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Net-Zero Investment Strategies Need an Absolute Emission Reduction Metric

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ABSTRACT

The climate crisis calls for rapid absolute reductions in greenhouse gas (GHG) emissions, requiring significant capital reallocation. In the financial industry, net-zero investment strategies are mostly guided by relative carbon intensity (CI) metrics rather than absolute GHG emissions. We show that such net-zero oriented investments can be misleading, cause insufficient investor action, and delay meaningful emission reductions. We propose two solutions: first, the rigorous and universal application of an inflation-adjusted CI metric that accounts for changes in a key financial fundamental relative to the portfolio inception year. Second, we propose the addition of absolute GHG emission limits at portfolio inception. These measures will better align net-zero investment strategies with real-world absolute GHG emissions targets and avoid “emission intensity loopholes” as large as the GHG emissions of the Netherlands and Sweden together.

JEL Classification: E61, G11, G23, G28, O16, Q54, Q58

1 | Introduction

The climate crisis is widely recognized as the most pressing global challenge, demanding rapid and sustained reductions in greenhouse gas (GHG) emissions across all sectors of the real economy (IPCC 2018). The Paris Agreement emphasizes the critical need to limit global temperature increases to 1.5°C above pre-industrial levels, requiring a 43% reduction in global emissions by 2030 compared with 2019 (IPCC 2022). Achieving this goal requires unprecedented capital mobilization for a net-zero transition, as emphasized in international agreements and policy frameworks (European Commission 2019; UNFCCC 2015).

In response, the European Union introduced the Climate Benchmark Regulation, establishing Climate Transition Benchmarks (CTB) and Paris-Aligned Benchmarks (PAB) as innovative investment tools to channel capital effectively (TEG 2019). With nearly USD 180 billion invested in PAB (EU Platform on Sustainable Finance 2024), these benchmarks are

leading net-zero investment products, setting a precedent for policymakers and future sustainable finance regulations. However, the regulation exhibits several loopholes (Jacob et al. 2025), which threaten its effectiveness in supporting decarbonization efforts.

We demonstrate that these loopholes stem from the carbon intensity (CI) metric used, which could lead to two significant issues. First, at inception, PAB products could include an additional 16.19 Mt. CO₂e compared with their conventional products, equivalent to 10% of the total emissions of the Netherlands in 2023 (Crippa et al. 2024). During the decarbonization period until 2049, this could result in an ‘emission intensity loophole’ of 201.04 Mt. CO₂e, reflecting the cumulative excess emissions arising from deviations from the intended decarbonization pathway. This excess is comparable in scale to either the total emissions of the Netherlands and Sweden combined (Crippa et al. 2024) or half of the annual emissions of France or Italy. Second, the loophole could delay meaningful decarbonization within these PAB products by up to 16 years,

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significantly postponing their intended contribution to real-world emissions reductions. If left unaddressed, this flaw could undermine net-zero investments and hinder the alignment of financial markets with climate goals.

The core issue stems from the difference in how emission reductions are assessed (Ellermann and Wing 2003), with science and climate policies focusing on absolute GHG emissions, while finance relies on CI metrics (Fraser and Fiedler 2023). Absolute GHG emissions are crucial in both scientific and policy contexts because they provide a direct measure of the environmental impact and ensure that reductions are aligned with climate targets. In contrast, CI metrics express GHG emissions relative to financial or economic values, such as enterprise value, making them useful for comparing companies and investment products (Fraser and Fiedler 2023). However, this approach has a major drawback (Rekker et al. 2023; TCFD 2021): It allows portfolios to appear aligned with net-zero goals without necessarily reducing absolute GHG emissions. A company or portfolio can improve its CI by increasing financial performance rather than by actually cutting emissions (Fraser and Fiedler 2023). This could lead to net-zero investment strategies failing to provide the necessary financing for real-world decarbonization (Schenzle and Busch 2025).

We demonstrate that this misalignment, primarily due to the reliance on relative CI metrics, introduces two key issues. First, investment portfolios could be on misleading decarbonization paths, as variations in underlying financial metrics (e.g., inflation) can create the illusion of progress. Second, it may cause temporal misalignment. Portfolios based on CI metrics can initially exceed real-economy GHG emission levels, delaying meaningful reductions and slowing the pace of decarbonization relative to climate science demands. By constructing CTB- and PAB-compliant portfolios optimized for absolute GHG emissions, we reveal excessively high initial emissions levels, coupled with significant delays in decarbonization.

To align decarbonization pathways with the Paris Agreement, absolute GHG emissions must decrease relative to a base year, with ongoing reductions adjusted for changes in fundamentals (Rekker et al. 2022). To ensure net-zero investment strategies fully reflect these principles, we propose two practical and easily implementable solutions for portfolio management. First, incorporating an enterprise value inflation adjustment factor (IAF) to prevent misleading decarbonization paths and to ensure that investment strategies contribute directly to absolute emission reductions. Second, implementing absolute GHG emission constraints at portfolio inception ensures that CTB and PAB products can fully support net-zero goals while remaining financially viable. These solutions bridge the gap between financial metrics and environmental imperatives, ensuring net-zero investments contribute effectively to global decarbonization. With these regulatory adjustments, sustainable finance can fulfill its promise and drive meaningful climate action. Overall, our study extends latest calls to assess the real economy's alignment with 1.5°C climate pathways through absolute GHG emissions (Hoepner and Rogelj 2021; Rekker et al. 2023), applying this approach to finance.

Our study contributes to the literature in three ways. First, we demonstrate how reliance on relative CI metrics may

misrepresent developments in absolute GHG emissions. Second, we introduce the IAF to ensure consistency in the evaluation of fundamental changes over time. Third, we propose the integration of absolute GHG emission constraints at portfolio inception. Ultimately, these contributions equip regulators and market participants with the necessary tools to mitigate the risk of large-scale capital misallocation in sustainable finance.

The remainder of this paper is organized as follows: Section 2 identifies the core issues in current emission metrics and decarbonization pathways. Section 3 describes the data and methodology, and Section 4 illustrates the identified issues through a case study of the EU Climate Benchmark Regulation. Section 5 concludes with a discussion.

2 | Key Issues in Portfolio Decarbonization Metrics and Pathways

2.1 | GHG Emissions in Natural Sciences and Finance: Absolutes Versus Intensities

In natural sciences, absolute GHG emissions are the standard metric for assessing the impact on the climate and environmental systems. These absolute GHG emissions, measured in tons of CO₂e, directly quantify the cumulative effect of human activities on global warming (IPCC 2021). This aligns with the Paris Agreement's focus on limiting total GHG emissions to stabilize global temperatures (UNFCCC 2015), as exceeding critical thresholds could trigger irreversible climate tipping points (IPCC 2021). Rising absolute GHG emissions contribute directly to intensified extreme weather events, ocean acidification, and biodiversity loss, underscoring the urgency of immediate and sustained reductions (Rockström et al. 2009).

In contrast, the financial sector primarily relies on CI metrics, which measure emissions relative to fundamental variables, such as revenue or enterprise value, to inform investment decisions and track net-zero progress. There are two main reasons why CI metrics are widely used in finance (Bolton and Kacperczyk 2023; Fraser and Fiedler 2023). First, they enable portfolio construction independently of portfolio size, allowing for scalability. Second, normalizing emissions by fundamentals facilitates cross-company comparisons, allowing investors to assess relative efficiency. However, this approach has critical shortcomings. Various CI metrics indicate that portfolio decarbonization targets can still be met even if absolute GHG emissions of the invested companies increase (Fraser and Fiedler 2023). This can occur solely due to variation in the denominator, making decarbonization achievements merely apparent. Consequently, financial strategies built on CI metrics may fail to align with the scientific imperative of reducing total emissions, due to two issues outlined in the following sections (IPCC 2021).

2.2 | Inflation Adjustment for Decarbonization Pathways

The first issue concerns misguided decarbonization targets based on CI metrics due to inflation of the underlying fundamentals used for the adjustment. To provide a prominent

example, The Financial Times' Europe's Climate Leaders 2023 report ranks companies based on GHG emission reduction achievements (Hawcock 2023). One notable example in this list is the publicly listed company Linde AG. According to the stated decarbonization success, Linde achieved a 14.30% reduction in CI (adjusted by net sales) over 5 years. However, its absolute CO₂e rose from 29.50 to 39.89 Mt. during this period—a staggering 35.20% increase. This is not an individual case, as 10% of the Climate Leaders listed have increased their absolute GHG emissions, despite reducing their relative CI.

A key challenge in sustainable finance is ensuring that reported CI reductions reflect real improvements rather than shifts in economic fundamentals. Investors may be misled by “artificial declines” in CI if economic growth outpaces emission reductions, reducing for incentives to stimulate change in companies through active strategies such as engagement (Bauer et al. 2023; Flammer et al. 2021) or divestment (Rohleder et al. 2022). Investors will always achieve an apparent reduction in the portfolio's CI if the increase in the fundamental value exceeds the increase in GHG emissions.

To some degree, practitioners and policymakers have addressed this issue using different approaches. BlackRock, for instance, recently adopted the reporting of both inflation adjusted and unadjusted carbon footprints (BlackRock 2023). JPMorgan began calculating their portfolio emissions using 3-year rolling averages of adjustment fundamentals to reduce the effects of their volatility (JPMorgan Chase and Co 2023). While the first approach enhances transparency and the second one controls for volatility, neither of them accounts for consistent change in fundamentals (i.e., inflation).

This problem can be addressed by the IAF (see Section 3), which ensures that adjustments for fundamental changes account for inflationary effects, stabilizing the denominator used to calculate CIs. Additionally, the IAF can be combined with a target decarbonization rate (e.g., 7%, as prescribed by the EU Climate Benchmark Regulation (Commission Delegated Regulation (EU) 2020/1818) to ensure that the adjusted target ensures

genuine alignment with the Paris Agreement's GHG emissions reduction goals.

To illustrate the impact of inflation adjustment on decarbonization pathways, Figure 1 presents two perspectives on the relationship between CI and absolute GHG emissions over time. We assume that the fundamental value increases while the portfolio must be aligned to a fixed decarbonization rate. On the left, the maximum permitted CI level decreases annually by 7%, reflecting the decarbonization target. The right-hand side compares the resulting developments in absolute GHG emissions with and without adjustment for inflation. Without inflation adjustment, absolute GHG emissions can increase despite meeting CI reduction targets. In contrast, the inflation-adjusted emissions pathway ensures an actual reduction in absolute GHG emissions, which is truly needed to achieve climate targets. Furthermore, it provides a more stable and transparent benchmark for assessing actual decarbonization.

It is important to use a base year as a reference when applying the IAF, as a fixed base year prevents cumulative distortions that can arise from annual recalculations and provides a stable benchmark for assessing long-term progress (EFRAG 2022; NZAOA 2022; TEG 2019). Relying on the previous year instead could obscure trends and undermine the credibility of emissions reporting.

2.3 | Baseline for Decarbonization Pathway

The second issue concerns the baseline as the reference point for determining decarbonization pathways. Decarbonization targets should ultimately aim to align with the goals of limiting global warming to 1.5°C or 2°C. Decarbonization pathways are typically expressed as annual percentage reductions relative to the previous year, starting from the baseline value. However, a critical aspect is the determination of the baseline from which the reduction paths are determined. The baseline value is initially set at inception of the investment and then reduced annually. Thereby, it significantly impacts the (temporal) feasibility of the net-zero target.

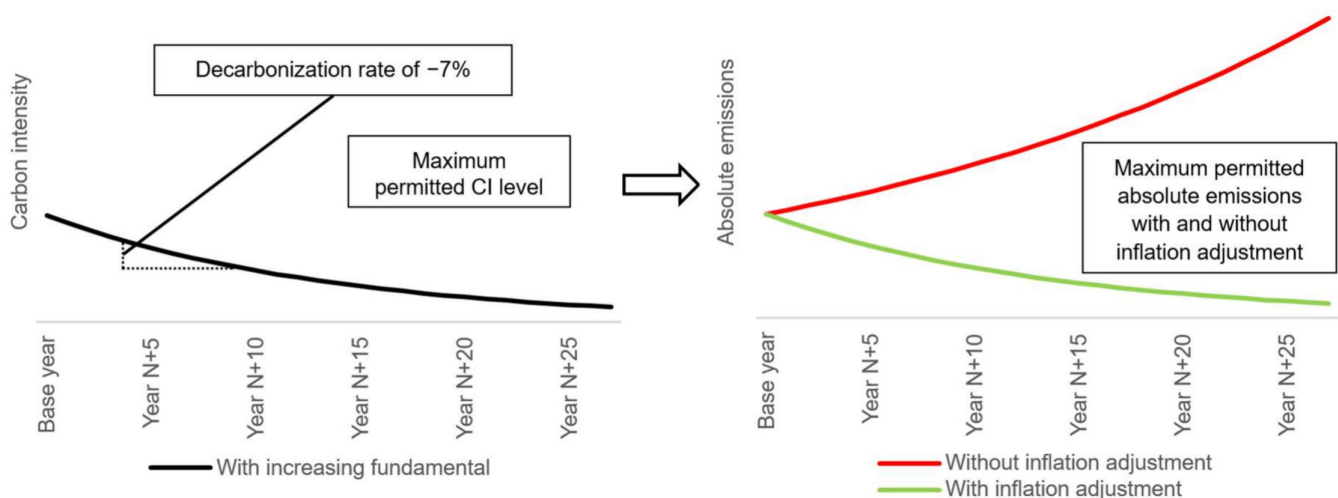


FIGURE 1 | Inflation adjustment for decarbonization pathways. This figure illustrates the relationship between carbon intensity (CI) and absolute GHG emissions. The left side shows CI assuming a rising fundamental, a –7% decarbonization rate, and the maximum CI level. The right side shows absolute GHG emissions under these assumptions, highlighting the impact of inflation adjustment on actual emission reductions.

In recent years, climate-oriented investment indices have been introduced, often promoted as having significantly lower CI compared with conventional investments (i.e., mostly a reference index) (EU Platform on Sustainable Finance 2023). However, net-zero investments may exhibit reduced CI while still exhibiting high absolute GHG emissions. This could delay the achievement of net-zero well beyond 2050, undermining the fundamental purpose of these investments and their alignment with long-term climate objectives. As such, the metrics used to define a decarbonization pathway (absolute versus/and intensities) are pivotal to ensuring that decarbonization pathways genuinely contribute to global climate goals (SBTi 2015).

This issue is not just theoretical but is also evident in the EU Climate Benchmark Regulation, where the focus on CI for the listed equities asset class could obscure the true impact of decarbonization efforts. Without considering absolute GHG emissions alongside CI, it becomes difficult to ensure that actual reductions are being made within the expected time (Rekker et al. 2023). To illustrate this, we examine the EU Climate Benchmark Regulation and highlight the risks of prioritizing CI over absolute GHG emissions in the initial decarbonization and the broader implications for climate targets.

3 | Methodology

3.1 | Data

To construct CTB- and PAB-aligned portfolios, we define appropriate data proxies for the mandatory minimum standards of the EU Climate Benchmark Regulation (Commission Delegated Regulation (EU) 2020/1818) and follow the approach of Jacob et al. (2025). First, we define the investable universe using a global equity dataset comprising the 1509 constituents and their respective weightings of the MSCI World Index as of December 2022. The MSCI World Index is used as a representative example due to its broad diversification and status as one of the most widely recognized global indices.

On the company level, we use data for the baseline exclusions (TEG 2019) from Morningstar (Controversial Weapons, Societal norms violators) and Refinitiv (Tobacco). For all activity exclusions (TEG 2019), we use data from Morningstar. Fundamentals, such as enterprise value including cash (EVIC), are sourced from Morningstar.

At the portfolio level, we primarily collect GHG emissions data (Scope 1, Scope 2, and Scope 3; reported and estimated values) from Refinitiv, and if no data is available, we estimate GHG emissions using the industry median (Kalesnik et al. 2022). Industry medians are computed at the NACE-code level separately for Scope 1, Scope 2, and Scope 3 emissions, as NACE serves as the regulatory classification framework for economic activities. Sectoral exposures are determined using NACE code-level data from Refinitiv. Corporate targets are assessed using information from the Science-Based Targets initiative, Reporting and Historical GHG Reduction information from Refinitiv, and Morningstar's "Carbon Risk Managed Score." The decarbonization trajectory is not relevant for portfolio construction at inception.

The CI of a portfolio is calculated as the portfolio-weighted sum of each company's Scope 1, 2, and 3 GHG emissions measured in tons of CO₂e divided by its EVIC in million USD. Although the regulation permitted a phased-in sectoral inclusion of Scope 3 emissions at the time of portfolio construction, we consistently include Scope 3 emissions for all firms. We apply the fully phased-in requirements to ensure that the identified loopholes reflect the final regulatory design rather than transitional effects.

Portfolios are constructed as of December 2022, consistent with the MSCI World Index constituents and weights. All input data used for portfolio construction refer to the end of 2021. This corresponds to the latest annually available reporting period accessible at the portfolio construction date.

3.2 | Optimization Model and Absolute GHG Emissions

To demonstrate the importance of considering absolute GHG emissions, we maximize CTB- and PAB-aligned portfolios with respect to absolute GHG emissions, which are not covered by the current regulation. We use the optimization model of Jacob et al. (2025), which imposes all regulatory minimum standards of the EU Climate Benchmark Regulation as constraints.

To calculate the absolute GHG emissions of portfolios, the individual portfolio weights $w_{i,t}$ are multiplied with the total Scope 1, 2, and 3 GHG emissions E of stock i in year t and then summed up for all N stocks in the portfolio. This approach is comparable with the one presented in Fraser and Fiedler (2023) but neglects the adjustment of the emissions and the portfolio value invested. Absolute portfolio GHG emissions are calculated as

$$\sum_{i=1}^N w_{i,t} E_{i,t} \quad (1)$$

This measure is unaffected by changes in company fundamentals and the portfolio value. It is directly linked to GHG emissions, making it a straightforward metric for assessing climate impact. It makes an investor fully accountable for all GHG emissions produced by the investee's companies instead of attributing them according to the shares owned (Fraser and Fiedler 2023). It should be noted that, unlike conventional CI metrics, this measure is not scaled in size. Therefore, larger companies will contribute more to portfolio emissions, as they generally have higher GHG emissions, even if they may operate more efficiently than smaller comparable companies. Therefore, this metric shall be applied only at inception of a net-zero-oriented investment portfolio to ensure a reasonable GHG emissions baseline and should be accompanied by a conventional CI metric.

3.3 | IAF

Dynamic decarbonization in net-zero investment strategies ensures alignment with the Paris Agreement's goal of limiting global warming to 1.5°C. A key challenge addressed by this approach is the reliance on relative CIs as a metric in finance,

where absolute GHG emissions are adjusted by a company's fundamental (e.g., net sales or enterprise value). However, this metric can be misleading if fundamentals inflate without actual improvements in GHG emission reductions, potentially decoupling financial metrics from real-world climate needs.

To account for changes in the fundamental of benchmark constituents over the past calendar year, an IAF is applied to each constituent's fundamental. This adjustment factor is determined by dividing the fundamental $f_{t,i}$ of each constituent i in year t by that at the inception date (i.e., base year), $f_{t=0,i}$. This ensures consistency in evaluating fundamental changes over time. Formula (2) introduces an inflation adjusted CI of a portfolio, CI_IA , maintaining the integrity of decarbonization pathways. In our case in Section 4, the base year corresponds to 2022.

$$CI_IA_t = \sum_{i=1}^N w_{t,i} \frac{Emissions_{t,i}}{\frac{f_{t,i}}{IAF_{t,i}}}, \text{ where } IAF_{t,i} = \frac{f_{t,i}}{f_{t=0,i}} \quad (2)$$

An annual decarbonization target d (e.g., 7% as prescribed by European Commission (Commission Delegated Regulation (EU) 2020/1818)) for a net-zero investment strategy must be defined, to reflect the continuous GHG emissions reductions needed to meet global climate targets. However, the minimum level for the decarbonization target should be increased if inflation in the fundamental value occurs. The decarbonization rate for the year is then calculated as

$$1 - \left(\frac{1 - d}{1 + IAF\%_{t,i}} \right), \text{ where } IAF\%_{t,i} = IAF_{t,i} - 1 \quad (3)$$

This formula can also be adopted for deflation, where “adjustments for corporate actions such as stock splits, spin-offs or acquisitions beyond launch year are permissible” (EU Platform on Sustainable Finance 2023).

4 | Case: EU Climate Benchmark Regulation

In December 2020, the EU introduced the Climate Benchmark Regulation, which aims to align financial products with climate targets by introducing CTB and PAB as standardized benchmarks (Commission Delegated Regulation (EU) 2020/1818). By combining mandatory disclosures with climate-focused minimum standards, these benchmarks are designed to incorporate emissions reduction targets and support investments that contribute to the transition to a low-carbon economy (TEG 2019). One of the minimum standards is to reduce the overall CI of the benchmark by 50% for PAB and 30% for CTB compared with the investable universe. Furthermore, the CI must be reduced by an average of at least 7% per annum. As CI is defined as absolute GHG emissions divided by EVIC (Article 1, point (c), of Commission Delegated Regulation (EU) 2020/1818), the EU introduced an IAF to account for the potential effects of inflation in the EVIC and thereby ensure a more accurate financial denominator for measuring CI.

According to the current regulation, the IAF is calculated using the previous calendar year instead of the base year (Article 7(3), of Commission Delegated Regulation (EU)

2020/1818). As mentioned, this approach can be problematic for several reasons. Primarily, it may result in cumulative distortions over time, obscuring actual progress. Additionally, it may lead to the misinterpretation of short-term fluctuations, such as those caused by economic cycles or external shocks, which do not accurately reflect long-term decarbonization trends. Furthermore, it undermines comparability, as the reference point shifts annually, complicating the analysis of long-term trends. To address these issues, the regulation should be revised to mandate the use of the base year as the consistent reference point.

Another issue arises as the current regulation does not provide any standards on the (initial) absolute GHG emissions of the benchmark but focuses solely on CI.

We construct CTB- and PAB-aligned portfolios based on the MSCI World Index as of December 2022, hereinafter referred to as investable universe.¹ First, we construct portfolios that meet solely the minimum regulatory standards while maximizing the absolute GHG emissions, which are not directly considered by the benchmark regulation. The resulting portfolios represent the worst-case portfolios that comply with the minimum standards while exploiting the highest possible level of absolute GHG emissions. Figure 2 shows the decarbonization pathway for the worst-case starting point for CTB (Figure 2a,b) and PAB (Figure 2c,d). The figure illustrates the development in terms of both CI (Figure 2a,c) and absolute GHG emissions (Figure 2b,d) over time and highlights the implications of different starting points and decarbonization targets for achieving emissions reductions in line with climate goals. The dashed lines represent the starting GHG emissions levels of the respective portfolios. The CTB and PAB targets are based on percentage reductions in CI outlined in the benchmark regulation (Figure 2a,c) and are applied by us to the absolute GHG emissions (Figure 2b,d). The solid lines depict the decarbonization pathways, reflecting a 7% annual emissions reduction from the starting point of each portfolio. For the target portfolios, the hatched area is relevant, as they are subject to the condition of being at least lower than the investable universe.

The first key finding is that it is possible to construct CTB- and PAB-aligned portfolios that exhibit higher absolute GHG emissions at their starting point compared with the investable universe (Figure 2b,d) while meeting the CI reduction requirement (Figure 2a,c). In the worst-case portfolios, absolute GHG emissions can be up to 366% higher for CTB and 323% higher for PAB than intended (see Figure 2b,d in 2022).

Another striking finding is the delay in reaching lower absolute GHG emissions levels for the optimized portfolios due to increased starting points. In the CTB case (Figure 2b), the optimized portfolio only reaches the same absolute GHG emissions level as the 30%-reduced starting point by approximately 2040, reflecting a delay of 18 years. Similarly, in the PAB case (Figure 2d), the optimized portfolio takes until approximately 2038 to reach the 50%-reduced starting point. These delays lead to the “emission intensity loophole” due to additional emissions, highlighted as the red-dotted area between the worst-case portfolio emissions and the target emissions (Figure 2b,d).

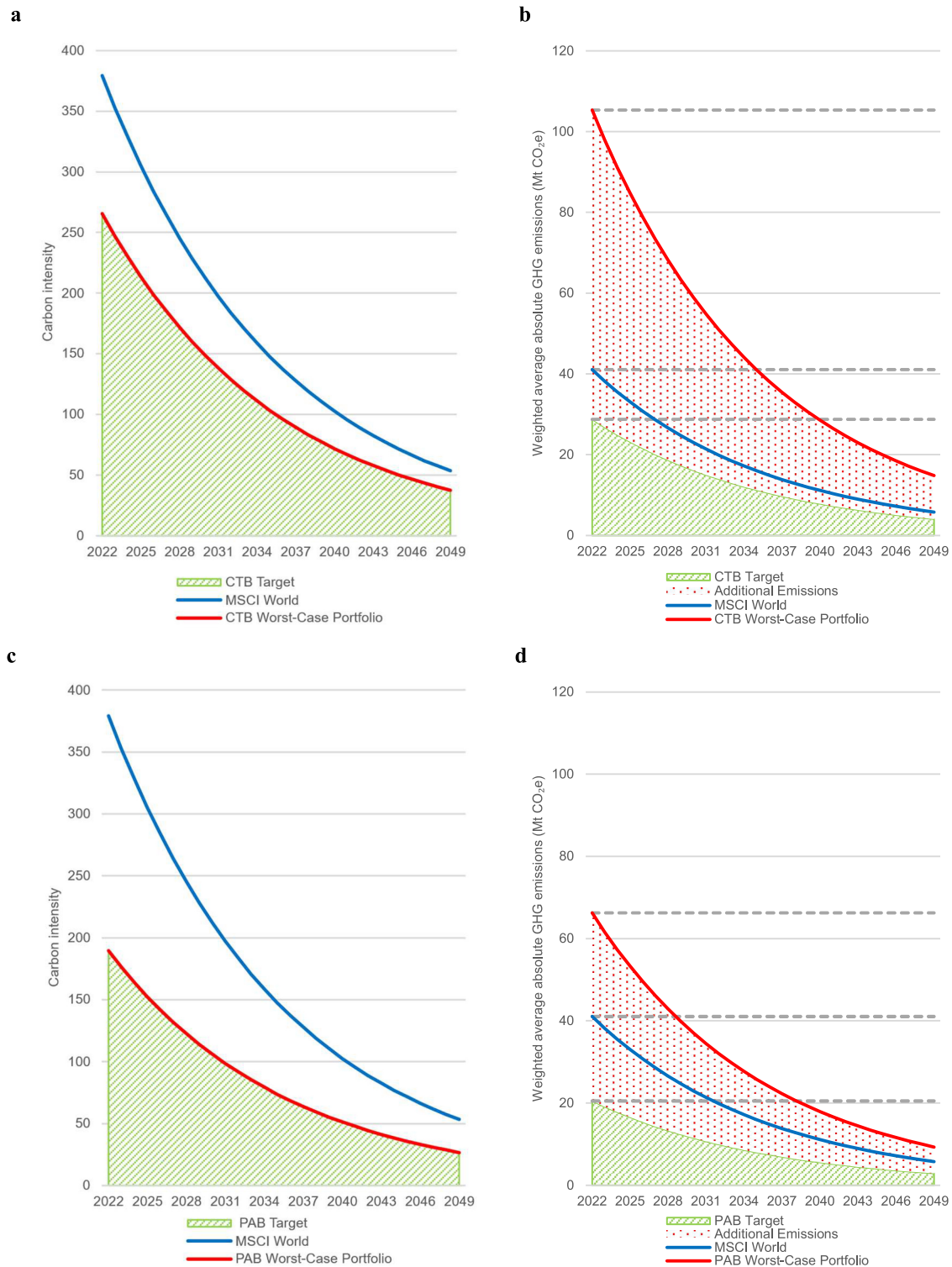


FIGURE 2 | Decarbonization pathway for the worst-case starting point for CTB and PAB portfolios. This figure shows the decarbonization pathway for the worst-case starting point for Climate Transition Benchmark (CTB) and Paris-aligned Benchmark (PAB). a indicate the carbon intensity (CI) reduction as prescribed by the regulation for CTB and c for PAB. CI is defined as the portfolio-weighted sum of each company's Scope 1, 2, and 3 GHG emissions measured in tons of CO₂e divided by its EVIC in million USD. The Worst-Case Portfolios show the highest possible absolute GHG emissions of optimized portfolios for CTB (b) and PAB (d) over time. The MSCI World Index (investable universe) is used as a reference. Targets indicate the CI reduction originally targeted at inception with subsequent 7% decarbonization (a, c) and applied to absolute GHG emissions instead of CI (b, d). Additional emissions represent the cumulative deviation of weighted absolute GHG emissions of the worst-case portfolio from the respective target decarbonization pathway. All optimized portfolios comply with the respectively mandatory minimum standards of the EU Climate Benchmark Regulation.

To evaluate the potential climate impact of these results, we extend our analysis to the entire capital market. For this purpose, we estimate the potential magnitude of the loophole in GHG emissions, using the following assumptions and calculations. Globally, USD 125.71 trillion is invested in equity (WFE 2024), with USD 180 billion allocated under a PAB mandate (EU Platform on Sustainable Finance 2024), representing 0.14% of global equity investments. We translate this market share into financed emissions using proportional scaling, assuming that emission exposure scales linearly with portfolio market capitalization. The total CO₂e of publicly listed firms amount to 11.30Gt per year as of 2023 (MSCI 2023).² Given their market share, PAB investments would account for 16.19 Mt. CO₂e without any decarbonization ambition. As PAB investment portfolios are required to achieve a 50% reduction in emissions at inception, they should instead account for only 8.09 Mt. CO₂e.

Following this assumption, our analysis reveals that the loophole could allow PAB portfolios to hold approximately three times the intended emissions level—up to 24.29 Mt. CO₂e. This means that, at inception, PAB portfolios could include an additional 16.19 Mt. CO₂e compared with their intended reduction targets—equivalent to 10% of the total emissions of the Netherlands in 2023 (Crippa et al. 2024). This increased emissions level at inception serves as a worst-case reference point for

the required annual 7% decarbonization. As a result, the portfolios experience a decarbonization lag compared with their intended pathway. Over time, this discrepancy could accumulate to an additional 201.04 Mt. CO₂e by 2049 compared with the intended PAB pathway—equivalent to the combined emissions of the Netherlands and Sweden in 2023 (Crippa et al. 2024).

In the second step, we introduce an additional constraint to better reflect real-world investment practices by limiting the deviations in the weightings of each constituent in our portfolios from those in the original MSCI World Index portfolio, while maintaining compliance with all minimum standards. To determine an appropriate maximum deviation, we analyze different levels of absolute weight deviations from the MSCI World Index and compare the results with publicly available investment products, for example, the Amundi MSCI World SRI Climate Net Zero Ambition PAB UCITS ETF.

Table 1 presents data on CO₂e and portfolio composition for different levels of deviations. To ensure adequate diversification, we control for both the absolute number of companies (NoC) and the effective number of companies, measured by the inverse Herfindahl–Hirschman Index (HHI^{−1}). Additionally, we consider key metrics commonly used in practice, such as tracking error (TE), which we estimate ex-ante based on daily returns over a 10-year period (December 2012 to December 2022).

TABLE 1 | Portfolio characteristics for different levels of absolute weight deviations from the MSCI World Index.

Panel A: CTB							
	MSCI World	Absolute deviation					MSCI World ETF
		±7 bps	±10 bps	± 15 bps	± 20 bps	± 30 bps	
CO ₂ e (in Mt)	41.08	45.37	48.16	51.91	54.88	59.20	12.92
NoC	1509	572	420	305	246	177	324
HHI ^{−1}	173	145	136	124	115	100	68
TE (%)		1.77%	1.97%	2.21%	2.26%	2.52%	3.62%
Max. weight	4.53%	4.75%	4.78%	4.83%	4.88%	4.98%	6.01%
Top 10 weight	16.38%	17.57%	17.92%	18.42%	18.92%	19.92%	30.86%
Median weight	0.03%	0.11%	0.16%	0.23%	0.30%	0.46%	0.15%
Panel B: PAB							
	MSCI World	Absolute deviation					MSCI World ETF
		± 7 bps	± 10 bps	± 15 bps	± 20 bps	± 30 bps	
CO ₂ e (in Mt)	41.08	28.69	32.22	36.00	38.82	42.93	12.92
NoC	1509	647	475	327	264	183	324
HHI ^{−1}	173	133	124	114	105	92	68
TE (%)		2.13%	2.42%	2.54%	2.61%	2.89%	3.62%
Max. weight	4.53%	5.24%	5.27%	5.32%	5.37%	5.47%	6.01%
Top 10 weight	16.38%	18.83%	19.39%	19.89%	20.55%	21.55%	30.86%
Median weight	0.03%	0.09%	0.13%	0.20%	0.25%	0.39%	0.15%

Note: Climate Transition Benchmarks (CTB), Paris-Aligned Benchmarks (PAB), CO₂e (in Mt) denotes weighted average absolute GHG emissions measured in Mt. CO₂e, number of companies (NoC), inverted Herfindahl–Hirschman Index (HHI^{−1}), tracking error (TE), Amundi MSCI World SRI Climate Net Zero Ambition PAB UCITS ETF (MSCI World ETF), basis points (bps).

Furthermore, we compare portfolio characteristics, including maximum weight (highest individual constituent weight), top 10 weight (aggregate weight of the 10 largest constituents), and median weight (median constituent weight).

The comparison reveals that the maximum acceptable weight deviation while maintaining comparability to a market-available product is a constraint of ± 15 basis points (bps) per constituent relative to its weight in the MSCI World Index (with a minimum weight threshold of zero). While permitting higher weight deviations would allow the optimizer to allocate significantly higher absolute GHG emissions into the portfolio, doing so would start

compromising diversification and drive the TE beyond acceptable limits for a broad market index. At the 15bps threshold, the portfolio retains strong diversification and a manageable risk profile.

Figure 3 shows the cases for CTB (Figure 3a) and PAB (Figure 3b) under this additional constraint. The first key finding is that it remains possible to construct a CTB-aligned portfolio where the absolute GHG emissions at the starting point are higher than those of the investable universe.

Moreover, the decarbonization trajectories reveal a significant delay in achieving the respective targets. Specifically, the

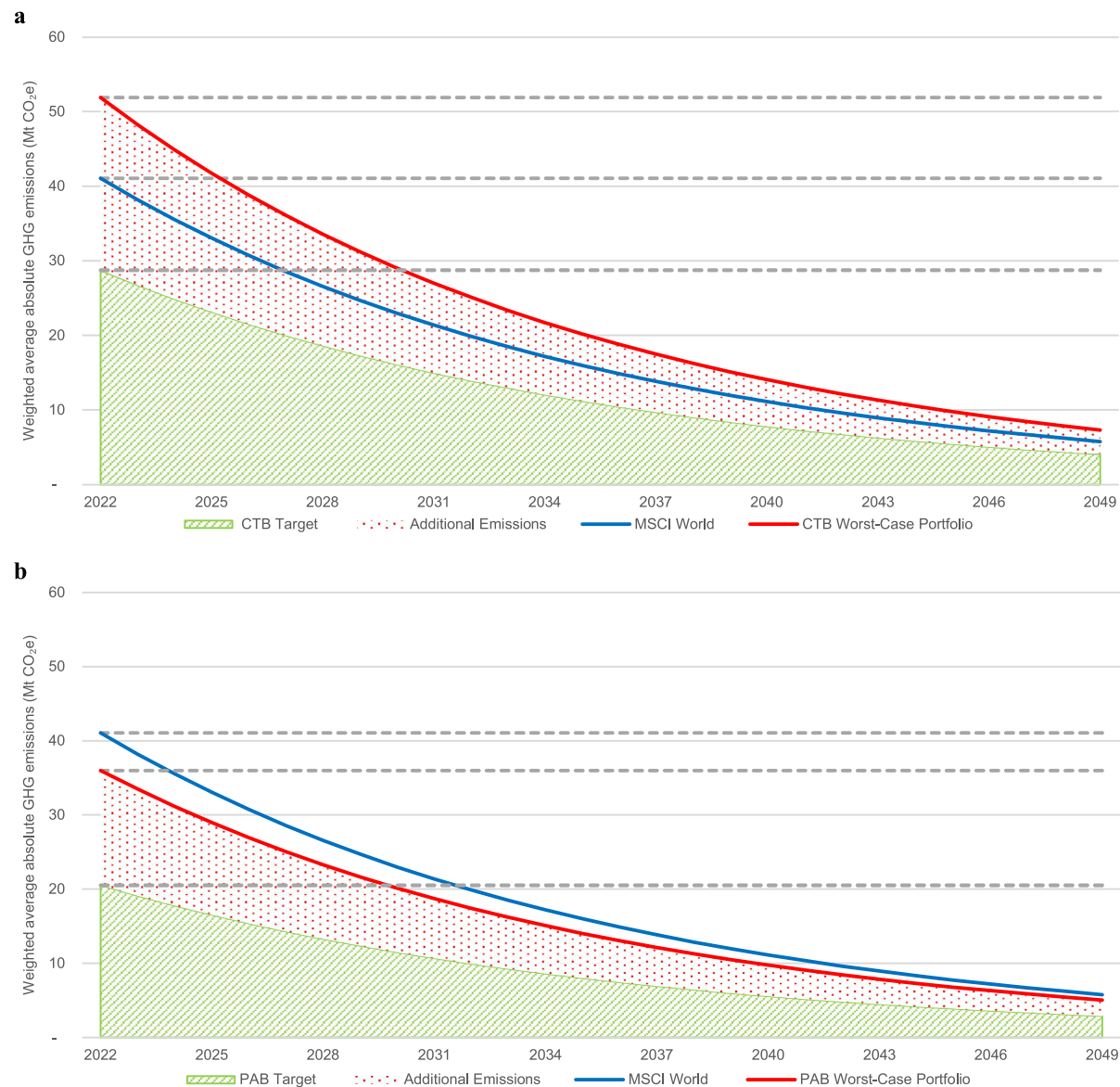


FIGURE 3 | Decarbonization pathway for the worst-case starting point for CTB and PAB portfolios with additional weight constraint. This figure shows the decarbonization pathway for the worst-case starting point for Climate Transition Benchmark (CTB) (a) and Paris-aligned Benchmark (PAB) (b). The Worst-Case Portfolios show the highest possible absolute GHG emissions of optimized portfolios for CTB and PAB over time. The MSCI World Index (investable universe) is used as a reference. Targets indicate the carbon intensity (CI) reduction originally targeted at inception with subsequent 7% decarbonization (a) and applied to absolute GHG emissions instead of CI (b). Additional emissions represent the cumulative deviation of weighted absolute GHG emissions of the worst-case portfolio from the respective target decarbonization pathway. All optimized portfolios comply with the respectively mandatory minimum standards of the EU Climate Benchmark Regulation. The portfolios are optimized under an additional constraint stipulating that the absolute weighting of each constituent may not deviate by more than ± 15 basis points from its weighting in the MSCI World Index.

CTB-aligned portfolio (Figure 3a) and the PAB-aligned portfolio (Figure 3b) only reach their respective emission reduction targets in 2030/2031, resulting in a delay of 8/9 years compared with the idealized target pathways.

Although the gaps are gradually narrowing, emissions in 2049 for the CTB and PAB portfolio remain approximately two times higher than their respective targets at that time. It would take another 10 or 9 years, respectively, for the CTB or PAB portfolio to reach the actual target value for 2049. Such delays could result in a “disorderly transition,” characterized by heightened transition risks due to the need for drastic and abrupt policy measures to curb climate change. In the worst-case scenario, prolonged delays could lead to a “hothouse world,” where the escalation of physical risks becomes unavoidable, posing severe consequences for both the planet and investors (NGFS 2022).

5 | Discussion

The study highlights the need to scrutinize absolute GHG emissions in current net-zero investment strategies in addition to CI metrics, especially at the starting point where the decarbonization pathway is defined. Without this focus, portfolios may fail to deliver meaningful reductions in time, diminishing their contribution to mitigating global warming. This calls for a more rigorous approach to ensure that decarbonization efforts are both timely and effective (Wade and Rekker 2020).

However, the implementation of the proposed measures could face challenges. Resistance may arise from investors and regulators. Moreover, while aligning investment strategies with absolute GHG emission reductions is a necessary step, it is not a universal remedy. Capital market incentives alone may not be enough to drive structural emissions reductions (Basse Mama and Mandaroux 2022; Talwar et al. 2025), especially in high emitting sectors where divestment strategies may simply shift capital (Kahn et al. 2024) rather than foster actual emissions reductions.

To ensure that financial markets effectively contribute to climate mitigation, the EU's current equity benchmark framework may need to be revised or at least accompanied by further guidance. The EU's current fixed income budget already prioritizes absolute emissions. The equity benchmark could simply follow their lead.

6 | Conclusion

This study demonstrates that reliance on relative CI metrics can lead to substantial inconsistencies when evaluated against absolute GHG emissions. We show that portfolios compliant with current climate benchmark standards, which are defined in terms of CI reduction, may still exhibit excessively high absolute GHG emissions at inception and along the decarbonization pathway.

To address this misalignment, we propose the use of the IAF and the integration of absolute GHG emission constraints at portfolio inception. Together, these measures enhance the

consistency, credibility, and environmental relevance of net-zero investment strategies.

Our findings highlight the importance of aligning financial decarbonization metrics with real-economy emissions. Strengthening the treatment of absolute GHG emissions at portfolio inception is essential to ensure that climate-oriented equity investment products deliver meaningful contributions to global decarbonization objectives.

Author Contributions

Andreas G. F. Hoepner: conceptualization, visualization, methodology, writing – review and editing. **Stefan Jacob:** writing – original draft, visualization, investigation, conceptualization, methodology, data curation, validation. **Sarah Koch:** writing – original draft, visualization, investigation, conceptualization, methodology, data curation, validation. **Marco Wilkens:** conceptualization, methodology, visualization, writing – review and editing. **Jonas Zink:** formal analysis, methodology, writing – review and editing, software.

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Endnotes

¹ Notably, some weights are set to zero due to exclusion criteria, while the weights of the remaining companies are scaled up to 100%.

² Reported values are rounded; underlying calculations use unrounded data.

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