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Building "Net-Zero-Aligned" Portfolios

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An increasing number of investors support a transition to a net-zero economy. The incorporation of net-zero ambitions into financial portfolios presents new considerations and uncertainties. We discuss some of these challenges and propose a methodology that allows for the construction of portfolios or indexes that are consistent with net-zero goals. In particular, we recommend the use of granular regional and sector-specific emission pathways to allow investors to make effective use of their risk budget.

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Introduction

The economy is decarbonizing at a rate that is insufficient to meet global climate goals (United Nations Environment Programme 2023; Black, Parry, and Zhunussova 2023). A variety of trends have emerged that demonstrate the intent of companies and investors to systematically decarbonize, including increased disclosure of climate-related risks, emission reduction target setting, and more precise standards for financed emission accounting. Sustainable and climate-aware benchmarks and associated regulatory guidelines have also come to the fore (e.g., Paris-Aligned Benchmarks, Climate Transition Benchmark). Despite these developments, however, financial markets continue to grapple with the concept of net-zero alignment of investment portfolios, with numerous different approaches having been proposed (Le Guenedal, Lombard, Roncalli, and Sekine 2022; Bolton, Kacperczyk, and Samama 2022). This struggle arises from varying interpretations of net zero, disagreement over what should constitute alignment, and the conceptual and analytical challenges faced when constructing portfolios that reflect a realistic decarbonization trajectory across heterogeneous sectors and geographies.

In this chapter, we elaborate on the intricacies of constructing net-zero-aligned portfolios. We first provide background on carbon budgets and transition pathways, outlining considerations for investors when designing net-zero strategies using a reference scenario. Next, we describe our approach to constructing portfolios that align with a net-zero trajectory. The methodology we propose is agnostic to the scenario selection and can be applied to any specified pathway or combination thereof.

This chapter builds upon existing literature in several ways. First, we provide guidance on the considerations to make when selecting a representative pathway. Second, we underline the importance of regional and sector specificity when measuring alignment and devise a framework for systematically applying modeled climate pathways to corporate issuers. Third, we propose a methodology for constructing a net-zero-aligned portfolio subject to a carbon budget constraint that is periodically rebalanced to ensure weights maintain alignment with the chosen pathway and the associated region–sector decomposition. Fourth, we provide an analysis of two hypothetical model portfolios' characteristics that are subject to these constraints. Finally, throughout, we highlight points for portfolio managers to consider when devising such strategies and maintaining net-zero alignment on an ongoing basis.

What Is Net Zero?

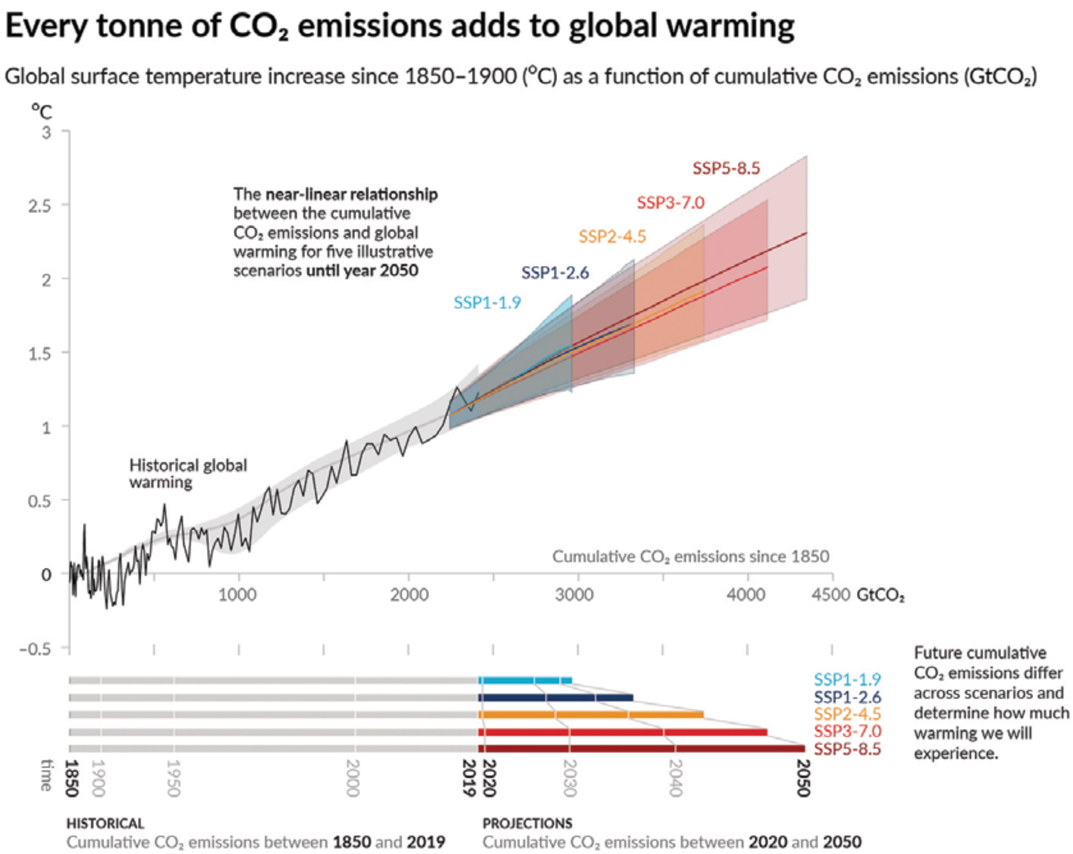
The concept of net zero has been diluted in recent years, with many companies and financial market participants using the term loosely to express decarbonization ambitions. The term originated in the climate science community to describe a state of equilibrium of the global carbon cycle, whereby "sources" of greenhouse gas emissions to the atmosphere are balanced by "sinks" that remove these gases. Greenhouse gases (GHGs) are gases in the atmosphere that trap heat and contribute to global warming. The Kyoto Convention classified seven gases as GHGs (sometimes collectively referred to as the "Kyoto gases"): carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). Of those, the dominant ones are carbon dioxide and methane.

The envisaged state where human contributions of GHG emissions to the atmosphere are at a net value of zero is described as necessary to halt further global warming. The term was used formally by the Intergovernmental Panel on Climate Change (IPCC) in its 2018 special report on global warming of 1.5°C, after which it rapidly gained traction more widely. "Reaching and sustaining net-zero global anthropogenic CO_2 emissions and declining net non-CO_2 radiative forcing would halt anthropogenic global warming on multi-decadal time scales (high confidence)" (IPCC 2022, p. 5).

The persistence of carbon dioxide in the atmosphere underscores the importance of achieving net zero. CO_2 has a relatively long residence time, ranging from approximately 5 to 200 years, with a significant portion remaining for up to 2,000 years due to the relatively slow drawdown by natural carbon sinks (Archer, Eby, Brovkin, Ridgwell, Cao, Mikolajewicz, Caldeira et al. 2009). This means that CO_2 emissions accumulate and their effects on global temperatures persist long after their release. Natural carbon sinks, such as oceans and forests, will eventually absorb atmospheric carbon, but this process can take millennia (Friedlingstein et al. 2023). Hence, carbon emissions and other GHGs emitted today lead to a "permanent" increase in surface temperatures, at least in terms of the timescales of humans alive today.

The described properties of atmospheric CO_2 suggest that emissions from human activities in a given year are not the ideal metric to track in the pursuit of net zero. The total emissions over time—cumulative emissions—are what will ultimately determine the extent of global mean temperature rise and the cascade of climate impacts on society and the economy, as exemplified by the near-linear relationship in **Exhibit 1** (IPCC 2023a).

Exhibit 1. Temperature Rise and Cumulative Emissions



Source: IPCC (2023a, Figure SPM.10).

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By extension, in order to stop or reverse the increase in global warming, GHG emissions from human activities will need to come to near zero at some point in time (Matthews and Cadeira 2008), irrespective of the targeted temperature rise selected (whether 1.5°C, 1.75°C, or 2.0°C). The variable that drives the difference in the amount of peak warming that will result from human activities is the total amount of GHGs emitted over time (cumulative emissions) until the point at which net zero is reached.

The quantity of emissions permissible between now and the point at which net zero is achieved is described as the remaining carbon budget. The concept of a carbon budget is a constraint that places a ceiling on emissions allowed to take place, while still maintaining global mean temperature rise below a particular threshold. What this threshold or temperature goal should be is a topic of debate in and of itself. In 2015, the Paris Agreement resulted in almost all countries committing to efforts to limit warming to "well below 2°C" and to "pursue efforts to limit warming to 1.5°C." But why 1.5°C?

The 1.5°C Threshold and the Remaining Carbon Budget

Limiting warming to 1.5°C aims to mitigate the more catastrophic impacts of climate change. Every increment of additional warming is projected to increase the frequency and severity of multiple and concurrent climate hazards—including droughts, heat waves, extreme rainfall, and flooding—and drive higher rates of biodiversity loss and extinction (IPCC 2022). The rationale for this warming threshold also relates to feedback mechanisms within the Earth System. For example, losses in sea ice reduce the overall reflectivity of the Earth's surface (albedo) and further contribute to warming. Lastly, each increment of additional warming increases the likelihood of tail risk events, such as a shutdown of the Atlantic meridional overturning circulation ocean current or the shearing and rapid melting of the West Antarctic Ice Sheet. These events are referred to as climate tipping points that can lead to a "cascade" of larger-scale climate impacts. While these possibilities are uncertain, every degree of additional warming increases the likelihood of these risks materializing. At global mean temperatures more than 2.0°C above preindustrial levels, the destabilization of the Earth System in light of these feedback effects, tipping points, and nonlinear dynamics becomes more likely (Steffen, Rockström, Richardson, Lenton, Folke, Liverman, Summerhayes et al. 2018).

Considering these risks, the IPCC (2023b, p. 19) has cautioned against breaching the 1.5°C threshold:

> If global warming transiently exceeds 1.5°C in the coming decades or later (overshoot), then many human and natural systems will face additional severe risks, compared to remaining below 1.5°C (high confidence). Depending on the magnitude and duration of overshoot, some impacts will cause release of additional greenhouse gases (medium confidence) and some will be irreversible, even if global warming is reduced (high confidence).

Estimates vary substantially for the remaining carbon budget corresponding to limiting temperature rise to below 1.5°C for a few reasons. The main reason is that researchers use different types of models and approaches for deriving these estimates, such as

- simulating the climate response under increasing levels of emissions using dedicated Earth System models;
- integrated assessment models (IAMs), which use carbon budgets as inputs and produce a range of compatible economic, energy production, and energy use scenarios; and
- modeling exercises constrained by empirical observations of the climate.

There are also many geophysical uncertainties to consider. We do not know exactly how much temperature rise will result from a certain quantity of emissions, because of certain properties of the Earth System, such as feedback loops (e.g., permafrost methane release) and natural variability (e.g., El Niño and La Niña). All of this means the carbon budget should not be seen as a discrete value but, rather, as an estimate with an associated exceedance probability. Part of this uncertainty is modeled in the different outcomes of the simulations and is codified in different ways. In **Exhibit 2**, we present data published in the IPCC's Sixth Assessment Report (IPCC 2023a), which reports the percentage of simulation paths that exceeded a specific temperature target as a function of the total cumulative CO_2 emissions. For example, if the world emits an additional 500 gigatons of CO_2, global warming will be more than 1.5°C in 50% of the paths. Hence, this path is characterized as having a 1.5°C target with limited overshoot.

Exhibit 2. Distribution of Remaining Carbon Budgets

Global Warming: 1850–1900 and 2010–2019 (°C)		**Historical Cumulative CO_2 Emissions from 1850 to 2019 in Gigatons of CO_2 ($GtCO_2$)**					
1.07 (0.8–1.3; likely range)		**2,390 (±240; likely range)**					
Approximate global warming relative to 1850–1900 until temperature limit (°C)	Additional global warming relative to 2010–2019 until temperature limit (°C)	Estimated remaining carbon budgets from the beginning of 2020 ($GtCO_2$) *Likelihood of limiting global warming to temperature limit*					Variations in reductions of non-CO_2 emissions
		17%	33%	50%	67%	83%	
1.5	**0.43**	*900*	*650*	*500*	*400*	*300*	Higher or lower reductions in non-CO_2 emissions can increase or decrease the values on the left by 220 $GtCO_2$ or more
1.7	**0.63**	*1,450*	*1,050*	*860*	*700*	*550*	
2.0	**0.93**	*2,300*	*1,700*	*1,350*	*1,150*	*900*	

Source: IPCC (2023a, Table SPM.2).

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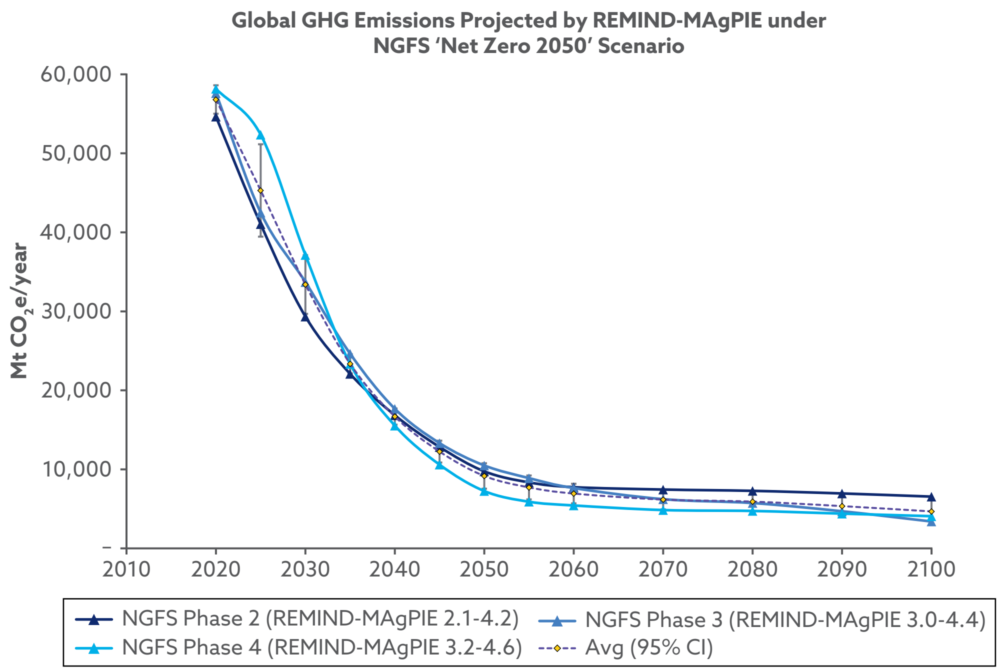
Investors striving to align portfolios to net zero using a carbon budget constraint should be cognizant of these uncertainties, not just for transparency and communication but also because of the likelihood that the budget needs to be updated over time in light of new scientific evidence and improved modeling.

Applying Net-Zero Considerations to Companies and Portfolios

There are many possible pathways to achieve a particular carbon budget. Climate scenarios, developed to understand how systems might evolve under different conditions, play a crucial role. Integrated assessment models represent these complex systems and their interactions to inform policy decisions. Investors must consider such factors as temperature outcomes, the role of carbon dioxide removal technologies, the likelihood of overshoot of the temperature goal, and the timing and pace of decarbonization when selecting a scenario. Selecting a representative pathway also involves being aware of models' relative strengths and weaknesses, such as how land-use change is modeled and the role of carbon capture and storage technology. Finally, practitioners should have systems in place for updating projections as new scenario phases and model versions are released, as demonstrated in **Exhibit 3** (NGFS 2023).

Exhibit 3. Changing GHG Emission Projections Due to Model and Data Updates



Note: The figure shows global GHG projections under the 1× Network for Greening the Financial System (NGFS) scenario and the 1× IAM, showing a range of values across published "phases."

Source: Data are from the NGFS Phase 4 Scenario Explorer (https://data.ene.iiasa.ac.at/ngfs/). The chart was originally created by Bloomberg.

The concept of net zero for investment portfolios should focus on targeting a reduction in cumulative GHG emissions to levels that are near zero. The targeted reduction should be grounded in some scenario-based carbon budget (Le Guenedal et al. 2022). Crucially, the method of assessing alignment should incentivize immediate and significant reductions in GHG emissions. Companies in the portfolio should be assessed against expected emission reduction trajectories that, in aggregate, resemble the modeled transition pathway to the best degree possible. This means accounting for the vastly different economic activities that the portfolio companies are involved in, as well as their locations of operation.

Principles

In 2020, the European Union issued guidelines for benchmark construction known as Paris Aligned Benchmarks (PABs). The guidelines include a number of exclusions of high-emitting economic sectors and activities, as well as a specific target for emission intensity reduction at the portfolio level. Initial implementations of the guidelines applied the emission reduction target universally without recognizing the ability of different economic sectors to decarbonize or the impact that such strict decarbonization targets may have on emerging economies. Eventually, it was understood that a one-size-fits-all approach was too crude and did not account for socioeconomic or technological reality.

This realization led to the development of the *pathways* concept. In this framework, the world economy is split into economic regions, and different GHG reduction pathways are prescribed for each. Developed economies are held accountable for the contribution of their historical emissions to climate change, which allowed them to prosper, and are therefore held to more aggressive emission reduction targets. In contrast, emerging and developing economies are allowed to maintain or even increase their emissions, permitting them to grow their economies without incurring large energy transition costs. This is commonly referred to as the principle of "common but differentiated responsibilities," which we will refer to as the *fairness principle*. Further, each region is split into economic sectors with different emission reduction pathways prescribed for each sector to account for technological and economic reality: the principle of *feasibility*. For example, the energy and automotive sectors are required to decarbonize much faster than the aviation sector, for which no viable technological substitutes are on the horizon. The total emissions prescribed by the various regional/sectoral pathways sum up to the global net-zero emission pathway.

Companies that are active in a particular region and sector are evaluated according to their emission intensity—that is, the emissions they contribute divided by a measure of their size. Companies with relatively high intensity are characterized as "brown," and those with relatively low intensity are characterized as "green." Investors concerned about climate change are seeking to direct their investments so that they can influence companies to reduce their emission footprint. One school of thought encourages the active ownership of brown companies with the goal of influencing their behavior through such strategies as voting and engagement. Another school of thought seeks to redirect investment dollars from brown to green companies.

Some studies have documented empirical evidence of a link between carbon intensity and cost of capital (Trinks, Ibikunle, Mulder, and Scholtens 2022). The theory is that even higher demand for green companies' securities could lead to a further relative reduction in the cost of capital for green companies over brown ones. That, in turn, could increase green companies' competitiveness and could translate to green companies gaining market share, thus reducing the total emissions of a sector without significantly affecting its size. To effect real change, though, it would require a significant set of investors to adopt green investing. It would also require that investors apply a similar philosophy across all sources of funding: public and private debt and equity markets. The principle underlying this investment approach is *substitutability*—that is, the fact that the products of companies within a given sector are substitutes for each other.

Investors may also consider that tilting their equity portfolios toward green companies may reduce their exposure to *climate transition risk*. While markets may have already priced the higher expected climate transition cost that brown companies are facing, the possibility of a faster and more dramatic climate change leading to stricter regulation of GHG emissions may not have been fully understood, exposing brown portfolios to significant tail risk.

Portfolio Construction

We now discuss how investors can tilt their portfolios toward greener companies while adhering to the fairness and feasibility concepts of the pathways. We estimate the relationship between the deviation of a tilted portfolio versus its benchmark (measured by the tracking error volatility) and the amount of emission intensity reduction achieved by the portfolio.

Transition Scenario Selection

As discussed before, a multitude of transition scenarios are consistent with the "1.5°C with limited overshoot" goal. These scenarios are produced by running a combination of Earth System models and integrated assessment models. For example, the IPCC's Sixth Assessment Report identifies 97 different scenarios (called the C1 group of scenarios) that are compatible with limiting global temperature rise to below 1.5°C with limited overshoot (IPCC 2023a). Under all these scenarios, global GHG emissions must reach net zero between 2050 and 2055. The 97 scenarios are grouped into three categories, each represented by an illustrative pathway to net zero: shifting development pathways, low demand, and high renewables.

The Network for Greening the Financial System (NGFS) identifies seven different transition scenario groups: Current Policies, Nationally Determined Contributions, Fragmented World, Delayed Transitions, Low Demand, Below 2°C, and Net-Zero 2050. Of these, the Low Demand and the Net-Zero 2050 scenarios are compatible with the 1.5°C global warming goal. For each of these scenarios, three different integrated assessment models are used to produce different compatible sets of pathways. Choosing a particular scenario has significant implications for portfolio construction. In this chapter, we have chosen to use data for the NGFS Net-Zero 2050 scenario generated by the REMIND-MAgPIE model. We chose this particular scenario and model because, based on our analysis, we have found evidence that it is highly representative of the IPCC C1 category of scenarios (n = 97) on the basis of (1) cumulative carbon emissions and (2) the future energy technology mix.

NGFS scenarios are updated annually. According to NGFS, the latest version (Phase 4), published in 2023, reflects the "latest economic and climate data, model versions and policy commitments, reflecting new country-level commitments to reach net-zero emissions made until March 2023."[1] NGFS also states that "the new scenarios also reflect the latest trends in renewable energy technologies (e.g., solar and wind), key mitigation technologies and the energy-market implications of the war in Ukraine."[2]

The NGFS scenarios contain projections for many climate and economic variables. Scenario emission projections are reported both for all GHGs considered in the Kyoto Protocol of 1997 (Kyoto gases) and for just carbon dioxide (CO_2). Kyoto gases are reported for 12 economic regions (see **Exhibit 4**) and five broad industrial sectors (see **Exhibit 5**). Carbon dioxide is projected for many industries at the global and regional levels.

Exhibit 4. NGFS REMIND-MAgPIE 3.2-4.6 Kyoto Gases Countries and Economic Regions

United States	China	Reforming ex-USSR	Latin America and Caribbean
EU28	India	Non-EU28 Europe	Middle East, North Africa, Central Asia
Japan	Canada, New Zealand, Australia	Other Asia	Sub-Saharan Africa

Exhibit 5. NGFS REMIND-MAgPIE 3.2-4.6 Kyoto Gases Economic Sectors

Transportation	Industry
Energy Supply	Agriculture, Forestry, and Other Land Use
Residential and Commercial	

[1]See www.ngfs.net/ngfs-scenarios-portal/ under the section titled "What Is New in the 2023 Version (Phase IV) of the NGFS Scenarios?"

[2]Ibid.

Peer Group Selection

The key assumption behind the green investment approach is the substitutability of the outputs of companies. For this reason, starting with a broad universe, we need to define peer groups of companies that produce substitutable products. For example, auto manufacturers will form one peer group including both electric vehicle manufacturers and traditional fossil fuel engine car manufacturers. In contrast, electricity producers and electricity distribution companies need to be in different groups. Since conglomerates and vertically integrated companies may belong to more than one group, more complex algorithms are required for their classification.

The choice of peer groups is guided by the granularity of pathways defined in the transition scenario. However, we may decide to further split the groups defined by the scenario pathways if they are too broad and contain companies that are not direct substitutes. If the portfolio universe contains too few companies associated with particular pathways, however, we may decide to merge groups together.

The treatment of sparsely populated buckets warrants further discussion. While pathways aim to prescribe emission trajectories for entire economic sectors, it is quite possible that within a geographical region there are very few public companies in that sector. If we wish to maintain the market weights of peer groups unchanged, respecting the fairness and feasibility principles, companies within a thin bucket will be allowed to be brown with little impact. Consider the case of a bucket with a single company—for example, an electric utility in an emerging market. If the weight of this bucket remains unchanged in the net-zero portfolio, then this company can ignore its pathway and be brown without its market weight being affected. To address this issue, we will seek to avoid thin buckets by combining multiple related peer groups together. However, we need to understand that combining peer groups undermines the principle of fairness if we combine groups across regions or undermines the principle of substitutability if we combine groups across industries. Therefore, such grouping must be performed thoughtfully to ensure the minimum violation of the principles. For example, we can combine groups across emerging market regions but not across developed and emerging markets, or we can combine groups whose products are weak substitutes for each other.

Ultimately, the choice of peer groups, which is possibly the most significant portfolio construction choice, has a degree of subjectivity and will depend on the universe of companies for which reliable emission data are available.

Emission Budget Allocation

The next step of portfolio construction is to allocate an emission budget to each peer group. The budget must be selected in a manner consistent with the chosen net-zero scenario. We do that by first associating the peer group with a particular scenario emission variable.

Note that the peer group does not represent all emitting entities whose net-zero budget is specified by the associated scenario variable. Indeed, transition scenarios specify allowable emissions from all agents, governments, households, and private and public companies. Furthermore, the peer group definition may be narrower than the economic sector associated with the scenario variable. For this reason, instead of reading the absolute value of emissions specified by the pathway of the associated variable, we apply only the rate of change of the variable relative to the base year of the scenario. Doing so allows us to use different measures of emissions in each peer group so that the chosen measure is the most representative of the emission contribution for that group. Generally, our preference would be the broadest definition of a company's carbon footprint—GHG Scope 1, 2, and 3, including financing activities. However, data availability is much higher for the most relevant parts of the carbon footprint of each company. Hence, for each peer group, we use a customized definition of emissions based on materiality and data availability. For example, we use Scope 1 + 2 GHG emissions for steel producers, whereas for the automotive sector we use Scope 1 + 2 + 3 GHG emissions. Furthermore, for the financial sector, we measure the emissions of companies funded by the financial institution rather than the direct emissions of the financial company.

The underlying assumption in this approach is that the aggregate emissions of companies in each peer group are consistent with the net-zero pathway on the base year of the scenario. This allows us not only to compare companies with each other within the peer group but also to evaluate the evolution of aggregate emissions of each peer group relative to the net-zero scenario.

If we denote the base year of the transition scenario with t_0, the emissions for which an individual company i is responsible with $E_{i,t}$, the actual and net-zero-compliant emissions of its peer group with $E_{p,t}$ and $E_{p,t}^{NZ}$, respectively, and the net-zero emissions of the corresponding scenario variable with $E_{S,t}^{NZ}$, we express our assumptions with the following equations:

$$E_{p,t_0} = \sum_{i \in p} E_{i,t_0}. \tag{1a}$$

$$E_{p,t}^{NZ} = E_{p,t_0} \frac{E_{S,t}^{NZ}}{E_{S,t_0}^{NZ}}. \tag{1b}$$

We will call the net-zero compliant emissions of a peer group the *emission budget* for that group.

The actual emissions of a peer group are equal to the sum of the emissions of the companies in the group. When investors seek to construct climate-aware portfolios, they typically do so within an asset class—that is, equity or bond portfolios separately. It is, therefore, useful to attempt to allocate the total emissions of a company to its various funding sources. This can be done by allocating emissions proportionally to the contribution of each funding source to the enterprise value including cash (EVIC):[3]

$$E_{i,t} = \frac{MV_{i,t}^{equity}}{EVIC_{i,t}} E_{i,t} + \frac{N_{i,t}^{bonds}}{EVIC_{i,t}} E_{i,t} + \frac{MV_{i,t}^{other}}{EVIC_{i,t}} E_{i,t}. \tag{2}$$

The total emissions that correspond to a peer group of companies can then be written as follows:

$$E_{p,t} = \sum_{i \in p} \frac{MV_{i,t}^{equity}}{EVIC_{i,t}} E_{i,t} + \sum_{i \in p} \frac{N_{i,t}^{bonds}}{EVIC_{i,t}} E_{i,t} + \sum_{i \in p} \frac{MV_{i,t}^{other}}{EVIC_{i,t}} E_{i,t}. \tag{3}$$

A sufficient condition to ensure that the total emissions of the peer group companies are below their emission budget is to allocate the budget proportionately to the three components of EVIC:

$$E_{p,t}^{equity} = \sum_{i \in p} \frac{MV_{i,t}^{equity}}{EVIC_{i,t}} E_{i,t} \leq \frac{MV_{p,t}^{equity}}{EVIC_{p,t}} E_{p,t}^{NZ}. \tag{4a}$$

$$E_{p,t}^{bonds} = \sum_{i \in p} \frac{N_{i,t}^{bonds}}{EVIC_{i,t}} E_{i,t} \leq \frac{N_{p,t}^{bonds}}{EVIC_{p,t}} E_{p,t}^{NZ}. \tag{4b}$$

$$E_{p,t}^{other} = \sum_{i \in p} \frac{MV_{i,t}^{other}}{EVIC_{i,t}} E_{i,t} \leq \frac{MV_{p,t}^{other}}{EVIC_{p,t}} E_{p,t}^{NZ}. \tag{4c}$$

Let us first consider the case of equities. If we consider a peer group as a portfolio that holds all the shares of the companies in the group, the emissions that correspond to the equity component of the peer group can be expressed as the market-value-weighted sum of the equity-financed emission intensity of each company, as follows:

$$E_{p,t}^{equity} = \sum_{i \in p} \frac{MV_{i,t}^{equity}}{EVIC_{i,t}} E_{i,t} = MV_{p,t}^{equity} \sum_{i \in p} \frac{MV_{i,t}^{equity}}{MV_{p,t}^{equity}} \frac{E_{i,t}}{EVIC_{i,t}} = MV_{p,t}^{equity} \sum_{i \in p} w_{i,t} \frac{E_{i,t}}{EVIC_{i,t}}. \tag{5}$$

Many investors prefer to define emission intensity in terms of company revenues rather than EVIC. Indeed, revenues represent a more stable representation of each company's production volume. If $R_{i,t}$ represents a measure of a company's revenues at time t, Equation 5 can be rewritten as follows:

$$E_{p,t}^{equity} = MV_{p,t}^{equity} \sum_{i \in p} w_{i,t} \frac{R_{i,t}}{EVIC_{i,t}} \frac{E_{i,t}}{R_{i,t}} \approx R_{p,t} \frac{MV_{p,t}^{equity}}{EVIC_{p,t}} \sum_{i \in p} w_{i,t} \frac{E_{i,t}}{R_{i,t}}. \tag{6}$$

[3]EVIC consists of the market value of all outstanding shares of a company, the notional amount of all bond instruments, and the cash in hand including all other private financing vehicles.

In Equation 6, we made the simplifying assumption that the ratio of revenues to EVIC is approximately the same for all firms within a peer group; hence, $\frac{R_{i,t}}{EVIC_{i,t}} \approx \frac{R_{p,t}}{EVIC_{p,t}}$.

We can now combine Equation 4a and Equation 6 and write the emission budget constraint for the equity component of peer group companies as follows:

$$\sum_{i \in p} w_{i,t} \frac{E_{i,t}}{R_{i,t}} \leq \frac{E_{p,t}^{NZ}}{R_{p,t}}. \qquad (7)$$

The same equation can also be derived for bond portfolios under the additional assumption that the prices of all bonds of the peer group are similar. While this may not be accurate, its impact on the eventual calculations is small.

Even while a revenue-based calculation of emission intensity is a better representation of the actual physical emission intensity of companies, it is still not perfect. Revenues of companies fluctuate year over year and are affected by inflation and price fluctuations. Furthermore, revenues do not include inventory changes. For these reasons, revenues need to be smoothed and possibly winsorized before they can be used in the emission intensity calculation. In the following, we will represent the smoothed-revenues-based emission intensity of a company with $e_{i,t}$. We can now write the emission budget constraint as follows:

$$\sum_{i \in p} w_{i,t} e_{i,t} \leq \frac{E_{p,t}^{NZ}}{R_{p,t}} \equiv e_{p,t}^{NZ} \qquad (8)$$

The left-hand side of the equation is commonly referred to in the literature as the weighted average carbon intensity (WACI).

Portfolio Construction with Mean–Variance Optimization

To simplify the calculations, we will assume a two-stage portfolio construction process, where the size of the investment in a company is first allocated within its peer group, and then the relative investment in each peer group is decided in a second phase.

The net-zero pathways represent an aggressive climate goal of keeping the global temperature rise below 1.5°C and, therefore, prescribe fast decarbonization. If the real-world aggregate decarbonization is slower, the emission budget constraint will be violated for most peer groups. The goal of green portfolio construction is to shift financing toward greener companies so that the total emissions of each peer group remain below their pathway-implied level at each time period. As discussed earlier, it is assumed that directing investments to greener companies will have an impact on the ability of companies to grow and will ultimately be reflected in the production size and emissions of companies. The underlying principle of this method is substitutability—that is, that the relative size of companies in a peer group can change without affecting the total size (e.g., revenues) of the group.

Let us represent a set of alternative company weights with $\omega_{i,t}$. Then, the total peer group emissions will be $R_{p,t} \sum_{i \in p} \omega_{i,t} e_{i,t}$. We would like to identify the set of weights, $\omega_{i,t}$, that satisfies the budget constraint (Equation 8). In general, many such weights satisfy the budget constraint. Of these, we can choose weights minimizing a measure of portfolio risk—either absolute risk or tracking error to a benchmark. Furthermore, because most investors want to avoid leverage, we require that the sum of investments in all companies be equal to their available capital.

If $\boldsymbol{\Sigma}_t$ represents the covariance matrix of investment returns between companies at time *t*, we can express the problem of finding the weights that satisfy the budget constraint in an efficient way as an optimization problem, expressed in vector–matrix notation:[4]

Minimize return variance:	$\min_{\omega_t}\{\omega_t' \Sigma_t \omega_t\}$
Emission budget constraint:	$\omega_t' \mathbf{e}_t \le e_{p,t}^{NZ}$
No leverage:	$\omega_t' \mathbf{1} = 1.$

For clarity of expression, we introduce the following notation:

- We denote the sum of the elements of the inverse covariance matrix with $\frac{1}{\upsilon_t} \equiv \mathbf{1}' \Sigma_t^{-1} \mathbf{1}.$
- We define the risk-weighted intensity average of the peer group as $\mu_t \equiv \frac{\mathbf{1}' \Sigma_t^{-1} \mathbf{e}_t}{\mathbf{1}' \Sigma_t^{-1} \mathbf{1}} = \upsilon_t \mathbf{1}' \Sigma_t^{-1} \mathbf{e}_t.$
- We define the risk-weighted variance of the intensity of companies in the peer group as $\sigma_t^2 \equiv \frac{\mathbf{e}_t' \Sigma_t^{-1} \mathbf{e}_t}{\mathbf{e}_t' \Sigma_t^{-1} \mathbf{1}} - \mu_t^2 = \upsilon_t \mathbf{e}_t' \Sigma_t^{-1} \mathbf{e}_t - \mu_t^2.$

The resulting optimal portfolio weights are given by the following equation:

$$\omega_t = \underbrace{\upsilon_t \Sigma_t^{-1} \mathbf{1}}_{\text{Minimum-variance weights}} + \upsilon_t \Sigma_t^{-1} \underbrace{\frac{e_{p,t}^{NZ} - \mu_t}{\sigma_t}}_{\text{Normalized target intensity change}} \underbrace{\frac{\mathbf{e}_t - \mu_t \mathbf{1}}{\sigma_t}}_{\text{Emission intensity weighted z-score}}. \qquad (9)$$

Investors who have no access to a risk model may simply assume that all issuers are equally risky and are perfectly uncorrelated. In this case, the normalized

[4]We use the symbol **1** to represent a vector of ones and the notation **X**′ to represent the transpose of vector or matrix **X**.

covariance matrix is the identity matrix divided by the number of issuers, and the minimum variance weights become equal weights.

Investors who are concerned about the deviation from a benchmark rather than absolute risk can use tracking error instead of absolute risk as an objective in the optimization problem. The solution is identical except that the starting weights are the benchmark weights rather than the minimum-variance weights.

In the previous formulation, the budget and no-leverage constraints are "hard"; that is, the investors prefer to take more risk rather than breach any of these constraints, something that can lead to solutions with excessive risk if the budget is too aggressive. In certain cases, however, there may not be a feasible set of weights—for example, if all issuer emission intensities are too high relative to the budget. To alleviate this issue, investors can make the budget constraint soft—that is, accept breaching the budget constraint to keep the resulting risk at acceptable levels. By expressing the relative preference between risk and emission budget with a relative risk aversion parameter λ_t, the problem can be formulated as follows:

Minimize risk and emissions: $\min_{\omega_t}\{\omega_t'\Sigma_t\,\omega_t + \lambda_t\omega_t'\mathbf{e}_t\}$

No leverage: $\omega_t'\mathbf{1} = 1.$

The resulting optimal weights are the minimum-variance weights tilted proportionately to their distance from the risk-weighted average sector intensity. The tilting strength is determined by the investor's relative preference for the portfolio risk and breaching the emission budget.

$$\omega_t = \upsilon_t\Sigma_t^{-1}\mathbf{1} + \lambda_t\,\Sigma_t^{-1}(\mathbf{e}_t - \mu_t\mathbf{1}). \tag{10}$$

The tilting strength determines both the resulting portfolio variance, V_t, and emission intensity, E_t:

$$V_t = \omega_t'\Sigma_t\,\omega_t = \upsilon_t + \lambda_t^2\frac{\sigma_t^2}{\upsilon_t}. \tag{11}$$

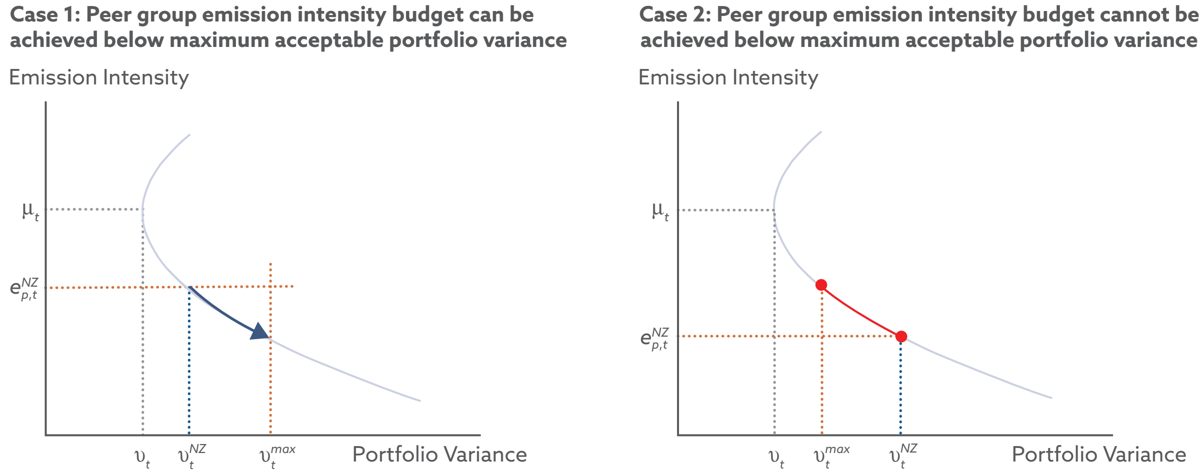
$$E_t = \omega_t'\mathbf{e}_t = \mu_t + \lambda_t\frac{\sigma_t^2}{\upsilon_t}. \tag{12}$$

As expected, if we set emissions equal to the emission budget, then Equation 10 reverts to Equation 9. This formulation allows us to build the efficient frontier between portfolio variance and emissions. Indeed, by eliminating the parameter λ_t, we get

$$V_t = \upsilon_t + \upsilon_t\frac{(E_t - \mu_t)^2}{\sigma_t^2}. \tag{13}$$

Portfolio variance is minimized for $\lambda_t = 0$ and is equal to υ_t. This corresponds to peer group emission intensity of μ_t. If the level of risk required to achieve the target peer group emissions is below a maximum acceptable portfolio variance

Exhibit 6. Efficient Frontier and Portfolio Choice



υ_t^{max}, as in the left panel of **Exhibit 6**, then the solution is acceptable. As a matter of fact, lower emissions can be achieved if portfolio weights are permitted to drift further toward lower-intensity issuers until the portfolio has the maximum acceptable variance (the arrow in the left panel of Exhibit 6). If, however, the emission budget requires the portfolio to have risk exceeding υ_t^{max}, as in the right panel in Exhibit 6, then investors must choose whether to accept higher emission intensity or higher risk or breach both constraints while staying on the efficient frontier (red section of the efficient frontier in the right panel in Exhibit 6).

In practical cases, portfolios are subject to additional constraints, such as no shorting; risk constraints, such as minimum and maximum issuer weights and industry and country exposures relative to the benchmark; and most importantly, regulatory constraints, such as exclusions of certain sectors and issuers. Once these additional constraints are added, the problem can no longer be solved analytically; it requires using iterative optimization algorithms. However, one needs to be judicious in including too many constraints in portfolio construction as they may lead to conflicts, rendering the problem infeasible. In such cases, investors may need to establish trade-offs between constraint breaches.

Portfolio Construction without Mean–Variance Optimization

Some investors may prefer simpler portfolio construction approaches to avoid the perceived complexity of the mean–variance methodology. One such popular approach prescribes that portfolio weight shifts relative to the benchmark weights, $\mathbf{w}_t$, be proportional to the starting weights and the distance of the issuer emission intensity from the pathway-prescribed intensity:[5]

$$\omega_t = \mathbf{w}_t - \lambda_t \mathbf{W}_t(\mathbf{e}_t - e_{p,t}^{NZ}\mathbf{1}). \qquad (14)$$

[5]We use the notation $\mathbf{W}_t$ to denote a diagonal matrix with elements equal to $\mathbf{w}_t$.

Equation 14 seeks to underweight companies whose intensity is higher than the pathway intensity (brown companies) and overweight those with intensity below the pathway (green companies). However, it does not guarantee lack of leverage for the resulting portfolio. In fact, the no-leverage constraint requires λ to be zero if the weighted average intensity of the peer group is different from the pathway-prescribed intensity, as shown in Equation 15:

$$\omega_t'\mathbf{1}=1 \Rightarrow \mathbf{w}_t\mathbf{1}-\lambda_t(\mathbf{e}_t'-e_{p,t}^{NZ}\mathbf{1}')\mathbf{W}_t\mathbf{1}=1 \Rightarrow \lambda_t(\mathbf{e}_t'\mathbf{w}_t-e_{p,t}^{NZ})=0. \quad (15)$$

One may attempt to normalize the weights so that they sum to 1; however, this has the unintended consequence of replacing the pathway intensity with the weighted average peer group intensity as the pivot intensity for overweighting or underweighting issuers. Indeed, as shown in Appendix A, the normalized weights are given by the following equation:

$$\omega_t^* = \mathbf{w}_t - \lambda\mathbf{W}_t\frac{\mathbf{e}_t-(\mathbf{w}_t'\mathbf{e}_t)\mathbf{1}}{1-\lambda_t(\mathbf{w}_t'\mathbf{e}_t-e_{p,t}^{NZ})}. \quad (16)$$

One way around this issue is to introduce a second parameter in the weight shift function. For example, we can use different tilt strengths for overweighting green issuers versus underweighting brown issuers:

$$\omega_t = \mathbf{w}_t - \lambda_t^+\mathbf{W}_t(\mathbf{e}_t-e_{p,t}^{NZ}\mathbf{1})^+ - \lambda_t^-\mathbf{W}_t(\mathbf{e}_t-e_{p,t}^{NZ}\mathbf{1})^-. \quad (17)$$

Now, both the leverage and the emission budget constraints can be satisfied and used to estimate the appropriate values of the lambda parameters. However, portfolio risk is not explicitly controlled. To do so, one would have to formulate the problem once again as an optimization problem with a trade-off parameter λ_t between risk and emission intensity:

Minimize risk and emissions: $\min_{\lambda_t^+,\lambda_t^-}\{\omega_t'\Sigma_t\omega_t+\lambda_t\omega_t'\mathbf{e}_t\}$

No leverage: $\omega_t'\mathbf{1}=1.$

Using Projected Emissions

So far, we have assumed a static view of company emissions, evaluating companies using only the latest known emission information. However, the net-zero concept is dynamic, requiring economic agents to reduce their emissions gradually over time and eventually achieving net-zero emissions for the economy as a whole. It would make sense then to evaluate companies according to their projected path toward net-zero emissions. We can consider two sources of information on which we could make a projection: historical performance and company-disclosed targets. Regardless of which projection method we use, we can rewrite the budget constraint for a future time $t + \Delta t$, holding company weights constant:

$$R_{p,t+\Delta t}\sum_{i\in p}\omega_{i,t}e_{i,t+\Delta t}\leq E^{NZ}_{p,t+\Delta t}\Leftrightarrow\sum_{i\in p}\omega_{i,t}e_{i,t+\Delta t}\leq\frac{E^{NZ}_{p,t+\Delta t}}{R_{p,t+\Delta t}}\equiv e^{NZ}_{p,t+\Delta t}. \qquad (18)$$

In Equation 18, we need to estimate three quantities: (i) the pathway-prescribed peer group emissions, $E^{NZ}_{p,t+\Delta t}$; (ii) the peer group projected revenues, $R_{p,t+\Delta t}$; and (iii) the company projected emission intensity, $e_{i,t+\Delta t}$.

(i) The pathway-prescribed emissions for the peer group can be estimated using Equation 1b applied for time $t + \Delta t$:

$$E^{NZ}_{p,t+\Delta t}=E_{p,t_0}\frac{E^{NZ}_{S,t+\Delta t}}{E^{NZ}_{S,t_0}}.$$

(ii) The peer group projected revenues can be estimated by extrapolating historical growth rate, or by drawing on projections of economic output from integrated assessment models under the representative scenario. It is also possible to use revenue projections from analysts' estimates.

(iii) We can use two sources of information to project company emission intensity in the future: historical observations and company-provided emission targets. Historical intensity observations can be extrapolated to provide a time-series estimate of intensity. Company-provided emission targets, if available, typically require interpretation, reconciliation, and interpolation to be translated into projected intensity at any future point in time. The two can be combined to arrive at a single path of future projected emission intensity of the company.

We can now derive the emission budget constraint for the entire time period $[t,t + \Delta t]$. Assuming that the company weights in the peer group remain constant during this period, we can write the following formula:

$$\sum_{i}\omega_{i,t}\int_{\tau=t}^{t+\Delta t}R_{p,\tau}e_{i,\tau}d\tau\leq\int_{\tau=t}^{t+\Delta t}E^{NZ}_{p,\tau}d\tau. \qquad (19)$$

If both of the quantities $E^{NZ}_{p,\tau}$ and $R_{p,\tau}e_{i,\tau}$ change linearly over time, we can rewrite the budget constraint as follows:

$$\sum_{i}\omega_{i,t}\left(e_{i,t}+\frac{R_{p,t+\Delta t}}{R_{p,t}}e_{i,t+\Delta t}\right)\leq\left(e^{NZ}_{p,t}+\frac{R_{p,t+\Delta t}}{R_{p,t}}e^{NZ}_{p,t+\Delta t}\right). \qquad (20)$$

Essentially, this is a modified budget constraint that linearly combines the current and projected budget constraints. The problem can be solved with any of the previously discussed methodologies by using the modified budget constraint. Additionally, users may decide to use different weights to combine the current and forward emission budgets reflecting their preferences and confidence in the estimates.

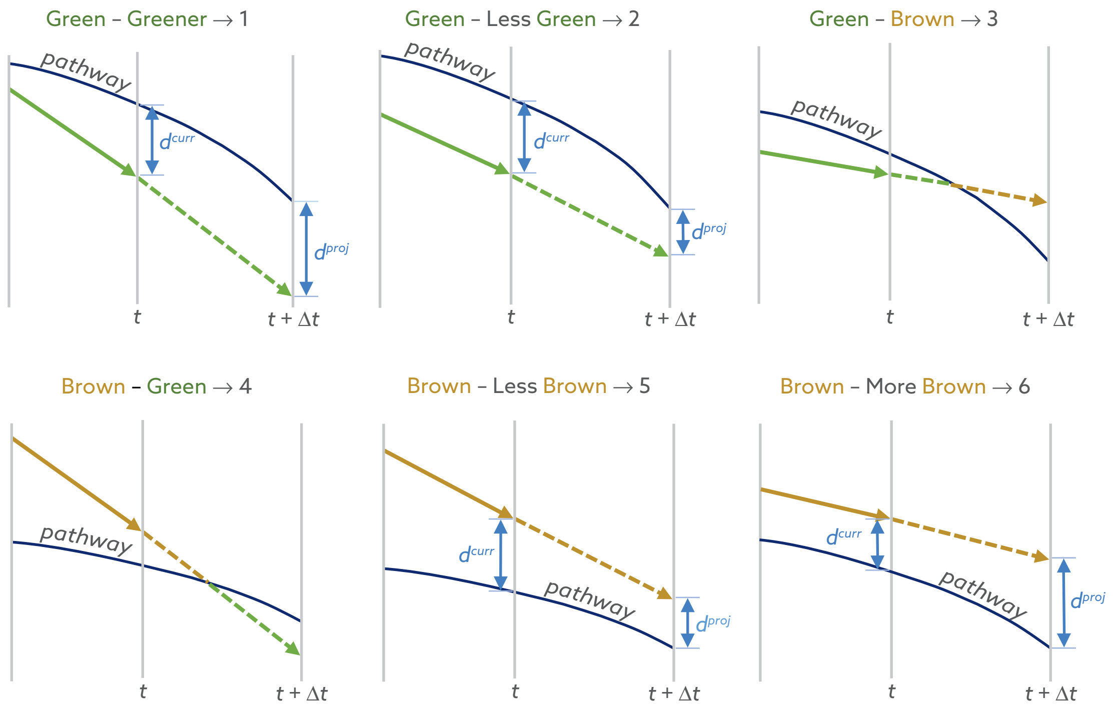
Using Alignment Scores

The methodology we have shown is elegant, but it applies very precise tools to data that are often inconsistent and, in many cases, estimated rather than reported—particularly for Scope 3 emission data. In addition, we have made a number of assumptions that, although reasonable, introduce another source of imprecision. To provide a simple solution that is more robust to data inputs, we introduce the idea of condensing the company emission data into a company *net-zero alignment score* that injects robustness into characterizing companies as green or brown. We will then seek to maximize the "greenness" of the portfolio as defined by its weighted alignment score subject to risk and leverage constraints.

There are many ways to build an alignment score. In the following, we propose one way that captures all concepts outlined in this chapter, uses both current and projected emission intensities, and does so in a manner that is transparent and interpretable.

If both the current and projected emission intensities of a company are lower than the pathway intensity and the distance from the pathway is growing (green getting greener), then the company is awarded a score of 1 (see **Exhibit 7**). If both the current and projected emission intensities of a company are lower than the pathway intensity and the distance is getting smaller

Exhibit 7. A Potential Pathway Alignment Score Scheme



(i.e., the company decarbonizes at a slower rate than the one required by the pathway), it receives a score of 2. If the current emission intensity is below the pathway but the projected intensity is above it (green becoming brown), it receives a score of 3. Currently, brown companies are split into three categories: Those that decarbonize fast enough so that their projected intensity falls below the pathway (brown becoming green) get a score of 4. Those that decarbonize faster than the pathway, reducing the distance from the pathway intensity but not falling below, receive a score of 5. Those that decarbonize slower than the pathway receive a score of 6.

As discussed previously, projected emissions can be estimated using either the historical trend or the company-disclosed targets. Scores can be calculated using both, if available, and combined using weights that reflect the confidence in or preference for either method. Further advantages of constructing a composite score are the ability to introduce additional metrics that are related to the future carbon footprint of a company, such as availability and quality of emission reporting, participation in net-zero alliances, emission reduction pledges, and green capital expenditures.

As shown in Exhibit 7, the proposed score is a reasonable proxy for the net area between the company emission intensity projected curve and the pathway (positive if the company curve is above the pathway, negative if it is below). This area corresponds to the excess cumulative GHGs of the company over its fair share of pathway-determined net-zero compatible emissions, which is the variable we ultimately want to target.

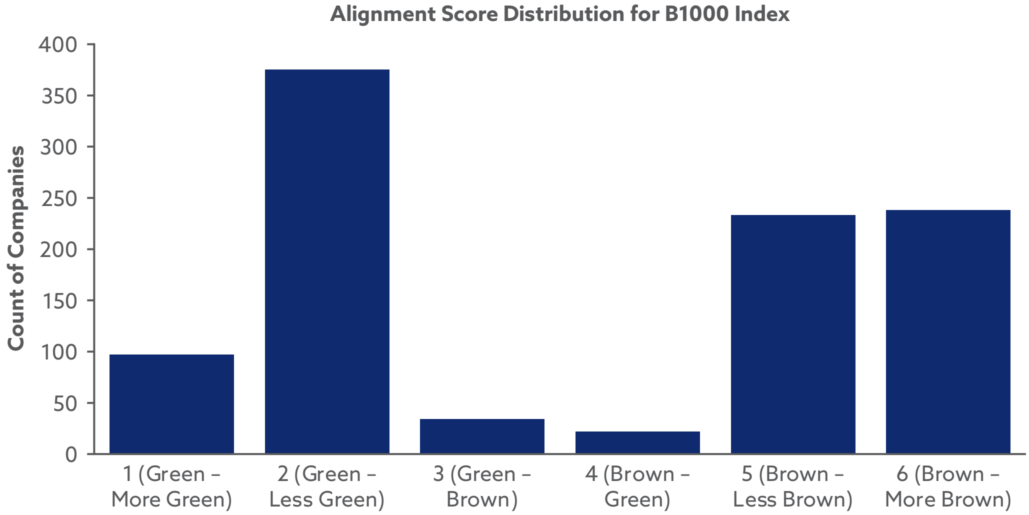
Once a score is constructed, the portfolio construction problem can be solved in any of the previously discussed methodologies by replacing the company emissions with the vector of their alignment scores, $\mathbf{s}_t$.

One criticism of this approach is that it does not directly control the resulting emissions of the portfolio and does not ensure that they are consistent with the net-zero pathway. However, it is a fallacy to believe that a methodology directly targeting portfolio emissions does so, given the numerous assumptions and imprecise data involved in portfolio construction. Furthermore, investors can calculate the resulting current and/or forward emission intensity of the optimal portfolio and adjust the trade-off parameters of the optimization problem to achieve the emission intensity level they wish to target.

Illustration: An Equity Example

Using Bloomberg data, we compiled alignment scores for all companies in the Bloomberg 1000 Equity (B1000) Index as of 29 September 2023. The average alignment score for this universe is 3.30. About half the companies are characterized as green, with the majority of those becoming less green relative to the pathway, as shown in **Exhibit 8**. Half the brown companies are improving, with a small fraction of those expected to become green on the forward date ($t + \Delta t$ in Exhibit 7).

Exhibit 8. Distribution of Alignment Scores for the Companies in the Bloomberg 1000 Equity (B1000) Index as of 29 September 2023



Source: Bloomberg.

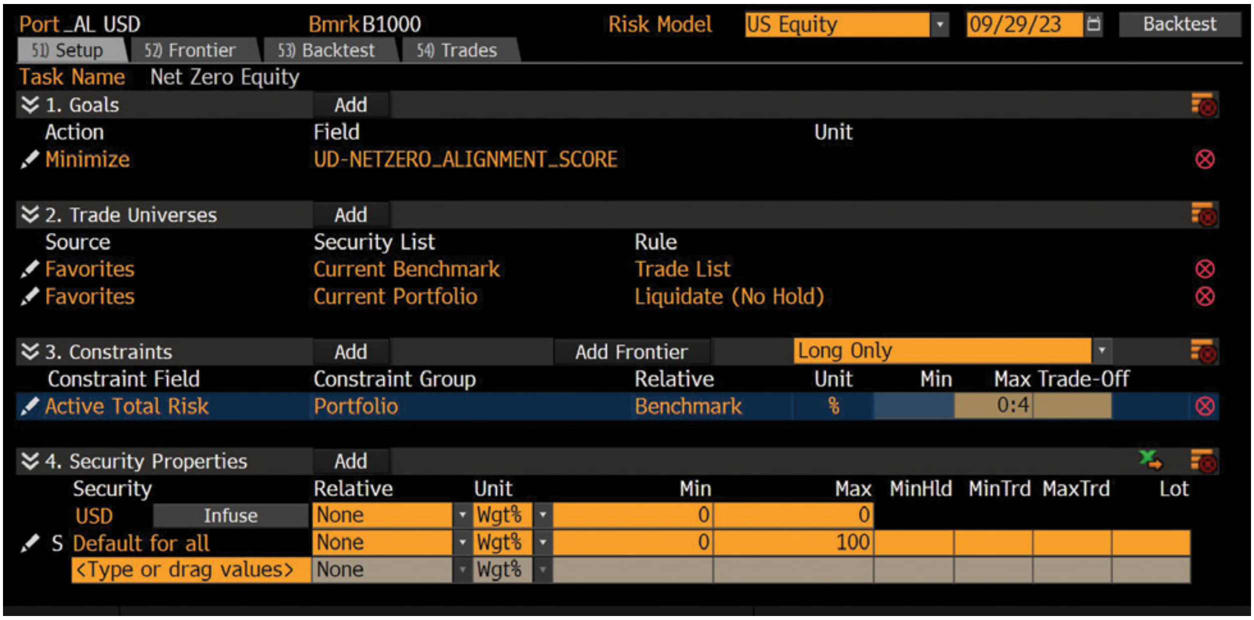
We seek to construct a portfolio that is "greener" than the B1000 index by reweighting the securities in the index to minimize the alignment score while controlling the tracking error relative to the index. In addition, we allow no leverage or short positions. The setup of the problem using the Bloomberg Optimizer is shown in **Exhibit 9**. For measuring tracking error volatility, we use the Bloomberg MAC3 GRM US Equity risk model at a quarterly horizon.[6]

The Bloomberg Optimizer allows users to specify a range of maximum allowable tracking error and generates the efficient frontier shown in **Exhibit 10**. We can see that when we ask the optimizer to construct a portfolio with zero tracking error to the index, it returns the index itself with the index alignment score of 3.32. For a very modest tracking error of 1% per year, the alignment score of the portfolio drops to 1.79. If the tracking error constraint is relaxed to a still quite modest 2% per year, the alignment score drops even further, to 1.32. The minimum alignment score of 1.00 (i.e., the score that results from selecting only improving green companies) can be achieved with a tracking error of 3.88% per year.

Investors who do not have access to the full power of a commercial optimizer and risk model can simplify the problem by adopting a CAPM-based risk model and expressing the portfolio weights as a function of a small set of parameters that can be handled by a less powerful optimizer. For example, if we assume that all stocks have equal market betas and the same specific risk, the covariance

[6]The Bloomberg MAC3 GRM suite of risk models allows users to choose an appropriate risk measurement horizon and provides a risk estimate calibrated to the chosen horizon. In portfolio construction, it is typical to choose a horizon that aligns with the rebalancing frequency of the investment strategy. Shorter-horizon models are used to measure the day-to-day investment risk.

Exhibit 9. Setup of the Bloomberg Optimizer



Source: Bloomberg.

Exhibit 10. The Equity Efficient Frontier: Net-Zero Alignment Score as a Function of Tracking Error Volatility (TEV)

Source: Bloomberg.

matrix of active portfolio returns is reduced to the identity matrix multiplied by the specific risk variance. We modify Equation 17 to define the weights as a function of alignment scores instead of the emission intensities. The parameter, s_0, is set to 3.5 to ensure that green companies are overweighted and brown companies are underweighted.

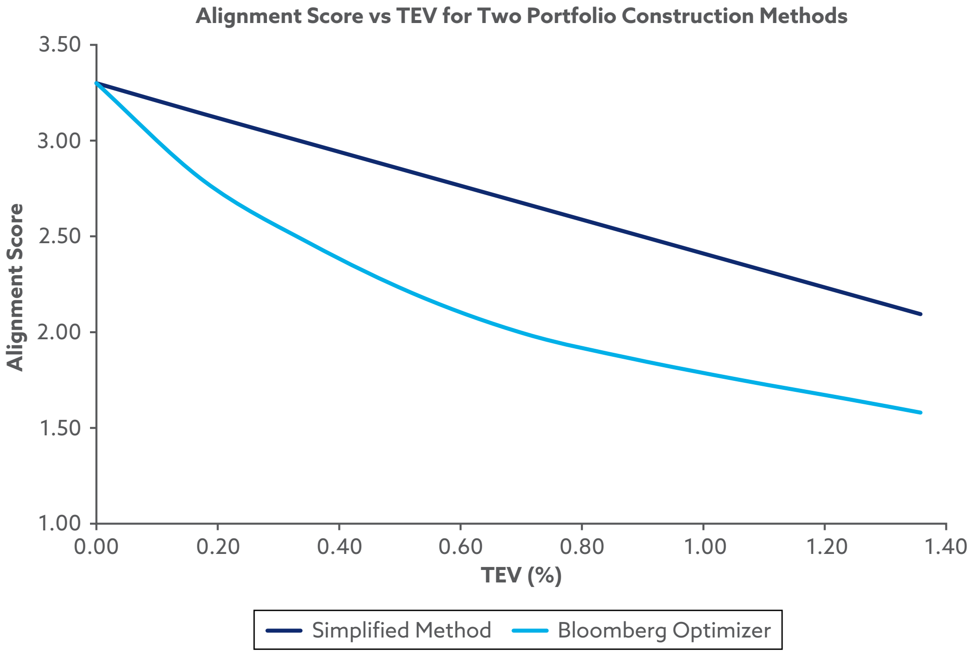
$$\omega_t = \mathbf{w}_t - \lambda_t^+ \mathbf{W}_t (\mathbf{s}_t - s_0 \mathbf{1})^+ - \lambda_t^- \mathbf{W}_t (\mathbf{s}_t - s_0 \mathbf{1})^- . \quad (21)$$

We now set up the portfolio construction problem as follows:

Minimize risk and alignment score:	$\min_{\lambda_t^+, \lambda_t^-} \{\omega_t' \omega_t + \lambda_t \omega_t' \mathbf{s}_t\}$
No leverage:	$\omega_t' \mathbf{1} = 1$
No shorting:	$\omega_t \geq 0.$

This problem can be easily solved to produce the efficient frontier. Using a specific risk volatility of 20%,[7] we can construct a portfolio with a TEV to the B1000 index of 1% per year with an alignment score of 2.40—considerably higher than the 1.78 score the Bloomberg Optimizer can achieve for the same tracking error. Of course, this result should be expected because of the additional structure imposed on the weight function. In **Exhibit 11**, we compare

Exhibit 11. Comparing the Efficient Frontiers of the Two Portfolio Construction Methods



Source: Bloomberg.

[7]This value is very close to the median specific volatility of the stocks in the B1000 index universe as of 29 September 2023.

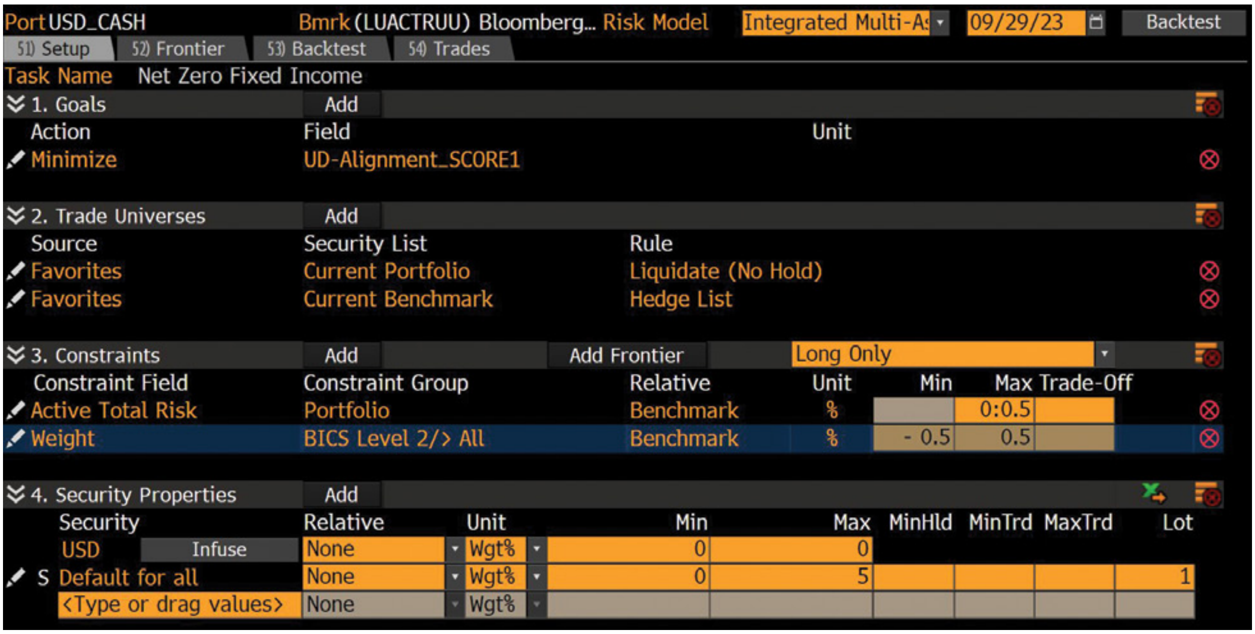
the efficient frontiers achieved with the Bloomberg Optimizer without any structure on the weight function and the one produced by the simpler and more constrained version described previously.

Illustration: A Fixed-Income Example

In this example, we seek to construct a portfolio that is "greener" than the Bloomberg US Investment Grade (IG) Corporate Bond Index. The optimization problem is set up in a similar way as the equity example with additional sector weight constraints (see **Exhibit 12**).

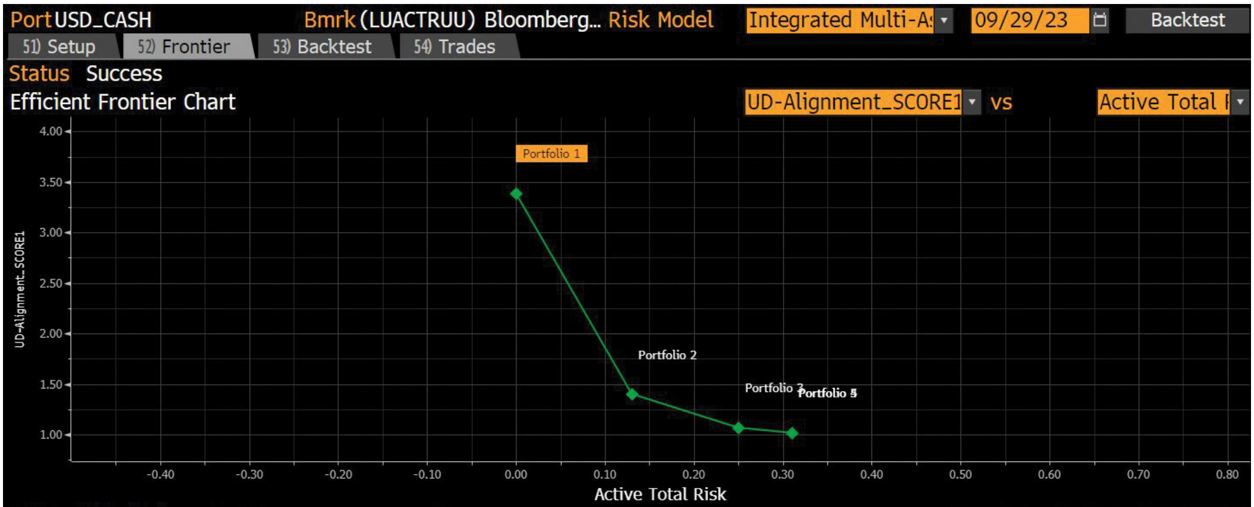
The efficient frontier for the bond portfolio is provided in **Exhibit 13**. Compared with the equity example, the efficient frontier is much steeper, with maximum TEV of 0.31% per year for a minimum alignment score of 1. In the equity example, the maximum TEV is 3.84% (see Exhibit 10). There are a few explanations for the difference. The primary one is that the equity index has a significantly higher volatility than the fixed-income index, and specific risk accounts for a much smaller portion of the total risk for an average IG corporate bond than it does for a stock. Additionally, the greater number of securities in the bond index (slightly fewer than 100 stocks in the equity index and nearly 500 bonds in the bond index have alignment scores of 1) also plays a part in the bond portfolio being able to achieve a portfolio alignment score of 1 with a lower TEV to the benchmark.

Exhibit 12. Setup of the Bloomberg Optimization for Fixed Income



Source: Bloomberg.

Exhibit 13. The Fixed-Income Efficient Frontier: Net-Zero Alignment Score as a Function of TEV



Optimal Portfolios (Click row to view trades) Export Frontier Summary

Optimal Portfolio	Active Total Risk (Constraint)	UD-Alignment_SCORE1 (Goal)
Portfolio 1	0	3.39
Portfolio 2	0.13	1.4
Portfolio 3	0.25	1.07
Portfolio 4	0.31	1.02
Portfolio 5	0.31	1.02

Source: Bloomberg.

Combining Peer Group Subportfolios into an Overall Portfolio

So far, we have discussed how to reallocate investment to different companies within a peer group. To combine the peer groups into a total portfolio, the investors can use an array of methodologies. The simplest one retains the benchmark weights for each peer group. If companies within each peer group have been reweighted such that the peer group emissions are consistent with the pathway, then the entire portfolio will be consistent with the pathway. An alternative way is to solve the same portfolio construction problem by treating each peer group as an individual unit with its own alignment score. The portfolio construction problem can be augmented with additional constraints controlling exposure to certain sectors or regions.

Conclusion

The construction of investment portfolios that are aligned with a realistic net-zero transition scenario is a task filled with unique challenges, as outlined throughout this chapter. These are challenges to which we must find adequate solutions if capital markets are to effectively incentivize decarbonization in line with global climate goals. The urgency to act in accordance with ambitious goals, such as the 1.5°C temperature limit set by the Paris Agreement, cannot be understated. Addressing this urgency will therefore require ongoing innovation in approaches to climate-aligned portfolio management.

One of the key challenges that portfolio managers will face is the uncertainty associated with estimated carbon budgets and the variability in climate scenarios and transition pathways. Investors will have to navigate this highly technical landscape when determining a representative pathway based on their objectives and acknowledge that these carbon budgets and associated pathways will need to be updated incrementally over time as new evidence emerges. The next set of challenges relates to the allocation of emission budgets within a portfolio, a problem that requires a careful balance between scientific rigor and practical considerations given data availability and the need for scalability. The methodology proposed in this chapter seeks to allocate carbon budget constraints based on rates of change in emission intensity terms. In doing so, the approach addresses a central limitation identified with other approaches to date, in that it allows us to use the full detail of modeled transition pathways and treat securities with region and sector specificity, thereby reflecting a more realistic decarbonization profile.

We have extended the approach by introducing projected emissions, such that alignment with the pathway's carbon budget is assessed in both the current period and a future period. We use projected emissions because of the conceptual acknowledgment that net-zero alignment is dynamic and that there are additional sources of information that can add value, such as historical trends in emissions and disclosed emission reduction targets. Despite the logic behind the outlined methodology, however, we recognize the sources of uncertainty introduced through our stated assumptions and challenges with the reliability of company emission data. For these reasons, we have built a net-zero alignment score that draws on the full detail of the outlined methodology but characterizes the current and projected alignment of issuers through an interpretable integer score. We then use this net-zero alignment score in conjunction with the Bloomberg Optimizer to demonstrate how an equity portfolio can be constructed to maximize "greenness" within a specified tolerance for tracking error.

The approach outlined in this chapter provides a platform for further research and ideation on the topic of net-zero-aligned portfolio construction. While we have a well-documented and robust process for determining our reference scenario, simulations of portfolios aligned with a wider range of transition pathways (characterized by different evolutions of socioeconomic and energy systems) are likely to yield interesting results for further consideration. Further iteration on the definition of peer groups can help form more insights on the trade-offs between the principles of fairness and substitutability. Other improvements may include additional factors, such as proxy measures for the credibility of company transition plans that can help us form a clearer picture of projected alignment. We hope that the quality and extent of relevant input data progressively improve over time. Further research is required to refine the net-zero alignment analytic to ensure it is as robust and comprehensive as possible.

Appendix A. Calculation of Normalized Weights

We will show that it is infeasible to use a single parameter to tilt higher the weights of green issuers and tilt lower the weight of brown issuers while constructing a portfolio with no leverage.

The functional form of weight tilts is given by the following formula:

$$\omega_t - \mathbf{w}_t = -\lambda_t \mathbf{W}_t (\mathbf{e}_t - e_{p,t}^{NZ} \mathbf{1}).$$

Normalizing by the sum of the new weights, $\omega_t' \mathbf{1}$, we get to the final weight tilts:

$$\omega_t^* - \mathbf{w}_t = \frac{\mathbf{w}_t - \lambda_t \mathbf{W}_t (\mathbf{e}_t - e_{p,t}^{NZ} \mathbf{1})}{\omega_t' \mathbf{1}} - \mathbf{w}_t .$$

Using the equation $\omega_t' \mathbf{1} = 1 - \lambda_t (\mathbf{w}_t' \mathbf{e}_t - e_{p,t}^{NZ})$, we get

$$\omega_t^* - \mathbf{w}_t = -\lambda_t \frac{\mathbf{W}_t (\mathbf{e}_t - e_{p,t}^{NZ} \mathbf{1}) - \mathbf{w}_t (\mathbf{w}_t' \mathbf{e}_t - e_{p,t}^{NZ})}{1 - \lambda_t (\mathbf{w}_t' \mathbf{e}_t - e_{p,t}^{NZ})}.$$

Working out the numerator, we arrive at the normalized weight tilt functional form:

$$\omega_t^* - \mathbf{w}_t = -\lambda_t \mathbf{W}_t \frac{\mathbf{e}_t - (\mathbf{w}_t' \mathbf{e}_t) \mathbf{1}}{1 - \lambda_t (\mathbf{w}_t' \mathbf{e}_t - e_{p,t}^{NZ})}.$$

We can see that the pivot intensity that determines positive and negative shifts is not the pathway intensity anymore; it has been replaced with the weighted average peer group intensity.

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