Factored In:

Carbon Reduction and Active Exposure in U.S. Equity Portfolios

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Reducing an equity portfolio's exposure to carbon emissions is an increasingly common investor goal. Doing so requires many decisions, including how and where to take active risk relative to a benchmark. In this paper, we examine emissions concentration, style factor exposure, and portfolio construction as key elements in that decision-making process. We argue that a thoughtful approach to these elements can help investors reduce unwanted active risk and factor exposure, freeing risk budget to add value beyond carbon reduction objectives.

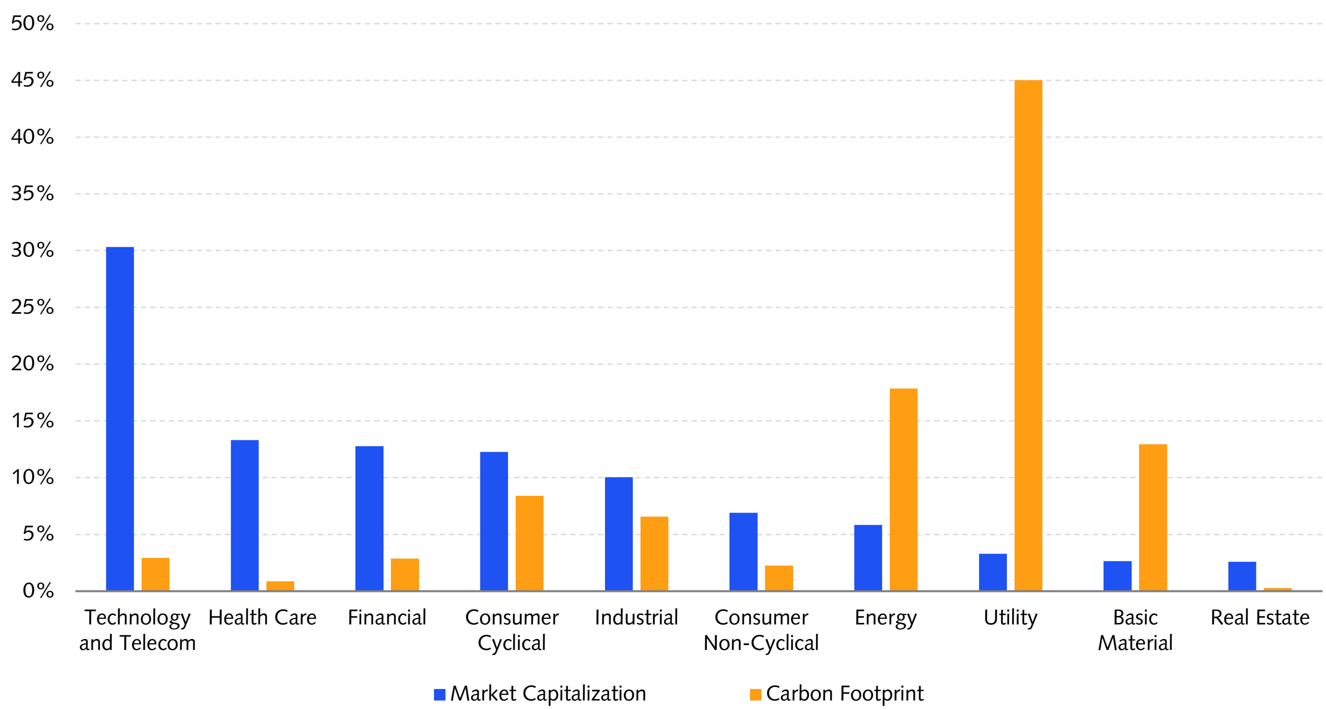
A preliminary step when seeking to reduce a portfolio's carbon exposure involves deciding how to quantify carbon emissions. In this paper, we focus on one common carbon metric: carbon footprint. This measure divides a company's metric tons of carbon dioxide-equivalent emissions (tCO_2e) by its market capitalization.[1]

Carbon Emissions Concentration

Some sectors are "cleaner" than others, and the distribution of carbon emissions across sectors differs markedly from the distribution of market capitalization. *Figure 1* presents carbon footprint and market capitalization data for Russell 1000® Index sectors from 2013 through 2022 (in descending order by market capitalization, with the largest sector on the left).

As can be seen, emissions are concentrated in a handful of relatively small sectors. This presents a potential opportunity to substantially reduce exposure to carbon emissions by underweighting or omitting entirely, for instance, the utility or energy sector. But that approach may not align with an investor's economic objectives or investment policy, and can also lead to

Figure 1: Average Proportion of Russell 1000® Index Market Capitalization and Contribution to Index Carbon Footprint by Sector
1/1/2013 – 12/31/2022



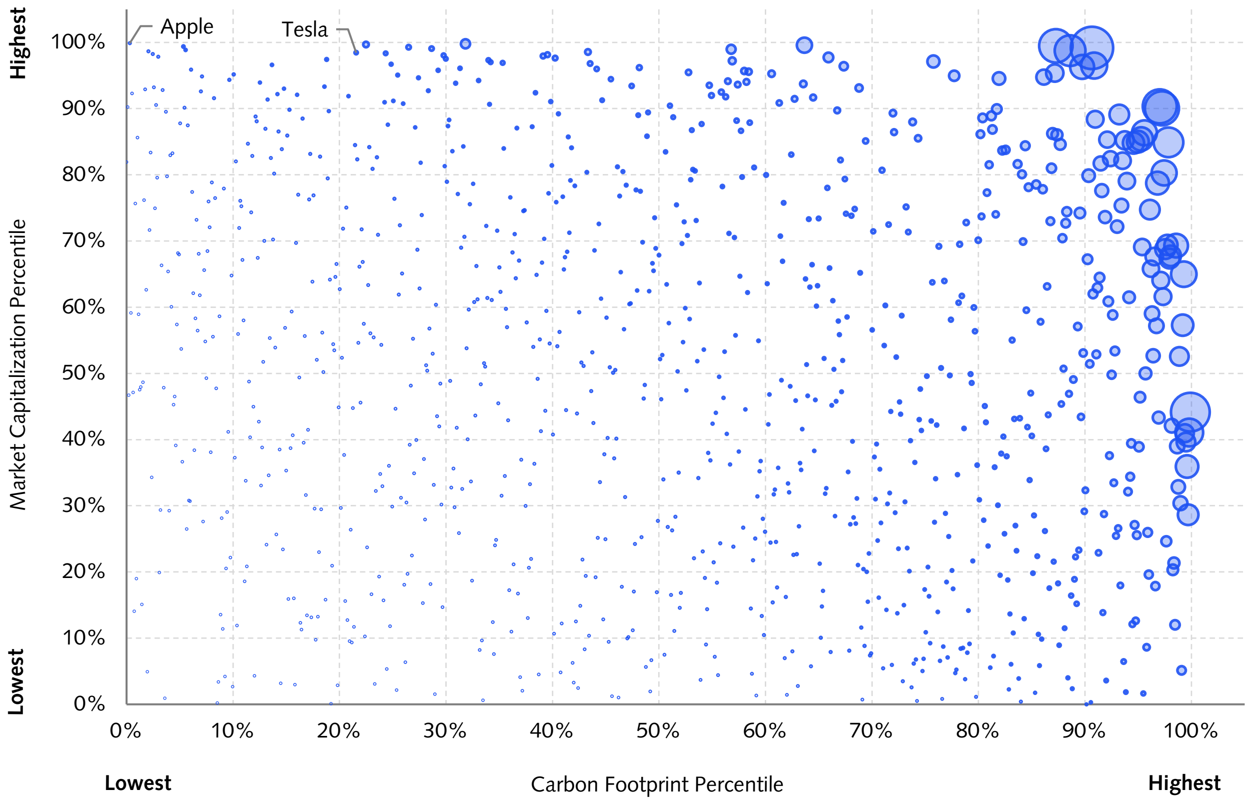
Sources: London Stock Exchange Group; MSCI; the D. E. Shaw group. All sector classifications reflected above are proprietary classifications developed by the D. E. Shaw group. Sector contributions to weighted average carbon footprint for sector S *and benchmark* B *are calculated as* $(\Sigma_{i \in S} w_i CF_i)/(\Sigma_{i \in B} w_i CF_i)$, *where* w_i *is the benchmark weight of company* i, *and* CF_i *is its carbon footprint.*

[1] An alternative emissions metric, "carbon intensity," divides a company's tCO_2e by its sales. Although beyond the scope of this paper to discuss, metric selection can impact a portfolio's decarbonization objectives and outcomes. In practice, robust decarbonization approaches may benefit from using both carbon metrics and carefully analyzing and understanding the tradeoffs they present.

taking active risk. Consider the example of the energy sector, which returned 64.36% in 2022 compared to -19.13% for the Russell 1000® Index as a whole—even a moderate underweight position in the sector might have had meaningful return implications. The same logic holds when investors contemplate applying overweights to relatively clean sectors like technology and telecom or health care.

Similarly, there is significant concentration of emissions at the individual stock level. *Figure 2* plots each constituent in the Russell 1000® Index by relative size and carbon footprint. The size of each bubble represents the stock's contribution to the index's total carbon footprint (the product of its index weight and carbon footprint).

Figure 2: Russell 1000® Index Constituents by Market Capitalization and Carbon Footprint, with Observation Size Scaled to Reflect Contribution to Total Index Carbon Footprint
As of 12/31/2022



Sources: London Stock Exchange Group; MSCI; the D. E. Shaw group.

We see that the size of the bubbles increases non-linearly as we approach the right-hand side of the chart, meaning that a relatively small number of companies (the larger bubbles) account for a sizable share of the index's carbon footprint. Conversely, companies at the top left represent a relatively large amount of market capitalization and few emissions. Overweighting the stocks of those large cap firms might materially reduce measured carbon emissions, but exposure to concentrated single-stock risk could also have adverse consequences. Consider, for example, Apple Inc. or Tesla Inc., which fell 26.40% and 65.03%, respectively, in 2022.

More generally, to the extent that the relationship between market capitalization and carbon emissions correlates to certain other variables, decisions to actively weight certain stocks have the potential to introduce additional biases, such as industry group effects, even after controlling for sector. For example, carbon emissions are concentrated among a small number of names within the consumer cyclical sector, but simply reducing or omitting those names would lead to a large underweight of the airline industry group as compared to other industry groups in the sector.

There are also tradeoffs to consider regarding portfolio sensitivity to emissions data estimates. Because a given company's emissions data are estimated by either a data provider or the company itself, an investor seeking to exploit concentration when targeting reductions in emissions exposure might place too much confidence in a small number of estimates. This creates the potential for a "single point of failure" problem if revisions are made to estimated data.

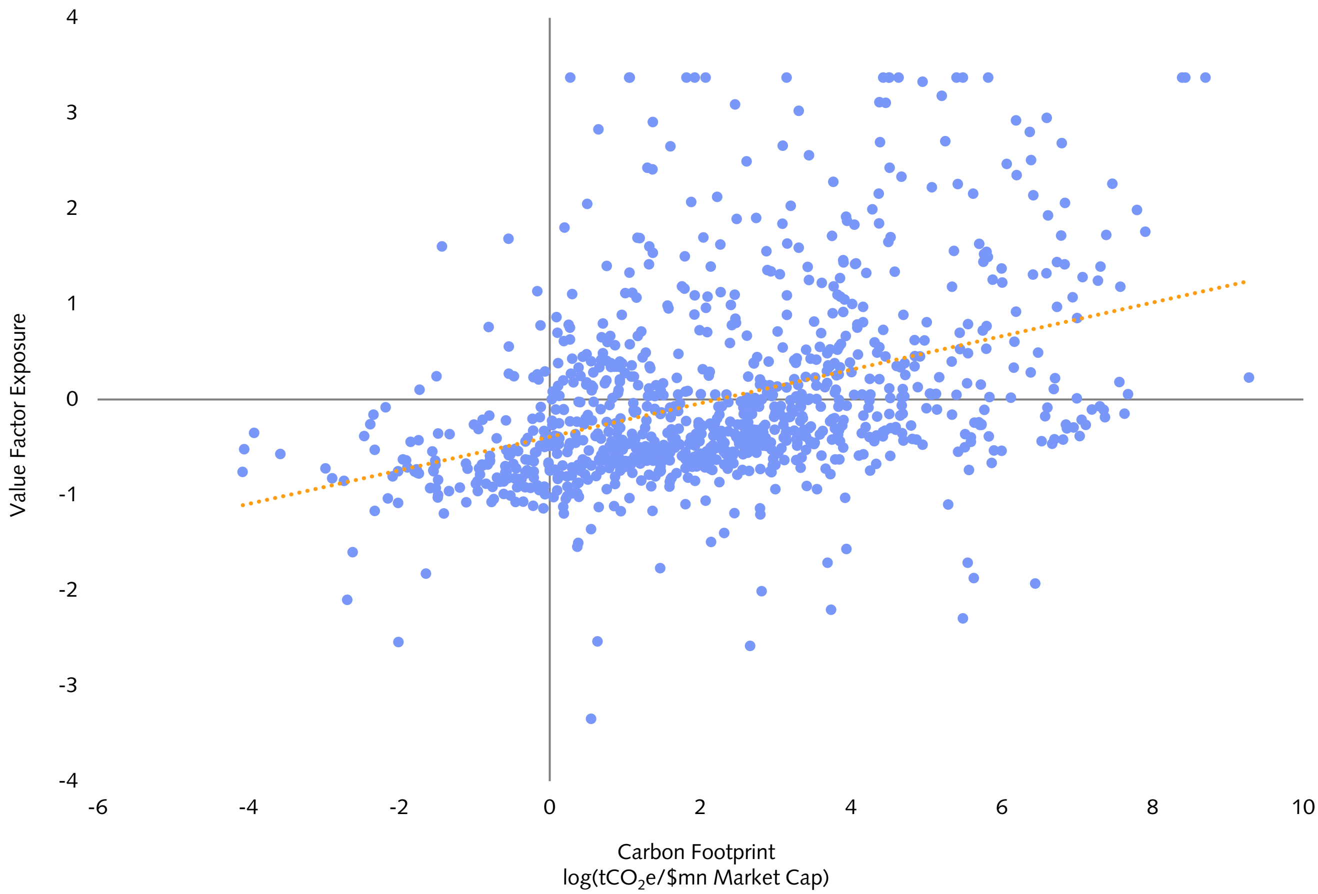
Carbon emissions concentration, therefore, presents both opportunity and risk in the form of economic and portfolio exposure tradeoffs. We believe that thoughtful portfolio and risk management, discussed later in this paper, can lead to more robust outcomes in light of these considerations.

Style Factor Exposure

A second and perhaps less well understood aspect to consider in reducing a portfolio's measured carbon emissions centers on exposure to traditional equity style factors. As one illustration, *Figure 3* shows the value factor exposure (y-axis) and carbon footprint (x-axis) of each Russell 1000® Index constituent as of year-end 2022.

The data indicate that value exposure is positively related to carbon footprint with a high degree of statistical significance (t-stat = 13.68). This makes intuitive sense because value companies tend to have high present-day levels of physical

Figure 3: Value Factor Exposure and Carbon Footprint of Russell 1000® Index Constituents
As of 12/31/2022



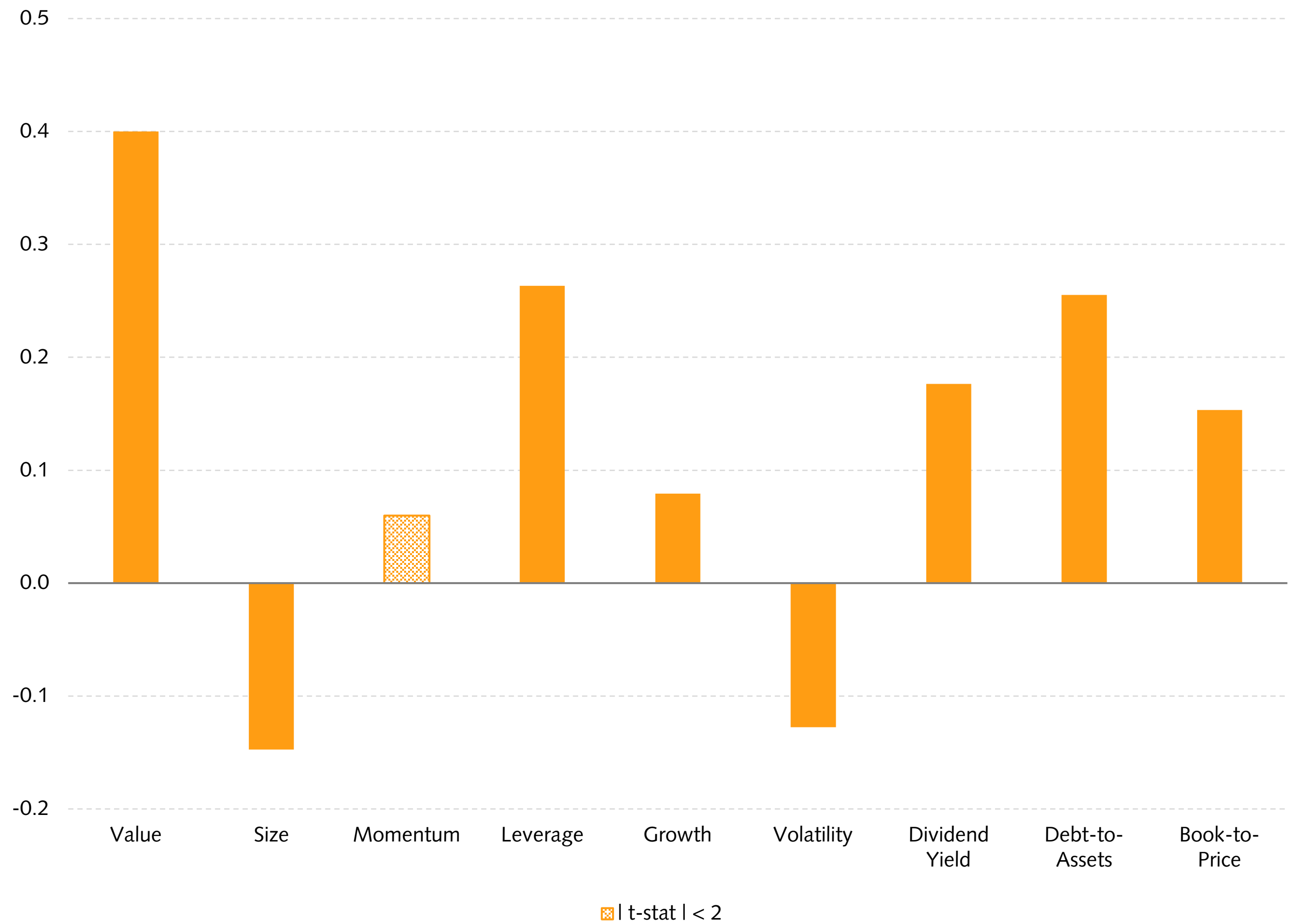
Sources: London Stock Exchange Group; MSCI; the D. E. Shaw group. All measurements of equity style factor exposures referenced in this document are proprietary values developed by the D. E. Shaw group.

assets (*e.g.*, as measured by book value) and fundamental economic activity (*e.g.*, as measured by sales or earnings) relative to their market capitalization, characteristics which correlate positively with high present-day carbon emissions relative to market capitalization.

We separately find that the relationship between value and carbon footprint for the Russell 1000® Index constituents has remained relatively stable since 2013 and holds within many sectors. All else equal, this suggests that an investor seeking to reduce a portfolio's carbon footprint might unknowingly introduce a negative value tilt. The observed stable relationship between value and carbon footprint over the past decade also suggests that relative exposures to value exhibited by many stocks were not heavily influenced by flows into ESG-focused investment products.

The link between a company's carbon emissions and its exposure to equity style risk is not limited to value. *Figure 4* shows the cross-sectional correlations of additional style factor exposures to carbon footprint.

Figure 4: Correlations of Select Factors to Carbon Footprint for the Russell 1000® Index
As of 12/31/2022



Sources: London Stock Exchange Group; MSCI; the D. E. Shaw group. All measurements of equity style factor exposures referenced in this document are proprietary values developed by the D. E. Shaw group. Each factor shown represents the cross-sectional correlation coefficient between factor loading and log(carbon footprint) *for individual companies in the Russell 1000® Index as of December 31, 2022. The carbon footprint units reflected are* log(tCO_2e/$mn). *Factor loadings are normalized z-score values.*

In most cases, the relationships are statistically significant. These correlations indicate that investors seeking to target a reduction in an equity portfolio's carbon footprint could inadvertently introduce negative tilts to a host of style factors in addition to value, as well as positive tilts to size and volatility.

Building on the data from *Figure 2*, *Figure 5* highlights stock-level exposure to the leverage and volatility style factors, showing that many individual stocks with a high carbon footprint also have exposure to certain style factors.

Figure 5: Russell 1000® Index Constituents by Market Capitalization and Carbon Footprint, with Observation Size Scaled to Reflect Contribution to Total Index Carbon Footprint and Highlighting Exposure to the Leverage and Volatility Factors
As of 12/31/2023

Sources: London Stock Exchange Group; MSCI; the D. E. Shaw group. All measurements of equity style factor exposures referenced in this document are proprietary values developed by the D. E. Shaw group.

For example, as shown in *Figure 5*, many high emitters fall within the top quartile of companies with the highest exposure to the leverage factor (orange bubbles, left panel) and within the bottom quartile of exposure to the volatility factor (blue bubbles, right panel). A naïve approach to excluding or underweighting high emitters could therefore lead to unintended exposures to these factors. However, *Figure 5* also reveals several high emitters with more modest exposure to these factors (gray bubbles), as well as a handful with factor exposure at the opposite end of the distribution. Given the variation in both carbon footprint and style factor exposures across stocks, careful portfolio design and construction can target carbon reduction while potentially mitigating inadvertent style factor exposures.

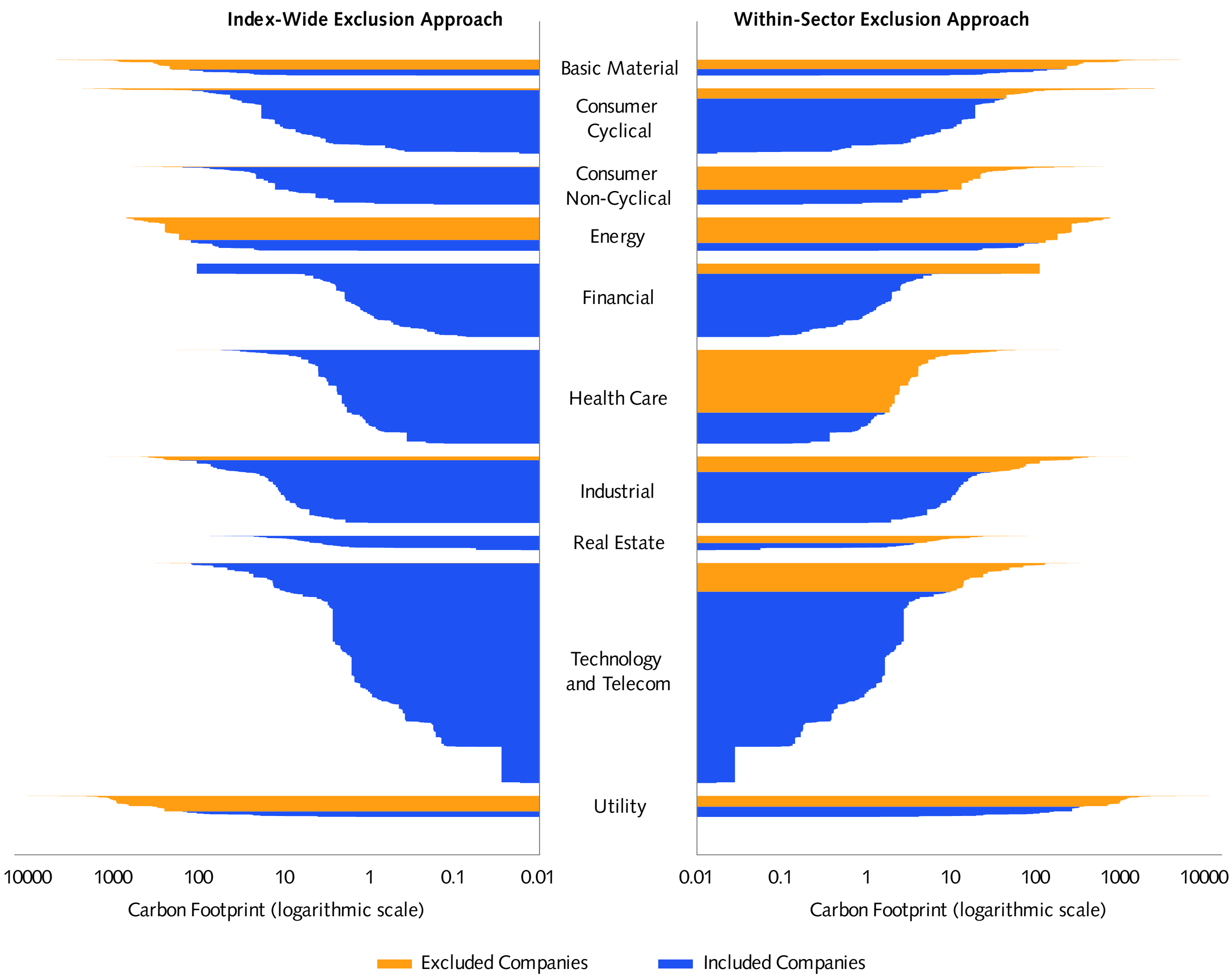
Portfolio Design and Risk Management in Carbon-Aware Investing

In this section, we seek to demonstrate the potential benefits of a carbon-aware portfolio construction approach that reduces exposure to sector and equity style risk. Such an approach can result in lower tracking error and a higher proportion of idiosyncratic risk, creating additional latitude to allocate active risk to other objectives.

Consider the two simplified portfolios depicted in *Figure 6*. Both achieve a 75% reduction in portfolio carbon footprint relative to the Russell 1000® Index but use different approaches to do so.

The "index-wide exclusion approach" depicted in the left panel of *Figure 6* progressively excludes the highest-emitting firms across the entire index until the 75% reduction target is met. As a result, most exclusions occur in sectors with relatively high emissions, such as the energy, utility, and basic material sectors. On the other hand, the "within-sector exclusion approach" depicted in the right panel of *Figure 6* achieves the overall reduction target by excluding high-emitting stocks *within* each sector until each sector's carbon footprint is reduced by 75%.

Figure 6: Index-Wide and Within-Sector Exclusion Approaches to Decarbonization, Russell 1000® Index
As of 12/31/2022



Sources: London Stock Exchange Group; MSCI; the D. E. Shaw group. All sector classifications reflected above are proprietary classifications developed by the D. E. Shaw group. Bar widths are scaled in proportion to a stock's weight in the Russell 1000® Index.

Consistent with our discussion of sector-level emissions concentration around *Figure 1*, the index-wide exclusion approach results in sizable biases across sectors relative to the baseline Russell 1000® Index portfolio. Underweights in high-emitting sectors are offset by corresponding overweights in sectors with few or no exclusions, such as technology and telecom, health care, and financial. Conversely, the within-sector exclusion approach requires a larger number of exclusions, with lower average carbon footprint across excluded companies, leading to substantial active weights to individual stocks within sectors, consistent with our discussion of stock-level emissions concentration around *Figure 2*.

Table 1 compares the *ex ante* tracking error of those two simplified approaches with a "risk-aware optimization approach" that seeks to achieve the same 75% carbon footprint reduction relative to the Russell 1000® Index while aiming to minimize active risk by constraining exposure to a set of risk factors reflecting certain definitions of beta, sector, and industry group risk.

Table 1: *Ex Ante* Annualized Tracking Error to the Russell 1000® Index and Active Risk Decomposition of Each Decarbonization Approach
As of 12/31/2022

Carbon Reduction Approach	Targeted Carbon Reduction Relative to Benchmark	Description	*Ex Ante* Annualized Tracking Error to the Russell 1000® Index	Idiosyncratic Risk as a Percentage of Total Risk
Index-Wide Exclusion	75%	Progressively exclude highest carbon footprint companies across entire index until 75% reduction is met	1.24%	7%
Within-Sector Exclusion	75%	Progressively exclude highest carbon footprint companies within each sector until 75% reduction is met	2.78%	11%
Risk-Aware Optimization	75%	Minimize active risk subject to achieving 75% carbon reduction	0.69%	15%

We see that the risk-aware optimization approach can lead to a substantial reduction in active risk compared to the two simplified exclusion approaches, while achieving the same level of portfolio decarbonization. *Table 1* also presents the results of a decomposition of that active risk to show how much is attributable to idiosyncratic sources rather than sector/industry group and style factors.

While incurring the least total active risk relative to the index, the risk-aware approach also results in the highest proportion of that risk attributable to idiosyncratic exposures, which may be less correlated to other return sources an investor may choose to target. The focus on idiosyncratic risk sources could be enhanced by further penalizing non-idiosyncratic risk, an option not available in the two simplified exclusion approaches. This suggests that taking even limited steps towards increased sophistication in risk management can create additional flexibility to reduce a portfolio's exposure to carbon emissions while simultaneously pursuing other investment objectives.

Conclusion

Making decisions about how to achieve carbon reduction targets in an equity portfolio introduces important tradeoffs and entails taking active risk relative to the parent (non-carbon aware) benchmark. That risk can comprise substantial sector, individual stock, and factor exposures. Carbon emissions concentration relative to sector and stock weights, and correlations between style factors and carbon emissions, are key drivers of that active risk.

Pairing decarbonization objectives with thoughtful risk modeling and portfolio construction can reduce unwanted active risk and help increase the amount of risk attributable to idiosyncratic sources. This in turn presents opportunities to add value to the portfolio in addition to an investor's targeted reduction in carbon emissions exposure.

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