguish three main categories of companies with respect to their CVI profile:

1. **Companies insulated from carbon risks:** This category includes companies in various sectors where the climate transition is expected to have limited financial impact. This includes most low-carbon sectors, where the costs of transition are generally low, with some exceptions. These companies tend to have a lower CVI. As such, investors may have a higher tolerance for companies that are not yet achieving rapid reductions in their emissions given that they are in a position to transition with relative ease (at limited costs and over a comparatively shorter time frame).
2. **Companies in sectors facing market opportunities:** Companies in these sectors are generally positively-exposed to the climate transition. They tend to offer products and services that stand to benefit from increased demand as the transition progresses (i.e. renewable energy companies and electric vehicles manufacturers). These companies tend to have a medium CVI. For these companies, while reducing their own emissions can unlock competitive advantages compared to other solution providers, they generally remain well-positioned in the market as a whole.
3. **Companies in sectors facing high transitional impact:** This generally includes high-emitting industries which are critical to the climate transition (i.e. energy, steel, glass and cement, etc.) where climate laggards face significant risks, but where transitioning leaders may access significant market gains. These companies typically have a high CVI. This is likely the most material category to meeting the objectives of the Paris Agreement, and concomitantly possibly the most important category for investors to understand.

Implied temperature rise (ITR) metrics are now rapidly gaining traction in the investment community precisely because they offer the means for investors to proactively manage the CVI of their portfolios and understand the alignment of the financial flows with the goals of the Paris Agreement (see UNFCCC, Article 2c). The year 2020 was a remarkably prolific year for the development of ITR metrics with several new methodologies coming to market (PAT, 2020). Simply put, ITR metrics allow investors to assess their investment(s)' climate performance – be it that of individual securities or of entire portfolios – against a reference benchmark. To say a company has a 1.5 °C temperature is to say that global warming could be limited to 1.5 °C above pre-industrial levels should the entire economy undertake an equivalent level of decarbonization. As such, the measure is intuitive and potentially helpful for investment decision-making as it brings a forward-looking perspective to carbon footprinting metrics, which assess historical emissions.

The concept of ITR began to emerge in the wake of the Paris Agreement as investors sought to quantify their investments alignment with its objectives. Some of the earliest records of the concept can be traced back to an OECD Conference in Japan in October 2016, where it was discussed amongst leading investors including Hiromichi Mizuno (CIO of the Japanese GPIF) and government ministers. Subsequently, the GPIF became the first major asset owner to publish its own ITR results (Trucost, 2019).

Although ITR metrics are relevant to all three categories of firms presented above, they are particularly salient to distinguish between high-emitting transition leaders and laggards in order to manage the CVI of investment portfolios.

While there is a significant body of scientific literature discussing the measurement and management of corporate greenhouse gas emissions (see for instance Rankin et al., 2011; Prado-Lorenzo, 2009; Plambeck, 2012), there is, to the best of our knowledge, no peer-reviewed scholarship on the theoretical and empirical tenets of ITR metrics in the context of financial decision-making. Absent of scientific literature, we do however note a burgeoning non-peer reviewed literature on the topic emanating from non-governmental agencies and think tanks as well as private sector organizations (most notably, see NZAOA, 2020; IIGCC, 2020; PAT, 2020; Institut Louis Bachelier et al., 2020; PAT, 2021). In this paper, we propose to address this gap in scholarship by reviewing, testing and elaborating on current best practices aimed at designing ITR metrics.

Our paper is organised as follows: Firstly, we review the state of the art of temperature alignment metrics. Secondly, we formalize a theoretical framework following PAT (2020), PAT (2021) and Institut Louis Bachelier et al., (2020) to guide the design of ITR metrics. Thirdly, we provide an in-depth description of the *fair share carbon budget approach* which resolves previously identified problems in using absolute emissions versus intensity based emissions to compute temperature metrics. Fourthly, we offer a case study to discuss, in light of empirical evidence, the strengths and weaknesses of different methodological choices. Our case study focuses on a high CVI company, ArcelorMittal,[1] a large European steel manufacturer. To conclude, we discuss limitations and offer ideas for future research efforts.

2. Temperature alignment metrics

2.1 State of the art

The link between climate change and financial risks is relatively well researched (Stolbova et al., 2018; Bretschger and Karydas, 2019; Roncorni et al., 2019) and is increasingly acknowledged by financial market participants (see for instance J.P.Morgan, 2019), supervisory authorities and central banks (Financial Stability Board, 2020; Bank of England, 2018; US CFTC; NGFS, 2021). Against this backdrop, considerable resources and efforts have been mobilized to develop metrics to help investors make climate-informed decisions. Whereas carbon footprints provide a historical insight into the scale of a company's emissions, ITR metrics seek to determine how their expected trajectory (based on a company's present rate of decarbonisation or its commitments) is aligned with different climate outcomes. These metrics seek to provide greater nuance to the climate transition, recognising that companies in high-emitting and climate-relevant sectors can be well-aligned to the transition if they are able to set credible decarbonisation strategies and targets. Whereas a focus solely on the carbon footprint of a company discourages investors from financing the transition in these cases, the insights provided by ITR metrics may encourage it.

Developing and implementing ITR, however, is paved with conceptual and methodological pitfalls, which start with the very nature of the climate change problem. Battiston et al. (2019) stress that because the occurrence of specific climate scenarios depends on the actions of investors, firms and policymakers, it follows that climate-related financial risks are largely endogenous. Furthermore, climate change and its socio-economic impact are characterised by deep uncertainty as they are subject to tipping points (Solomon et al., 2008) and tail risks. (Weitzman, 2009). Finally, temperatures do not quite follow a normal distribution and past observations have little to no predictive value – the non-linearity problem (Ackerman, 2017).

Nonetheless, the intricacies of co-modelling climate and social sciences have not discouraged innovation (see for instance the IAMC's MESSAGE GLOBIOM, 2020). We now count more than a dozen financial risk assessment metrics related to decarbonisation. Interestingly, empirical research suggests that these metrics suffer from the same problem of low commensurability observed in environmental, social and governance (ESG) ratings (see Bingler et al., 2020 and compare with Berg et al., 2019). Simply put, two different metrics often provide significantly different assessments of a single firm's climate-related risks.[2]

Building on Berg et al. (2019), Hughes et al. (2021) argue that ESG ratings tend to diverge because of differences in theorization (key sustainability issues selection), sources (where the underlying data comes from), analytics (how the data is processed – human analysts, artificial intelligence or a combination of both), and weighting (how the data is aggregated into scores). In the case of climate-related financial risk metrics, Bingler et al. (2020), find that heterogeneity in measurement is driven by heterogeneity in methodological approaches. Given the narrower scope of the issue (i.e. climate change versus the dozens of sub-issues covered by

[1] Any reference to a specific company or security does not constitute a recommendation to buy, sell, hold or directly invest in the company or securities. It should not be assumed that the recommendations made in the future will be profitable or will equal the performance of the securities discussed in this document.

[2] Specifically, these differences tend to be more pronounced for firms with average exposure to transition risks and are less pronounced for firms exposed to low or high transition risks.

ESG), it may seem surprising to see such divergence. However, closer scrutiny reveals a swath of complexity commensurate to the scientific complexity of climate change which is subject to processes best studied through the lens of half a dozen of social and natural sciences (i.e., physical geography, economics, politics, sociology, to name a few). However, complexity in itself is not a reason not to do something. Furthermore, the urgency of the climate change problem calls for initiative. In this unprecedented context, we argue that new tools that are approximately right (and strive for continuous improvement), are far more desirable than old ones that are precisely wrong, and do not improve.

Finally, it can be argued that low commensurability may not necessarily be a problem in a normative sense. Indeed, as we show in our empirical demonstration, different conclusions may be reached on the basis of different input assumptions, scenarios and decarbonisation benchmarks. Alternative perspectives may add relevant additional data points and disagreement can lead to healthy debates. From a financial perspective, these different perspectives may also reflect individual investors' unique convictions as regards to technologies, economic and policy outlooks, and the likely shape that the transition to a lower-carbon economy may take. Ultimately, differences in opinion on ESG or ITR metrics allow investors to “back their convictions with their capital” (Carney, 2015).

At any rate, ESG ratings are now mature and mainstream enough to have begun to receive particular regulatory attention aimed at better protecting investors as well as market integrity. In mid-December 2020, the French and Dutch financial market authorities have issued a position paper calling for the European Securities and Markets Authority (ESMA) to roll out a new regulation on ESG ratings (AMF, 2020).[3]

Albeit climate-related financial risk metrics still remain a more recent innovation, 2020 saw the publication of two major reviews of existing ITR metrics. *The Alignment Cookbook* was published in the first half of the year by the Institut Louis Bachelier. It assessed ten existing providers and offered a thorough review of the state of the art for ITR metrics. Later, in November 2020, the Portfolio Alignment Team (PAT) published a report as part of a consultation on ITR metrics from the Task Force for Climate Related Financial Disclosure (TCFD). This consultation has been followed by a more detailed, technical guidance on ITR metrics by the same team, which at the time of writing, is part of an open TCFD public consultation (PAT, 2021). Given the institutional weight and legitimacy carried by these institutions, in the next section we unpack the substance of these reports and draw out some of the key unresolved issues to lay the groundwork for our analysis in section 3. In this section, we offer a detailed discussion of three approaches to emissions accounting in ITR metrics construction, namely: i. the convergence approach, ii. the rate-of-reduction approach and iii. the fair share carbon budget approach, which is effectively a hybrid of the first two approaches. Here we diverge from Institut Louis Bachelier (2020) that treats the convergence and rate-of-reduction approaches as mutually exclusive and provide some clarifications about the benefits of the fair share carbon budget which, we contend, offers superior insights and can be calculated in a robust way (compare with PAT 2021) which we illustrate empirically in our case study.

2.2 Methodological choices

According to PAT (2020), the specific methodological and assumptive choices involved in the construction of ITR metrics can be divided into three steps, namely: (1) the translation of carbon budgets into benchmarks; (2) the assessment of company-level alignment against these benchmarks; and (3) the aggregation of these results to a portfolio level. From a theoretical perspective we argue that the first step is the most significant, since the next two are largely driven by the choice of benchmark and additional considerations around data quality, data availability, and the functional purpose of the metric.

Step 1: translating carbon budgets into benchmarks

ITR metrics operate by comparing a company's actual and projected emissions to benchmarks that allow for a direct or indirect comparison to global carbon budgets that, through the use of climate models, may be associated with different levels of global warming. Sector, industry, or company-specific benchmarks seek to define the degree of decarbonisation that individual companies and portfolios need to achieve to ensure alignment to these carbon budgets, using various allocation methods to determine the specific carbon budget attributable to the relevant sector, industry or company.

PAT (2020) and PAT (2021) describe the construction of these benchmarks as consisting of three key judgements, concerning the type of benchmark and its underlying scenarios, the source and granularity of those benchmarks, and finally the choice between an intensity or absolute-based approach.

As part of the first judgement, a key question concerns the approach taken to the integration of scenario-based assumptions into the benchmark. As benchmarks and the distributive choices around carbon budgets reflect underlying scenario-based assumptions around environmental, social, economic and technological conditions, this first judgement involves a choice between a single-scenario benchmark with a single set of well-defined assumptions, or an approach drawing on *multiple* scenarios, each with their own set of assumptions. The former approach allows one to assess the deviation of a company's emissions from a single benchmark more directly, whereas the

[3] Specifically, it aims at improving the transparency of ESG rating agencies with regards to their methodological choices and the source of their data, and calls for new requirements on the identification and management of conflict of interests.

latter approach requires the construction of a "warming function" through which one assesses a company's deviation against a selection of the various benchmarks. PAT (2021) recommends the use a single-scenario benchmark, noting that while the use of multiple scenarios reduces selection bias, the approach makes interpretation of the results and their sensitivity to individual assumptions more difficult to assess.

As part of the second judgment, the source and granularity of the benchmarks must be considered. The Institut Louis Bachelier (2020) identified two main sources for such benchmarks, comprising data from the International Energy Agency – in particular that derived from its Energy Technology Perspectives (ETP) – and data underlying the reports of the International Panel for Climate Change (IPCC). Since then, alternatives have emerged including the Climate Scenarios of the Network for Greening the Financial System (NGFS, 2020). Each of these sources provide a breakdown of global carbon budgets into sector and region-specific benchmarks, defining how quickly each would be expected to decarbonise. Owing to distinct views on the relative difficulty of abating a given sector, the allocation of the carbon budget across each sector and the shape of these benchmarks may differ between sources, requiring investors to choose the source that best reflects their investment convictions. A further limitation of these sources is their general lack of granularity, as they typically focus on a limited number of high-level sectors that may fail to capture industry-level differences in exposure to sources of emissions and opportunities for abatement. This lack of granularity implicitly penalizes harder-to-abate industries and can lead to a skewed assessment of companies' climate alignment and, consequently, skewed investment signals. PAT (2021) for this reason recommends the development of more granular benchmarks that capture these nuances. We illustrate how to approach this in our case study in section four.

As part of the third judgment, but closely related to the choice of type of benchmark, perhaps the most critical consideration in the construction of ITR metrics is the choice between so-called convergence approaches, typically associated with metrics based on physical or economic carbon intensity, and rate-of-reduction approaches, that can apply either to such intensity-based emissions, or to absolute emission trends. While Institut Bachelier (2020) distinguishes between convergence and rate-of-reduction (or contraction) approaches and imply that these approaches are mutually exclusive, PAT (2021) suggests a third *fair share carbon budget* approach which is effectively a hybrid approach but stresses limitations related to additional assumptive choices and complexity. We dedicate section three to discuss this in depth and show how the method can offer superior insights. We then illustrate how to implement it in section four.

Step 2: Assessing a company's alignment with its benchmark

Once the benchmark is defined, PAT (2020 and 2021) outlines five further judgements related to the company-specific analysis, providing high-level recommendations for each. Key judgments four and five involve the consideration of what scope of emissions to include, and the choice of third-party versus self-reported data. Emission scopes are defined through the GHG Accounting Protocol and are distinguished between scope 1 direct emissions, scope 2 emissions linked to external supplies of power, heat, cooling and steam, and scope 3 emissions covering the remainder of wider upstream and downstream lifecycle emissions. Although scope 3 emissions may often be among the most significant and financially material to a company, few companies presently report on these emissions. This, combined with concerns over data quality and double-counting, has led to some investors being hesitant to include these emissions in their climate analysis. We have argued elsewhere that these concerns are largely misplaced and arise from a misunderstanding both to the nature of scope 3 emissions data, and its implications. In particular, we contend that a correct understanding of how scope 3 emissions data are calculated supports the use of third-party modelled figures, and that delaying the inclusion of these emissions would lead to undesirable outcomes from an investment perspective. In section four, we demonstrate how benchmarks for each of these emission scopes may be constructed, and use our case study to demonstrate how the choice of what emission scopes to include can be material to the final analysis. Although we do not discuss the use of third-party observation using remote sensing and geographic information systems (GIS) we note such methods are gaining traction (see for instance IPE, 2019).

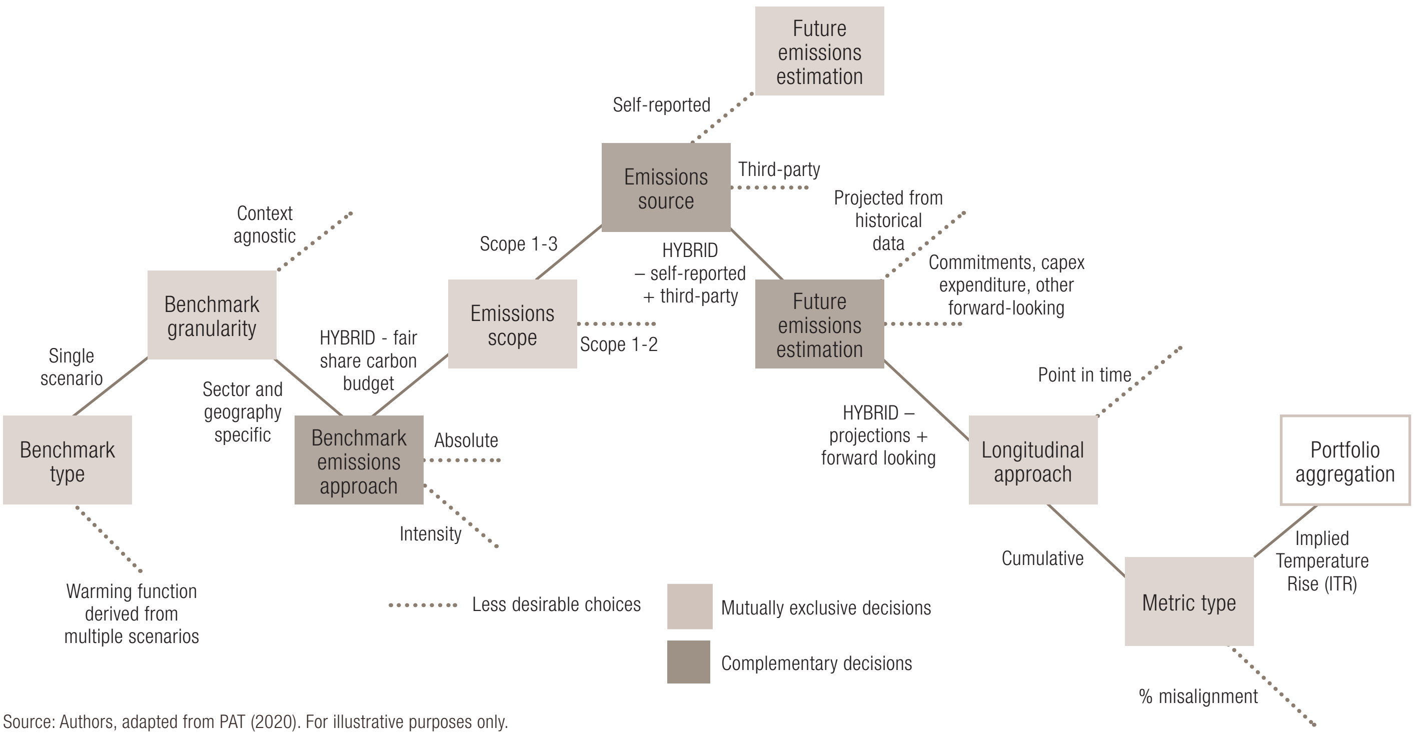
The sixth judgement outlined by PAT concerns the projection of a company's future emissions. Externally audited and verified science based targets (see for instance SBTi, 2019 and 2020) "with regular progress reports and clear, costed plan of action" are a gold standard (Institut Louis Bachelier et al., 2020). Although the Science Based Targets (SBT) initiative comes close to it (see for instance Faria and Labutong 2019), they remain controversial and debated in the literature – Trexler and Schendler (2015) go insofar as to call SBTs "a costly distraction" and "green fluff". Finally, while targets coverage is rapidly expanding (SBTi, 2019), additional estimation methods are required both in recognition of the fact that not all targets will be met, and to inform the assessment of companies that have not yet set SBT or other targets. PAT (2021) also recognizes that a metric based solely on announced targets would incentivize good target-setting, but not necessarily reward actual emission reductions and for this reason recommends a hybrid approach, considering both recent emission performance as well as company commitments. In section four, we explore how these recommendations can be implemented in an empirical context.

Key judgements seven and eight concern the calculation of the final metric. Once one has established an emissions benchmark and the ability to assess a company's future positioning against that benchmark, the metric may be defined either on a cumulative or point-in-time basis, and then in the form of a percentage overshoot or undershoot, or using a temperature figure (ITR). With respect to the former choice, the use of cumulative emissions in evaluating the alignment of a company's future emissions is clearly more desirable (PAT, 2021). This is because global warming results from cumulative emissions. Consequently, alignment assessments need to reflect whether total emissions fall within a cumulative carbon budget. This also avoids greenwashing, that might result from company targets that promise delayed radical reductions of emissions, but have inadequate interim targets. With respect to how the final metric is expressed, we argue in favor of ITR metrics that express alignment as the level of global warming that would result if the company's level of ambition were to be representative of that of the economy as a whole. The advantage of this approach, over a more generic over/undershoot figure, is that the metric is intuitively more understandable and easier to relate to policy goals by a large set of users, from the general public all the way to climate scientists.

Step 3: aggregating company-level metric into portfolio-level metric

Where the objective of an investor is to consider the alignment of a portfolio, a final step is required to aggregate investment-level results into a single portfolio-level measure. In this step, the most precise calculation (referred to by PAT (2021) as the aggregated budget approach) involves the aggregation of individual benchmarks that define the carbon budget for each company along with the projected emissions for each, resulting in an aggregated portfolio benchmark and aggregated portfolio emissions, from which a temperature score can be calculated as for an individual company. Here, portfolio emissions can be calculated by aggregating the owned emissions – defined as total emissions multiplied by the ratio of investment value to enterprise value – of each portfolio holdings. This aggregated budget approach ensures that the warming metric of a portfolio "is a direct function of the cumulative overshoot or undershoot of its unique proportion of the global carbon budget" and is described by PAT (2021) as the most scientifically robust approach. Simpler and less precise approaches involve the calculation of a weighted-average of individual company-level scores, using either a simple weighting by portfolio weight or a weighting by financed emissions, whereby an investor owning 10% of a company's enterprise value would also be assumed to be allocated 10% of its emissions. Both approaches result in a single score and can serve different purposes. One should note however that only the first approach gives a fair reflection of the portfolio's actual contribution to global warming by giving greater weight to the alignment of higher-emitting companies than low-emitting ones – these considerations are comprehensively described by PAT (2020 and 2021) and Institut Louis Bachelier (2020). Figure 1 below summarizes each key judgements and highlights what we argue to be the more robust and investment decision-making relevant path to construct an ITR.

FIG 1: DESIGNING AN IMPLIED TEMPERATURE RISE (ITR) METRIC – DECISION TREE



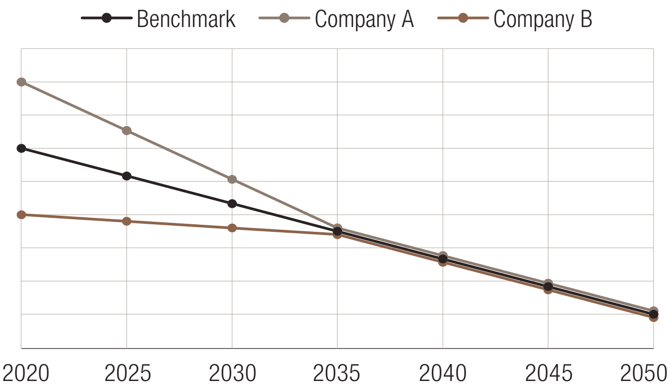
Source: Authors, adapted from PAT (2020). For illustrative purposes only.

3. Convergence, rate-of-reduction and fair share carbon budget approaches

Convergence (intensity-based) approach

Both the Institut Louis Bachelier (2020) and PAT (2021) distinguish two key approaches to ITR metrics, based on some of the common approaches adopted by metrics in the market today. The first approach described by both sources is the so-called *convergence* approach. Here, the benchmark is defined in terms of *carbon intensity* (the amount of emissions per unit of output, where that unit may be defined in either physical or economic terms). To ensure alignment with lower levels of global warming, industry intensity needs to fall, with industries on *average* needing to reach net zero intensity around 2050 to be aligned with 1.5C global warming. This approach is called the convergence approach as companies with worse-than-average emissions intensity will need to decrease their emissions more rapidly than the improvement in intensity inherent in the benchmark, while companies with better-than-average emissions may further improve their intensity but do so at a slower rate. In Figure 2 below, the two companies are expected to reduce their emissions at different rates. On a *cumulative* basis company B is still better aligned than company A, although both reach the same end point by the end of the period.

FIG 2: THE CONVERGENCE (INTENSITY-BASED) APPROACH



Source: LOIM Research. For illustrative purposes only.

The convergence approach has been described as a comparatively simple approach, which has the additional benefit of recognising the *baseline* intensity of a company compared to its industry, rewarding companies that may have already achieved significant decarbonisation, and penalizing those that lag behind (PAT, 2021). On the other hand, the intensity-based approach suffers from a number of disadvantages, some of which we believe remain underappreciated.

Firstly, as recognized by PAT (2021), the fundamental climate objective should not be for a company to reduce its emissions intensity, but rather for it to reduce its absolute emissions, for it is absolute emissions that define cumulative emissions and impact on global warming. Changes in intensity provides only an indirect proxy for changes in absolute emissions, and depend on assumptions regarding projected changes in an industry's *volume* of output. Where and when industry growth exceeds or underperforms expectations, intensity-based benchmarks will no longer be aligned with global carbon budgets, and will need re-adjustment. The PAT report recognizes this and, for this reason, suggests that benchmarks be updated regularly, although it concedes that such revisions may involve a multi-year lag and therefore cannot fully eliminate the discrepancy. We argue that in the context of the growing focus on net zero targets, this multi-year lag is likely to prove too problematic for investors, as achieving interim targets (typically involving a 50% reduction in emissions by 2030, compared to 2019) requires rapid and immediate decarbonisation. Lagged revisions of benchmarks would alert investors belatedly that a company may have been more poorly aligned than originally believed, so that a multi-year lag would raise the risk of targets being missed.

A second concern relates to the specific difficulties faced by physical intensity and economic intensity metrics, respectively. Measures of economic intensity (emissions per unit of revenue) are straightforward to calculate, but are highly exposed to price volatility as well as inflation. While correcting for inflation is straightforward, adjusting for price volatility is not, as price trends for major product classes (aside from some key commodities) are not readily or reliably available, and may not correspond well to trends in prices for the specific product produced by a company. PAT (2021) partially addresses this by recommending the use of physical intensity metrics (emissions per ton of steel, per cars sold, etc.) for selected other sectors, but the complexity of constructing physical intensity metrics means this is not a viable solution for the majority of other sectors. Moreover, physical intensity metric are more difficult to apply to diversified companies (Institut Louis Bachelier, 2020).

Thirdly, and potentially of greatest concern, intensity metrics are better suited to assess changes in *efficiency* than to assessing the more comprehensive range of strategies that are likely to be required as part of a transition to a net zero economy. The PAT (2021) report recognizes that intensity-based metrics are poorly adapted to tracking the effect of changes in the output *volume* of oil and gas companies, where it states that "standard emissions metrics will not properly reflect the way these firms decarbonize" because "one of the main ways these sectors will decarbonize is by reducing output of hard-to-decarbonize products. If progress is measured solely in terms of emissions intensity, these companies will not receive credit for doing this". This same weakness affects every other sector of the economy. A steel company diversifying into timber or green aluminium or transitioning to a service-based enterprise offering recycling, repair and engineering services and gradually phasing out the steel segment out of its business model would get little credit for doing so. This is because the intensity of its steel production would remain largely unaffected.

This further puts intensity-based metrics at odds with the parallel need for a transition to a more circular economy. A growing body of work has highlighted that full decarbonisation of the economy cannot be achieved merely by improvements in energy efficiency. For instance, in key sectors such as steel, plastic, aluminium, cement and food, as much as 40% of the reduction in emissions may be achieved not through efficiency gains, but by extending the life of assets, products and components, and designing out waste (Ellen MacArthur Foundation, 2019). Such circular business models have been argued to provide a potential solution to the "partial decarbonisation" that a focus on more traditional energy efficiency gains might otherwise result in (Oxford Institute for Energy Studies, 2021). Studies that have adopted a bottom-up approach to the definition of industry benchmarks, including one that we draw on to support our empirical analysis in section 4, have similarly found that the adoption of circular economy principles will play a key role in the transition to net zero, and that companies that have done so have achieved economic outperformance (European Climate, 2018).

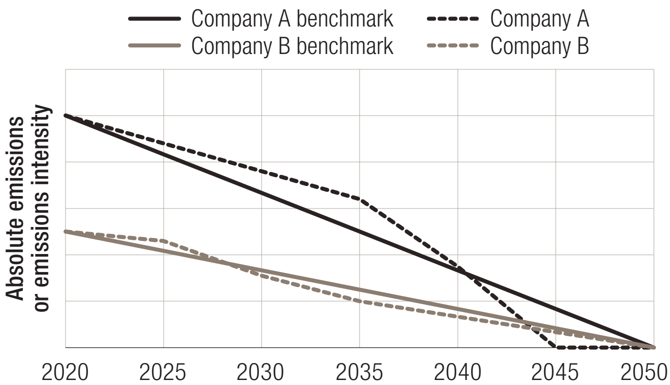
Rate-of-reduction (or contraction) approach

This brings us to focusing not on the carbon intensity of a company, but rather on the evolution of its absolute emissions. Tracking changes in absolute emissions has a number of advantages including (a) its more direct linkage to carbon budgets and global warming; (b) the more immediate availability to assess changes in company alignment given the reduced need to correct benchmarks for unexpected changes in industry growth trends; (c) its lack of exposure to price volatility; (d) the fact that they are able to assess the full spectrum of decarbonisation strategies that may impact a company's emissions, including strategies linked to the circular economy (such as those linked to dematerialization and a transition to a sharing or service-based economy); and (e) the relative ease to aggregate absolute metrics using the aggregated budget approach described in section which is deemed to be the most scientifically robust aggregation approach (PAT, 2021).

These advantages provide a strong case for the use of absolute-based metrics and might in principle make them the preferred metric of choice. Their integration, however, requires at least two innovations to ensure the adoption of these metrics does not introduce new, equally undesirable anomalies. We describe these innovations hereafter and further demonstrate them empirically in section 4.

To understand the need for these adjustments, one must first understand the manner in which absolute-based metrics have typically been constructed.[4] The contraction approach recognizes that meeting global carbon budgets requires a reduction in global carbon emissions, that specific sources of sectoral benchmarks may also translate into sectoral and industry-specific emission benchmarks. The approach may be applied to intensity metrics, but when used to assess changes in absolute emissions, benchmarks are defined using a specific rate of reduction applied to a company's baseline level of emissions to account for the fact that companies of a different size will inevitably have different levels of emissions.

FIG 3: THE RATE OF REDUCTION APPROACH



Source: LOIM Research. For illustrative purposes only.

Whereas the approach above is straightforward to implement, these metrics – in the form described above – are exposed to two specific biases. As argued by the Institut Louis Bachelier (2020), "a pure contraction method tends to favor companies that have not yet started to decarbonize, as each company needs to decarbonize at the same rate regardless of their past and actual performance." Compared to the convergence approach, where companies with a lower carbon-intensity can reach alignment through a lower rate of decarbonisation, in the absence of a relevant safeguard, the pure contraction (or rate of reduction) method may thus penalise better-performing companies that have already succeeded in reducing their carbon intensity (PAT, 2021).

A second concern observed by PAT (2021) is that the use of absolute emissions "disincentivizes the pursuit of inorganic growth (e.g., a company's absolute emissions might go up if it increases its market share, even if it is reducing emissions across all the assets it owns"). Intensity-based approaches are agnostic to a

4 Absolute-based metrics have been variously referred to as a rate-of-reduction approach (PAT, 2021) or a contraction approach (Institut Louis Bachelier, 2021).

company's size--for instance, a company displacing other market participants or expanding through mergers or acquisitions would not affect the analysis. Provided these changes in size do not affect the industry's *overall* growth trend (a necessary though dubious assumption for intensity-based metrics), it would be undesirable to penalize fast-growing, successful companies for such shifts in market share as their gain in revenues and emissions would be offset by losses among their competitors. From an investment perspective, such a bias, if uncorrected for, would clearly be undesirable.

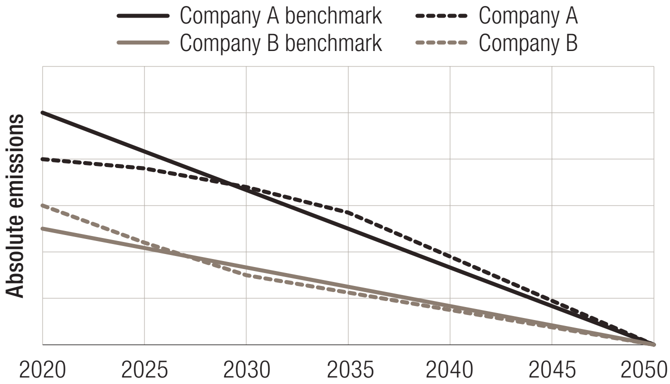
Fair share carbon budget approach

In this section, then, we outline a third approach that recognises that the two approaches described above are not mutually exclusive, but may be combined for a more comprehensive assessment. Whereas the use of absolute emissions has a number of fundamental advantages, a pure rate-of-reduction approach does not allow to recognise that a company might have already decarbonised (or may be lagging behind), as the intensity-based convergence approach allows for.

The fair share carbon budget approach illustrated below provides a remedy, and may be seen as the integration of a convergence approach into the rate-of-reduction approach. It is essentially a hybrid version of the two. This approach still tracks reductions in absolute emissions as in the pure rate-of-reduction approach. In this approach, the benchmark defines the rate of reduction and carbon budget (the area under the curve) that a typical company of the same size of the company in question would need to achieve. The innovation in this approach, however, is to recognise that depending on how the company's initial carbon intensity compares to that of its industry, the company may start below this benchmark (as in the case of Company A below, indicative of a company with better-than-average emissions), or above the benchmark (as in the case of Company B below, indicative of a company with worse-than-average emissions).

In Figure 4 below, for Company A to be aligned with the carbon budget implied by the benchmark, it can afford to decarbonise at a slightly slower rate, recognising it is already emitting fewer emissions than average. Company B, on the other hand, is exhausting its carbon budget at an elevated rate and will need to decarbonise at a faster rate and, to compensate for its higher emissions in the beginning of the period, will need to outperform the benchmark later on. Conversely, if rather than compensating for their respective over- and underperformance (as in the example below), both A and B decarbonised at the same rate (say, at the rate of the benchmark), company A's cumulative emissions would be below those of the benchmark, resulting in a lower temperature score than that associated with the benchmark, whereas company B's would be higher.

FIG 4: THE FAIR SHARE CARBON BUDGET APPROACH



Source: LOIM Research. For illustrative purposes only.

The fair share carbon budget approach as described above is comparatively simple to implement, as it only requires the application of an intensity-based comparison to the rate-of-reduction approach. As this is routinely done by convergence-based approaches, this adjustment adds little additional complexity. However, it maintains the advantages of absolute emissions approaches. Firstly, it ensures a direct correspondence to global carbon budgets. Secondly and relatedly, it does not require adjustments to the benchmark if the growth of specific industries under- or outperform a priori expectations. Thirdly, although it uses an intensity-based comparison for the initial positioning of the company against its benchmark, it tracks the evolution in absolute emissions rather than carbon intensity, insulating the metric from exposure to price volatility that intensity-based metrics are exposed to (unless they use physical intensity, but the problems associated with this have been described previously). Fourthly, the metric is able to track improvements in emissions linked both to efficiency gains as well as reductions in output of high-carbon products, through the adoption of circular strategies, such as dematerialization. Fifthly and finally, the approach naturally lends itself to the aggregated budget approach described in section 2 (stack 3), that we developed to support the fair share carbon budget approach.

This schematic representation and interpretation of the fair share carbon budget approach provides additional insights and clarifications to the overview provided by PAT (2021). Other, earlier approaches that are similar in intent to the approach described here have also been reviewed by Institut Louis Bachelier (2020), which discusses alternatives to the "pure" contraction approach that seek to calculate a custom carbon budget and custom rate of contraction at a micro level, apportioning by share of sales or production, least-cost approaches, historical responsibility, or asset-by-asset analyses. Several of these, however, are difficult to implement in the face of data constraints (the asset-by-asset approach), are more relevant from a liability than from an investment perspective (historical responsibility), or still fail to reward better-performing players (the remaining two). In contrast, the approach described above is conceptually simpler, involves only the combination of the convergence and rate-of-reduction approaches that are already well understood, and faces no greater data requirements than these two approaches.

Avoiding penalization for inorganic growth (changes in market share)

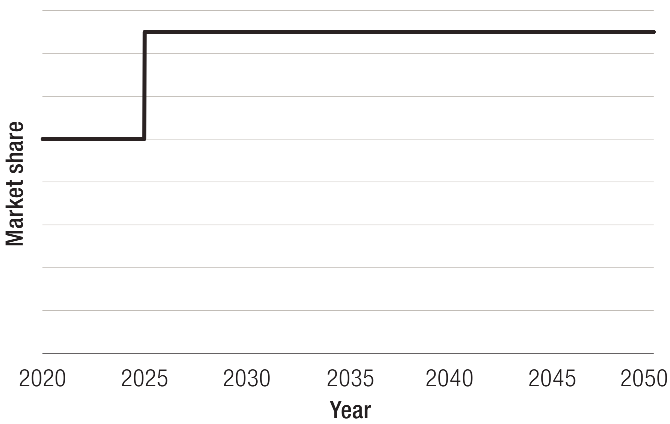
The approach described above provides a solution for the first concern regarding the use of absolute emissions (i.e. that a pure rate-of-contraction approach would effectively penalize (or fail to reward) companies that have already achieved a degree of decarbonisation). This still leaves the second concern identified by PAT (2021), however, in that absolute emissions of a company may increase through "inorganic growth", i.e. changes in the company's market share either through displacement of its competitors, mergers, or acquisitions. This is a legitimate concern, as it would be desirable for a more carbon-efficient company to displace its higher-carbon competitors, but rapid growth in volume could lead to an increase in absolute emissions, even if the company has far superior carbon efficiency. Similarly, if a company acquires a smaller entity, its absolute emissions would increase, even though no change in emissions occurred in the economy as a whole. In the absence of an appropriate adjustment, this would worsen the company's assessment in an absolute-based metric.

This is a material problem with a straightforward solution. In Figure 5 below, we show an illustrative case reflective of an acquisition of a smaller entity by company A. As seen on the figure on the left, the acquisition increases the market share of Company A. In the figure on the right, we also show the illustrative trend in Company A's emissions. Its reported emissions – unadjusted for these changes in market share – will accordingly show a similar spike in its emissions, as its reported emissions will now include both its original emissions and those of the entity it has acquired. Absent a correction, this spike would push the company's emissions well in excess of its benchmark, and prevent it from meeting its carbon budget, even if all assets owned by the company are still aligned with a rapid decarbonisation.

The solution we propose involves the adjustment of Company A's reported emissions by integrating the trend in market share into the calculation. Specifically, if from one year to the next the company's market share doubles, the adjustment would reduce the company's raw emissions by half, to give a market-neutral trend that reflects *the rate of emissions attributable to the company at its baseline market share.* We argue that it is this latter trend that provides a more meaningful comparison to the company's benchmark.

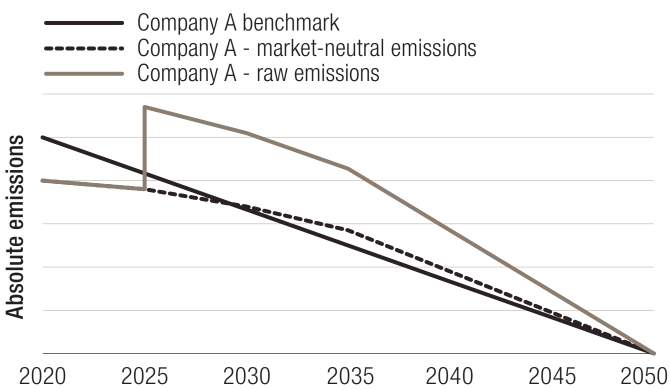
The adjustment described here has a number of attractive features. Firstly, it depends only on revenue data, which is generally widely available for any investee company and can be disaggregated at a sectoral and industry level. Secondly, it does not depend on a calculation of the absolute market share of any company (which would require a complete dataset), but only on the *change* in the company's market share (which can more easily be calculated by comparing the company's growth trends relative to the rest of the industry). Thirdly, although the adjustment for changes in market share adds an additional processing step to the ITR assessment, it is generally easier than adjusting for changes in prices that would be required to address the exposure of economic intensity metrics for price volatility as explained earlier. Fourthly, as we discuss in section four, although the resulting calculation may be an approximation, in the comparison of the company's trend in emissions to that of its benchmark (which may be required, for instance, to project its future emissions), basing such an analysis on *average* or *median* rates of change may further reduce anomalies linked to changes in inorganic growth.

FIG 5A: TREND IN MARKET SHARE



Source: LOIM Research. For illustrative purposes only.

FIG 5B: MARKET SHARE ADJUSTMENT



Source: LOIM Research. For illustrative purposes only.

In sum, then, we argue that the fair share carbon budget approach described above provides an alternative to pure convergence or rate-of-reduction approaches. The fair share carbon budget approach integrates the strengths of each of these methods, taking into consideration a company's starting point intensity (a benefit of the convergence approach) while retaining the closer link to carbon budgets and the more comprehensive view of decarbonisation offered by the analysis of absolute emissions (as rate-of-reduction approaches allow). The initial baseline adjustment inherent in this approach and the inclusion of the additional market share adjustment described here avoids the penalization of well-performing or successful companies, and addresses the two main weaknesses identified by PAT (2021). In the next section, we provide an empirical demonstration of this combined approach.

4. Empirics

4.1 A general methodology for implied temperature rise metrics calculation[5]

For our empirical demonstration of the approach discussed in section 3, and the analysis of the implications of the various metric construction steps outlined in section 2, we select a case study from the European steel industry for illustration. We select the steel industry because it is a major contributor to total emissions – it accounts for over 4% of European GHG emissions (European Climate Foundation, 2018) – and is recognized as a priority sector within the climate transition (see for instance TEG, 2020). Steel epitomizes the concept of CVI. It is a hard to abate sector where investors can find climate laggards and leaders that are most material to investment returns. Within the steel industry, we select ArcelorMittal – the world's largest producer of steel – as our main case study. ArcelorMittal is a multinational steel manufacturing corporation headquartered in Luxembourg City. It was formed in 2006 from the takeover and merger of Arcelor by Indian-owned Mittal Steel. In 2020, ArcelorMittal generated USD 53.3 billion of revenues, of which 42% were generated in Europe (data sourced from Trucost).

In what follows we describe a step-by-step process to assess the alignment of ArcelorMittal with the European Union decarbonization benchmark. We structure our empirical analysis chronologically following key judgements one to eight. Since we use a single case study approach, key judgement nine (portfolio aggregation) is beyond the scope of this paper. A full version of this model was developed by the authors, and provides coverage of 163 industries across six world-regions, with separate and aggregated coverage of scope 1, 2, 3 upstream and 3 downstream emissions. In the below, we rely on a number of simplifications that allows us to focus on the core features of the approach but describe the various additional considerations involved in the construction of a full model. Before discussing our results, we follow the same structure to describe our methodology and data sources.

Key judgement 1-3: construction of benchmarks. The first step in the development of our indicator is the construction of an appropriate set of benchmarks for selected industries. At present, the two main sources for such benchmarks are sectoral benchmarks developed by the IEA and the IIASA/IPCC (Institut Louis Bachelier et al., 2020). Although the benchmarks derived from the IEA provide a convenient starting point, they do not permit the selection of alternative input assumptions. As such, they hamper the ability to undertake sensitivity analysis, or to adjust baseline outcomes to the internal convictions of an investor. The IPCC benchmarks, in contrast, offer a less granular sectoral breakdown and require further development to be used in an ITR metric.

We introduce a third avenue for the development of these metrics, drawing on an interactive model developed as part of the Carbon Transparency Initiative. This model, focused on the EU, explores the individual demand-side and technological levers that may contribute to the decarbonisation of key sectors within the EU. Overall, the CTI 2050 Roadmap Tool details the possible range and relevance of over 150 individual levers. For instance, with respect to airline travel, its business as usual model assumes an 84% increase in air transport demand by 2050, and no transition to electrified short-haul flights, bio-fuels or e-fuels. In contrast, under best-case assumptions, the model assumes a possible 23% drop in air transport demand, 10% short-haul air transport electrification, and a complete transition in remaining fuel demand to bio-fuels and e-fuels by 2050.

The benefit of transparent, modifiable, bottom-up approaches such as that offered by the CTI 2050 Roadmap Tool is that it allows for the construction of benchmarks with greater sectoral granularity, highlighted as a priority by PAT (2021). By identifying individual technology- and demand-side levers and mapping their applicability to individual industries, it is then possible to identify the individual sectoral segments that are comparatively easier- or harder-to-abate

[5] The case studies provided in this document are for illustrative purposes only and do not purport to be recommendation of an investment in, or a comprehensive statement of all of the factors or considerations which may be relevant to an investment in, the referenced securities. The case studies have been selected to illustrate the investment process undertaken by the Manager in respect of a certain type of investment, but may not be representative of the Fund's past or future portfolio of investments as a whole and it should be understood that the case studies of themselves will not be sufficient to give a clear and balanced view of the investment process undertaken by the Manager or of the composition of the investment portfolio of the Fund now or in the future.

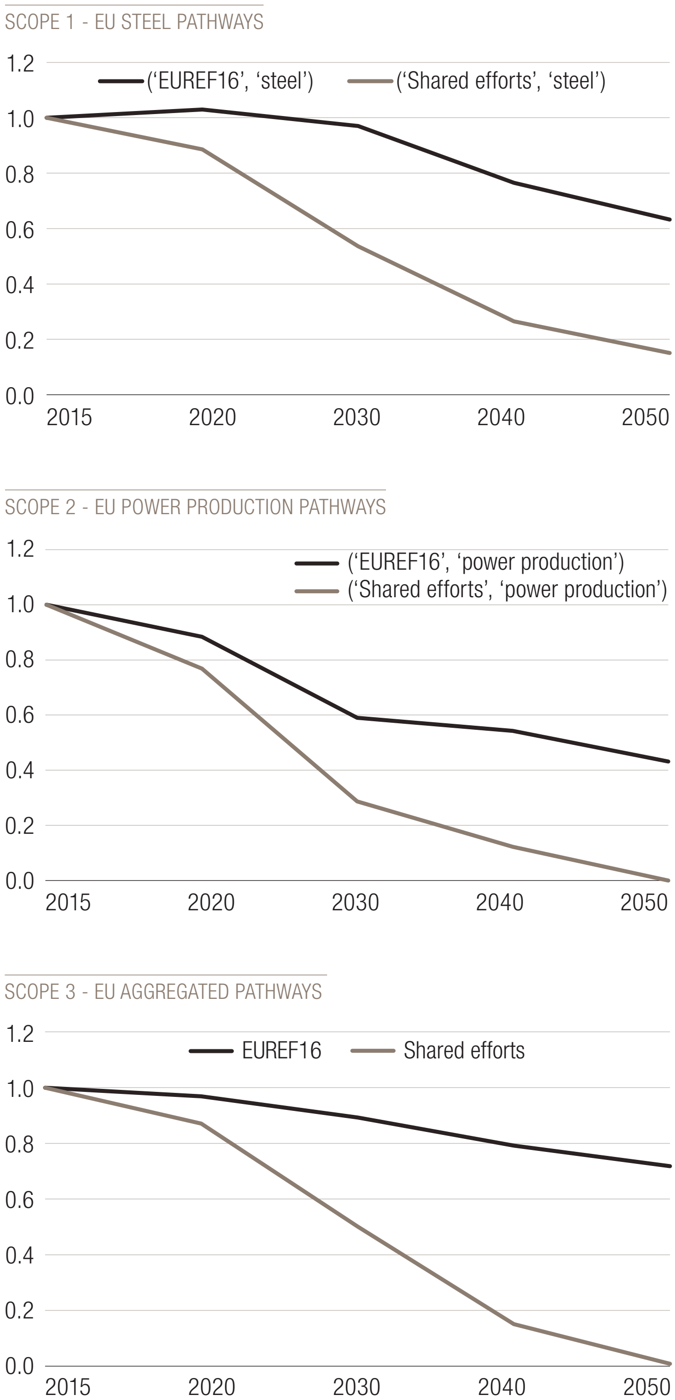
and breakdown sectoral benchmarks (and carbon budgets) into smaller industry components for superior granularity. This more detailed breakdown is beyond the scope of our analysis since the steel sector is already specifically defined by the CTI 2050 Roadmap Tool (and other sources, such as the IEA). Whereas tools such as the CTI 2050 Roadmap Tool can offer a useful starting point to investors, investment decision-makers may wish to consider whether CTI's assumptions match their investment convictions, and ensure the replicability of this approach across other regions.

The Roadmap Tool provides a business-as-usual analysis based on the widely used European Commission's EU-Ref 16 scenario, which assumes GHG emissions will significantly fall short of the net zero objective as they will reach 3,074 $MtCO_2$ by 2050, a 43% reduction relative to a 1990 baseline. The Roadmap Tool also provides three net zero scenarios, namely "Demand-led", "Technology-led" and "Shared Effort", each outlining various combinations of levers that would suffice to bring about a net zero economy within the EU by 2050. The shared-efforts scenario assumes that net zero GHG emissions will be reached in 2050 (a 100% GHG emissions reduction relative to 1990 baseline which accounted for 5,411 $MtCO_2$) through a combination of demand-led and technology-driven levers. Different investors may take divergent views as to the most likely transition path to net zero. Choosing between these three different scenarios or a custom set of assumptions should allow an investor to work with a scenario that best matches their investment convictions. For the purpose of this analysis, we adopt the Shared Effort scenario for our net zero benchmarks.

In the fair share carbon budget approach that we outline in section 3, benchmarks are defined in terms of the necessary reduction in absolute emissions. For scope 1 emissions, we select two benchmarks (one for business as usual and one for Shared Efforts) specific to the EU Steel sector to help us assess the rate at which the steel industry should decarbonize for the EU economy to reach its overall 43% emissions reduction under business as usual and a 100% emissions reduction under shared-efforts by 2050. For scope 2 and 3 emissions, we derive a similar series of benchmarks.[6]

For scope 2 emissions, we select the EU's two power production benchmarks (one for business as usual and one for Shared Efforts). This is an over-simplification since we assume the power benchmark for steel is similar to the benchmark for the power industry for the economy overall. A more accurate approach would require building custom power benchmarks for each industry taking into account each industry's unique energy mix, exposure to electrification and energy efficiency levers, and relative growth trends. For the purpose of this case study, however, we assume that the overall power benchmark is approximately representative of the specific one for steel.

FIG 6: BUSINESS AS USUAL (EU-REF 16) AND SHARED EFFORTS BENCHMARKS FOR SCOPE 1, 2 AND 3 EMISSIONS OF AN EU STEEL COMPANY



Source: CTI 2050 Roadmap Tool. For illustrative purposes only.

6 The authors have developed more advanced benchmarks, using the more sophisticated methodologies, covering scope 1, 2, 3 (upstream and downstream) emissions, across 163 industries and multiple regions. The authors reserve the more detailed description of the construction of these benchmarks, using the general approach outlined here, for a future research paper. For the purpose of the present paper, focused on an empirical demonstration of the fair share carbon budget approach, we rely on the simplified benchmarks outlined here.

For scope 3 emissions, we use the aggregated EU benchmark. This, too, is an oversimplification since we do not distinguish between upstream and downstream scope 3 emissions and do not draw specific benchmarks to reflect the specific supply chain structure and lifecycle of European steel. A more sophisticated approach would be to use input-output models to derive a more precise estimate of scope 3 upstream emissions. For scope 3 downstream, one would have to draw individual benchmarks for the emissions incurring during processing, distribution and transport (for which transport and other sectoral benchmarks can be used) and a custom mapping for benchmarks linked to emissions generated during product use. These more advanced approaches would result in distinct scope 2 and 3 benchmarks for each individual industry (in the same way that scope 1 benchmarks would be distinct), recognizing that each industry has a unique exposure to various upstream and downstream economic sectors. Since steel is a product with diversified uses throughout the economy, however, we use the aggregate benchmark as a simplified but reasonable proxy for illustration purposes.

Even with these simplifications, Figure 6 shows notable difference in the shape of each of the benchmarks. While power (reflected here in the benchmark for scope 2 emissions) is generally considered to be easy to abate and therefore exhibits a steep decarbonization curve, the steel sector (reflected here in the benchmark for scope 1 emissions) is relatively harder to abate and has a much shallower shape. This demonstrates the need for granular approaches, not only on a sectoral but on a more detailed industry level, for each of the different emission scopes, and for each region.[7]

A further implication of the above is that in the application of these benchmarks to a specific company, a custom company benchmark would need to be created in order to reflect the specific mixture of activities that a company may be involved in. Given the different shape of the benchmarks of individual sectors and industries, for instance, a company involved in both copper and steel would face a different benchmark than one involved solely in steel. Similarly, where regional variations of benchmarks are used, a company involved in steel production in different regions of the world would face a benchmark that would be a combination of the benchmarks of individual regions. Once individual benchmarks for each industry and region have been created through the process described above, a company-specific benchmark may be created by estimating the relative contribution of each activity to the company's overall emissions, and creating a weighted-average benchmark. The construction of such company-specific benchmarks is an essential additional step that avoids the introduction of biases when diversified companies are considered. Although the PAT (2021) report describes the creation of such company-specific benchmarks only when referencing metrics using absolute emissions, this step would be required of any metric that seeks to appropriately distinguish pure players from diversified ones.

For the purpose of this example, we assume the European benchmarks for steel created above to be roughly representative of ArcelorMittal's overall benchmark, although this is clearly a further simplification given the company's regionally-diversified production base.

Key judgement 4 and 5: Scopes of emissions and data sources: We use data on historical emissions for ArcelorMittal from two sources. For scope 1 and 2 emissions, we rely on company disclosures made to the Carbon Disclosure Project. For scope 3 emissions, we rely on estimates from Trucost, a third-party data provider. For scope 3 upstream emissions, Trucost uses a single input-output model to estimate company upstream emissions, which helps ensure greater consistency than using company-estimated models, and ensures consistency in the categories included and in methodologies used over time. For scope 3 downstream emissions, not reported by the company, Trucost provides industry models to estimate downstream emissions linked to, inter alia, processing, distribution, use and waste. Owing to differences in estimation procedures and data sources of individual data providers, a commercial version of the model described here would typically need to rely on multiple sources of data and verification, but for the case study shown here, the sources above suffice to illustrate our approach.

Table 1 below highlights the materiality of the decision whether or not to include scope 3 emissions in the analysis. Not only are scope 3 emissions estimated to be significant (amounting to an average of 42 Mt CO_2e per year over the years 2015-2019), but inclusion of these emissions also reveals meaningfully different trends in emissions. Whereas the company's scope 1 and 2 emissions have fallen over time, the company's scope 3 emissions are estimated to have continued to rise, resulting in a flatter trend in overall emissions. The discrepancy in trends between scope 1 and 2 emissions on the one hand, and scope 3 emissions on the other, is typical across many companies and industries, as many companies continue to primarily target the reduction of their own emissions and are still lagging behind in ensuring reductions across their wider supply chain (Farsan et al., 2018).

[7] In the global version of our model, we use assumptions from IIASA, additional literature and expert input to adjust assumptions from the CTI 2050 Roadmap Tool to reflect regional differences in underlying trend, including as regards to demographic trends, economic growth, demand-side pressures and energy mixes.

TABLE 1: REPORTED AND ESTIMATED EMISSIONS FOR ARCELORMITTAL, IN MT CO_2E

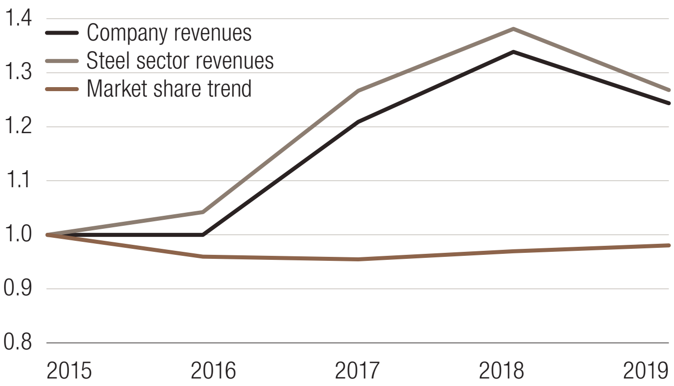
	2015	2016	2017	2018	2019	2015-2019 (% CHANGE)	2015-2019 (MEDIAN CHANGE)
Scope 1	176	176	179	174	170	-3.5%	-1.2%
Scope 2	16	14	15	14	13	-21.5%	-8.2%
Scope 3	44	37	36	46	48	8.3%	1.5%
Scope 1+2	192	190	194	188	182	-5.0%	-2.0%
Scope 1+2+3	236	226	230	234	230	-2.5%	0.0%

TABLE 2: ESTIMATED, MARKET-NEUTRAL TREND EMISSIONS FOR ARCELORMITTAL, IN MT CO_2E

	2015	2016	2017	2018	2019	2015-2019 (% CHANGE)	2015-2019 (MEDIAN CHANGE)
Scope 1	176	183	187	179	173	-1.5%	-0.5%
Scope 2	16	15	16	15	13	-20.0%	-7.0%
Scope 3	44	38	38	47	49	10.5%	1.2%
Scope 1+2	192	198	203	194	186	-3.1%	-0.8%
Scope 1+2+3	236	236	241	241	235	-0.6%	0.1%

To appropriately use absolute emissions in ITR metrics one requires a further adjustment on the basis of changes in a company's market share. As described in section 3, this is an essential adjustment, to account for mergers and acquisitions, and to avoid penalising fast-growing companies that are gaining market shares from their competitors, with increases in their emissions thereby offset by decreases among their competitors. Vice versa, for a company losing market share, such an adjustment ensures that a decrease in emissions is the result of true reductions, and not merely of the company's faltering ability to keep up with the market. The analysis for ArcelorMittal is shown in the figure below, which shows that revenues for the company are estimated to have marginally lagged behind that of its wider industry, suggesting a slight fall in the company's market share.

FIG 7: TRENDS IN ARCELORMITTAL MARKET SHARE



Source: LOIM Research. For illustrative purposes only.

Although the adjustment may appear to be a minor one, it reveals that the decrease in emissions shown in Table 1 is, at least in part, the result of underperformance which would have been offset by increases in emissions elsewhere in the industry. We therefore calculate an adjusted, market-neutral emissions trend, dividing the figures in Table 1 by the estimate trend in the company's market share, shown in Figure 7, which we argue provides a better basis for the comparison of the company's emissions against its benchmarks.

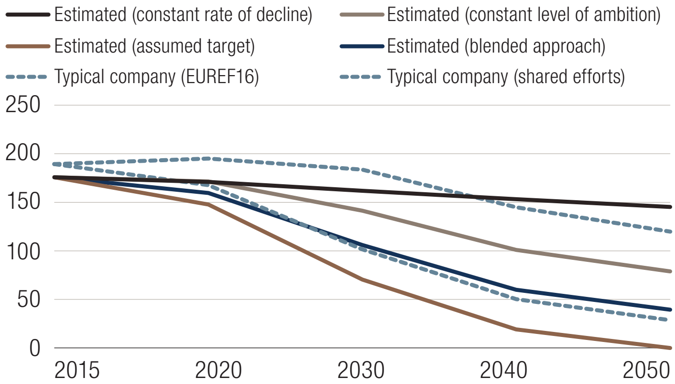
Key judgement 6: Projection of company emission trajectories and comparison against benchmarks. As described in section 2, the next step in the process is to assess the expected evolution of a company's emissions, for which we outline a number of alternative approaches. The first approach, the simplest and, in our view, the least appropriate, applies a constant rate of reduction over the projection period. The rate of decline is estimated here as the median rate of change over the company's scope 1, market-neutral emissions over the period 2015 to 2019. Alternative approaches (such as the use of compound growth rates or otherwise) might lead to slightly different results, but we argue that median rates of change provide a more reliable indication of long-term trends than average rates of change would. Even so, the projection shown is unsatisfactory, as it does not adequately capture non-linearities, as described by the Institut Louis Bachelier (2020). Such non-linearities, for instance, include the introduction and reduction of cost of new decarbonisation technologies, such as carbon storage, hydrogen, biofuels and others, as included in the assumptions of the Roadmap Tool. Owing to the changing availability and economics of these technologies, emission reduction trends might be expected to accelerate in the steel industry over time.

A second, more fruitful approach that addresses such non-linearities consists of using a projection that maintains the company's level of ambition constant, rather than the rate in decline in its emissions. In Figure 8 below, the business as usual EU-Ref 16 and Shared Efforts benchmarks assume an average change in steel (scope 1) emissions of 0.6% and -2.3% per year respectively over the period 2015 to 2020. Once again using the median rate of change in ArcelorMittal's market-neutral scope 1 emissions for comparison, the company's median rate of change (-0.5%) is significantly more ambitious than the EU-Ref 16 trend, but falls short of the rate of change deemed achievable as per the Shared Effort benchmark. The observed rate of change of -0.5% lies at approximately 40% along the range between the EU-Ref 16 and Shared Effort trends, and maintaining this same weighting during the remainder of the project results in the constant level of ambition trend shown in Figure 8.

The third approach also shown in Figure 8 considers the targets announced by the company. Although ArcelorMittal has not yet disclosed the specific details of any carbon reduction commitments via the Carbon Disclosure Project, and has not set any targets verified by the Science-Based Targets initiative, in September 2020 the company announced a group-wide target to achieve net zero emissions by 2050 (ArcelorMittal, 2020). Without more detailed disclosures as to the scope and nature of this target, it is difficult to interpret it with much confidence. We presume the target would include scope 1 and 2 emissions, as we found no indication in the company's announcement that it may also include scope 3 emissions. It is also unclear to what extent the target would rely on carbon offsets. If so, an additional level of scrutiny would be required to ensure credibility, additionality and compatibility with benchmarks. If taken at face value, however, a net zero target applied to the company's scope 1 emissions would imply a steep rate of reduction, at a higher ambition even than the Shared Efforts benchmark, given that this latter benchmark is aligned to net zero emissions across the EU as a whole, but assumes some remaining positive emissions for hard-to-abate sectors such as steel.

Given the various caveats around company targets, Figure 8 also shows a final, fourth approach. This "blended approach" represents a weighted average of the trajectory of the company's emissions based on the second and third approaches above, in effect taking into consideration both the trend implied by the company's decarbonisation to date, as well as the forward-looking commitments that it has set. In this blend, we opt for the inclusion of the second approach (assuming constant level of ambition) rather than the first (constant rate of decline) for the projection based on the company's historical emissions, owing to the aforementioned benefit of better capturing non-linearities in the expected transition. For the purpose of this example, we give 50% to this approach, and 50% to the company's target. In a more sophisticated version of this model, more advanced weighting schemes might be considered, taking into account the status of the target, its independent verification or lack thereof, the presence of interim targets, the company's ESG or governance ratings, the industry's relative abatement costs, or otherwise.

FIG 8: FOUR APPROACHES TO ASSESS THE EXPECTED EVOLUTION OF A COMPANY'S EMISSIONS, SCOPE 1



Source: LOIM Research. For illustrative purposes only.

While the analysis above provides us with the projection and shape of the company's emission trajectory under different assumptions, the comparison to the respective benchmarks requires an additional adjustment for the company's starting intensity. As discussed in section 3, the recognition of a company's baseline efficiency into this absolute emissions metric is the defining feature of the fair share carbon budget approach that we outline here, and ensures that the efforts of companies that have already achieved a degree of decarbonisation are appropriately recognised.

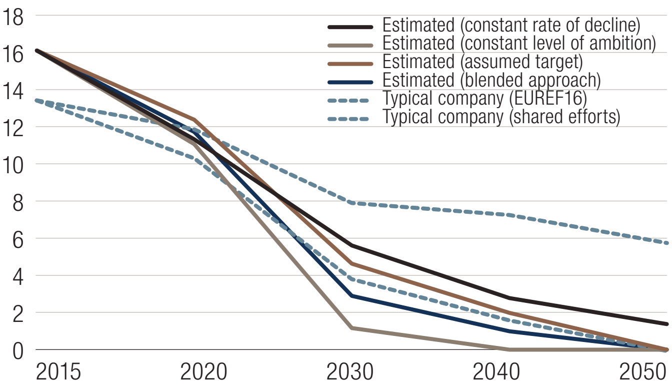
Based on analysis of the carbon intensity of ArcelorMittal[8] compared to that of its peers in the steel industry, we estimate that the company's scope 1 emissions are approximately 7% lower than those of its peers. We use data for 2018 for this part of the analysis, to ensure the highest quality and consistency of data, as data for earlier years may include a greater amount of estimated data for other industry players. In Figure 8, the EU-Ref 16 and Shared Effort benchmarks are therefore calculated by applying the indexed shape of these benchmarks that was discussed under key judgements 1-4 earlier in this section, to a starting point that is exactly 7% above the level of the company's emissions. This recognises, as in the convergence method, that even if the company's emissions were to follow the same trend as that assumed in the EU-Ref 16 scenario, its cumulative emissions would nonetheless be 7% lower than that of a typical similar-sized peer in its industry, and hence make a lesser contribution to global warming.

8 Any reference to a specific company or security does not constitute a recommendation to buy, sell, hold or directly invest in the company or securities. It should not be assumed that the recommendations made in the future will be profitable or will equal the performance of the securities discussed in this document.

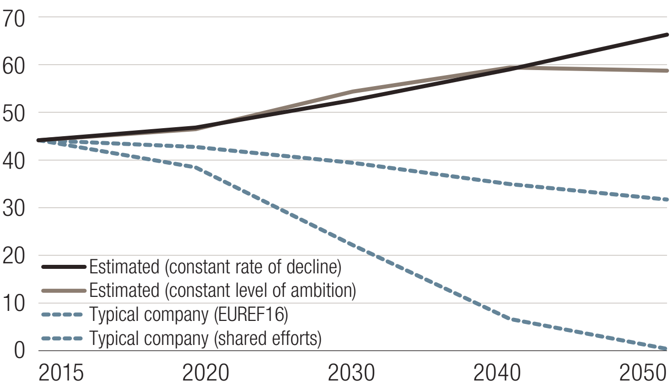
We replicate the above analysis for the company's scope 2 and scope 3 emissions, summarised previously. We apply the specific benchmarks developed earlier in this section as part of key judgements 1 to 4 for these scopes, recognising their distinct shape from the benchmarks used for steel's direct emissions. For scope 2 emissions, we estimate that the company's carbon intensity is comparatively higher than that of its peers (potentially owing to the high exposure of its production base in India), while for scope 3 we assume a comparable starting point intensity. For scope 2 we once again replicate each of the four approaches described above. Our interpretation of the company's target announcement is that it only covers scopes 1 and 2, so that for scope 3 we only show the assessment based on the company's historical track record. These emissions, we believe, are still trending up, at a level in excess even of the EU-Ref 16 benchmark, and more in line with trends in emissions across the global economy more broadly. Finally, we aggregate each of the three scopes to show the combined benchmarks and trajectories for the company as a whole.

FIG 9: FOUR APPROACHES TO ASSESS THE EXPECTED EVOLUTION OF A COMPANY'S EMISSIONS, SCOPE 2, SCOPE 3 AND SCOPES 1+2+3

SCOPE 2



SCOPE 3



Source: LOIM Research. For illustrative purposes only.

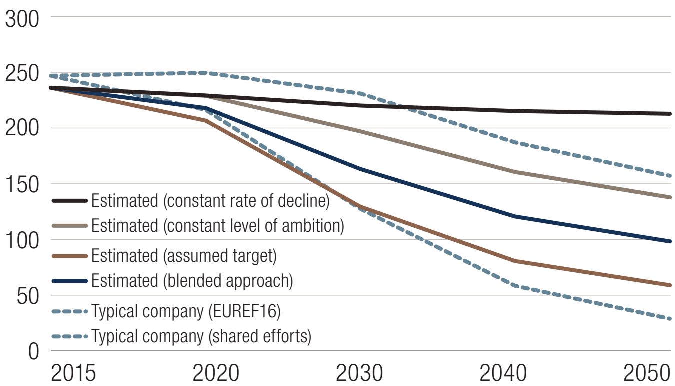
Key judgement 7 and 8: Calculation of implied level of global warming. With the above analysis complete, the final translation of these emission trajectories and their comparison to the company's benchmark is comparatively straightforward, and demonstrated in Tables 3 and 4 below.

As a first step, we need to understand the temperature alignment not of each trajectory, but of the benchmarks themselves. For this step, we consider for both the EU-Ref 16 and the Shared Efforts scenario how the decrease in the overall emissions across all the sectors in the EU economy compares to the carbon budgets associated with different global warming outcomes. For this analysis, we draw on figures provided by two reference scenarios offered by IPCC. We use the S1/P2 (SSP1 "sustainability") S2/P3 (SSP2 "middle of the road") scenarios, representing two of the marker scenarios highlighted by the IPCC (2018) in its Global Warming of 1.5°C report. We choose these two scenarios as they make conservative assumptions with respect to the future scale of net negative emissions beyond 2050, which PAT (2021) cautions against.

The data underlying the chosen scenarios provides an analysis of the level of cumulative emissions expected to result in different levels of global warming, where the measure of global warming is derived from the MAGIC model. We show levels of global warming for a confidence level of at least 66%, where a lower confidence level (such as 50%, which is also commonly used) would result in slightly lower figures. Datasets underlying these market scenarios provide specific emissions not only for the world as a whole, but also for the specific region of the OECD and the EU.

To assess the temperature alignment of the CTI Roadmap Tool scenarios, we convert the cumulative emissions of the two market scenarios and those assumed by the CTI Roadmap Tool into a multiple of 2005 emissions, to make the two sets of figures comparable. This analysis places the EU-Ref 16 scenario just outside the SSP1-26 and SSP2-26 scenarios associated with

ALL SCOPES



1.91°C of global warming by the end of the century. The Shared Efforts scenario assumes an even more ambitious rate of reduction than that of the SSP1-19 and SSP2-19 scenarios. We estimate the aligned temperature rise of the EU-Ref 16 and Shared Efforts scenarios at 1.95°C and 1.21°C when using the S1/P2 scenario, and 2.08°C and 1.19°C when using the S2/P3 scenario. For the purpose of this article, we use figures from the S2/P3 scenario to calculate the final company-level scores shown in Table 4, leading to slightly more conservative scores. The use of such a single scenario is also recommended by PAT for offering greater transparency, and allowing investors to explore underlying assumptions and match these to their investment convictions. The choice of different scenarios will lead to marginal differences in results.

Having identified the aligned temperature of the EU-Ref 16 and Shared Efforts benchmarks, we now repeat the analysis for a comparison with the alternative trajectories estimated for ArcelorMittal. In the table below, we show the cumulative emissions between 2015 (the starting point for our analysis) and 2050 (the end point), using the various projection approaches discussed above. In the first two columns, we also show the cumulative budgets for the company-specific benchmark. The comparison of the cumulative emissions for each trajectory and scope to these benchmark cumulative emissions allows us to estimate the company's temperature through interpolation. For instance, a level of cumulative emissions across scopes 1+2+3 that falls exactly in the middle benchmark figures of the EU-Ref 16 and Shared Efforts (7,455 Mt CO_2e and 4,243 Mt CO_2e) would be estimated to have a temperature in the middle of 2.08°C and 1.19°C.[9]

TABLE 3: INDICATIVE 2005-2050 CARBON BUDGETS FOR OECD + EU REGION

MODEL	SCENARIO	2005-2050 CUMULATIVE EMISSIONS (MT CO_2E)	2005 MULTIPLE	2100 WARMING C (MAGICIP66)
IPCC S1/P2 marker scenario				
AIM/CGE 2.0	SSP1-19	463,558	28.5	1.43
	SSP1-26	567,429	34.9	1.91
	SSP1-34	659,112	40.5	2.42
	SSP1-45	720,341	44.3	2.98
	SSP1-Baseline	793,119	48.8	3.75
IPCC S2/P3 marker scenario				
MESSAGE-GLOBIOM 1.0	SSP2-19	495,766	28.3	1.44
	SSP2-26	594,046	33.9	1.91
	SSP2-34	665,329	38.0	2.41
	SSP2-45	692,011	39.5	2.88
	SSP2-60	726,097	41.5	3.57
	SSP2-Baseline	743,173	42.4	4.23
CTI Roadmap Tool scenarios using S1/P2 scenario as reference				
EU-Ref 16		181,472	35.4	1.95
Shared Efforts		118,751	25.4	1.21
CTI Roadmap Tool scenarios using S2/P3 scenario as reference				
EU-Ref 16		181,472	35.4	2.08
Shared Efforts		118,751	25.4	1.19

[9] PAT (2021) describes the interpolation approach outlined above in its report, but also outlines an alternative approach, using multipliers for the transient climate response to cumulative carbon emissions (TCRE). TCRE multipliers seek to estimate the marginal increase in global warming for every additional unit of emissions. The report estimates this at 0.000545 per $GtCO_2$. The report suggests that, by calculating the percentage overshoot of a reference benchmark and applying this same overshoot to the global carbon budget, the global level of overshoot can be calculated that may be multiplied by the above multiplier. We believe this approach is problematic because (a) it goes against PAT's own recommendation to rely on the choice of a single scenario for added transparency, rather than the use of a weighted-average or warming function approach, which the above multiplier is implicitly based on. In addition, (b) the approach assumes a perfectly linear relationship between emissions and warming. The data in Table 3, which can be used to calculate the ratio of the increase in temperature and the increase in carbon budgets between each scenario, shows this relationship is in fact not constant. Finally, (c) the approach assumes that a percentage overshoot of a carbon budget in a given industry can be generalised to the same percentage overshoot of the economy as a whole. For this approach to be valid, sectoral carbon budgets would need to increase by the same amount for every sector, from one scenario to the next. This assumption, too, does not hold true in most climate models, including the S1/P2, S2/P3 and CTI Roadmap scenarios discussed in this article.

TABLE 4: CUMULATIVE EMISSIONS AND ESTIMATED WARMING POTENTIAL FOR 2015-2050 FOR ARCELORMITTAL (MT CO_2E)

	EU-REF 16 BENCHMARK	SHARED EFFORTS BENCHMARK	CONSTANT RATE OF DECLINE	CONSTANT LEVEL OF AMBITION	ASSUMED TARGET	BLENDED APPROACH (50% TARGET WEIGHT)	BLENDED APPROACH (30% TARGET WEIGHT)
Cumulative emissions (2015-2050)							
Scope 1	5,819	3,390	5,601	4,544	2,444	3,494	3914.0
Scope 2	303	164	216	135	199	167	154.1
Scope 3	1,333	689	1,908	1,890	1,890	1,890	1,890
Scope 1+2	6,122	3,554	5,817	4,679	2,643	3,661	4,068
Scope 1+2+3	7,455	4,243	7,726	6,569	4,533	5,551	5,958
Global warming potential (P66)							
Scope 1	2.08	1.19	2.00	1.62	0.84	1.23	1.38
Scope 2	2.08	1.19	1.53	1.00	1.42	1.21	1.13
Scope 3	2.08	1.19	2.88	2.85	2.85	2.85	2.85
Scope 1+2	2.08	1.19	1.98	1.58	0.88	1.23	1.37
Scope 1+2+3	2.08	1.19	2.16	1.84	1.27	1.56	1.67

Table 4 shows that by most of our estimates, ArcelorMittal is reasonably well-aligned to the climate transition. The fair share carbon budget approach recognises that the company has a better-than-average carbon intensity, specifically in scope 1 emissions, and that its emissions across the most significant emission scopes (scope 1+2) has been declining. The inclusion of our market share adjustment results in a more nuanced assessment of this rate of decline, but is still sufficient for the company to achieve an implied temperature rise score below 2°C by most estimates. Albeit this is not yet sufficient to ensure alignment to a net zero economy, it is significantly ahead of most of the wider economy today (ClimateActionTracker, 2021).

The table above shows a degree of sensitivity to the different estimates. For this case study, the range of variability is limited, but the use of the different projection methodologies can lead to more meaningful differences in other cases. In the authors' view, a blended approach, drawing on both a company's historical decarbonisation rate (but projected using our constant level of ambition approach, rather than a constant rate of decline), as well as taking into account the company's targets, represents the most reasonable solution. Future assessment of the actual trajectory of emissions may lead to a further analysis of the predictive power of these assessments. Following the best practices suggested in Figure 1, ArcelorMittal's ITR ranges from 1.56°C to 1.67°C. In other words, although the company operates in a high CVI sector, it is well aligned with the objectives of Paris Agreement.

5. Conclusion

The private sector is increasingly aware of the physical and transition risks and opportunities associated with climate change. The investment community is now hard at work to quantify this challenge by developing ITR metrics. ITR metrics allow to put a fairly intuitive number on the level of (mis)alignment of a given company or portfolio with a particular decarbonisation objective. To say a company or portfolio has a 1.5 °C temperature—consistent with a 2050 net zero CO2 objective—is to say that global warming could be limited to 1.5 °C above pre-industrial levels should the entire economy undertake an equivalent level of decarbonisation. Such measures can potentially be helpful for investment decision-making, as they provide additive forward-looking information to traditional carbon footprinting metrics, which assess historical emissions. In particular, assessing a company's alignment with ITR places a core focus on the company's pace of transition – whether it is *becoming green* – rather than the scale of its emissions today – whether it is *green* or *not*. As such, ITR allows market participants to invest in well-aligned, transitioning leaders in high-emitting industries, which are most meaningful to the climate transition, and avoid laggards and their associated risks.

In this paper, we have provided an overview of some of the existing and emerging best practices in the development of ITR metrics. We argue that while early metrics have largely opted for either convergence (intensity-based) or rate-of-reduction (either intensity-based or relying on absolute emissions) approaches, it is the combination of these two approaches through the fair share carbon budget approach outlined here that provides the most comprehensive analysis. The use of absolute emissions has a number of inherent advantages, offering a more comprehensive overview of the climate transition, including transitions linked to the circular economy, as well as offering a more direct link to carbon budgets. We have shown that the two adjustments needed to metrics using absolute emissions – an adjustment for baseline carbon intensity and for changes in market share – are both conceptually straightforward and not difficult to implement, and no more complex than adjustments required of intensity-based metrics.

One should keep in mind that the above analysis incorporates numerous simplifications. Most significantly, we have constructed benchmarks only for European steel, and not for each of the other activities of the company (particularly, steel activities outside of Europe), for which we used these same benchmarks as a proxy. Similarly, we applied a number of simplified assumptions even in the construction of the European benchmarks themselves, especially for the construction of our scope 2 and scope 3 benchmarks. Illustrating more sophisticated approaches empirically could prove fruitful and worthy of additional research. Nonetheless, we believe the case study demonstrates the feasibility and ease of implementation of the fair share carbon budget approach as described in section 3. It provides an illustration of the means through which the approach captures the baseline starting point intensity of a company, and can address anomalies linked to a company's inorganic growth (i.e. changes in its market share), that were identified by PAT (2021) as the key challenges facing metrics using absolute emissions.

ITR remains a niche topic in academic research. We hope this paper can stimulate a healthy debate in both academic and practitioner circles interested in the economic and financial causes and implications of climate change. Significant scope for further research remains, particularly as regards the construction of more granular and regionally-varied benchmarks, the back-testing and verification of the predictive power of ITR metrics, and empirical research comparing the sensitivity of these metrics across a larger range of company-level and portfolio-level case studies.

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