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Reducing Carbon in Equity Portfolios

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- Investors are increasingly building portfolios with explicit carbon-reduction targets, temperature alignment goals, and climate objectives such as mitigation and adaption.
- We construct and back-test five equity portfolios targeting carbon reduction — two using a screening approach, two using a tilting approach, and one using an optimization approach — varying across risk and return dimensions.
- Ultimately, we find that employing optimization for building reduced-carbon portfolios is the preferred approach, as it best balances the multiple objectives investors have that go beyond carbon reduction.

Fossil fuels have been a mainstay of the global economy since the Industrial Revolution, powering economic growth and raising living standards. But growing fears around the threat of man-made climate change, combined with the increasing attractiveness of renewable energy, have led to a paradigm shift that is driving a steady transition toward renewables. Investors are aware of the potential systemic risks climate change poses to the financial system and are increasingly accounting for climate risk in the way they allocate capital and manage risk.[1]

In just the last two years, we have seen a rapid expansion in the ways institutional investors are integrating climate considerations. Where once screening-based or exclusionary approaches were the primary approach, investors are now building portfolios with explicit carbon-reduction targets, temperature alignment goals, and climate objectives such as mitigation and adaption. This trend away from pure divestment of fossil fuels has been aided by advancements in data and risk management as well as portfolio construction tools.

In this paper we focus on how to build portfolios with lower carbon footprints. We discuss different approaches ranging from simple screening to optimization-based portfolio construction. We show the pros and cons of these approaches and how they differ along risk and return dimensions. Ultimately, we find that employing optimization for building reduced-carbon portfolios is the preferred approach, as it best balances the multiple objectives investors have beyond just reducing carbon. In particular, tracking error to the benchmark, which measures the amount of active risk investors have to take on to reduce carbon, is best managed using optimization.

Approaches to Reducing a Portfolio's Carbon Footprint

As we begin this discussion, it is helpful to distinguish between three broad construction approaches that are used to build reduced-carbon:

- **Screened (Rules-Based)** Securities are excluded based on certain criteria — such as what industry they are in or where they derive the majority of their revenue — or because they appear on "blacklists" from government entities or third-party ESG vendors. The remaining securities are typically market-cap-weighted. Traditional ex-fossil fuel portfolios are examples of screened portfolios.

- **Tilted (Rules-Based)** Securities are selected by ranking and sorting based on certain criteria. Security weights can deviate from market-cap weighting and can be set by rules or formulas. For example, securities can be sorted on carbon emissions, with the highest-quartile emitters removed and the remaining securities weighted inversely to their carbon emissions.

- **Optimized (Algorithm-Based)** Security selection and security weighting are determined using an algorithm that is designed to solve a problem (the objective function). For example, the objective function could be set to minimize portfolio tracking error at a certain carbon emissions level.

More details on these approaches for building reduced-carbon portfolios are shown in Figure 1.

Figure 1
Approaches to Building Reduced-Carbon Portfolios

	Rules-Based		Algorithm-Based
	Screened	**Tilted**	**Optimized***
Approach	Securities are excluded based on certain criteria — such as their industry or where they derive the majority of their revenue — or because they appear on "blacklists" from government entities or third-party ESG vendors The remaining securities are typically market-cap-weighted	Securities are selected by ranking and sorting based on certain criteria (e.g., carbon emissions) Security weights can deviate from market-cap weighting and can be set by rules or formulas	Security selection and weighting are determined using an algorithm that is designed to solve for an optimal portfolio given an objective function
Example	Remove securities based on their industry, their fossil fuel reserves, or their carbon emissions Traditional ex-fossil fuel portfolios are "screened"	Securities are sorted on carbon emissions and the highest-quartile emitters are removed The remaining securities are weighted inversely to their carbon emissions	An optimization is run whereby the objective function is to minimize tracking error while reducing carbon emissions by 50% An optimization is run to minimize carbon footprint subject to an ex-ante tracking error limit
Pros	Easy to understand Simple performance attribution	Relatively easy to understand Direct link between each security's signal and weight	Can balance multiple objectives (e.g., return, risk, targeted exposure, liquidity, climate/ESG objectives) Can build portfolios that target benchmark-like characteristics
Cons	Cannot control risk, tracking error, liquidity, concentration, or other portfolio objectives	There is a limit to how much risk, tracking error, liquidity, concentration, or other portfolio objectives can be controlled	May be difficult to understand (can seem like a "black box") Sensitive to data inputs and parameters Overly constrictive parameters may negatively impact optimality of the portfolio

*A variety of optimization constructs exist in this category, such as Benchmark and Absolute Relative Decarbonization and Year-Over-Year Decarbonization.
Source: State Street Global Advisors.

Screened and tilted portfolios are generally intuitive and easy to understand. There are two decisions — security selection and weighting. This makes it easy to understand why certain securities are being held or over/underweight. The greater the amount of stocks screened or the more aggressively the weighting scheme departs from cap weighting, the higher the tracking error, the higher the turnover, and so forth. Thus, the impact of portfolio construction decisions is also easier to understand. And, in a related vein, these features also make performance attribution (return and risk attribution) more straightforward, which is something we will touch on later.

Optimized portfolios have the advantage of finding the best balance between multiple objectives, including return, risk, and exposure targets such as reduced carbon, liquidity, and concentration. While there are ways to accommodate one or two of these aspects in tilted portfolios (e.g., refining the weighting scheme to take into account risk or liquidity), as the number of objectives increases there is a limit to how many can be accommodated (usually only a handful).[2] An optimization framework is the most efficient way to handle multiple objectives; we provide an optimization primer in Appendix A.

So far, we have been discussing optimization broadly, but within the realm of ESG and climate investing there are several different approaches that are possible, depending on the exact client objective. The most broadly accepted approach has been to decarbonize relative to a portfolio benchmark, e.g., reducing carbon intensity by 50% relative to a broad market index. But other approaches are emerging, e.g., where the portfolio meets a year-over-year decarbonization target.

This approach, motivated in large part by recent EU requirements around Paris-Aligned benchmarks, also uses optimization but has a slightly different set of constraints.

So far, we have been focused on portfolio construction. Regarding reduced-carbon portfolios, the other important question is how to measure carbon emissions. There are two main decisions — first, the choice of Scope 1, 2, and 3 in the carbon measure (typically the question is whether to include Scope 3 or a subset of Scope 3), and second, how to normalize the measure of carbon to make it comparable across companies (enterprise value, market capitalization, and revenue are typical choices). These decisions are not trivial and deserve a more in-depth discussion, which we leave for a later date. That said, we do provide a brief overview of the different approaches to measuring carbon, including the pros and cons of each, in Appendix B.

Empirical Results: Different Approaches to Building Reduced-Carbon Portfolios

To better understand performance characteristics of these portfolio construction approaches, we constructed and undertook back-testing of five developed market equity portfolios over the period January 1, 2009, through June 30, 2021. The universe of securities was the MSCI World Index's constituents, and the benchmark was the MSCI World Index. Portfolios were rebalanced quarterly. The five portfolios were:

- **Divest 10 (Screened)** The 10% highest carbon emitters in the MSCI World Index universe are removed (i.e., 10% of market cap is removed).

- **Divest 20 (Screened)** The 20% highest carbon emitters in the MSCI World Index universe are removed (i.e., 20% of market cap is removed).

- **Pure Tilting** A simple tilt is applied on carbon intensity with no constraints applied.[3]

- **Iterative Tilting** A cumulative normal distribution is applied to carbon emissions, and weights are assigned to securities based on their transformed carbon scores. Additional security, sector, and country constraints are applied.[4]

- **State Street Global Advisors Low-Carbon Framework (Optimized)** A mean-variance optimization is employed to either minimize tracking error at a target carbon-reduction level or minimize carbon emissions at a target tracking error. For illustrative purposes, we opt for the latter, specifically minimizing carbon emissions at 75 bps tracking error.

The back-testing results are shown in Figure 2. Focusing first on tracking error, the Divest 20 and Pure Tilting approaches have significantly more tracking error than the other approaches. The Low-Carbon Framework (optimized approach) has a relatively modest tracking error of 0.85. But how much carbon reduction do we realize for that tracking error? Looking at Average WACI[5] reduction, all of the portfolios are within a range of 60–80% reduction. By dividing these reductions by their accompanying tracking error, we see that the Low-Carbon Framework portfolio delivers the highest carbon reduction per unit of tracking error, and thus provides the best tradeoff.

Figure 2
Performance Characteristics of Reduced-Carbon Portfolios (Back-Tested)

	Divest 10	Divest 20	Pure Tilting	Iterative Tilting	Low-Carbon Framework	MSCI World
Return (%)	13.33	13.87	13.40	13.05	13.25	12.81
Risk (%)	15.10	15.29	16.02	15.14	15.22	15.22
Sharpe Ratio	0.88	0.91	0.84	0.86	0.87	0.84
Excess Return (%)	0.52	1.06	0.59	0.24	0.44	—
Tracking Error (%)	0.66	1.21	1.70	0.79	0.85	—
Information Ratio	0.78	0.88	0.35	0.30	0.52	—
Max Drawdown (%)	-19.90	-19.65	-20.96	-20.28	-20.41	-20.93
Beta	0.99	1.00	1.05	0.99	1.00	—
Transaction Cost Impact (%)	-0.04	-0.05	-0.04	-0.06	-0.05	—
Average Annual One-Way Turnover (%)	6.89	7.97	6.65	10.76	9.79	—
Average Predicted TE (%)	0.6	1.1	1.2	0.7	0.8	—
Average Number of Names	1,422	1,276	1,634	1,490	640	1,634
Average Effective Number of Names	284	261	259	249	247	330
Average WACI Reduction (%)	-61	-75	-61	-71	-78	—
Average WACI Reduction/Realized TE	-0.91	-0.62	-0.36	-0.89	-0.92	—

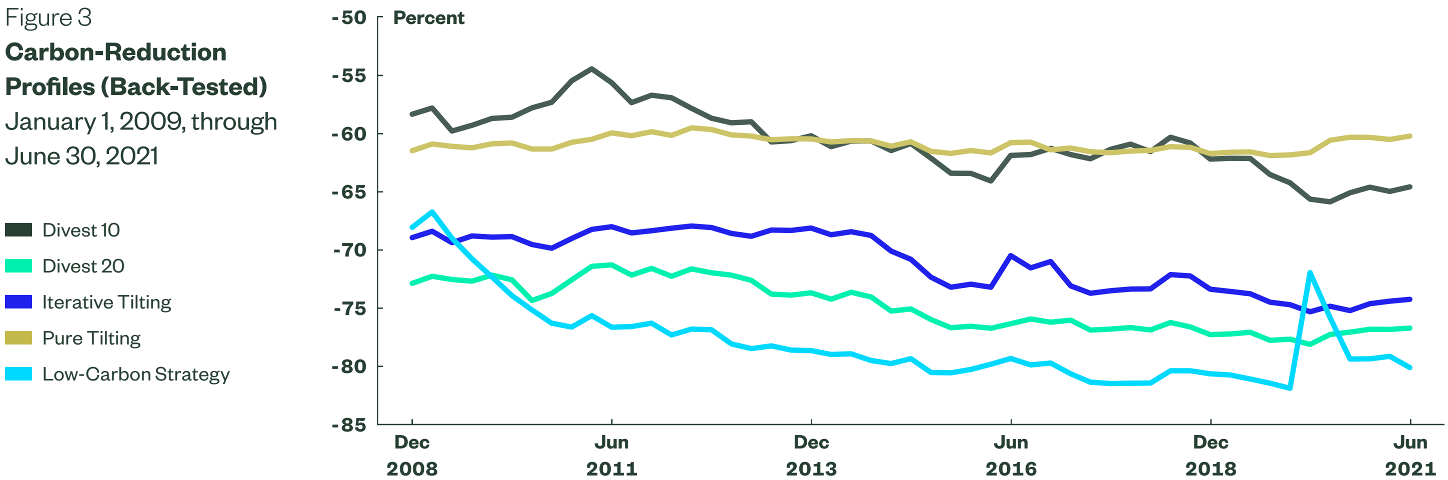
WACI = Weighted Average Carbon Intensity.
TE = Tracking Error.
Source: MSCI, State Street Global Advisors, as of June 30, 2021. The back-tested results depicted are not those of any existing State Street Global Advisors strategy or strategies. All returns are expressed in USD and are net of fees at 10bps. Returns do not represent those of an index, composite, or fund but were achieved by mathematically combining the actual performance data. **The performance assumes no transaction and rebalancing costs, so actual results will differ. The data displayed for Divest 10, Divest 20, Pure Tilting, Iterative Tilting, and Low-Carbon Framework is a hypothetical example of Back-Tested Performance for illustrative purposes only and is not indicative of the past or future performance of any State Street Global Advisors product.** Back-Tested Performance does not represent the results of actual trading but is achieved by means of the retroactive application of a model designed with the benefit of hindsight. Actual performance results could differ substantially, and there is the potential for loss as well as profit. The Back-Tested Performance may not take into account material economic and market factors that would impact the adviser's actual decision-making. The performance reflects management fees, transaction costs, and other fees and expenses a client would have to pay, which reduce returns. Please reference Backtested Methodology Disclosure in the Appendix C for a description of the model methodology as well as an important discussion of the inherent limitations of back-tested results. Reduced-carbon portfolio performance includes the reinvestment of dividends. Index performance reflects capital gains and losses, income, and the reinvestment of dividends. Index returns are unmanaged and do not reflect the deduction of any fees or expenses; an investor cannot invest in an index.

Figure 3 plots the carbon profile of the five portfolios over the back-tested period. Carbon reduction is shown on the y-axis, so the more negative the number, the more effective the decarbonization. The optimized Low-Carbon Framework approach produces the greatest amount of carbon reduction over time, with the exception of a short period in the first half of 2020. We note that Pure Tilting reduces carbon more consistently over time, though it results in less carbon reduction than the optimized approach. (During the onset of COVID in the first half of 2020, there was increased market volatility. Because we employ a tracking error constraint for this portfolio, it constrains the amount of active risk the portfolio can take — and in a high-volatility environment, this pulls the portfolio closer to the benchmark. Note that versions of the portfolio without hard tracking error constraints would not have seen this shift).

Figure 3

Carbon-Reduction Profiles (Back-Tested)

January 1, 2009, through June 30, 2021



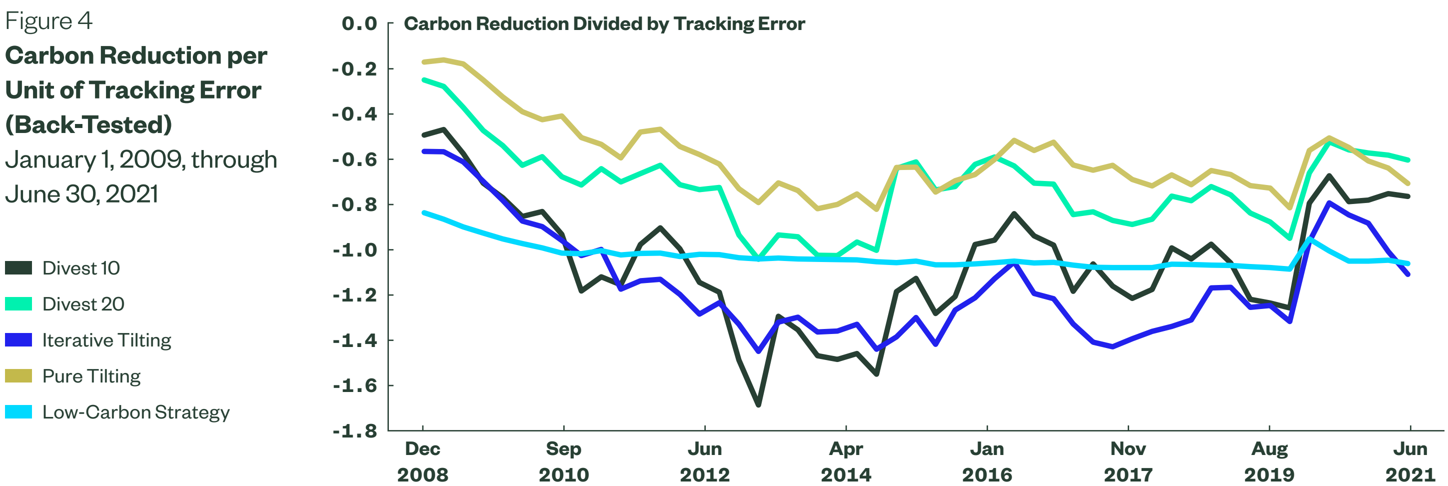
Source: MSCI, State Street Global Advisors, as of June 30, 2021. The back-tested carbon-reduction profiles depicted are not those of any existing State Street Global Advisors strategy or strategies. Carbon-reduction profiles shown do not represent those of any index, composite, or fund. **The data displayed for the Divest 10, Divest 20, Pure Tilting, Iterative Tilting, and Low-Carbon Framework models is a hypothetical example of a Back-Tested carbon-reduction profile for illustrative purposes only and is not indicative of the past or future carbon-reduction profile of any State Street Global Advisors product.** The portion of profiles through June 30, 2021 represents a back-test of the Divest 10, Divest 20, Pure Tilting, Iterative Tilting, and Low-Carbon Framework models, which means that those profiles were achieved by means of the retroactive application of the model, which was developed with the benefit of hindsight. All data shown above does not represent the results of actual carbon-reduction profiles, and in fact, actual carbon-reduction profiles could differ substantially. Please reference Backtested Methodology Disclosure in the Appendix C for a description of the methodology used as well as an important discussion of the inherent limitations of back-tested results.

Figure 4 plots carbon reduction per unit of tracking error — the lower the line, the more carbon reduction achieved per unit of tracking error; the straighter the line, the more consistent the tradeoff over time. The optimized approach produces the most stable carbon-to-risk tradeoffs.[6] This finding is critical, as this measure suggests the best potential outcome for investors who care about risk.

Figure 4

Carbon Reduction per Unit of Tracking Error (Back-Tested)

January 1, 2009, through June 30, 2021

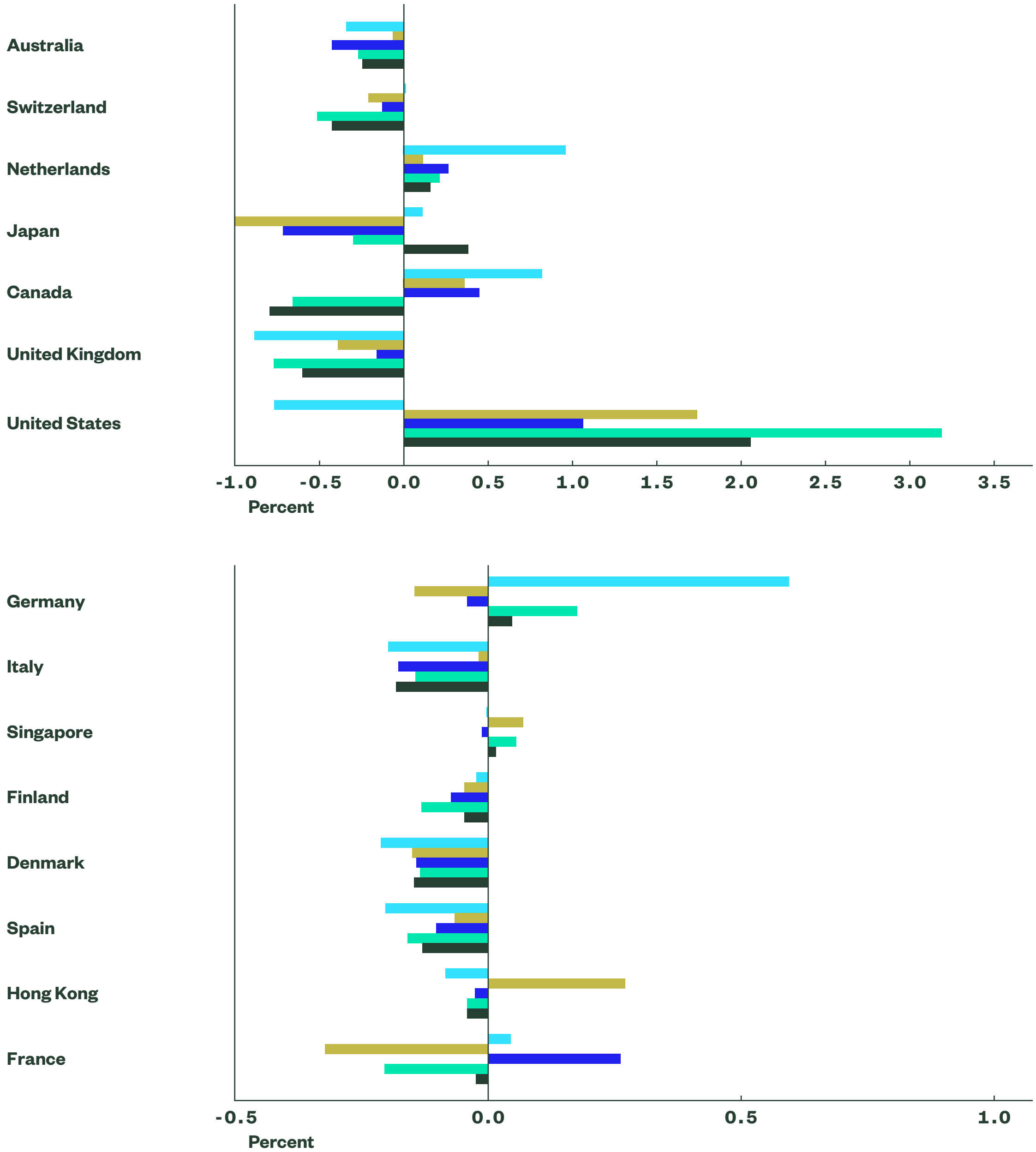


Source: MSCI, State Street Global Advisors, as of June 30, 2021. The back-tested carbon-reduction profiles depicted are not those of any existing State Street Global Advisors strategy or strategies. Carbon-reduction profiles shown do not represent those of any index, composite, or fund. **The data displayed for the Divest 10, Divest 20, Pure Tilting, Iterative Tilting, and Low-Carbon Framework models is a hypothetical example of a Back-Tested carbon-reduction profile for illustrative purposes only and is not indicative of the past or future carbon-reduction profile of any State Street Global Advisors product.** The portion of profiles through June 30, 2021 represents a back-test of the Divest 10, Divest 20, Pure Tilting, Iterative Tilting, and Low-Carbon Framework models, which means that those profiles were achieved by means of the retroactive application of the model, which was developed with the benefit of hindsight. All data shown above does not represent the results of actual carbon-reduction profiles, and in fact, actual carbon-reduction profiles could differ substantially. Please reference Backtested Methodology Disclosure in the Appendix C for a description of the methodology used as well as an important discussion of the inherent limitations of back-tested results.

Figure 5 plots the active country exposures of the different strategies. Three of the portfolios — Divest 10, Divest 20, and Pure Tilting — are unconstrained, and the remaining two are constrained to have active exposures at an absolute maximum of 1%. Due to differences in the portfolio construction approaches, in some cases all the screened/tilted approaches are biased in the same manner. In contrast, the optimized approach has more complex trade-offs, so country biases are more varied. That said, even among screening approaches, Iterative Tilting stands out with much more controlled active exposures.

Figure 5
Active Country Exposures (Back-Tested)
As of June 30, 2021

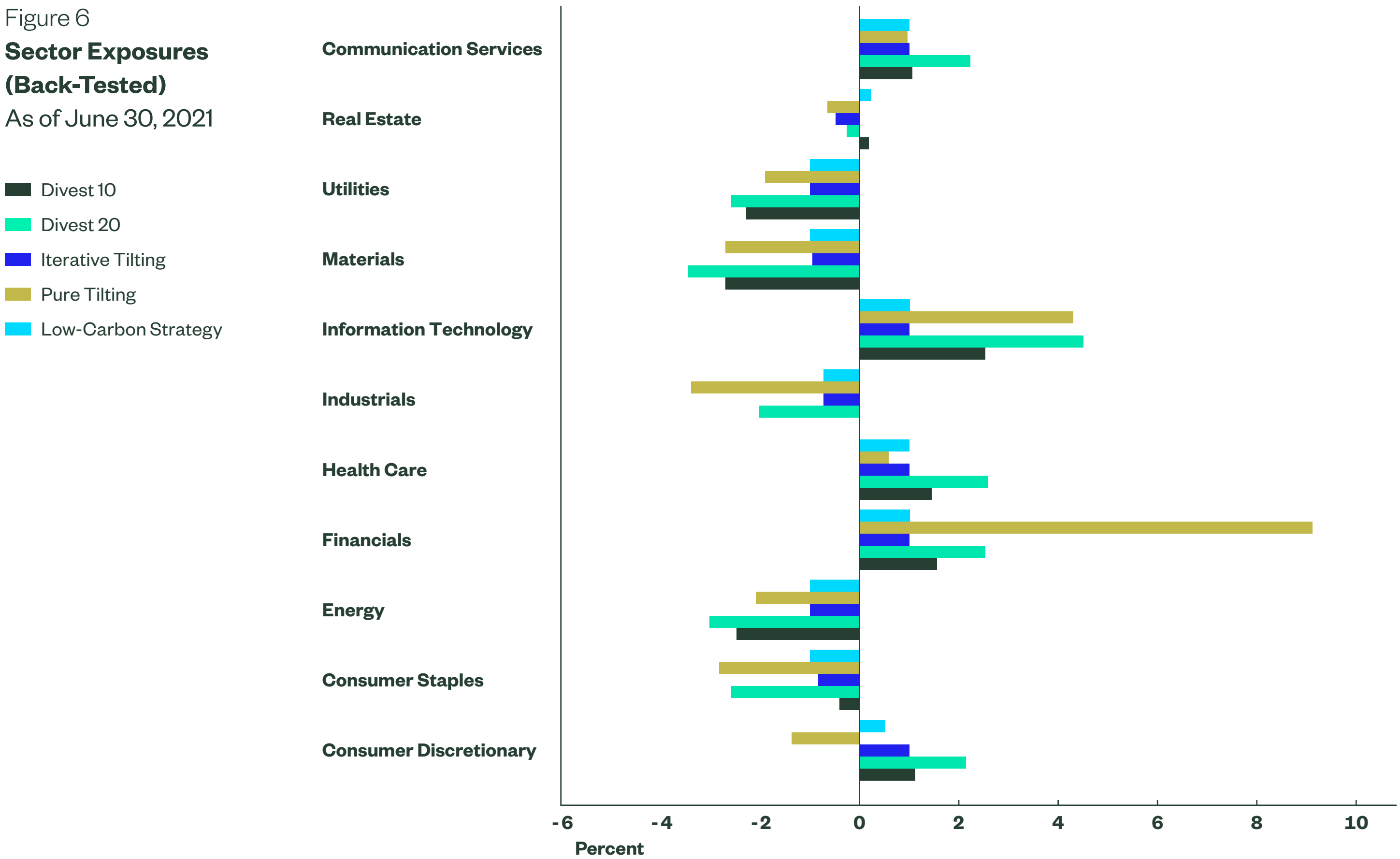
- Divest 10
- Divest 20
- Iterative Tilting
- Pure Tilting
- Low-Carbon Strategy



Source: MSCI, State Street Global Advisors, as of June 30, 2021. The back-tested active country exposures depicted are not those of any existing State Street Global Advisors strategy or strategies. Active country exposures shown do not represent those of any index, composite, or fund. **The data displayed for the Divest 10, Divest 20, Pure Tilting, Iterative Tilting, and Low-Carbon Framework models is a hypothetical example of a Back-Tested active country exposure for illustrative purposes only and is not indicative of the past or future active country exposure of any State Street Global Advisors product.** The portion of active country exposures through June 30, 2021 represents a back-test of the Divest 10, Divest 20, Pure Tilting, Iterative Tilting, and Low-Carbon Framework models, which means that those active country exposures were achieved by means of the retroactive application of the model, which was developed with the benefit of hindsight. All data shown above does not represent actual active country exposures, and in fact, actual active country exposures could differ substantially. Please reference Backtested Methodology Disclosure in the Appendix C for a description of the methodology used as well as an important discussion of the inherent limitations of back-tested results.

Figure 6 shows the sector exposures across the five portfolios. While overall the results are similar to those of the country exposures (constrained vs. unconstrained), this is where the constraints become far more important. We observe that most of the naïve techniques have very substantial negative active weights to the carbon-intensive sectors, and have very large overweights to the carbon-light sectors. This is a common critique of carbon-reduction strategies, i.e., that they reduce carbon exposure by rotating out of carbon-intensive sectors and overweighting low-carbon sectors. This approach isn't desirable for index investors because it may result in significant tracking error and potentially discounts the relevance of these sectors to the economy.

Figure 6
Sector Exposures (Back-Tested)
As of June 30, 2021



Source: MSCI, State Street Global Advisors, as of June 30, 2021. The back-tested sector exposures depicted are not those of any existing State Street Global Advisors strategy or strategies. Sector exposures shown do not represent those of any index, composite, or fund. **The data displayed for the Divest 10, Divest 20, Pure Tilting, Iterative Tilting, and Low-Carbon Framework models is a hypothetical example of a Back-Tested sector exposure for illustrative purposes only and is not indicative of the past or future sector exposure of any State Street Global Advisors product.** The portion of sector exposures through June 30, 2021 represents a back-test of the Divest 10, Divest 20, Pure Tilting, Iterative Tilting, and Low-Carbon Framework models, which means that those sector exposures were achieved by means of the retroactive application of the model, which was developed with the benefit of hindsight. All data shown above does not represent actual sector exposures, and in fact, actual sector exposures could differ substantially. Please reference Backtested Methodology Disclosure in the Appendix C for a description of the methodology used as well as an important discussion of the inherent limitations of back-tested results.

A more appealing approach for index investors is to derive a majority of the carbon reduction from security selection within sectors. In fact, regulatory bodies such as the EU TEG[7] have defined high-impact sectors and recommended that the lower end of active weight to such sectors be capped. We see in the optimized approach that the sector constraints bring the active weights into check, consequently driving much of the carbon reduction to selection rather than allocation.

We acknowledge that we have placed a heavy emphasis on tracking error. For institutional investors, incorporating climate implies a departure from their stated policy objectives (via their benchmarks). Thus, tracking error is arguably the most important metric because it represents how much risk is being taken on, relative to policy objectives, by reducing carbon. Figure 7 recaps our key observations related to the back-testing of the five portfolios.

Figure 7
Key Observations by Portfolio Construction Approach

Screening Approaches do not take into account risk, liquidity or other portfolio features. As more securities are screened out, tracking error can rise significantly.

While the Divest 10 approach does result in strong carbon reduction per unit of tracking error, the fact that Divest 20 does not means that there is an element of luck when employing screening to achieve the best carbon-to-risk tradeoff.

Tilted Approaches can be effective at reducing carbon. The Iterative Tilting approach is far superior to the Pure Tilting approach in balancing the carbon reduction/tracking error tradeoff.

Iterative Tilting accounts for outliers in carbon emitters and, moreover, tries to bring in active country and sector exposures — which has the natural effect of bringing down tracking error.

All else equal, Iterative Tilting essentially makes the portfolio more like an optimized construct, where there is greater attention paid to how much the portfolio deviates from the benchmark.

For investors preferring a rules-based approach, Iterative Tilting would be a preferred route.

An Optimized Approach most appropriate way to realize precise tradeoffs between carbon reduction and tracking error.

The Low-Carbon Framework realizes a carbon-reduction objective and many standard portfolio objectives.

Source: State Street Global Advisors.

Conclusion

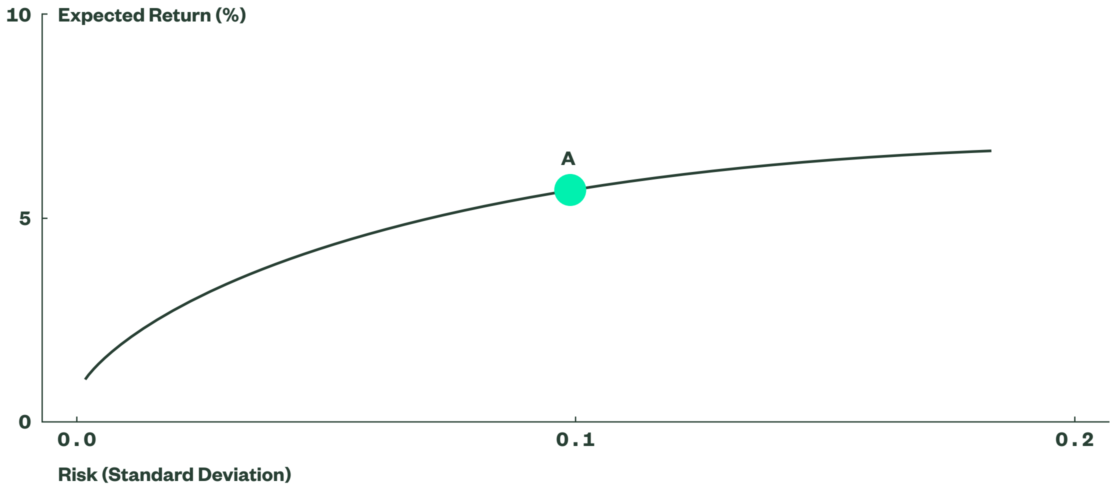
In this paper we discussed different ways to build reduced-carbon portfolios. We analyzed different approaches ranging from simple screening to optimization-based portfolio construction. We showed the pros and cons of each. Ultimately, we determined that employing optimization for building reduced-carbon portfolios is our preferred approach, as it best balances the multiple objectives investors have that go beyond carbon reduction.

In particular, the tradeoff between carbon reduction and tracking error is best managed using optimization. In our preferred approach, investors can meet their carbon-reduction targets while also minimizing the amount of risk they have to assume in deviating from their policy benchmarks. In contrast to rules-based approaches, optimization is generally more risk-efficient.

Appendix A: Optimization Overview

Optimization for portfolio construction can trace its roots back to 1952, when Harry Markowitz developed Modern Portfolio Theory (MPT). As part of MPT, Markowitz introduced mean-variance analysis, which was the first broadly recognized method for constructing an optimal portfolio. Here, the objective seeks to maximize a portfolio's expected return for a given amount of risk (or vice versa). These preferences can be expressed on an "efficient frontier" (Figure 8) and represent the set of portfolios that are deemed optimal. That is, for each unit of risk, that particular mix of securities delivers the highest expected return. Portfolios that sit above or below this line are deemed "not optimal" or not "mean-variant efficient."

Figure 8
The Efficient Frontier of Portfolios

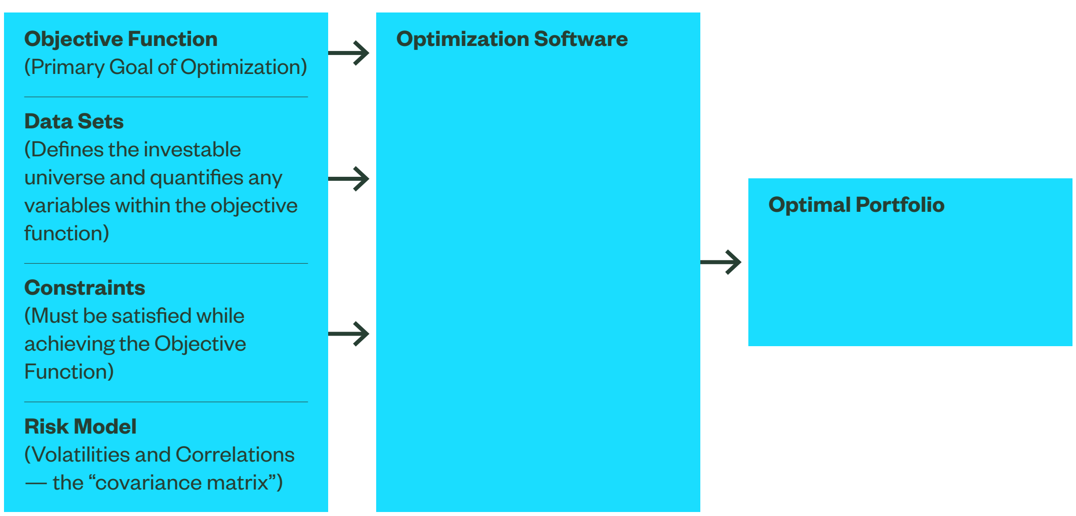


Source: State Street Global Advisors.

While optimization in practice is more complicated than this simple example, it illustrates what is at the heart of optimization — an assessment and continuous trade-off of risk. This basic concept, a delicate balancing act between objectives (e.g., return, factor exposure, or carbon reduction) and risk, forms the foundational element of many optimization problems used in investment portfolios today.

Optimization has been a workhorse of quantitative portfolio management for decades. At its core, optimization is a mathematical equation that leverages software and algorithms to arrive at the most optimal solution (i.e., the portfolio that best satisfies the objectives and constraints). It typically comprises the main components shown in Figure 9.

Figure 9
Components of a Portfolio Optimization



Source: State Street Global Advisors. For illustrative purposes only.

The Objective Function represents the primary goal or objective of the portfolio. This could be expressed in terms of return maximization (e.g., for active quantitative managers with alpha models), an explicit exposure target to style factors (e.g., for multi-factor strategies), risk minimization (e.g., for low-volatility index strategies), or carbon minimization (e.g., for climate solutions). In the case of mean-variance objectives, there can be both return/exposure and risk variables in the objective function, which mean that the optimal balance between return and risk is traded-off as risk conditions evolve through time.

As an example, for our Low-Carbon Framework, the objective function might be:

Minimize $f — \lambda \cdot \omega$

Where f is the portfolio's carbon emissions, λ is a risk-aversion parameter, and ω is either the portfolio's active risk (tracking error) or total risk, depending on whether the investor's preference is to measure risk relative to a benchmark.

Data Sets The primary objective of the optimization, along with the pre-determined constraints, will determine what data is required. Active models will require alpha signals, carbon portfolios will require carbon data, and so forth. Additional data may include benchmark weights, sector and country flags, and transaction cost estimates or liquidity or trading volume metrics for each stock.

Risk Model Mean-variance optimization requires a risk model that provides estimates of stock volatility and correlations between stocks.

Constraints These are additional requirements that must be satisfied while simultaneously targeting the primary objective. In portfolio management, constraints typically represent real world implementation criteria, or investor-specific portfolio restrictions. Constraints also act as guardrails to ensure that the optimization doesn't run amok and return overly concentrated, unrealistic, or unimplementable portfolios. Constraints can also be expressed as "hard" (must be satisfied) and "soft" (could be relaxed if solutions are difficult to find). Common constraints applied in optimization include sector, country, and currency limits (benchmark-relative or maximum), stock limits (minimum, relative, or multiples of the parent index), factor exposure bands (on or off target factor exposure), ESG or carbon footprint metrics (benchmark % improvements), and turnover and liquidity (maximum allowable stock buy/sell ADV limits). Figure 10 provides a sample list of constraints.

Figure 10
Examples of Constraints for Global Equity Portfolios

Sector Constraints (Total or Active)	+-5% active sector weights
Country Constraints (Total or Active)	+-5% active country weights
Stock Constraints (Total or Active)	+-2% stock weights (grandfathered to 2.5%)
Liquidity Constraints	20% of 20-day ADV buy max
Turnover Constraints	10% two-way quarterly turnover soft constraint
Exposure Constraints	0.5 minimum, 1.0 maximum for each individual factor

Source: State Street Global Advisors.

Constraints specification can be both an art and a science. It is important to keep in mind that, while constraints allow for more precise control over the output, the more constrained the solution, the less optimal it will be. Constraints should be detailed enough to balance the objective with implementation characteristics, but not so restrictive such that they limit the opportunity set of potential portfolios and, ultimately, end up driving the investment outcome.

There are some caveats we highlight around optimized factor portfolios. Optimized portfolios are heavily dependent on inputs; therefore, errors in risk estimates will be reflected in the final portfolio. The constraints we specify are designed to check the impact of these errors. However, this introduces another issue that is well-known in optimization. Once constraints are imposed, the optimality of the optimized solution becomes less clear-cut. Significantly restrictive constraints may lead to outcomes where the constraints drive most of the final portfolio or, worse yet, lead to an infeasible solution. Here is where experience in using optimization is critical; our decades of experience running optimized portfolios inform how we calibrate constraints.

Appendix B: Measuring Carbon

There are two main modeling choices with respect to measuring carbon.

- The first is how to define carbon emissions to include Scope 1, 2, and/or 3.
- The second is how to normalize carbon emissions so they are comparable across securities of different sizes and across different industries.

Defining Carbon Emissions

Starting with the first, carbon emissions are generally classified into three categories:

- **Scope 1** emissions are direct emissions from sources that are owned or controlled by a company and includes, for example, on-site fossil fuel combustion and fleet fuel consumption.
- **Scope 2** emissions are indirect emissions from sources that are owned or controlled by a company and include emissions that result from the generation of electricity, heat, or steam purchased from a utility provider.
- **Scope 3** emissions are from sources not owned or directly controlled by a company that are nonetheless related to the company's activities. They include emissions generated by a company's non-electricity supply chain, employee travel and commuting, and emissions associated with contracted solid waste disposal and wastewater treatment. Scope 3 is often referred to as "upstream" emissions.

Scope 1 and 2 are easier to measure than Scope 3 from the perspective of a company. There remains an ongoing debate about the methods for estimating Scope 3 emissions and how accurate such estimates are. Currently the TCFD[8] encourages companies to report their Scope 1 and 2 emissions, which more and more companies are beginning to do. Reporting Scope 3 emissions, however, is still far from the norm.

Providers of carbon data have done a good job of estimating likely Scope 3 emissions. For instance, S&P Trucost identifies a category of emissions called "First Tier Indirect" that represents emissions from a company's first-tier suppliers and includes Scope 2 and some upstream Scope 3 emissions. Whether or not Scope 3 is included does have a significant impact on building carbon portfolios. We have found that, when including any amount of Scope 3, a higher level of tracking error must be allowed to achieve similar levels of carbon reduction had only Scope 1 and 2 been used.

Normalizing Carbon Emissions

The second issue important to defining the carbon metric is how to normalize the measure of carbon. Without normalization, companies of different sizes could not be fairly compared. Common normalization denominators have been proposed, the main ones being market capitalization, enterprise value, and revenue. Revenue has traditionally been the industry standard. It is intuitive: Revenue is an annual number, which means it is ties to the same time scale as carbon emissions, which are usually measured over the last year.

Critics of revenue say it creates biases in favor of sectors such as coal. A measure of a company's size may be a better measure to normalize with, such as market capitalization or enterprise value. Critics of market capitalization argue it is a function of stock price and therefore can lead to spurious fluctuations in carbon emissions due purely to stock price fluctuations. Critics of enterprise value argue that it reflects equity market volatility. In sum, none of the normalization metrics is perfect and what is industry standard today may evolve over time.

Appendix C: Back-Testing Methodology

This Appendix provides the methodology for back-tested performance shown in Figure 2.

Hypothetical portfolios that were Back-Tested: Divest 10, Divest 20, Pure Tilting, Iterative Tilting, State Street Global Advisors Low-Carbon Framework.

Returns are back-tested from January 1, 2009, through June 30, 2021.

Back-tested results are not indicative of the past or future of any State Street Global Advisors product. Results were achieved by means of the retroactive application of the models which were developed with the benefit of hindsight. All data shown does not represent the results of actual trading, and in fact, actual results could differ substantially, and there is the potential for loss as well as profit.

The testing methodology is an optimized process to generate historical portfolios. The data used was only the data which would have been available at the time when the historical portfolios were generated, not what is available now. These processes help to eliminate various forms of survivorship bias, both in terms of a "smarter model" and in terms of making decisions based on information that was not available at the time.

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The back-tested returns shown are net of management fees and other fees and expenses a client would have to pay. Additional fees, such as the management fee, would reduce the return. For example, if an annualized gross return of 10% was achieved over a 5-year period and a management fee of 1% per year was charged and deducted annually, then the resulting return would be reduced from 61% to 54%. The performance includes the reinvestment of dividends and other corporate earnings and is calculated in USD.

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Endnotes

1 See: Bond, Kingsmill, and Carlo Funk, "The Trillion Dollar Energy Windfall," State Street Global Advisors, January 2020; Bond, Kingsmill, and Carlo Funk, "2020 Vision: The Coming Era of Peak Fossil Fuels," State Street Global Advisors, January 2020; and State Street Global Advisors, "The World Targets Change," Research Report (ESG), November 2021.

2 For instance, one can take risk into account by adjusting all factor scores by security volatilities, but that only takes into account individual security volatility and not correlations between securities. As another example, one can control country and sector active weights by establishing limits and redistributing excess weights pro rata back to securities such that the limits are met; however, this involves increased computational complexity.

3 Here we apply a simple scaling method for determining security weights. We convert carbon intensity into scores (z) and set the security weights as follows. Securities with a positive score receive a weight of 1+z. Securities with a negative score receive a weight of $(1+z)^{-1}$.

4 To apply constraints to a tilted portfolio — we follow an iterative process — we first apply the security, sector, and country constraints in that order. After this, we evaluate whether all constraints are satisfied. If they are not, we redistribute the excess (deficit) weight proportionally to all other groups in the same classification. For example, if we find that the country constraint is not binding, because Australia has an active weight of +3%, whereas the constraint is +/- 1%, then the excess 2% weight is removed proportionally from all Australian securities and redistributed proportionally in the rest of the universe. This process is iteratively repeated until all constraints are satisfied.

5 Weighted Average Carbon Intensity.

6 Again, we note that the carbon reduction per unit of tracking error for the optimized approach rises markedly in the first half of 2020. This is because our setup constrains the amount of active risk the portfolio can take — and in a high-volatility environment, this pulls the portfolio closer to the benchmark.

7 The EU Technical Expert Group on Sustainable Finance (TEG) was established in 2018 to advise the European Commission on the implementation of the Action Plan on Financing Sustainable Growth.

8 Task Force on Climate-related Financial Disclosures.

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- Build from breadth
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* Pensions & Investments Research Center, as of December 31, 2020.
† This figure is presented as of December 31, 2021 and includes approximately $61.43 billion of assets with respect to SPDR products for which State Street Global Advisors Funds Distributors, LLC (SSGA FD) acts solely as the marketing agent. SSGA FD and State Street Global Advisors are affiliated.

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