Investing in a Warming World

How Market-Driven Valuation Effects Can Impact Portfolio Decarbonization

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Executive Summary

Popular carbon metrics, such as carbon footprint, applied to benchmark indices give the impression of significant decarbonization by publicly traded companies. In fact, most of that reduction stems from the bull equity market of the last two decades, rather than from reductions in underlying carbon emissions. While these carbon measures are useful for comparison between portfolios and asset classes, at their heart, they are cross-sectional metrics rather than time-series measures. As a result, they can overstate progress when used in isolation for portfolio decarbonization over time and should be understood as measures of relative carbon exposure. In contrast, financed emissions provide a more direct link to real-world outcomes. Used together, these measures can provide a more complete picture of climate-related portfolio outcomes for climate-aware investors than any metric in isolation.

Climate-aware asset owners should consider these insights to the extent relevant when formulating their climate change mitigation objectives. Financed emissions across aggregate holdings can provide a useful high-level indicator of the emissions associated with investments, although changes in financed emissions should be interpreted in light of portfolio growth and capital flows. Absolute decarbonization pathways, such as those based on the EU Climate Transition Benchmarks (EU CTBs) and EU Paris-Aligned Benchmarks (EU PABs), have the ability to deliver strong carbon improvements initially but remain highly sensitive to large market fluctuations. A more robust approach is to adopt benchmark-relative strategies, which maintain a persistent reduction in carbon exposure while naturally adjusting to changing market conditions, making them a cleaner measure of active carbon exposure. For investors seeking to go further (whether in the reduction of their portfolios' economic exposure to carbon or in exerting influence via cost of capital effects), equity extension portfolios offer a direct way to achieve zero net carbon while preserving market exposure.

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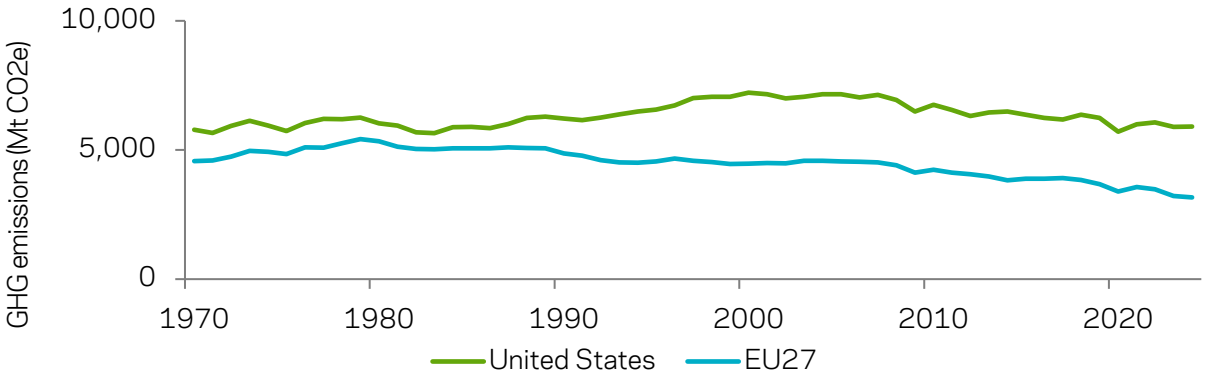
Introduction

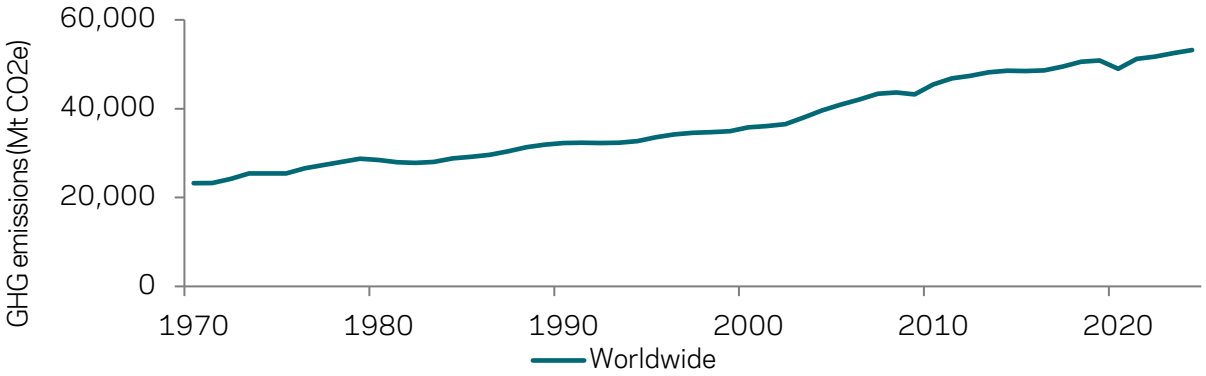
Climate change is seen by many as a systemic risk factor in the financial system with potentially irreversible consequences (NGFS, 2025). Some governments have responded to this risk through decarbonization policies and emissions reduction targets, subsidies for green technologies, as well as in some cases, emissions trading systems. These interventions seem to have had some impact in developed markets, where emissions have stabilized or even modestly declined, e.g., see Figure 1(a). However, these efforts have been uneven in scope, timing, and enforcement, and, as shown in Figure 1(b), appear to have had little impact on worldwide emissions. It would appear that decarbonization efforts remain insufficient to meaningfully limit global warming (Climate Action Tracker, 2026).

Figure 1(a) Regional Annual GHG Emissions
1970 – 2024



Source: AQR, Crippa, et al., 2025. EU27 indicates the current 27 European Union member states.

Figure 1(b) Worldwide Annual GHG Emissions
1970 – 2024



Source: AQR, Crippa, et al., 2025.

Some institutional investors aim to bridge the gap between climate ambition and real-world outcomes by seeking to decarbonize their own investments and portfolios. The underlying theory of change is that capital allocation influences firms' cost of capital. By directing capital towards lower-carbon firms and away from higher-carbon firms, investors may lower financing costs for the former while increasing them for the latter. In turn, because

investor demand in both primary and secondary markets affects asset prices and firms' financing conditions, these shifts in capital allocation can incentivize lower-carbon economic activity and help mitigate climate change (Pedersen, 2026). Strategies to achieve this can take many forms, including targeted investment into low carbon technologies, engagement with portfolio companies, exclusion of specific sectors and/ or high emitters, as well as portfolio-level carbon tilts. Depending on the type of investment and portfolio, a different combination of these strategies might be appropriate. Targeted investment and meaningful engagement are mostly used in the context of concentrated portfolios, while exclusions and tilts are most common when looking at well-diversified portfolios. Here, we examine carbon tilts as well as the metrics used to construct them, as these also serve as key tools for measuring and reporting decarbonization progress at the entity and portfolio level.

Carbon Metrics

When aiming to mitigate climate change, only overall real-world GHG emissions matter. For investors interested in this, the most relevant absolute carbon metric is financed emissions, which is a measure of how much emissions are attributed to the portfolio based on its underlying holdings. This metric is straightforward to calculate as financed emissions of an individual holding are that holding's emissions multiplied by the ownership share:[1]

$$Financed\ emissions = \sum_{i}^{n} \left(\frac{value\ of\ investment_i}{market\ capitalization_i} \times GHG\ emissions_i\right)$$

In principle, this provides a direct link between portfolio holdings and real-world emissions. However, in practical terms, there are drawbacks to the use of this metric as a portfolio management tool. Asset owners usually invest via several managers into multiple portfolios across a range of asset classes, making comparisons between portfolios of different sizes, benchmarks, or asset classes challenging. Similarly, these consistency issues complicate target setting for carbon reductions. Lastly, financed emissions are affected by capital flows, e.g., an inflow into a portfolio would cause the portfolio's financed emissions to rise simply because the ownership shares have grown.

As a result, investors more frequently use relative carbon metrics for portfolio management and reporting. Broadly speaking, the relevant metrics fall into two categories depending on how emissions are normalized: by portfolio value or by revenue. Carbon footprint scales financed emissions by portfolio value to capture emissions owned per million dollars invested:

$$Carbon\ footprint = \frac{\sum_{i}^{n}\left(\frac{value\ of\ investment_i}{market\ capitalization_i} \times\ GHG\ emissions_i\right)}{portfolio\ value}$$

[1] The financed emissions formula presented here applies to public equities and uses market capitalization to determine the ownership share. Alternative formulations exist that use other measures of firm value, such as enterprise value including cash (EVIC), as the denominator. The same consideration applies to the other emissions-related metrics discussed here that rely on market capitalization. We focus on Scope 1 and Scope 2 emissions because reported data for these emissions categories are more widely available and generally of higher quality. While Scope 3 emissions can also be incorporated, doing so does not alter the underlying mechanics of the calculations examined in this analysis.

Carbon intensity scales financed emissions by owned revenue to capture emissions relative to economic output:

$$Carbon\ intensity = \frac{\sum_i^n (\frac{value\ of\ investment_i}{market\ capitalization_i} \times GHG\ emissions_i)}{\sum_i^n (\frac{value\ of\ investment_i}{market\ capitalization_i} \times revenue_i)}$$

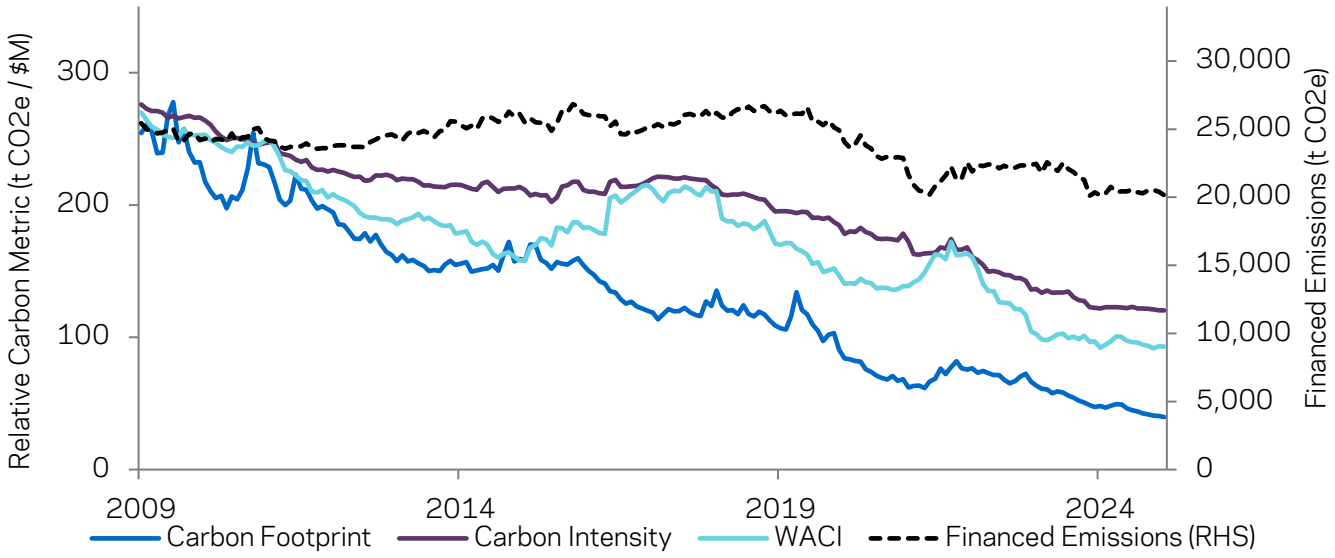
A widely used variation of carbon intensity, weighted average carbon intensity (WACI), integrates both portfolio value and revenue:

$$WACI = \sum_i^n (\frac{value\ of\ investment_i}{portfolio\ value} \times \frac{GHG\ emissions_i}{revenue_i})$$

Regardless of their specific construction, all of these metrics effectively aim at assessing the carbon efficiency of a portfolio rather than measuring the total level of GHG emissions associated with it.

In a fully decarbonized portfolio, financed emissions, carbon footprint, carbon intensity, and WACI all converge to zero. At first glance, this suggests a consistent relationship between these portfolio-level metrics and real-world emissions reductions. However, this consistency holds only in the limit. In practice, relative metrics can decline even when financed emissions remain unchanged, or even increase, due to factors unrelated to actual emissions reductions, such as changes in market valuations. We can get a glimpse of this when comparing how these metrics have developed in the real world, as shown in Figure 2.

Figure 2: Relative Carbon Metrics and Financed Emissions of MSCI World Index
December 31, 2009 – December 31, 2025



Source: AQR, MSCI, S&P Trucost. Relative Carbon Metrics represent (t CO2e / $M) and Financed Emissions represent (t CO2e). Financed emissions calculation assumes initial portfolio value of $100M.

Over a 16-year period from December 2009 to December 2025, the MSCI World Index achieved substantial reductions in the three relative carbon metrics, ranging from 56% for carbon intensity to 84% for carbon footprint. In contrast, financed emissions declined by only 21% over the same period.[2] This observation underscores the disconnect between the goals of "improving portfolio-level metrics" and "improving real world outcomes." It also raises an important question: which metric should climate-aware investors use to guide their investment decisions? Without a clear answer, such investors risk optimizing for reported portfolio metrics rather than real-world outcomes. Simply tilting portfolios toward low-carbon assets may improve relative carbon measures yet have limited impact on real-world emissions. Moreover, such tilts may introduce uncompensated active risk, potentially reducing portfolio efficiency without delivering the intended environmental benefits.

Carbon Metric Decomposition

To better understand what is driving this disconnect, we decompose the metrics into their underlying components. Taking carbon footprint as an example, it can be expressed as a function of portfolio weights, company-level emissions, and market capitalization:

$$Carbon\ footprint = \sum_i^n \frac{(\frac{value\ of\ investment_i}{market\ capitalization_i} \times GHG\ emissions_i)}{portfolio\ value}$$

$$= \sum_i^n (\frac{value\ of\ investment_i}{portfolio\ value} \times \frac{GHG\ emissions_i}{market\ capitalization_i})$$

$$= \sum_i^n (portfolio\ weight_i \times \frac{GHG\ emissions_i}{market\ capitalization_i})$$

This allows changes to be broken down into three primary effects by varying only one component (denoted by delta) at a time:

1. A **weight effect,** capturing shifts in portfolio allocations toward more or less carbon-intensive firms.

$$\sum_i^n (portfolio\ weight_{i,\Delta} \times \frac{GHG\ emissions_{i,t=0}}{market\ capitalization_{i,t=0}})$$

2. A **carbon effect,** reflecting changes in firms' underlying emissions.

$$\sum_i^n (portfolio\ weight_{i,t=0} \times \frac{GHG\ emissions_{i,\Delta}}{market\ capitalization_{i,t=0}})$$

3. A **market capitalization effect,** which arises from changes in valuations.

$$\sum_i^n (portfolio\ weight_{i,t=0} \times \frac{GHG\ emissions_{i,t=0}}{market\ capitalization_{i,\Delta}})$$

[2] The reduction in financed emissions mirrors the reduction of emissions in the EU27 shown in Figure 1(a) but is substantially faster than the corresponding reduction in US emissions. This is unsurprising given that financed emissions are measured only for publicly listed companies in the MSCI World Index, whereas Figure 1 reflects economy-wide emissions, including privately held businesses and household activities such as private vehicle use. As a result, financed emissions can change at a different rate than aggregate national emissions.

Stocks entering and exiting the portfolio create an additional composition effect, further complicating the interpretation. To limit this complication, we can instead carry out the decomposition at the level of sectors. Such an approach simply "buries" the composition effect inside the sector groups, since a given sector's emissions and market capitalization may change due to changes in the stocks that comprise it.

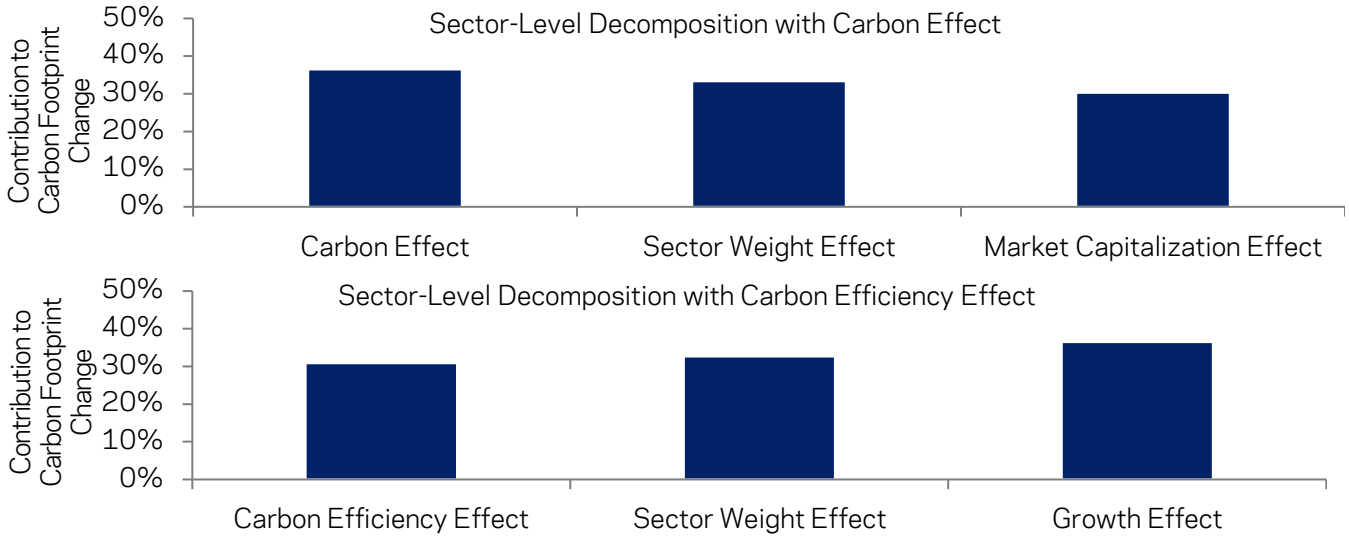
We can adjust the "carbon effect" by incorporating revenue to account for business expansion beyond market capitalization. This is important if investors don't want to penalize companies where increases in emissions are solely the result of an increase in output. Making this adjustment reveals an alternative carbon efficiency effect, capturing improvements in emissions per unit of economic output:

$$\sum_{s}^{n}(sector\ weight_{s,t=0} \times \frac{GHG\ emissions_{s,\Delta}}{revenue_{s,\Delta}} \times \frac{revenue_{s,t=0}}{market\ capitalization_{s,t=0}})$$

While the carbon effect reflects changes in absolute emissions, improvements in carbon efficiency may arise even when firms continue to expand and increase absolute emissions. Consequently, improvements in carbon efficiency should be interpreted as evidence of decarbonization relative to output (as measured by revenue) rather than absolute decarbonization.

As shown in Figure 3, we find empirically that, looking at the sector-level decomposition and ignoring interaction effects,[3] the carbon and carbon efficiency effects account for only about one-third of the observed carbon footprint reduction.[4] That is to say that around two-thirds of carbon footprint reduction for the MSCI World Index is due to changes in sector weights and changes in valuations – not decarbonization.

Figure 3: Sector-Level Decomposition of Carbon Footprint of MSCI World Index
December 31, 2009 – December 31, 2025



Source: AQR, MSCI, S&P Trucost.

[3] The decomposition generates interaction effects that arise from simultaneous changes in multiple individual effects. These interaction effects are allocated proportionally across the main three decomposition components.

[4] For the period between 12/31/2009 and 12/31/2025, we find that – for the MSCI World – between 31% and 36% of the total change in carbon footprint is due to changes in carbon and carbon efficiency respectively when looking at sector-level decomposition and ignoring interaction effects. When looking at company-level decomposition, and also ignoring constituent effects, this increases slightly to 39% and 43% respectively.

Furthermore, the changing sector composition of the index provides a useful illustration of a hidden market capitalization effect. From 2009 to 2025 the weight of the Information Technology sector in the MSCI World Index more than doubled from around 12% to around 27%, while the emissions-intensive sectors like Energy, Materials, and Utilities declined from around 23% collectively to around 9%. These changes coincide with substantial differences in sector-level carbon emissions and contribute meaningfully to the observed decline in carbon footprint. However, because sector weights in a capitalization-weighted index are themselves determined by market values, these shifts are better interpreted as manifestations of the market capitalization effect than as an independent source of decarbonization. Even if one grants that Information Technology is more carbon-efficient than the more emissions-intensive sectors, this is still largely a valuation effect. With this in mind, we can attribute around two-thirds of carbon footprint reduction to changes in company valuations over the period, and only around one-third to genuine reductions in emissions and emissions intensity. We decompose this valuation effect in the next section.

Rising Valuations Affect Carbon Metrics

Carbon footprint scales emissions by market capitalization. As a result, rising valuations mechanically reduce carbon footprint even in the absence of decreases in the underlying emissions. However, this also translates into increases in portfolio value, effectively offsetting the reduced carbon footprint when looking at financed emissions. To illustrate this, let us consider a simple example of a one-holding portfolio for illustrative purposes:

Year 0: Baseline
10% ownership of ExampleCorp with market cap of $1M and 100t of CO2e emissions
- Portfolio value: $100k
- Financed emissions: 10% * 100t CO2e = 10t CO2e
- Carbon footprint: 10t CO2e / $100k = 100t CO2e / $M

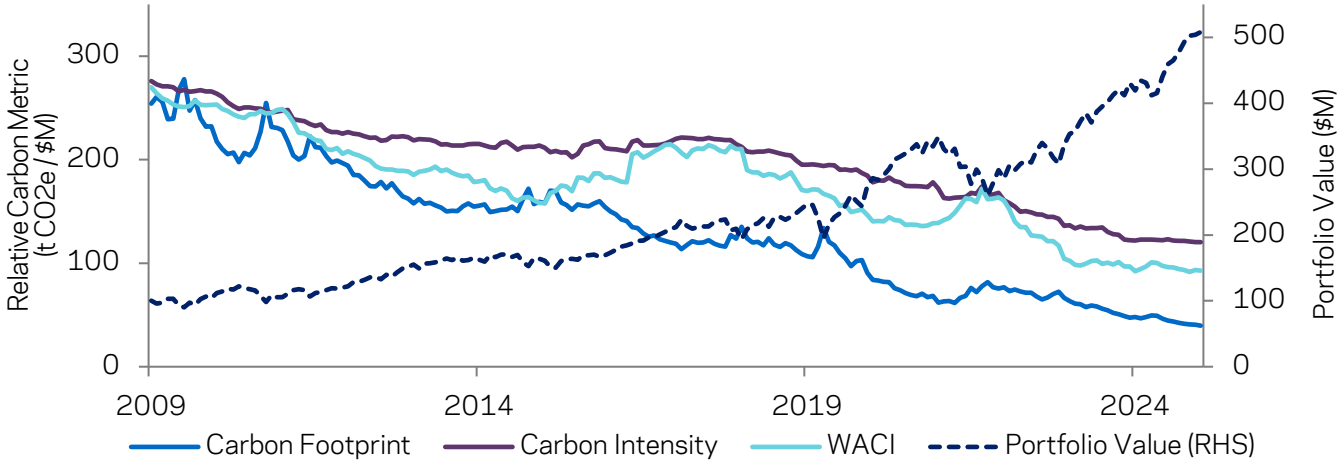
Year 1: ExampleCorp's market value doubles while their production and emissions stay the same
10% ownership of ExampleCorp with market cap of $2M and 100t of CO2e emissions
- Portfolio value: $200k
- Financed emissions: 10% * 100t CO2e = 10t CO2e
- Carbon footprint: 10t CO2e / $200k = 50t CO2e / $M

While nothing has changed in terms of ExampleCorp's CO2e emissions, the portfolio's carbon footprint has been cut in half purely because of the increased valuation.

Source: AQR. For illustrative purposes only.

In other words, as equity markets appreciate, investors appear to "own" fewer emissions per unit of capital (e.g., per $M)", even without corresponding improvement in real-world outcomes. This creates the impression of successful decarbonization at the portfolio level, while in reality a substantial part of the effect might be driven by financial market performance rather than reductions in corporate emissions. With this in mind, it should come as no surprise that there is a very high negative correlation (~-0.9) between the three relative carbon metrics and portfolio value, as shown in Figure 4.

Figure 4: Relative Carbon Metrics and Portfolio Value of MSCI World Index
December 31, 2009 – December 31, 2025



Source: AQR, MSCI, S&P Trucost. Relative Carbon Metrics represent (t CO2e / $M) and Portfolio Value represents ($M). Portfolio value calculation assumes initial portfolio value of $100M.

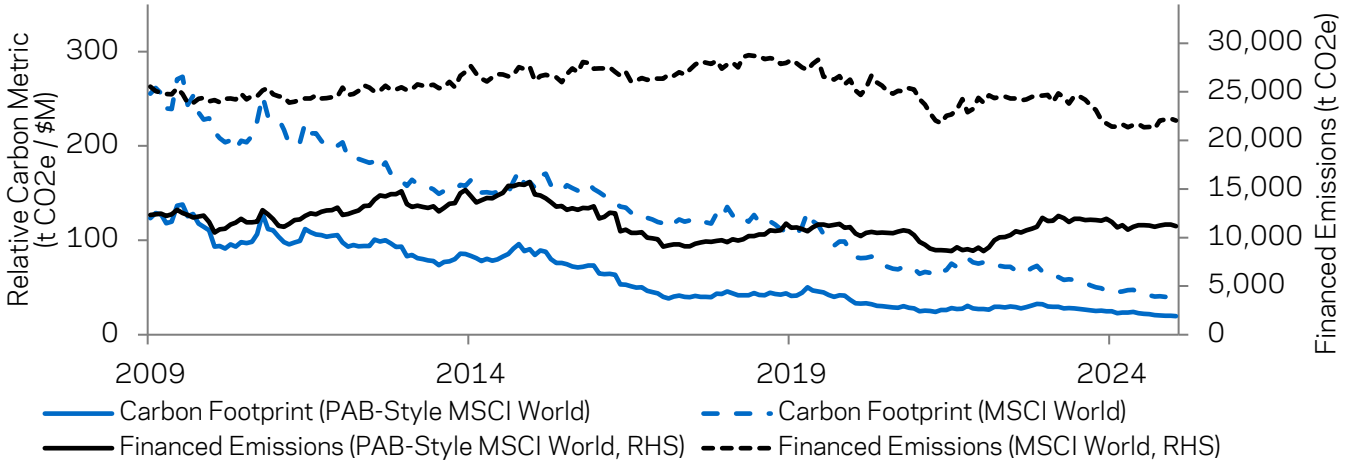
It is important to note that this effect goes beyond mere impacts of inflation, as equity market returns may significantly outpace inflation; inflation-adjusted carbon measures still show a much higher correlation to portfolio value than to financed emissions.

Implications for Carbon-Aware Portfolios

We have established that rising valuations have a meaningful impact on popular carbon metrics, specifically causing these popular metrics to drop. This result raises the question of how climate-aware investors should approach efforts to decarbonize their portfolios in a way that most closely aligns with real-world outcomes.

One common framework is to follow decarbonization pathways with fixed percentage reductions, such as those implemented in the EU Climate Transition Benchmarks (CTB) and Paris-Aligned Benchmarks (PAB). These benchmarks impose an initial reduction of 30% and 50% respectively relative to the benchmark and a further 7% year-over-year reduction. We illustrate how the carbon footprint and financed emissions metrics of such portfolios would evolve over time in Figure 5.

Figure 5: Carbon Footprint and Financed Emissions of MSCI World Index and PAB-Style MSCI World Portfolios
December 31, 2009 – December 31, 2025

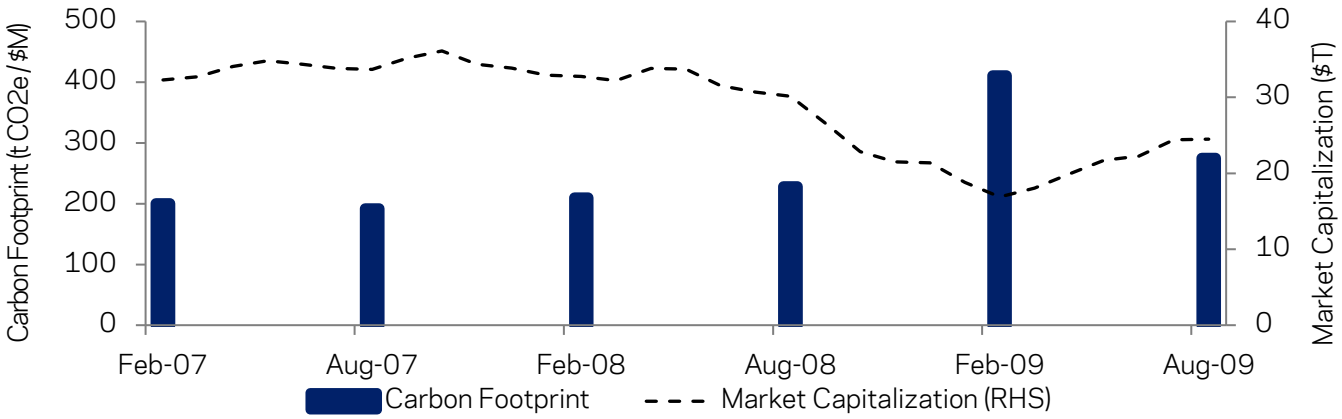


Source: AQR, MSCI, S&P Trucost. Carbon Footprint represents (t CO2e / $M) and Financed Emissions represent (t CO2e). Financed emissions calculation assumes initial portfolio value of $100M. The Hypothetical PAB-Style MSCI World seeks to minimize tracking error relative to the MSCI World Index, subject to constraints on three portfolio-level carbon metrics: carbon footprint, carbon intensity, and weighted-average carbon intensity. For each metric, the portfolio targets an initial reduction of 50% relative to the MSCI World Index as of December 31, 2009. The required reduction then increases by 7% per year on a compounded basis, consistent with the decarbonization trajectory used for EU Paris-Aligned Benchmarks. The portfolio is rebalanced monthly, with the applicable carbon-reduction target updated annually at year-end. Hypothetical performance results are presented for illustrative purposes only. Please read the information in the Disclosure for a description of the investment universe and the allocation methodology used to construct the Hypothetical PAB-Style MSCI World backtest. Hypothetical data has certain inherent limitations, some of which are disclosed in the Appendix hereto.

At first glance, the PAB-style version of the MSCI World looks like a success, with a significant reduction in carbon footprint of ~92% (other relative carbon metrics not shown in Figure 5 showed similar declines: ~79% reduction in carbon intensity, and ~85% reduction in WACI). However, this portfolio showed only a ~56% reduction in financed emissions. This indicates that the majority of this improvement is driven by the initial 50% step-down at portfolio inception, while the subsequent declines are largely attributable to the valuation effects discussed above rather than to sustained reductions in company emissions. As a result, if a reduction pathway with fixed percentage reductions is used, the required year-over-year reduction in these types of dollar-scaled metrics needs to be set sufficiently high, in order to keep pace with equity market appreciation, and to thereby guarantee meaningful reductions in the portfolio's financed emissions. Depending on the carbon target and reference point, this could mean annual reductions of 10% or more.

There is one additional complication: in the event of a severe market downturn, falling market valuations can lead to an abrupt increase in a portfolio's carbon footprint. Consider the Global Financial Crisis of 2008 which saw the MSCI World's aggregate market capitalization drop by over 50% peak-through-trough. During such an event the drop in market capitalization would cause a substantial, and mechanical, increase in the measured carbon footprint of the portfolio. As illustrated in Figure 6, with carbon emissions held constant, a replay of the market capitalization decline of 2008 would cause a doubling of the measured carbon footprint of a global market capitalization-weighted equity portfolio at the market low.

Figure 6: Carbon Footprint and Market Capitalization of MSCI World Index during 2008 Global Financial Crisis
February 28, 2007 – August 31, 2009



Source: AQR, MSCI, S&P Trucost. Carbon Footprint represents (t CO2e / $M) and Market Capitalization represents ($T). Holdings data from 12/31/2007 to 08/31/2009 with carbon data as of 05/31/2009 due to data availability.

Maintaining a fixed-path decarbonization in an environment where equity markets crash, and the benchmark doubles its carbon footprint purely as a result of these price moves, would force the portfolio manager to make severe, potentially return-degrading adjustments to the portfolio, at a time when returns are already poor. Likewise, as the IT sector's emissions increase due to increased energy usage for data centers, it is not guaranteed that major benchmarks keep on showing decreases in carbon footprint going forward. This means that, while portfolio carbon footprint may be useful for reporting, using decarbonization pathways with fixed year-over-year reductions may not be the optimal choice from a portfolio management point of view for climate-aware investors.

In contrast, a simpler benchmark-relative approach, that is maintaining a persistent reduction in carbon exposure relative to the benchmark, implicitly adjusts for changes in market capitalization –both up and down– and avoids relying on mechanically declining targets. Empirically, such approaches can achieve comparable reductions in financed emissions with less reliance on path-dependent constraints.

If zero-net economic exposure to carbon is the objective, another way to address these challenges is to move beyond long-only implementations and to consider equity extension implementations. In such portfolios, investors maintain a beta of one to the benchmark but introduce a modest amount of leverage alongside an offsetting short book. This set-up allows investors to short high-emission firms rather than merely divesting from them. As a result, the portfolio can be constructed to have zero-net carbon exposure, while simultaneously preserving the risk and return characteristics of a comparable long-only portfolio, including full market exposure.

Beyond portfolio construction benefits, shorting may also strengthen the potential real-world impact of sustainable investing. If investor demand affects asset prices and firms' cost of capital, then selling or shorting high-emission firms can increase their financing costs by putting pressure on security prices (Jones, Mendelson, & Pomorski, 2023; Asness, Shorting Counts, 2022). Shorting therefore provides a potentially powerful complement to divestment-based approaches because it allows investors to express negative views directly rather than merely abstaining from ownership (Asness, Shorting Your Way to a Greener Tomorrow, 2021). From this perspective, long-short implementations can provide a more direct mechanism for reducing economic exposure to carbon while potentially amplifying the channels through which capital markets influence real-world outcomes.

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Broad-based securities indices are unmanaged and are not subject to fees and expenses typically associated with managed accounts or investment funds. Investments cannot be made directly in an index.

The MSCI World Index is a free float-adjusted market capitalization weighted index that is designed to measure the equity market performance of developed markets.

The Hypothetical PAB-Style MSCI World seeks to minimize tracking error relative to the MSCI World Index, subject to constraints on three portfolio-level carbon metrics: carbon footprint, carbon intensity, and weighted-average carbon intensity. For each metric, the portfolio targets an initial reduction of 50% relative to the MSCI World Index as of December 31, 2009. The required reduction then increases by 7% per year on a compounded basis, consistent with the decarbonization trajectory used for EU Paris-Aligned Benchmarks. The portfolio is rebalanced monthly, with the applicable carbon-reduction target updated annually at year-end, ending at December 31, 2025.

HYPOTHETICAL PERFORMANCE RESULTS HAVE MANY INHERENT LIMITATIONS, SOME OF WHICH ARE DESCRIBED BELOW. NO REPRESENTATION IS BEING MADE THAT ANY ACCOUNT WILL OR IS LIKELY TO ACHIEVE PROFITS OR LOSSES SIMILAR TO THOSE SHOWN. IN FACT, THERE ARE FREQUENTLY SHARP DIFFERENCES BETWEEN HYPOTHETICAL PERFORMANCE RESULTS AND THE ACTUAL RESULTS SUBSEQUENTLY ACHIEVED BY ANY PARTICULAR TRADING PROGRAM.

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