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Research

Net-Zero Carbon Portfolio Alignment

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We outline a simple and robust methodology to align portfolios with a science-based, carbon budget consistent with maintaining a temperature rise below 1.5 °C with 83% probability. We show how to keep the tracking error at a negligible level. This approach works for both passive and active managers. It also establishes an exit roadmap for carbon-intensive corporates, thereby generating a form of competition to decarbonize within each sector. We also discuss four sources of risks: uncertainty around a rapidly shrinking carbon budget, time impacts on decarbonization rates, implementation risk due to market-wide selling pressure, and uncertainty about taxes on polluting companies.

Keywords: benchmarking; climate change; net neutrality; net-zero portfolio construction

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Introduction

Over the last few years, the world has witnessed a major shift in its approach to tackle the looming climate crisis. One of the defining moments has been the Paris Agreement of 2015, which set in motion a global effort to reduce carbon emissions with the highly ambitious goal of containing global average temperature increases to no more than 2 degrees Celsius, and later an even more ambitious target of 1.5 °C. This latter goal requires a reduction in global emissions to zero by 2050, an objective coined as *carbon net neutrality*. The carbon neutrality objective has by now been embraced by many players, including governments, corporates, municipalities, asset owners, asset managers, and banks. In this paper, we address the question of how to structure net-zero aligned portfolios of investors, in a world where companies are not necessarily aligned with this objective. The premise of our analysis is that even if companies are not fully aligned with carbon neutrality, then at least investors should strive to be aligned by gradually reducing their carbon footprint through divestment of high-carbon emitters.

Investors may want to do their part even if others do not, and if a sufficient mass of such investors align their portfolios to a net-zero target, then companies will be more incentivized to follow suit. But how can investors be aligned while maintaining their market exposure and reducing the tracking error of their portfolio with respect to the market benchmark? We approach the alignment question from the perspective of an investor who takes the world as given, in contrast to most other current approaches that focus on corporate pathways to carbon neutrality and the implied risks for investors holding these companies. Corporate decarbonization commitments are in their infancy and the projected carbon reduction trajectories are still highly unreliable. It is thus highly uncertain to what extent and at what speed companies will decarbonize their activities, so that investors need to be prepared to implement a scenario where they can

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decarbonize their portfolios even if many companies do not decarbonize their activities sufficiently.

We propose a robust and straightforward approach to constructing portfolios aligned with a science-based carbon budget, as defined by the Intergovernmental Panel on Climate Change (IPCC). The goal is to align the portfolios with a carbon budget while maintaining a low tracking error and reasonably small sector-weighted deviations. In short, we allocate to the portfolio, year after year, a carbon budget expressed in level of emissions, and not in intensity, and reshuffle it while minimizing the tracking error. The sums of all the yearly carbon budgets mirror the efforts requested to be carbon neutral at the planet level. Using various economically plausible scenarios, we illustrate the feasibility of integrating net-zero footprint constraints into *large-scale* portfolios with resulting tracking errors that are not substantial. An additional advantage of the carbon budget-based approach is that it provides a form of active engagement with corporates: Companies can predict when they would be excluded from portfolios aligned with a net-zero pathway. In effect, companies are put in a competitive race to decarbonize, so as to maintain their place in the portfolio (excluded companies can be reintegrated if they are back on track toward net zero).

At a broad level, our approach addresses most of the main risks that net-zero committed investors are currently facing: reputational risk with respect to meeting their commitments, which is magnified by the lack of transparency in the choice of metrics, implementation risk given the finite timeframe, uncertainty with respect to changing constraints, liquidity and market impact risk, and the risk of working with noisy forward-looking data leading to potential dynamic tracking error. In this respect, our analysis highlights the need for mainstream net-zero benchmarks based on a straightforward methodology.

Global Convergence Toward Climate Objectives

There is an undeniable momentum building around the need to manage climate-related risks. Last year, 2021, saw an unprecedented number of actors, public and private, setting net-zero targets. Despite the global pandemic, the number of net-zero commitments almost doubled in less than a year, as countries prioritized climate action in their recovery.[1] Take for instance *the Race to Zero* campaign around the Conference of the Parties (COP) 26. This all-encompassing campaign is the largest alliance committed to net-zero and aims to rally support from businesses, cities, regions, and investors to promote a resilient zero-carbon future. All adhering parties commit to halving their emissions by 2030 and reaching net-zero by 2050 at the latest. It represents 31 regions, 733 cities, 622 Higher Education institutions, 173 of the biggest investors, and 3067 businesses, collectively making up nearly 25% of global emissions and over 50% of world GDP.[2] In sum, these initiatives by 'real economy' actors join the commitments of countries, covering at least 68% of the global economy, 61% of global greenhouse gas emissions, and 56% of the global population.

Today, more than 130 countries have set a target to become carbon neutral by 2050, and China by 2060.[3] Not only have countries begun to integrate these pledges into tighter climate policies, but twelve countries, including some of the top greenhouse gas (GHG) emitters such as Japan, Canada, and the European Union[4] have also enshrined their commitments into law.

The emissions covered by these pledges have risen to 70% of global emissions in the span of just 5 years (International Energy Agency (IEA) 2021). Moreover, the global distribution of net-zero pledges is almost balanced between emerging markets and advanced economies (IEA 2021). Still, many of the commitments lack near-term milestones and concrete policies to successfully implement the targets. Moreover, the current pledges still leave us with around 22 billion tons of CO_2 worldwide in 2050, which translates to a temperature increase of 2.1 °C by 2100 (IEA 2021).

Private sector financial institutions are also beginning to mobilize. From asset owners to multi-national corporations, commitments to net-zero are becoming mainstream. Through the UN-convened Asset Owners Net-Zero Alliance launched in September 2019, 66 institutional investors representing over $10 trillion in assets under management, have committed to align their portfolios with a 1.5 °C consistent decarbonization trajectory by 2050.[5] Quickly thereafter, in December 2019, the Net Zero Asset Managers Initiative was launched to urge the asset management industry to commit to net-zero emissions. The Initiative now counts 220 signatories and represents $57 trillion in assets under management. UNEP FI's UN-convened Net-Zero Banking Alliance has also been launched in 2021, bringing together 43% of global banking assets, representing 98 banks, 39 countries, and $66 trillion.[6] The world's leading insurers and reinsurers will shortly be joining these alliances through the soon-to-be launched UN-convened Net-Zero Insurance Alliance.[7] Beyond banks, corporations are also increasingly embracing decarbonization commitments and net zero targets. As of November 2021, more than 1,000 companies worldwide joined the Business Ambition for 1.5° campaign (part of the Science-Based Target initiative [SBTi 2021]) just after 2 years since its launch, representing $23 trillion in market capitalization, spanning 53 sectors, and representing 60 countries.[8] An important caveat, though, is that so far many of the companies that have joined the SBTi are the best in class (have lowest emissions) within their industrial sectors, which reaffirms the need to mobilize more large-scale emitters (Bolton and Kacperczyk 2021b). In preparation for the COP26, Mark Carney launched the Glasgow Financial Alliance for Net Zero[9] (GFANZ) in partnership with the Race to Zero Campaign, bringing together existing and new net-zero finance initiatives and uniting 450 financial firms with total AUM of about $130 trillion.[10]

A Robust Portfolio Model with a Carbon Budget Constraint

We build on an approach that has already been adopted by several asset owners and asset managers (Eccles and Klimenko 2019), which is to construct low-carbon indexes that (i) reduce the weight of carbon-intensive companies in the reference index, and (ii) minimize the tracking error of the low-carbon index with respect to the reference market index (Andersson, Bolton, and Samama 2016). We generalize this approach by dynamically constructing a low-carbon portfolio, starting from a reference market index and gradually decarbonizing this index to satisfy an overall carbon budget constraint that is consistent with a 1.5 °C scenario according to the IPCC. We further derive a dynamic tracking error of the decarbonized portfolio with respect to the reference index. This dynamic tracking error depends on investor expectations regarding changes in the carbon emissions regulatory environment and actions taken by corporates to reduce their carbon emissions.

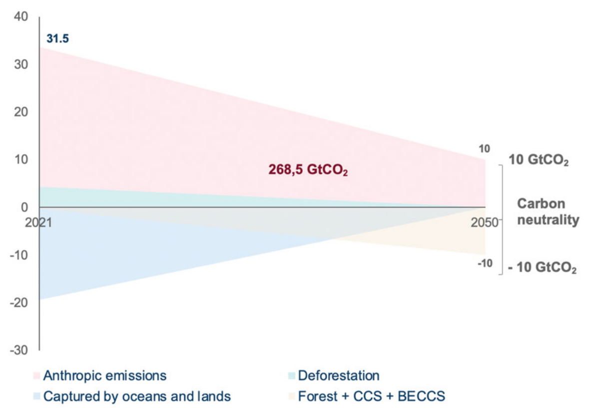
The Carbon Budget. The latest climate research establishes that, to limit global warming from pre-industrial levels to 1.5 °C with an 83% probability, all emitters globally, as of 2020, should be allowed to emit a maximum combined total amount of 300 gigatons (Gt) of CO_2 (IPCC 2021).[11] This carbon budget is the reference point of our approach. It is of course only an estimate, which could be reevaluated as more data come in on how the planet is warming.[12] Our methodology, however, is not tied to a specific number for the carbon budget. Several important considerations could lead to significant revisions in this estimate. First, the thawing permafrost and associated methane release would reduce the budget by approximately 100Gt CO_2. Second, the evolution of Methane and Sulphur-dioxide emissions as well as aerosol cooling[13] could change the budget by a range of -400 to $+200$Gt CO_2. Third, uncertainty with respect to the effect on global warming of CO_2 emissions (transient climate response to cumulative carbon emissions) could also contribute to $+100$ to $+200$Gt CO_2. Finally, there is the uncertainty around different scenario assumptions regarding the future evolution of non-CO_2 emissions ($\pm$250Gt CO_2).

Besides corporate emissions there are also emissions from changes in the biomass reservoir amounting to net positive emissions of 5.5 GtCO_2 per year.[14] We have not included these emissions in our baseline simulations, but these could easily be added. In short, we make the simplifying assumption that the carbon budget of 300 GtCO_2 only includes emissions tied to human activity. Note also that our calculations are based on CO_2 emissions rather than CO_2 equivalent emissions. Corporates tend to report in terms of CO_2eq/yr. We assume that both follow a similar trajectory. Furthermore, our calculations use Scope 1 (direct emissions produced at source) & 2 (emissions from the consumption of energy), and Scope 3 (emissions generated within the production/consumption chain) upstream first-tier data, which only covers the direct supply chain. Depending on data availability, future calibration of the model can also include Scope 3 downstream emissions into the remaining carbon budget.

Given that we set up our portfolios as of 2021, the remaining carbon budget of 300GtCO_2 needs to be adjusted as it has evolved since the beginning of 2020. According to the IEA annual reports, global annual energy-related emissions were 31.5GtCO_2 in 2020.[15] Therefore, in 2021, the remaining carbon budget amounts to approximately 268.5 GtCO_2.

Given the revised carbon budget of 268.5 GtCO_2, and assuming a constant rate of annual emissions of 31.5 GtCO_2, we would have 8.5 years' worth of carbon budget (268.5/31.5) to spend. Alternatively, with a 2050 Net Zero target, emissions would have to be gradually reduced to be able to spread the budget over the next 29 years (see Figure 1 below).

Figure 1. Trajectory to Net Zero Emissions Based on Carbon Budget



Source. Carbone4, Authors.[16]

Constructing Carbon-Neutral Portfolios.

The carbon footprint of the portfolio is calculated as the emissions of the constituent companies multiplied by the respective shares of the individual stocks in the portfolio. The portfolio is dynamically constructed in a way that all the capital remains invested, while the carbon footprint is constrained to satisfy the overall carbon budget given above. The portfolio optimization problem is also constrained by sector allocations. In general, this roadmap can also become a pilot for all fixed income securities for insurers.

We consider two different scenarios. First, based on the initial carbon footprint, the reduction trajectory is assumed to follow a constant geometric reduction rate, with an initial 25% reduction at implementation, followed by a yearly 8% emissions reduction until 2050. The other scenario has no initial reduction in carbon footprint, but a yearly geometric reduction rate of 10%. Distinguishing between the two scenarios is a simple way of illustrating the effect of delaying emission reductions on future decarbonization rates that are consistent with a net zero target. We also need to account for possible inflows into the portfolio. We calibrate them to the carbon neutrality trajectory, applying the portfolio weighting to this inflow of capital.

Two main approaches can be taken to solve the portfolio problem: (i) first determine all asset allocations that achieve the carbon objective and then optimize the tracking error of the portfolio by optimally weighting the asset holdings that are consistent with the carbon objective, or (ii) optimize the tracking error of the portfolio subject to a carbon budget constraint. Under the first approach, we first eliminate high-carbon footprint composite stocks, with the objective of meeting planned target carbon footprint budgets for the portfolio, and then we reweigh the remaining stocks to minimize tracking error with the benchmark index. Under the other formulation, we begin by combining a minimized tracking error with the benchmark index with the objective of the planned carbon footprint budgets that have been set-up at inception. The two portfolio optimization approaches can be represented as follows:

Suppose that there are N constituent stocks in the benchmark index and that the weight of each stock in the index is given by $w_i^b = \frac{Mkt\ \ Cap\ \ (i)}{Total\ \ Market\ \ Cap}$. Suppose next that each constituent company is ranked in decreasing order of absolute carbon emissions, w_I^i, with company $\mathrm{I}=1$ having the highest carbon emissions level and company $\mathrm{I}=\mathrm{N}$ the lowest emissions.

In the first approach, the carbon-neutral portfolio can be constructed every period by choosing new weights, w_i^g, for the constituent stocks to solve the following minimization problem:

$$\text{Min TE} \ = \ \text{sd}(R^g - R^b),$$

where,

$$w_i^g = \ 0 \quad \text{for all } \mathrm{i} = 1, \ldots, k$$
$$0 \ \leq w_i^g \quad \text{for all } i = k+1, \ldots, N$$

That is, the carbon-neutral portfolio is constructed by first excluding the k worst performers in terms of absolute carbon emissions up to the threshold that is consistent with the sum of carbon emissions of all the remaining constituents satisfying the carbon budget.

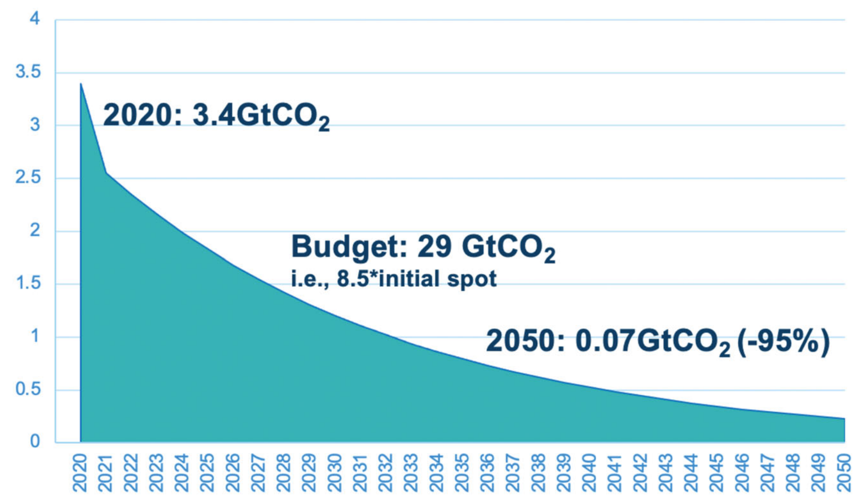
In the second problem formulation, the first set of constraints ($w_i^g = 0$ for all $\mathrm{i}=1, \ldots k$) is replaced by the constraint that the neutral portfolio's carbon footprint must be not more than a given threshold:

$$\sum\nolimits_{I=1,\ldots,N} w_I^g q_I \leq Q,$$

where Q is the carbon budget for that year that has been established based on the portfolio's carbon footprint from the previous year to mimic the net-zero carbon budget of the planet. In other words, the second problem only seeks to reduce the carbon footprint of the portfolio by reweighing the stocks to achieve the carbon budget. In both cases, the set of assets from which we can draw the candidate constituents is limited to the members of the benchmark portfolio.

As in Andersson, Bolton, and Samama (2016), the ex-ante tracking error (TE) is given by the estimated

Figure 2. Carbon Emissions Reduction that Mimics the Required Path to Achieve Carbon Neutrality by 2050 on MSCI Europe



Assumptions: 25% Initial Haircut Followed by an 8% Geometric Reduction; Emissions Are Constant.

standard deviation of returns of the decarbonized portfolio from the benchmark, using a multifactor model of aggregate risk. This multifactor model significantly reduces computations and allows for a decomposition of individual stock returns into a weighted sum of common factor returns. This weighted sum provides a good approximation of individual stocks' expected returns. More formally, under the multifactor model, the TE minimization problem has the following structure:

$$\text{Min}(W^p - W^b)' \; (\beta\Omega_f\beta' + \Delta^{AR}) \; (W^p - W^b)$$

Subject to the constraint:

$$|W^b_{sect} - W^g_{sect}\;| \leq \;\delta,$$

where:

$$w^g_l = \;0 \quad \text{for all } l = 1, \ldots, k$$
$$0 \;\leq w^g_l \quad \text{for all } k = k+1, \ldots, k$$

$(W^p - W^b)$ = the vector of the difference in portfolio weights of the carbon budget portfolio and the benchmark,

Ω_f= the variance–covariance matrix of factors,

β= the matrix of factor exposures,

Δ^{AR}= the diagonal matrix of specific risk variances,

W^g_{sect} is the vector of the portfolio sector weights,

W^b_{sect} is the vector of the benchmark sector weights,

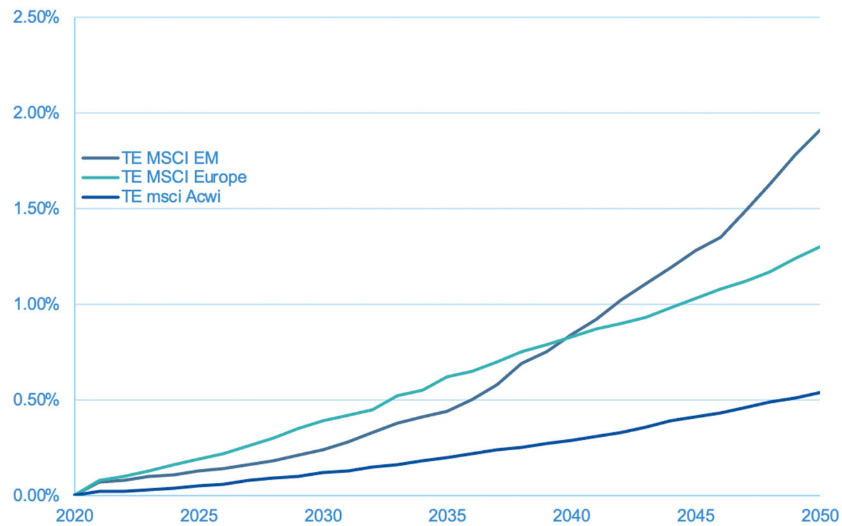
δ is the pre-determined limit in sectorial deviation (in our case 2%).

We perform several simulations using the MSCI Europe Index as the reference index. We first consider a scenario with a 25% initial reduction followed by an 8% annual reduction over 29 years. We account for scope 1, 2, and upstream scope 3 (based on Trucost data) emissions and further assume that the corporate emissions remain constant into the future (the impact of this assumption is tested later). Finally, we impose a sector-deviation constraint[17] (+/− 2% compared to initial portfolio) to avoid a shift of the portfolio toward low-emitting sectors. The result is a portfolio aligned with a 1.5 °C objective, as illustrated in Figure 2.

In this simulation, $3.4GtCO_{2e}$ is the sum of all the emissions in 2020 of the constituents of the MSCI Europe. And, in line with global net-zero targets, the overall budget is 8.5 times the 2020 emissions of the MSCI Europe constituents (see Figure 2). In short, the approach allocates a yearly carbon budget, and the portfolio is then reshuffled to minimize the tracking error. Further, the sum all the yearly carbon budgets is aligned what is necessary to achieve the carbon neutrality.

To compare tracking errors in different regions, we can assume that MSCI ACWI offers a good

Figure 3. Ex-Ante Tracking Errors for MSCI Indexes 1.5 °C Aligned



Source. Authors. Assumptions Are Like Those in Figure 2.

representation of the economy and the decarbonization rate determined for the planet should be applied to it (i.e., a 25% haircut followed by an 8% reduction). However, since Europe and EM have respectively lower and higher starting points in terms of their carbon intensity,[18] the trajectory to achieve a net-zero objective can be fine-tuned as being a 25% hair cut for Europe followed by a 6.4% decrease and a 50% haircut for EM followed by a 12% annual decrease. Under these assumptions, we observe, in Figure 3 below, that the initial tracking error for Europe is very low (0.08%) and remains below 1.3% until 2050. Our tracking error results are very similar when we use the MSCI ACWI benchmark instead. The tracking error starts at a low level, of 0.02% in 2021, and reaches 0.5% in 2050. Regarding the Emerging Markets index, the tracking error also remains low and reaches 2% in 2050. In all three cases, tracking errors do not exceed 2%, even though we assume constant emissions.

In Figure 4, we report the sector deviations of the decarbonized portfolio from the MSCI sector allocations.

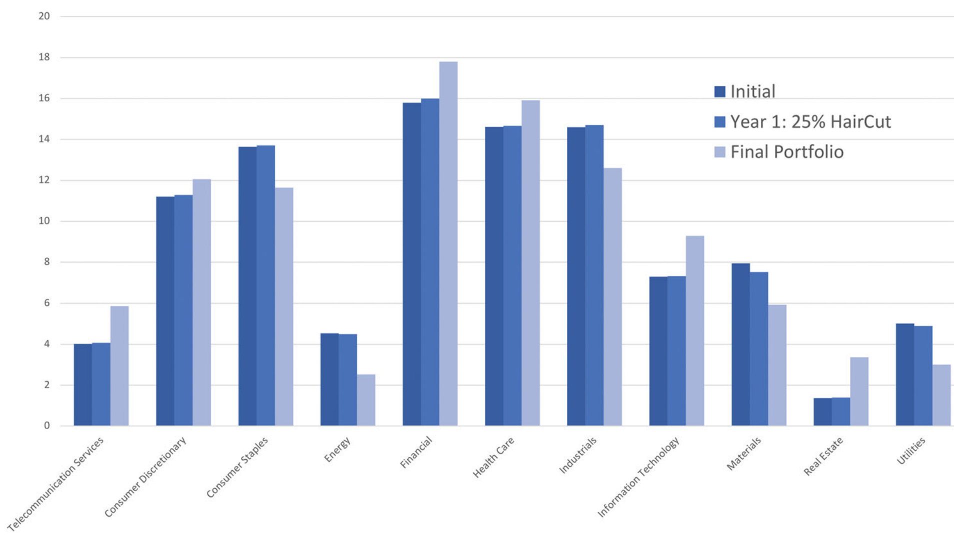
As can be seen, the decarbonized portfolio overweighs the telecommunication services, consumer discretionary, financial, health care, real estate, and information technology sectors and underweights consumer staples, energy, industrials, materials, and utilities sectors. Except for consumer staples and consumer discretionary sectors, the direction of these re-weightings is not entirely surprising given what is known about the sectoral distribution of carbon emissions.

Our baseline model considers one path of emission reduction to reach carbon net neutrality but one could also consider other ways of reaching carbon neutrality, starting in 2021. With a geometrical rate of emission reduction, the path can be either an immediate 25% reduction in carbon footprint, followed by an 85% decrease, or a constant annual 10% reduction. With a linear rate, the pathway can be either a 25% initial reduction, followed by an annual 3.2% reduction, or a constant annual 4.6% reduction. All these paths are structured so that the entire carbon budget of 268.5 $GtCO_2$ is spent.

A first important question is whether financial markets offer enough decarbonized assets to be able to construct a net-neutrality compatible portfolio. One way of determining whether this is possible is to see if the portfolio reaches a market cap limit for corporates, which would lead to investments into less correlated stocks, thus resulting in a higher tracking error. We evaluate this problem assuming a $1tn value portfolio, which is about 60% of the total market cap of MSCI Europe.

Our estimates show that a $1tn position in MSCI Europe would generate a 0.11% higher tracking error in 2050, compared with a position without any supply constraints. In other words, it is feasible to replicate the MSCI Europe portfolio while aligning the carbon footprint of the portfolio with the carbon

Figure 4. Sector Deviations of Decarbonized Portfolio from MSCI Europe



Assumptions Are Similar to Those in Figure 2.

budget assessed by the IPCC and remain within a limited ex-ante tracking error. Furthermore, the transaction costs of implementing the strategy are fairly small, as can be seen from the ex-ante turnover on MSCI Europe, which is 4.7% (for the net zero aligned portfolio[19]). Even though turnover is a simple way of estimating transaction costs with the very low numbers we obtain it seems that transaction costs should not pose a significant cost for our strategy. Also, within the MSCI Europe many of the holdings are very liquid so the expected price impact of trade should be relatively low.

A key variable in our analysis is the time constraint. As there are only about 8.5 years of carbon budget left at the current rate of reduction, it will quickly become very hard to align portfolios with a net-zero objective. For example, if one started the process 5 years from now, the reduction in emissions would rise from a 10% geometrical rate as of today to an 18% rate. We illustrate this shift in Figure 5.

Similarly, the tracking error is sensitive to the size of the carbon budget considered, as is illustrated in Figure 6.

Not surprisingly, the tighter is the budget the more tracking error gets cumulated in the strategy. Interestingly, this process is not linear in scale but only picks up speed for the extreme tightness of the budget, which in our case means a 50% initial reduction in the most conservative carbon budget. In this regard, the tradeoff between an increased tracking error and the tightness of the carbon budget is somewhat insensitive for a range of different budgets.

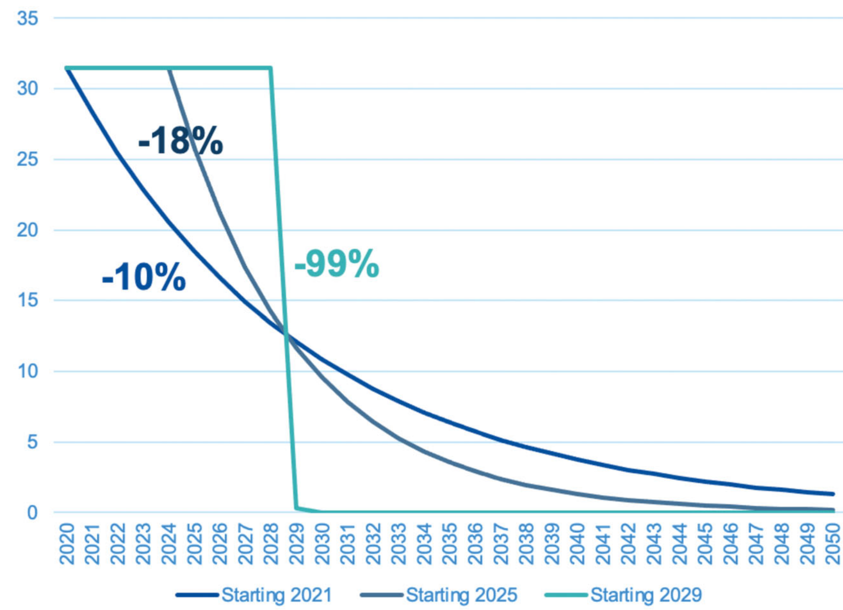
Notably, in the simulations above, emissions are multiplied by the weight of the assets (equity or fixed income) in the portfolio. The carbon footprint pathway is calculated by multiplying corporates' carbon emissions by the capital owned in the portfolio that is gradually aligned with the 1.5 °C trajectory. This approach differs from past approaches, which focus on carbon intensity reductions, and from the Paris Aligned Benchmark index approach, which takes the Enterprise Value Including Cash (EVIC) as a denominator.

Expected Regulatory Changes. How do expected regulatory and carbon tax changes affect the performance of the net-zero aligned portfolios? The NGFS (2020) considers four possible forward-looking scenarios labelled: (1) no transition, (2) sudden transition, (3) orderly transition, and (4) delayed transition.

One can also assign an implied carbon tax to each of the scenarios (ACPR 2020). In the delayed scenario the implied carbon tax is rising quickly and significantly at about 400US2010/TCO_2 in 2040.

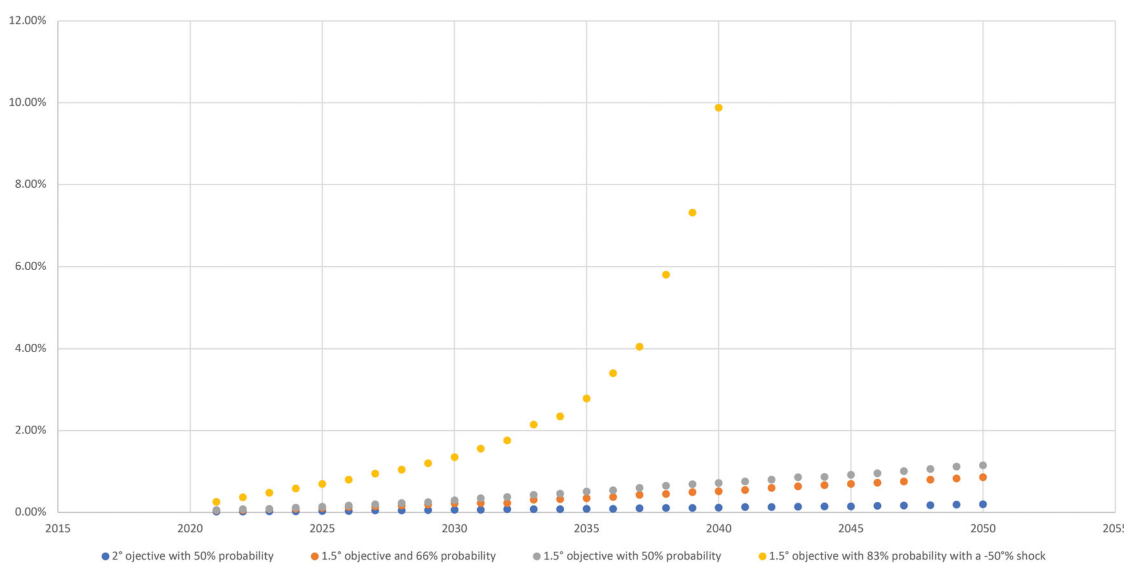
In an *optimistic* scenario, investors believe that companies in all sectors will gradually reduce their emissions in line with the net-zero target. In this scenario, the initial tracking error is obviously low. If

Figure 5. Impact of Starting Date on Carbon Pathways



Assumptions Are Similar to Those in Figure 2.

Figure 6. Impact of the Different Carbon Budget Scenarios on the Tracking Error



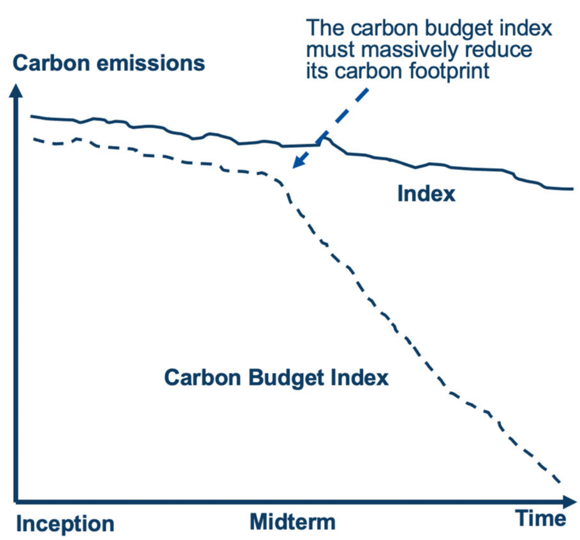
Assumptions Are Similar to Those in Figure 2.

corporates do their job as expected and align to the climate constraints, the tracking error remains low as the overall carbon emissions of the index remain consistent with the budget.

In the scenario where corporates *do not* lower their emissions, the aligned portfolio will have to dramatically reduce its carbon footprint, which generates a high tracking error. At the same time, both physical risks and regulatory risks will rise under this scenario, which means that investors will have to quickly divest from high-emitting companies to hedge the risk of a major carbon price increase (a $400 carbon tax in 2040 in the delayed scenario) which could severely impact them. They would have to operate in a new and demanding regulatory environment. We present the required path of adjustment in Figure 7.

Assessing the current regulatory environment is not an easy task. On the one hand, there is a clear increase in regulatory interventions (and commitments); on the other hand, projected emissions are still on the rise, and therefore the risks of disruptive, sudden regulatory adjustments are high. This raises the question of how one should assess the risks tied with the current expected volumes of corporate carbon emissions.

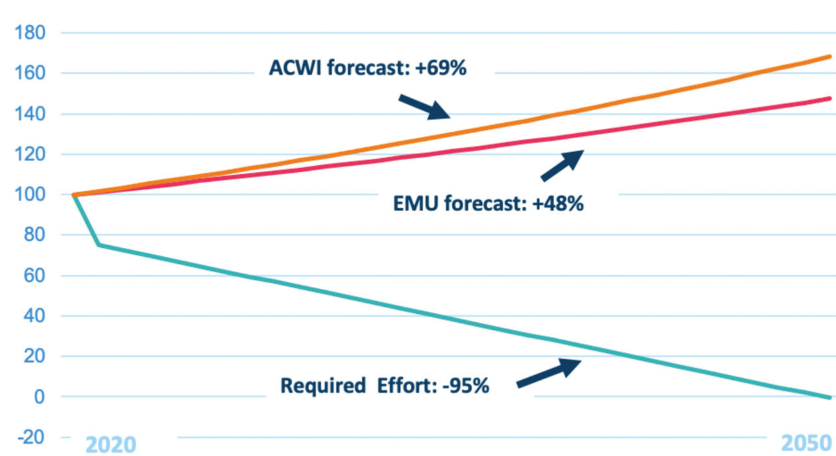
Figure 7. The Pessimistic Scenario Where Corporates Do Not Adjust Their Behavior



One possible way forward is to build on corporations' own commitments. The number of corporations that are making SBTi certified commitments, that are validated by external experts, is growing. Based on their current emissions and expected sales growth, and with the carbon emission projections of *Iceberg*,[20] we can estimate future pathways of emissions for all the MSCI EMU, and 90% of MSCI ACWI constituents. We find that although many corporates are communicating on their engagements and efforts to curb their emissions, there is still a significant projected increase in the aggregate level of corporate emissions (+48% by 2050 for the MSCI EMU constituents and +68.5% for EM), as is illustrated in Figure 8, which stands in stark contrast to the required emissions reduction efforts.[21]

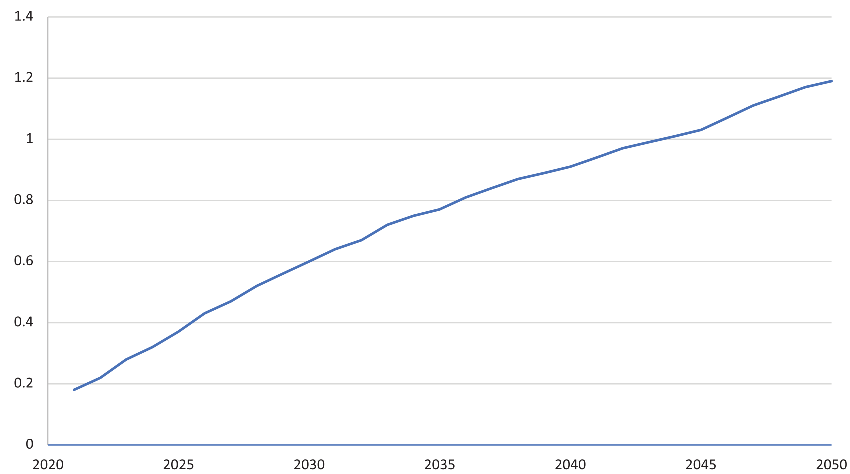
Notably, in this simulation, Scope 3 downstream emissions are also included, which is important for the fossil fuel energy sector, whose most important emissions are downstream. Similarly, 97% of total carbon emissions of the automotive sector are Scope 3 emissions. Combustion of oil and gas accounts for 50% of global emissions, over 60% of which are typically downstream Scope 3 emissions. Yet, companies do not commit to downstream Scope 3 emission reductions (with a few exceptions). Partly, the reason is that data on downstream Scope 3 emissions is still patchy. Only 37% of companies within the MSCI ACWI disclose any Scope 3 data, while 63% disclose Scope 1 and 2 emissions (Blood and Levina, 2021). Importantly, when we combine forward-looking data and downstream Scope 3 emissions, the tracking error remains low (Figure 9).

Figure 8. Estimated Corporate Emissions for the MSCI EMU and ACWI



Source: Authors, Iceberg.

Figure 9. Ex-Ante Tracking Error with Forward-Looking Data Relative to MSCI EMU



Assumptions Are Similar to Those in Figure 2.

Figure 10. Utilities Exit Roadmap from MSCI Europe

2021	2022	2023	2024	2025	2026	2027	2028	2032	2035	2036	2037	2041	2044	2049
VEOLIA ENVIRONNEMENT SA	RWE AG	ENDESA SA	NATURGY ENERGY GROUP SA ENGIE FORTUM OYJ EDP ENERGIAS DE PORTUGAL SA	SUEZ SA	ELECTRICITE DE FRANCE SA	SSE PLC	ENEL SPA	E.ON SE	IBERDROLA SA	NATIONAL GRID PLC	ELIA GROUP SA	VERBUND AG	TERNA RETE ELETTRICA NAZIONALE SPA RED ELECTRICA CORPORACION SA	ORSTED A/S SEVERN TRENT PLC ENAGAS SA SNAM SPA

Assumptions Are Similar to Those in Figure 2.

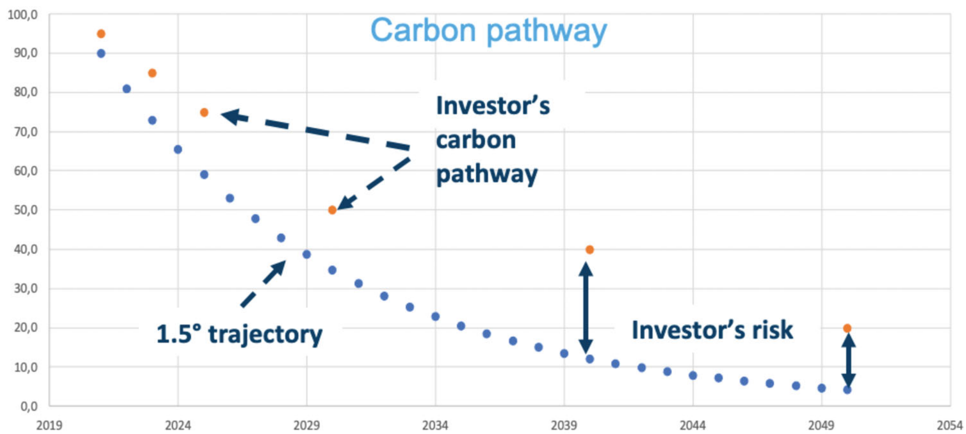
Predicted Divestment Pathways. Under our dynamic portfolio strategy, based on constituents' current carbon footprints, investors in the net-zero aligned portfolios can disclose their intended divestment pathways to corporates and what is driving them. Corporates then know in advance if they remain in the aligned portfolios based on their emissions levels and, conversely, when they will be removed due to their insufficient emissions reduction trajectory. Figure 10 illustrates this process for the utilities sector, with the assumption that the volatility and correlations of the different constituents remain constant and would benefit from the full scope 3 integration when available.

Knowing aligned investors' divestment trajectory helps corporates adapt and avoid exclusion, thus pushing the entire sector to perform continuously better. If a company improves its emissions-reduction track record, it can remain in the portfolio, or reenter after its exclusion if it is able to improve further. In other words, the exit process creates a structural competition within each sector toward a low-carbon economy.

Possible Use of Forward-Looking Data. Another way of constructing net-zero aligned portfolios is to base the portfolio composition on projected future emissions. There are two different sources of forward-looking data: (i) from corporate commitments (through SBTi for example), and (ii) through model-based projections. Given the high autocorrelation in the level of corporate emissions (Bolton and Kacperczyk 2021a), one can extrapolate a 3-year budget based on current emissions and observed trends with a high degree of confidence. Importantly, these data are readily available (e.g., from Trucost). As corporates are increasingly committing to SBTi targets, it is also possible to construct from SBTi intensity commitments (90% of the SBTi-approved firms only commit to intensity targets) carbon emission volume projections (e.g., by applying an average growth rate to company sales based on the expected sales growth in each respective sector).

It is then possible to also base the portfolio construction on forward-looking carbon footprint pathways. Instead of allocating a yearly carbon budget to corporates based on their respective carbon footprints, it

Figure 11. Investors' Carbon Pathway



is possible to work with interim budgets (for example 3 years). These budgets could be allocated to companies based on their respective expected decarbonization pathways over this 3-year period, thereby reducing tracking error. Every 3 years, when the portfolio is rolled over period, one can then adjust the next carbon budget and decarbonization pathway based on the emissions that have occurred over the 3-year period. By relying on the forward-looking data from corporate commitments, it is also possible to remove a company from the portfolio if it misses its target. This is a simple step that rewards corporates that are abiding by their commitments and avoids going overweight on corporates that are not on track and are therefore exposed to future costly adjustments.

Furthermore, as with earnings, where corporations commonly provide guidance on future earnings, corporates could also provide guidance on future carbon emissions. These data would then be used to determine the carbon budget of a portfolio over a given period. Such an approach would promote stronger engagement of investors with corporations, ensuring that corporate emission pathways are aligned with the portfolios' net-zero objectives. Ideally, this carbon guidance should be adopted by all listed corporations. To achieve this outcome, however, is likely to require regulatory intervention.

Regulators could demand from institutional investors (i.e., banks, insurance companies, pension funds, etc.) that they report their "carbon pathways," and the methodology used to estimate their future carbon reductions over 1, 3, 5, 10, and 20 years. Regulators and supervisors can then aggregate this information and assess whether the combined pathways are consistent with the 1.5° objective, as we show in Figure 11. Reporting on pathways would be a simple, transparent tool to examine institutional investors' future exposure to carbon transition risk and, if necessary, to require adjustments in portfolios with incompatible net-zero trajectories. Pathway reports would also provide supervisors with valuable information to assess systemic execution risk associated with the carbon transition. These reports would be a complementary tool to the current climate stress-tests.

Another important benefit in estimating and reporting pathways is that this information can help guide the future supply and demand of carbon offsets and help forecast the future market price of offsets. Similarly, Central Banks could use the carbon budget approach for their collateral management. It would be a way for them to reduce their climate risks and at the same time spread net-zero commitments within the financial sector.

There are, however, some important caveats to our proposed portfolio strategy. First, our portfolio construction is based on a 1-year lagging carbon footprint. Second, we are not including indirect emissions, as Scope 3 data construction is still a work in progress. Third, we have only taken account of carbon emission levels. Other greenhouse gas emissions, such as methane, have not been fully accounted for.[22] Moreover, other corporate conduct is relevant, such as investment plans in green technologies. Our approach could be refined by adding these dimensions. Finally, we have only explored a partial-equilibrium strategy which does not consider possible general equilibrium feedback effects.

Relation to Other Methodologies

The approach we have proposed here only requires the use of yearly disclosed emissions by corporates. Other approaches that have been considered are more ambitious and complex, but they are also harder to understand and implement. A first alternative approach is based only on corporates' disclosed commitments. Despite the growing mobilization of multiple players to combat climate change, it must be recognized that there is a gap between what countries and corporations promise and what they do to meet their targets. Even though an unprecedented number of commitments have been made by countries worldwide, the data reveals that in 2021 global emissions will increase substantially, the second largest increase in history (IEA 2021). One of the main problems with many of the commitments that have been made is that they remain vague and are too far in the future, without any precise interim milestones.

A related difficulty with this alternative strategy is that only a relatively small number of companies have validated targets. As of November 2019, only 700 companies had committed to set SBTi targets, representing approximately 3% of 2019 global emissions (Blood and Levina 2021). This number has grown to over 1000 companies by the end of 2020. In the MSCI Europe, 13% of the lowest emitters (within the bottom 30% in carbon intensity) have made SBTi commitments, while this number reaches 30% overall. This makes it difficult to construct an optimized portfolio with a low tracking error using only those companies.

The lack of agreement on the scope of gases included in the targets is another important concern. For example, the European Union targets all greenhouse gases by 2050 but China's net-zero plan focuses on balancing CO_2 emissions only (excluding methane and other GHG representing a quarter of total emissions with climate-warming effects) by 2060 (Cowie et al. 2020). At the current levels of saturation in the atmosphere, methane has an atmospheric lifetime of around 12 years with a warming potential of approximately 25 times that of carbon dioxide over a 100-year period.[23] Reducing those emissions would diminish warming faster, but eliminating their emissions completely is currently complicated and no technology exists to actively remove them from the atmosphere, unlike for CO2 (Cowie et al. 2020). The Paris Agreement considers that all greenhouse gases that cannot be eliminated should be reduced.

In another approach, the IEA, which SBTi uses as a benchmark, makes strong carbon capture and storage (CCS) assumptions in its scenarios, increasing over time with more ambitious temperature objectives (IEA 2017). Under the 2 °C scenario, CCS represents 14% of the effort and 32% of the additional emission reductions necessary to reach the below 2 °C scenario. In absolute terms, this means that to reach a 2 °C scenario, CCS technologies must capture 142GtCO_2, and approximately 227GtCO_2 in the below-2 °C scenario by 2060 (IEA 2017).

In yet another, Sectoral Decarbonization Approach (SDA) taken by the IEA and SBTi, the carbon budget is allocated to high-intensity, homogenous sectors (mostly energy), representing over 60% of global emissions, proportionally based on their emissions and abatement capacities, and up to 87% of the carbon budget up to 2050. However, under a more ambitious scenario of a 50% probability of limiting warming to 1.5 °C, other sectors will be required to make a bigger reduction effort. Therefore, depending on the scenario and the sector, corporates will need to make very different efforts to be aligned. In short, the same trajectory for a corporate will lead to a different temperature score depending on the scenario that is chosen (as its sector will be impacted differently). As a result, corporates that are aligned to a 2 °C scenario may not be aligned to a 1.5 °C target at all.

Last, the SBTi allows for both intensity and absolute measures targets, making it difficult to aggregate emissions at portfolio level and to understand global consequences of the absolute budget depletion. Indeed, intensity reduction can be achieved without absolute emissions reduction that is nevertheless required to limit global warming. For instance, most corporates tend to develop renewable capacities on top of existing fossil fuels holdings as emphasized in Alova (2020). Also, in the cross-section of global firms the correlations between the levels and intensities of emissions are far from perfect, see Bolton and Kacperczyk (2021c).

A number of current methodologies are built around forecasts as far as 30 years into the future that are taken as a certainty even though there is a growing consensus on the high unpredictability and on the nonlinear forces at play on climate change (Bolton et al. 2020). Therefore, finding a robust predictor of future emissions is very complex, as future technological developments are unpredictable (Blood and Levina, 2021). For example, looking back 30 years, there was no internet or cellphones, and such developments could not have been predicted. Also, the turnover of companies within the S&P 500 Index keeps increasing. At the current churn rate, about half of S&P 500 companies will be replaced within the next 10 years (Bolton, Levin, and Samama 2020).

The climate benchmark methodologies (the Paris-Aligned Benchmark (PAB) and the Climate Transition Benchmark (CTB)) released by the European Commission have become standard methodologies for investors willing to align their portfolios with the Paris Agreement. The PAB is designed for more ambitious, climate-related investments, requiring stricter measures, whereas the CTB is less strict and allows for more diversification, targeting mostly the needs of institutional investors.

These benchmarks mix in two different approaches, requiring an initial reduction of 50% for PAB and 30% for CTB, followed by a yearly reduction of at least 7%, and adding various exclusion requirements. Notably, the PAB requires certain activity exclusions, green exposures, and carbon targets in addition to the reduction requirements. Emissions are calculated on an intensity basis using the EVIC as a denominator.

Finally, the absence of clearly specified dynamic revisions in the carbon budget is a significant limitation of this approach. As we have argued, the remaining carbon budget is finite and depleting rapidly. As a result, there should be an adjustment in the slope of the reduction pathway depending on the initial starting year.

Conclusion

The COP 21 and the Paris Agreement of 2015 were major milestones, bringing nearly all governments and other major actors around the table to commit to and coordinate their climate change mitigation actions. More recently, we have witnessed another major change: the commitment by a growing number of nations, municipalities, companies, banks, asset owners, asset managers, and insurers to net-zero targets.

Editor's Note

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In this paper, we have proposed a robust and straightforward method (based around science-based carbon budgets) for investors to align their portfolios to a net-zero target. Through multiple simulations, we have shown how to construct a large-scale, net-zero aligned portfolio that has a limited tracking error with respect to a major market index. As the carbon budget gradually shrinks, the situation becomes quickly problematic. Our approach brings out that time is the essence to solve the climate crisis. The net-zero aligned portfolio also provides a form of active engagement with corporates, letting them know if and when they would be excluded from the portfolios based on their emission pathways. Investors can also use forward-looking data, either by estimating future emissions or by relying on corporate carbon guidance. Regulators could require that systemically important institutions estimate and report their carbon pathways (their expected carbon emissions in 5, 10, 20 years) to determine systemic execution risk associated with the necessary alignment of carbon emissions with global net-zero targets.

Given that the countries with net-zero commitments now cover around 70% of global CO_2 emissions and given that the Glasgow Financial Alliance for Net Zero brings together 450 financial firms, representing $130 trillion in assets, for a major investor today not to be itself aligned to net zero is an increasingly material source of carbon transition risk. A net-zero alignment or net-zero carbon indexes may therefore be necessary for standard market benchmarks, to better incentivize corporate executives, and for asset owners and asset managers to reduce an investment risk by integrating this new reality.

Notes

1. https://unfccc.int/news/commitments-to-net-zero-double-in-less-than-a-year.
2. https://racetozero.unfccc.int/what-is-the-race-to-zero.
3. https://www.un.org/en/climatechange/net-zero-coalition
4. https://commonslibrary.parliament.uk/global-net-zero-commitments/
5. https://www.unepfi.org/net-zero-alliance/
6. https://www.unepfi.org/net-zero-banking/members/
7. https://racetozero.unfccc.int/net-zero-financial-alliance-launches/.
8. Status Report: Business Ambition for 1.5°C: Responding to the Climate Crisis.

9. https://www.unep.org/news-and-stories/press-release/mark-carney-un-race-zero-campaign-and-cop26-presidency-launch-net#:~:text=The%20Glasgow%20Financial%20Alliance%20for,the%20transition%20to%20net%20zero

10. https://www.gfanzero.com/about/

11. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

12. Rogelj et al. (2018).

13. Aerosol cooling comes from atmospheric aerosols, suspensions of liquid, solid or mixed particles with highly variable chemical composition and size distribution, scattering or absorbing the solar radiation. These aerosols scatter incoming solar radiation, leading to a cooling effect and some types of aerosols can also absorb radiation. Strongly absorbing aerosols have a warming effect.

14. Dugast et al. (2020).

15. IEA (2020).

16. CCS stands for carbon capture and storage; BECCS stands for bioenergy with carbon capture and storage.

17. Sector allocation is based on MSCI allocations and data.

18. See https://www.msci.com/index-carbon-footprint-metrics

19. To obtain the number, we first compute for each instrument the difference in terms of weightings from one year to another. Next, for each year, we sum the absolute values of this difference to obtain the turnover measure.

20. The methodology used by Iceberg Data Lab, derived from its SB2A methodology uses corporates' current levels of emissions (including Scope 3 assumptions on the automotive, oil & gas, and airline sectors), the projection of these emissions up to 2050 assuming a flat 1.8% p.a. GDP growth. and factoring the company's emissions reduction targets, with a credibility discount applied which depends on the credibility for that target. It covers about 90% of the market capitalizations and for the missing ones, the overall rate applies.

21. Note that it is possible to calculate the temperature alignment of a portfolio based on our carbon budget approach. If the rate of CO2 footprint reduction of the portfolio is aligned with the net-zero objective for the planet, then the portfolio is carbon neutral. Otherwise, the distance with the IPCC pathway determines the temperature. This is a simple way of assigning a temperature to a portfolio as a function of different states of nature.

22. We only account for methane indirectly, to the extent that companies disclose all their GHG emissions in Co2 equivalent metrics.

23. https://www.c2es.org/content/short-lived-climate-pollutants/

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