ROBECO
The Investment Engineers

WHITE PAPER

Efficiently reducing carbon emissions in government bond portfolios

Sustainable Investing Expertise by ROBECOSAM

Executive summary

This paper presents two low-carbon solutions for government bond investors: one for investors who do not aim to generate alpha, and one for investors who want to combine decarbonization with alpha generation using multi-factor investing.

Investors are increasingly trying to reduce the carbon footprint of their portfolios. Several climate solutions are available for asset classes like equities and credits. We propose solutions for government bond portfolios. As these bonds are issued by countries rather than by companies, we explain how countries' emissions are measured based on their production or consumption. The normalization of emissions is also different from that used for companies, as there is no direct equivalent to the enterprise value for countries. Instead, country emissions are expressed as emissions per capita or per unit of GDP. For developed bond markets the different metrics provide similar rankings.

The simplest way to create a portfolio with lower emissions is to take a regular index as a starting point and adjust the country weights solely based on emissions. The pitfalls of this naïve decarbonization approach are that it changes the portfolio's risk profile in unintended ways, it can result in a portfolio with lower yield, and it can harm the profile with respect to other dimensions of sustainability. We demonstrate how this naïve approach can increase the interest-rate risk and sovereign credit risk. Our risk-controlled portfolio construction avoids these pitfalls and decarbonizes portfolios more efficiently, resulting in a stronger reduction of emissions for a given tracking error.

We propose two solutions to combat this problem. The first solution is for investors who do not aim to generate alpha. This green beta solution efficiently reduces the portfolio's carbon emissions without altering its risk profile, maintains the broader sustainability profile, and aims to avoid overpaying for sustainability to reach index-like returns.

“ Green beta: efficient decarbonization without overpaying for sustainability

The second solution, sustainable enhanced index, combines lower carbon emissions with multi-factor investing. Academic evidence shows that factors like value, momentum and low-risk can be used to select government bonds with superior risk-adjusted returns. The portfolio construction process efficiently uses the risk budget to meet the twin goals of decarbonization and return enhancement.

“ Sustainable enhanced index: decarbonization with return enhancement

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Marketing material for professional investors, not for onward distribution.


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Introduction

Carbon reduction is increasingly gaining interest amongst investors. In this research paper we discuss the carbon intensity of sovereign bond portfolios, present common pitfalls to naïve decarbonization, and propose solutions that efficiently combine decarbonization and risk-return tradeoffs in bond portfolios.

Many investors are actively trying to reduce the carbon footprint of their portfolios. Initially, attention has been focused on companies and several climate solutions are available for asset classes like equities and credits. As government bonds, with their USD 33 trillion market value, comprise a significant part of many portfolios, we propose solutions for government bond portfolios. Firstly, we discuss why one would prefer to invest in a portfolio tilted to bonds from countries with lower carbon emissions, then we explain how countries' emissions are measured and how they can be normalized.

We then turn our attention to portfolio construction, to examine the pitfalls of the naïve decarbonization approach. We show that a risk-controlled portfolio construction can avoid these pitfalls and decarbonize portfolios more efficiently. Building on these foundations we then propose two solutions. The first solution is for investors who do not aim to generate alpha. This green beta solution efficiently reduces the portfolio's carbon emissions, while it maintains the broader sustainability profile and aims to produce index-like returns. The second solution, sustainable enhanced index, combines lower carbon emissions with multi-factor investing, aiming for return enhancement. We briefly introduce the factors used to select government bonds with superior risk-adjusted returns and show how the portfolio construction process uses the risk budget to meet the twin goals of decarbonization and alpha generation.

Why invest in government bonds with lower carbon emissions?

Before discussing how to construct government bond portfolios with lower emissions, let's first consider why one should want to do so.

Countries' carbon emissions are relevant for sovereign bond investors as these indicate how challenging the transition to a Paris-aligned world will be. As part of the Sustainable Development Goals, the United Nations' 193 member states have unanimously agreed to take urgent action to combat climate change (SDG 13). The Paris Agreement specifically calls upon developed countries to reduce their economy-wide emissions, as these countries account for the bulk of cumulative historical emissions; it states that countries have "common but differentiated responsibilities". Countries with high emissions have to make bigger efforts and will face higher costs to align their economies to the Paris Agreement.

they are more energy-efficient or they employ more renewable energy.

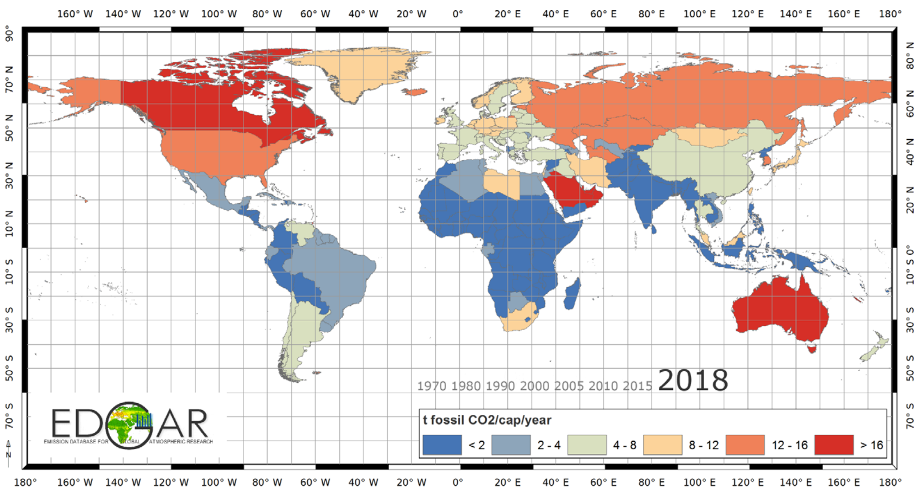
Moreover, by favoring bonds issued by countries with lower emissions, investors can effectively communicate their endorsement of emission-reduction policies to governments.

Governments have an important role to play in the climate transition. They set the rules that regulate companies and households and are responsible for enforcing those rules. Additionally, the government can use financial incentives to influence company and household behavior. When investors take carbon emissions into account, failing to tackle climate change will also have financial implications for governments as investor appetite for debt issued by these countries is reduced and borrowing costs potentially rise.

" High-emission countries face larger economic and financial risks in the transition to a Paris-aligned world. Sovereign bond investors can mitigate these risks

The transition to a cleaner world is likely to be more disruptive for economies that are strongly dependent on fossil fuels or on highly pollutive production processes. These countries face the risk that important sectors of their economy will become obsolete or require a drastic restructure. Investors can mitigate risks to their government bond portfolio by tilting it towards bonds from countries that already have lower emissions, for example because

Finally, initiatives like the Net Zero Asset Owner Alliance and regulations like the EU SFDR require investors to disclose data on the carbon emissions of their sovereign bond holdings, potentially spurring greater interest in lower-emission solutions.



Comparing countries' carbon emissions

In this chapter we discuss how countries' carbon emissions are measured and how these emissions can be normalized to compare bond markets.

We are interested in the carbon emissions of countries, not just in the direct emissions by governments – for example for heating of government offices and powering government vehicles. Country emissions are the relevant risk measure for government bond investors, because high emission countries face higher costs and run larger risks in the climate transition. And governments have pledged to reduce their countries' emissions , not just their own direct emissions.

Measuring country emissions

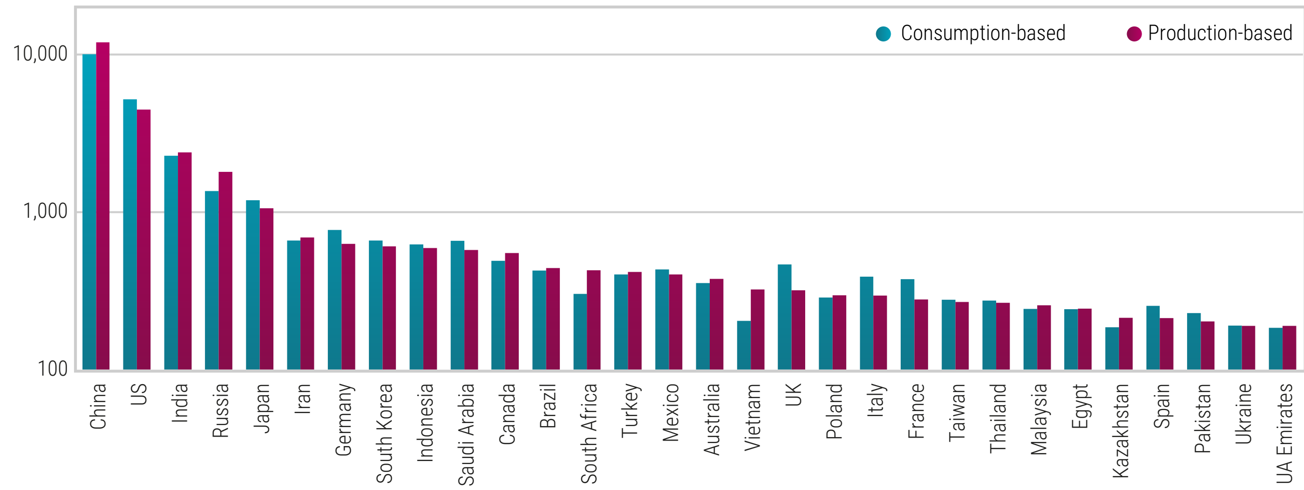
Data on countries' greenhouse gas (GHG) emissions is determined by combining data on activities (for example power generation, transportation and industrial processes like steel-making) with the typical emissions caused by these activities, and then by each type of fuel used for these activities. Detailed standards for these computations were developed by the Intergovernmental Panel on Climate Change. These numbers are called production-based emissions because they measure the emissions related to what is produced in a country. In recent times, consumption-based measures have emerged as additional metrics. The premise being that when something is produced in country A, then exported to country B and used there, the related emissions should be counted as emissions of country B. The OECD publishes data on the amount of CO_2 emissions embedded in international trade, which is then used to adjust production-based emissions for exports and imports to derive consumption-based emissions.

Figure 1 shows production-based and consumption-based emissions for the 30 countries with the highest emissions. China has the highest emissions on both measures. However, consumption-based emissions are lower than production-based emissions for China, reflecting that some of the products that China produces are not consumed there but are exported to other countries. In the US, the opposite holds true as consumption-based emissions are higher than production-based emissions. US consumption causes more emissions than US production, as the US consumes more (or more pollutive products) than it produces. This is the case for most high-income countries.

Currently production-based emissions are used more widely than consumption-based numbers. The Paris Agreement framework only refers to production-based emissions. The Global GHG Accounting and Reporting Standard issued by PCAF (Partnership for Carbon Accounting Financials), however, recognizes that consumption-based emissions are "an important metric in the context of broader sovereign responsibility for emissions caused".

Production-based emissions data for the main greenhouse gas CO_2 is published annually. Ideally, we would include emissions of other greenhouse gases like methane, nitrous oxide and fluorinated gases as well. Data for these emissions are available, but this data is updated less frequently and with an additional publication lag. Consumption-based emissions are for now published only for CO_2 emissions, not for other greenhouse gases, and this data has an additional publication lag of one year compared to production-based estimates.

Figure 1 | Consumption-based and production-based country emissions in 2020, megaton fossil CO_2 (log scale)



Source: Robeco, Global Carbon Project (2023), EDGAR 2022 report[1]

1. Crippa, et al, CO_2 emissions of all world countries - 2022 Report, EUR 31182 EN, Publications Office of the European Union

Figure 2 compares CO_2 emissions to the total greenhouse gas (GHG) emissions for the countries with the highest emissions. Emissions of other greenhouse gases like methane have been converted to CO_2-equivalent emissions based on their Global Warming Potential values. All numbers are representative of 2018, at the time of writing this was the most up to date greenhouse gas data available. For countries like Brazil and Pakistan, the difference between the two emission numbers is large. However, for the major developed bond markets CO_2 typically accounts for circa 80% of greenhouse gas emissions. Therefore for these countries we get a similar picture when we look only at CO_2 instead of at total emissions. For developed market government bonds, we can use the most recent data on countries' CO_2 emissions to get a good picture of their total greenhouse gas emissions.

When including emerging bond markets, the choice is more complex: for some emerging markets it is important to use consumption-based measures, which are currently only available for CO_2, while for other markets it is more relevant to use the broad greenhouse gas emissions. Finally, attempts have been made to include emissions related to land use and change of land use (like deforestation). According to the PCAF standard, there is a divergence of views among emissions data providers and climate experts regarding the methods for collecting land use, land-use change, and forestry (LULUCF) emissions, and this creates significant data uncertainty.

In the remainder of this paper, we use production-based CO_2 emissions excluding LULUCF. However, the solutions we present to decarbonize portfolios can also be used with consumption-based data, or with broader GHG data instead of fossil CO_2 emissions.

Figure 2 | Country emissions in 2018, greenhouse gas emissions and fossil CO_2 emissions, megaton CO_2 equivalent (log scale)

Source: Robeco, EDGAR

Normalizing country emissions

The mere fact that the US emits more CO_2 than Denmark is not surprising, as the US is a much larger country with a higher population and bigger economy than Denmark. But the question is, what is the relevant measure of a country's size? How should we normalize emissions to assess which country is emitting more in a relative sense?

Equity and credit investors often use the emissions of a company divided by the sum of the market value of its equity and debt. This allows investors to express their carbon footprint by how much of a company's emissions they "own" (or finance). Exactly the same cannot be done for a country, as countries have no tradeable equity; investors cannot "own" a country. And it doesn't make sense to divide a country's emissions only by the market value of its debt; firstly, because countries finance themselves primarily with tax income rather than debt issuance (so an investor holding 1% of a country's debt doesn't finance 1% of the country's emissions); secondly, as this leads to undesirable results for countries with very high or very low debt levels. Bonds of a country with hardly any debt like Norway would be considered extremely "dirty" (or carbon-intensive), while highly indebted countries would be considered relatively "clean" as their emissions are divided by a large pool of debt. Therefore, country emissions have to be normalized in a different manner than company emissions.

Two measures are commonly used to normalize country emissions: the size of the population and the size of the economy (GDP). Normalizing emissions by the size of the population makes lower-income countries' emissions compare more favorably and dividing by the size of the economy puts the emissions of high-income countries in a more favorable light. PCAF recommends the use of GDP based on purchasing power parity to normalize production-based emissions and to use population size to normalize consumption-based emissions, while SFDR asks for reporting emissions normalized by GDP.

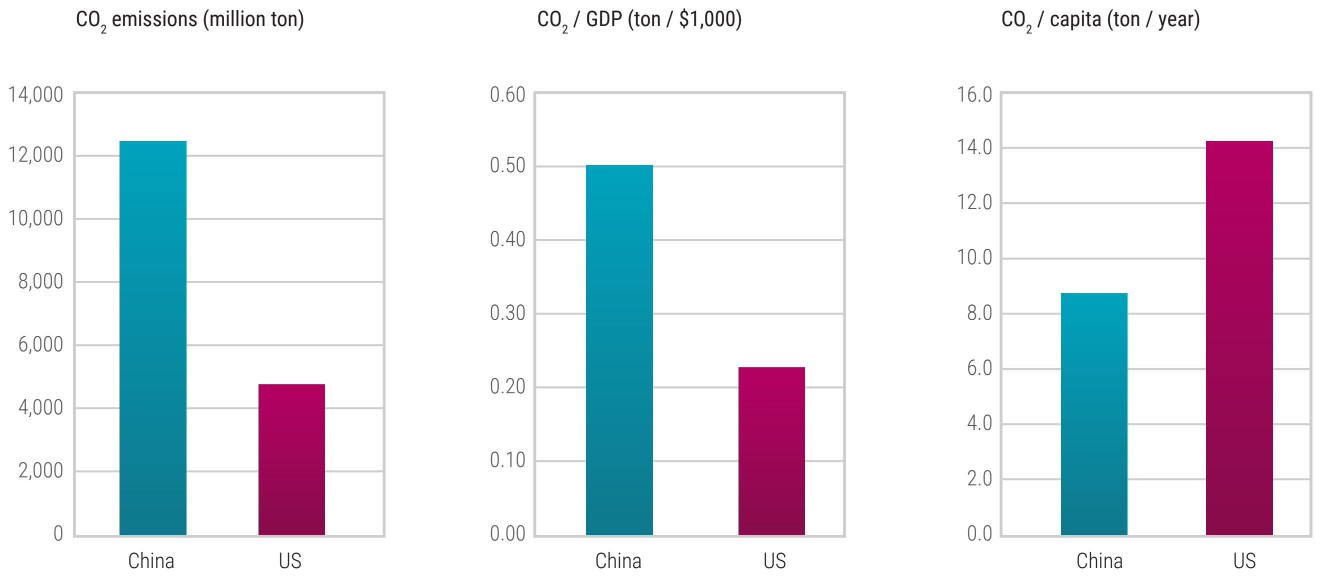
To illustrate the difference between the two measures, Figure 3 compares the carbon emissions of China and the US in 2021. China emitted 12.5 gigaton of CO_2, the US emitted 4.8 gigaton. Using the size of the economy to normalize the emissions, we see that the Chinese economy can be considered less carbon-efficient: China emitted 0.5 ton of CO_2 per 1,000 US dollar of GDP, compared to 0.23 ton for the US. If we use the size of the population to normalize emissions instead of the size of the economy, we get a different picture: China emitted 8.7 ton of CO_2 per inhabitant, while the US emitted 14.2 ton per person per year. Because the average income level (GDP/capita) is higher in the US than in China, emissions per person are higher in the US, despite the lower emissions per 1,000 dollar of income.

represented by a block: the height of each block corresponds to that market's CO_2 emissions per capita and the width corresponds to the market value. Therefore, the largest government bond markets in the index are the US, Japan, France and the UK (the widest blocks). The markets with the highest emissions are Canada, Australia and the US (the highest blocks). The US, with its large market cap weight and high emissions, contributes most to the index emissions, as seen from the size of its block.

We can distinguish three groups of countries with similar emissions per capita in Figure 4:

- Canada, Australia and the US have the highest emissions: 14-15 ton per capita in 2021
- Japan, the Netherlands, Belgium and Germany: emissions of 8-9 ton per capita, ca 40% below the first group
- Italy, Spain, the UK, Denmark, France and Sweden: emissions are 60-70% lower than in the first group.

Figure 3 | Comparing CO_2 emissions of China and US in 2021: total, per $1,000 of GDP and per capita



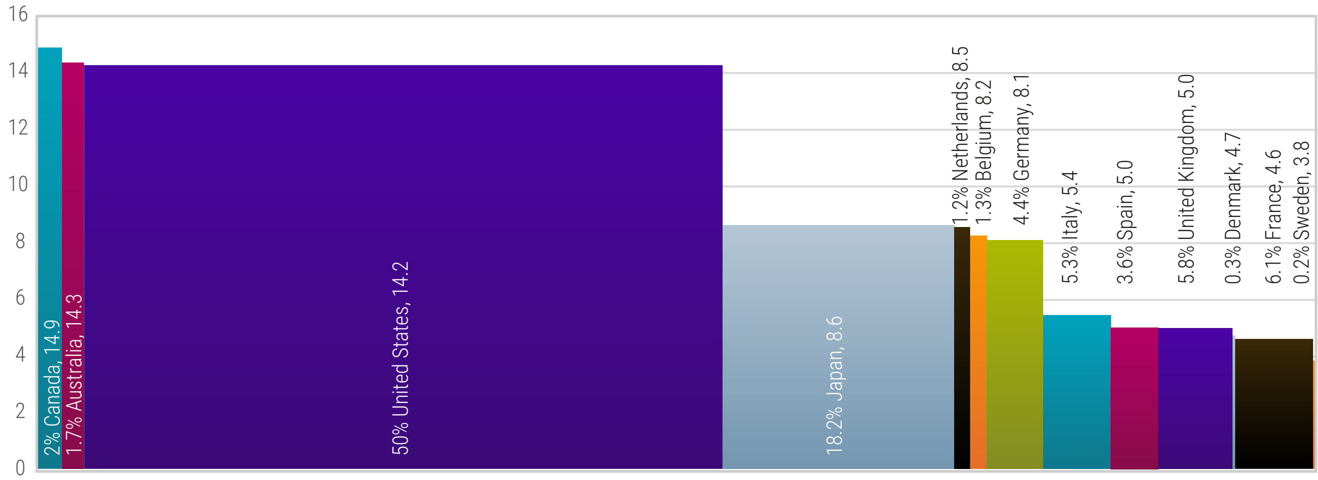
Source: Robeco, EDGAR

Note that the distinction between CO_2/capita and CO_2/GDP is mainly relevant when comparing countries with markedly different income levels. When comparing countries with similar GDP/capita, both measures will result in similar outcomes. For a portfolio containing only developed market government bonds, the distinction between the two measures is less important: in this case, a portfolio with low CO_2/capita will generally also have low CO_2/GDP.

Figure 4 illustrates the CO_2 emissions of the global developed government bond market, represented here by the JP Morgan Global Government Bond index. Each bond market in the index is

The three high emission markets comprise more than half of the JP Morgan Global Government Bond index. This index has a weighted average of CO_2/capita of 10.8 ton per year (using the end of 2022 index weights and the 2021 CO_2 data published in 2022). We can construct portfolios with a lower carbon intensity by shifting weight from high-emission countries to countries with lower emissions. The lowest emissions would be reached when we invest only in bonds from the country with the lowest emissions – Sweden. Diversified global portfolios will have higher average emissions than Sweden's 3.8 ton/year as they contain bonds from countries with higher emissions.

Figure 4 | CO_2/capita and market value weight of main developed government bond markets



Source: Robeco, JP Morgan, EDGAR

The highest country emissions are almost four times higher than the lowest country emissions in this universe of developed government bond markets. This is much smaller than the differences between the highest and lowest company emissions, especially when comparing companies from vastly different sectors, like an oil company and a tech company. As a result, the potential decarbonization percentage in an equity or credit portfolio is bigger than what is possible in the government bond universe.

Nevertheless, with a difference in CO_2 emissions of about a factor 4, meaningful portfolio decarbonization can also be achieved in developed market government bond portfolios. Assuming countries reduce their emissions in line with their commitments, over time the portfolio's emissions will decline further.

Constructing low-carbon portfolios

To decarbonize government bond portfolios efficiently, risk should be taken into account. A risk-controlled portfolio construction process results in stronger decarbonization and lower tracking error versus the regular index than a naïve approach.

To construct a government bond portfolio with a lower carbon intensity, one has to reduce the weight of the bonds of high-emission countries and increase the weight of bonds of countries with lower emissions. Some index providers do just that: reduce the weight of all bonds from the most polluting countries and increase the weight of all bonds from low-emission countries. This approach reduces the portfolio's carbon intensity, but it can also change its risk profile in unintended ways.

Pitfalls of naïve decarbonization

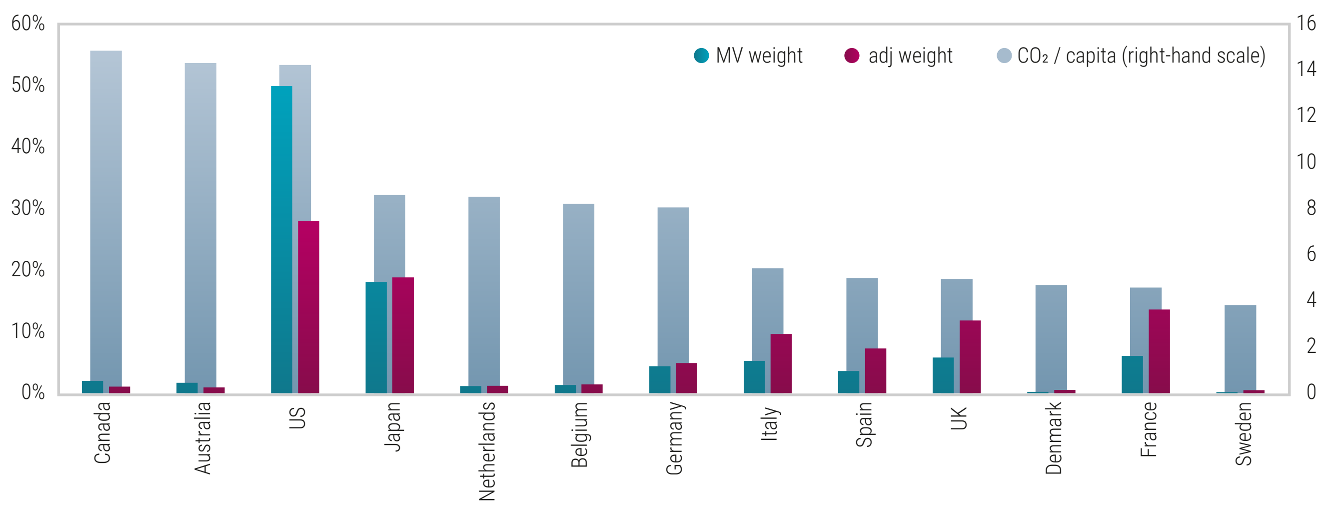
To demonstrate the potential pitfalls of the naïve approach to decarbonization, we apply this approach to the JP Morgan Global Government Bond index. This index contains government bonds from developed bond markets. In this example, we use the method to create an index with 20% lower carbon emissions. We reduce the weight of all bonds from countries with high emissions and increase the weight of all bonds from countries with low emissions. The higher the emissions, the more we reduce the weight; the lower the emissions, the more we increase the weight. We then rescale all weights to ensure that the sum of the new country weights is again 100%.

The process above is illustrated in Figure 5. The countries in the index are ordered by their emissions from high (Canada, 14.9 ton/year) to low (Sweden, 3.8 ton/year). The CO_2/capita emissions for each country is shown by the grey bars, which refer to the right-hand scale. The blue bars show the weight of these countries in the regular, market value weighted index; the purple bars reflect the adjusted weights.

The weights of all Canadian, Australian and US bonds are nearly halved, as these countries have the highest emissions. The weights of Japanese, Dutch, Belgian and German bonds are increased slightly. The weights of all Italian, Spanish and UK bonds are roughly doubled and the weights of Danish, French and Swedish bonds are more than doubled, as these are the countries with the lowest emissions.

Table 1 contains the original and adjusted country weights. It also shows other characteristics of these bond markets such as their average duration and credit rating.

Figure 5 | Country weights in original and adjusted index, and CO_2/capita per country



Source: Robeco, EDGAR, JP Morgan

Table 1 | Bond market characteristics and weights in market value weighted index and naïve decarbonized index

	CO_2 / capita	Duration	Rating	Market value index weight	Decarbonized index weight
Canada	14.9	6.57	AAA	2.0%	1.1%
Australia	14.3	6.63	AAA	1.7%	0.9%
United States	14.2	6.89	AAA	50.0%	28.0%
Japan	8.6	10.05	A	18.1%	18.8%
Netherlands	8.5	9.2	AAA	1.2%	1.2%
Belgium	8.2	9.8	AA	1.3%	1.5%
Germany	8.1	8.21	AAA	4.4%	4.9%
Italy	5.4	7.22	BBB	5.3%	9.7%
Spain	5.0	7.94	A	3.6%	7.3%
United Kingdom	5.0	12.66	AA	5.8%	11.9%
Denmark	4.7	9.15	AAA	0.3%	0.6%
France	4.6	8.88	AA	6.1%	13.6%
Sweden	3.8	7.27	AAA	0.2%	0.5%
Total	CO_2/capita: 10.84 → 8.67		Duration: 8.1 → 8.7		

Source: Robeco, EDGAR, JP Morgan

The weighted average of the carbon emissions in the original index is 10.84. With the adjusted weights, this is 8.67. By adjusting the weights, we have created an index with 20% lower carbon emissions as intended. However, we have also shifted weight from the markets with the lowest durations to markets with higher durations. For example, we halve the weight of all US bonds, and we double the weight of all UK bonds.

In the US, 80% of the bonds have a remaining maturity of less than 10 years. In the UK, this is only 54%, where 46% of bonds have a maturity of more than 10 years. By shifting weight from the US to the UK, we have also shifted weight from shorter-dated bonds to longer-dated bonds. As a result, the adjusted index has a duration of 8.7, clearly higher than the 8.1 of the original index. A higher duration exposes the portfolio to larger losses in times of rising yields.

We have also shifted weights from highly-rated countries to lower-rated countries. This is illustrated in Figure 6. For example, the weight of BBB-rated bonds increases from 5% to 10%. The increased weight of lower-rated bonds increases the vulnerability of the portfolio in times of heightened sovereign credit risk like the eurozone sovereign debt crisis.

The naïve decarbonization thus unintendedly increased the portfolio's absolute risk: the duration has increased and the credit profile has deteriorated. Because of this altered risk profile, the performance of the decarbonized index will differ from that of the regular index. The naïve approach to carbon reduction doesn't control this relative risk, i.e. tracking error versus the market value weighted index. Finally, the naïve approach to decarbonization does not take other dimensions of sustainability into account. While the resulting portfolio will have a lower average carbon intensity, it might accidentally score less well on other environmental, social and governance measures.

Figure 6 | Rating distribution of market-value weighted index (left) and naïve decarbonized index (right)

Source: Robeco, JP Morgan

This example demonstrates why we call this the naïve approach to decarbonization. It adjusts the weights of bonds based only on the carbon emissions of the country that issued the bond. Therefore, it adjusts the weights of all bonds from a country by the same factor. In our example, the weight of all US bonds is reduced, and the weight of all UK bonds is increased.

However, we have seen that the UK has more long-dated bonds outstanding than the US. Therefore we are replacing some 5-year US Treasury bonds with 30-year UK Gilts. While replacing US bonds with UK bonds is a valid way to reduce the portfolio's average carbon emissions, it would make sense to replace short-dated Treasuries with short-dated Gilts instead of increasing the weight of all UK bonds, including the longest ones. This is an obvious way to improve upon the naïve approach. In other cases, it will be somewhat more complicated, but the general idea is to adjust weights on a bond-by-bond basis rather than on a country-by-country basis by taking more characteristics into account than just the issuing country's emissions. By doing this we can control risk more effectively.

Efficient decarbonization: controlling risk and safeguarding the ESG profile

To avoid the drawbacks of the naïve carbon reduction, we have to control risk. Instead of adjusting the weight of all bonds from a country by the same factor, based only on its emissions, we use a portfolio construction algorithm that takes multiple dimensions of risk into account. This allows us to construct portfolios with a lower carbon intensity, while controlling risk measures like duration, the weight in lower-rated bonds, the weight in less liquid market segments and the deviations from the regular market-weighted index. We also ensure that we do not weaken the portfolio's ESG score.

Furthermore, the naïve portfolio has a higher duration than the original index and twice its exposure to lower-rated countries within the Eurozone. The mismatch of the naïve portfolio versus the index, in terms of duration and credit ratings, results in return differences caused by interest-rate changes and movements in country spreads. As a result, the naïve portfolio has a tracking error of 0.92% compared to the JP Morgan index over 2001-2022.
We have also constructed a portfolio using our risk-controlled framework. This portfolio has an average carbon intensity of 8.2, 31% below the JP Morgan index. We do not allow the portfolio's ESG score to be below that of the index, in fact we have even improved the average ESG score. As we control the interest-rate

Table 2 | Naïve and risk-controlled portfolio with lower carbon intensity than regular index

	JP Morgan index	**Naïve**	**Risk-controlled**	**Benefit**
CO_2/Capita 2001 – 2022	11.9	9.0	8.2	Stronger decarbonization
Country ESG 2001 – 2022	7.66	7.58	7.82	Improved ESG profile
Duration latest	8.4	9.8	8.4	Controlled interest rate exposure
Relative rates risk		0.81%	0.66%	Lower relative interest rate risk
Relative spread risk		0.42%	0.20%	Lower relative spread risk
Tracking error (TE)		0.92%	0.64%	Lower TE

Source: Robeco, EDGAR, JP Morgan

Table 2 compares this approach to the naïve index solution. We took the JP Morgan Global Government Bond Index as the starting point. The naïve portfolio is constructed as explained in the previous section: the weights of all bonds from a country with high emissions are reduced by the same factor, while the weights of bonds from a country with low emissions are increased – again with the same factor applied for all bonds from a given country. In this example we generated a portfolio that over the past two decades had 25% lower carbon intensity than the JP Morgan index.

The table shows that the average CO_2/capita of the resulting "naïve" portfolio was 9 ton/year, 25% below the 11.9 average for the JP Morgan index. However, as the weights are adjusted solely on carbon intensity, the naïve approach has unintentionally resulted in a small deterioration of the average ESG score (for these RobecoSAM country ESG scores, a higher number indicates a better sustainability profile).

and spread risk of the portfolio, its returns remain aligned with those of the JP Morgan index: the tracking error is 0.64%, nearly a third lower than that of the naïve approach. By controlling risk, we can decarbonize government bond portfolios more efficiently and therefore reach a stronger decarbonization with a lower tracking error.

Even stronger decarbonization can be achieved when a higher relative risk is allowed. A portfolio that has to mimic the index closely can achieve less carbon reduction than a portfolio that is allowed to deviate more strongly from the index. The risk-controlled approach is more efficient, because it can reach the same level of decarbonization with a lower tracking error than the naïve approach. Or put differently: for any given tracking error budget, it can reach a stronger decarbonization than the naïve approach.

Green beta: efficient CO_2 reduction with index-like risk and returns

For investors looking for decarbonization without explicitly aiming for alpha, we propose our green beta solution. This approach shifts the portfolio to bonds from countries with lower emissions while controlling risk and valuation.

We have explained that our low-carbon solutions avoid the main pitfall of the naïve approach as they manage risk in several dimensions. One further pitfall of the naïve decarbonization approach is that it might result in a portfolio with a lower yield than the regular index. As the naïve approach adjusts the country weights solely based on carbon emissions, it can also shift weight from attractively valued bond markets to lower-yielding bonds.

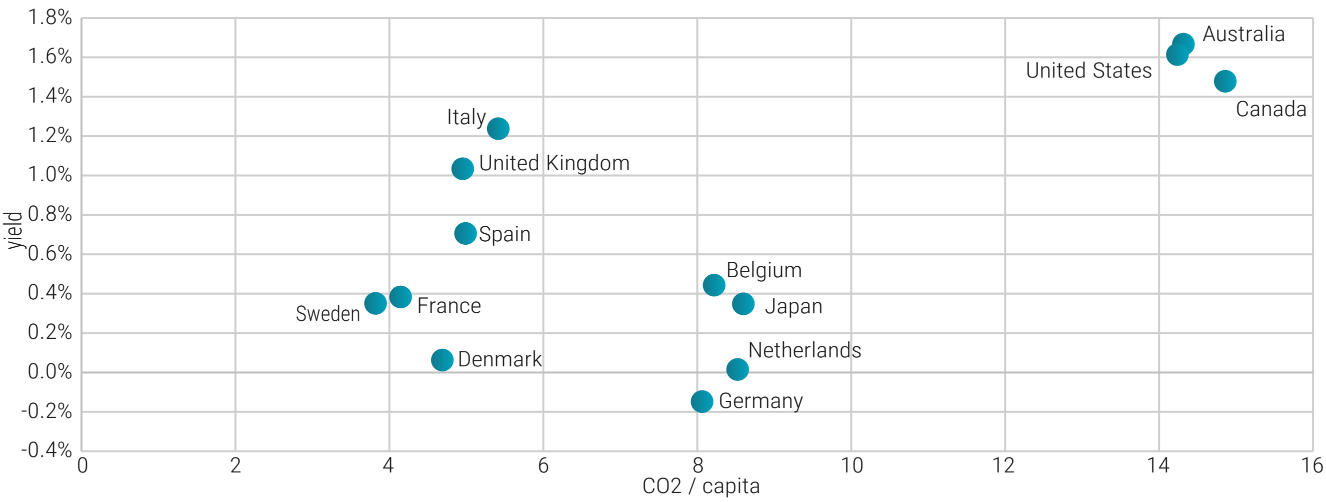
Even when investors are not actively aiming to outperform the regular index, they might not want to give up too much yield when decarbonizing their portfolio – especially when there are less costly alternative ways to decarbonize. That's why our green beta solution takes valuation into account, aiming to avoid a low-yielding portfolio.

To illustrate the point, the figure below shows the carbon emissions and the average yield levels of the main developed government bond markets at the end of 2021, using the JP Morgan indices to represent these bond markets.

Figure 7 shows there was a clear relationship between countries' emissions and yield level at the end of 2021: the bond markets with the highest emissions – Canada, Australia and the US – were also the markets with the highest yield levels, while the countries with the lowest emissions – Denmark, France and Sweden – had much lower yields. We don't claim that this will always be the case, in fact we deliberately chose to use end of 2021 data here as it is such a strong example. It serves to illustrate that there can be periods where countries with lower emissions generally have lower yields. In these periods, the naïve decarbonization will result in a portfolio with a lower yield than the regular index, as it adjusts country weights solely based on emissions.

In this example we can also see opportunities to protect the portfolio's yield while decarbonizing. For example UK bonds offered clearly higher yields than Danish bonds, despite both countries being similar in terms of emissions per capita. Shifting weight from bonds of high emissions countries to UK bonds, instead of to Danish bonds, results in a similar decarbonization, while giving up less yield. Replacing Belgian bonds by French bonds reduces the portfolio's average emissions without lowering yield. And replacing German bonds by Swedish bonds even combines decarbonization with a higher yield. Obviously, we must consider risk, but these examples show that we can improve on the naïve decarbonization approach by taking valuation into account, aiming to avoid lowering the portfolio's yield.

Figure 7 | CO_2/capita and average yield level (ultimo 2021) for main developed government bond markets



Source: Robeco, EDGAR, JP Morgan

Green beta: efficient decarbonization

We simulated our green beta solution over the period 2001-2022, using the JP Morgan Global Government Bond index as starting point. Each month we construct a government bond portfolio that has at least 20% lower carbon intensity than the regular index, whilst remaining comparable to that index in terms of risk. We also ensure that the decarbonization does not harm the portfolio's ESG score and we aim for a portfolio that is as attractive as the index in terms of valuation, i.e. we aim to avoid overpaying for sustainability. The results are summarized in Table 3.

Table 3 | Simulated results for green beta portfolio, 2001-2022

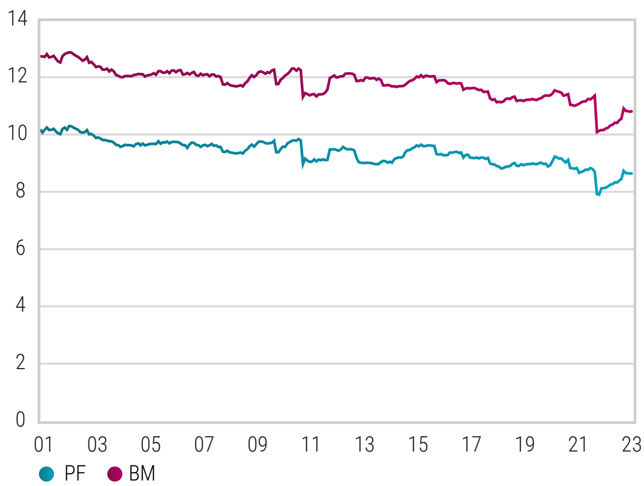
	Green beta	JPM index
Return	2.85%	2.81%
Volatility	3.54%	3.52%
Sharpe	0.53	0.53
Tracking error	0.51%	-
CO_2/capita	9.37	11.80
ESG score	7.72	7.64

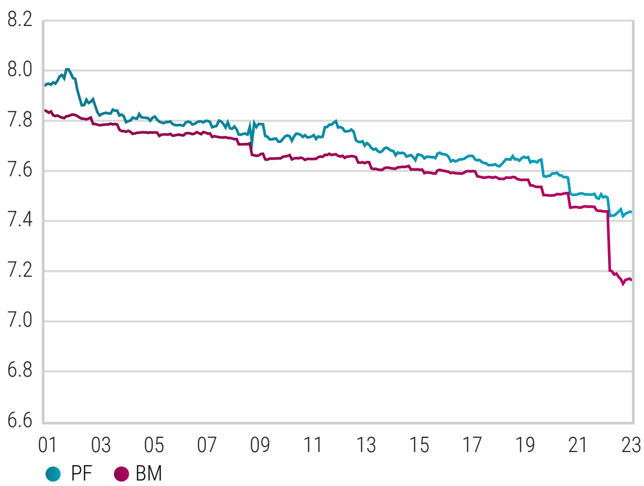
Source: Robeco, EDGAR, JP Morgan

The green beta solution is indeed comparable to the regular index in terms of risk and return, as it has similar average return, volatility, and Sharpe ratio. The portfolio has a tracking error of 0.5% to the index, indicating its return difference against the regular index is modest. And the average CO_2/capita is reduced by 20% as intended. This strategy reduces the portfolio's carbon emissions without materially altering its risk profile or expected return.

Figure 8 shows the average carbon intensity of the portfolio and the index over time, and the average ESG scores. The average CO_2/capita of the JP Morgan index has gradually declined from 12.7 to 10.8 ton/year. The portfolio's emissions are at least 20% below the index emissions every month. As the figure on the right illustrates, this has been achieved without harming the broader sustainability profile. The portfolio's ESG score is always at least as good as that of the index and sometimes even slightly better than that (a higher score indicates a better ESG profile).

Figure 8 | Sustainability profile of green beta solution: Carbon intensity (left) & ESG score (right) versus index

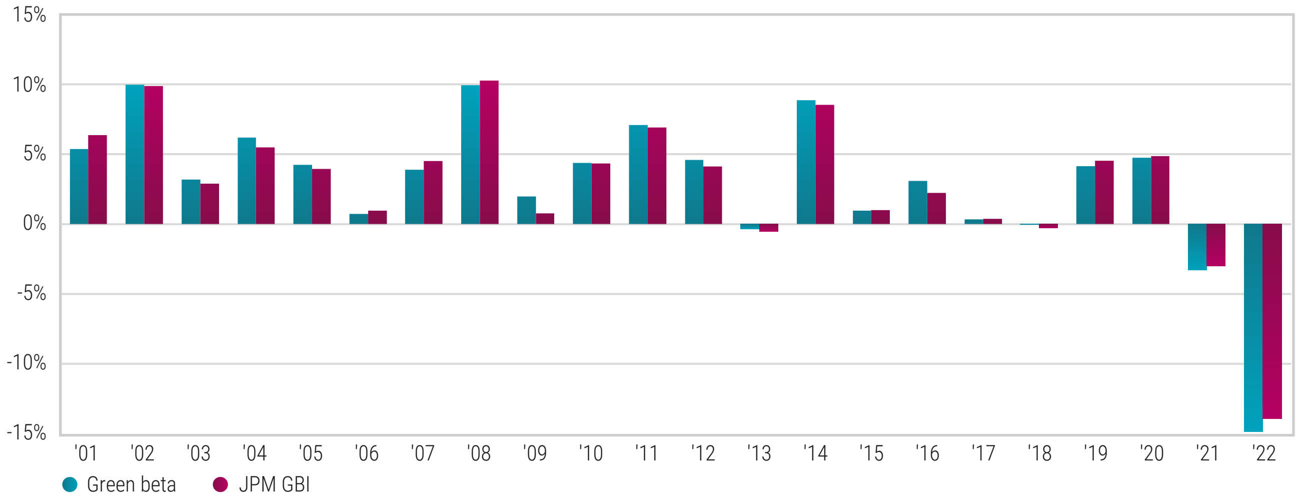




Source: Robeco, EDGAR

Figure 9 shows the annual returns of the green beta portfolio and the index. The returns of the portfolio are similar to those of the regular index, as we would expect given the limited tracking error. We can thus decarbonize without running large risks versus the regular benchmark – and we don't have to give up financial returns in return for the lower carbon emissions.

Figure 9 | Calendar year returns of green beta and index, simulation, 2001-2022



Source: Robeco

Our green beta solution can thus reduce a government bond portfolio's carbon intensity whilst controlling risk and avoiding paying for it. The green beta approach can be customized based on client preferences and it can be applied to other global government bond indices too. In addition, adjustments can be made to both the required level of decarbonization and the tracking error. Stronger decarbonization requires larger deviations from the regular index, thus resulting in a higher tracking error.

Sustainable enhanced index: carbon reduction and alpha

For investors who want to combine carbon reduction with return enhancement, we propose our sustainable enhanced index government bonds solution. This approach combines decarbonization with multi-factor investing. It shifts the portfolio to bonds from countries with lower emissions, while aiming for superior risk-adjusted returns.

The sustainable enhanced index solution combines carbon reduction with the objective of enhancing returns. Our multi-factor government bond strategy, due to its quant nature, is well-suited to meet both goals and control risk. Before demonstrating this, we will first briefly introduce factor investing for government bonds.

Introduction to multi-factor investing in government bonds

The goal of factor investing is to earn superior risk-adjusted returns by selecting securities based on factors like value and momentum. Factor investing is well established in equities and increasingly so in credits. As the existence of factor premiums is based on human behavior, factor investing should work in any asset class, including in government bonds. The academic evidence underpinning factor investing in government bonds is growing rapidly. We have contributed to this stream of literature by documenting deep-sample evidence for the well-known factors value, momentum and low-risk in government bonds.

We can thus enhance the returns of a global government bond portfolio by selecting bonds based on these factors. This is also attractive for investors who already employ factor investing in equities or credits, as the correlation between the factor returns in different asset classes is low.

To build a multi-factor government bonds portfolio, we first rank all bonds based on the factors, i.e. we measure each bond on how well it scores on these factors. Then we construct a portfolio with strong factor exposures, i.e. with bonds that have attractive valuation, momentum and so on. To harvest the factor premiums efficiently, we aim to get as much factor exposure as possible within a given risk budget, while avoiding unrewarded risks. This risk-controlled portfolio construction process strongly resembles what we described earlier in this paper. In fact, to construct the efficient low-carbon portfolios we used the same portfolio construction algorithm, only with different settings.

Combining carbon reduction with multi-factor government bond investing

A rules-based portfolio construction algorithm is well-suited for combining multiple goals, like alpha generation and decarbonization. To see this advantage, one must consider the many ways to reduce the average carbon emissions of a portfolio. The first solution might be to avoid Australian bonds, as Australia is among the countries with the highest emissions per capita. However, if Australian bonds are considered attractive from a return perspective, one can also overweight Australian bonds, while strongly reducing the weight of US bonds, which also have high emissions.

Replacing German bonds with British, French, or Swedish bonds also lowers the portfolio's average intensity. A quantitative portfolio construction process is ideally suited to compare all potential ways to reduce emissions within the risk constraints and choose the option with the most attractive factor exposures – and hence, the highest expected return.

Factor Investing in Sovereign Bond Markets: Deep Sample Evidence

Guido Baltussen, Martin Martens, and Olaf Penninga

CHAPTER FORTY-SEVEN

FACTOR INVESTING IN FIXED INCOME SECURITIES

THE HANDBOOK OF FIXED INCOME SECURITIES

FRANK J. FABOZZI

FACTOR INVESTING

Nevertheless, even with a sophisticated portfolio construction process, meeting multiple goals can be challenging at times. Let's assume, for example, that all bonds from countries with lower emissions have negative momentum and all bonds from countries with high emissions have positive momentum. In such a case, it can be impossible to build a portfolio that has both low emissions and strong exposure to the momentum factor. The decarbonization target can impair the ability to take balanced factor exposure. Thus, we should expect a somewhat lower risk-adjusted performance than for an unconstrained multi-factor strategy.

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Sustainable enhanced index – combining carbon reduction with outperformance

We simulated our sustainable enhanced index solution over the period 2001-2022, taking the JP Morgan global government bond index as a starting point. Each month we construct a government bond portfolio that combines our sustainability goals with strong factor exposures, while remaining comparable with the regular index in terms of risk. To be more precise: the portfolio's average CO_2/capita has to be at least 20% below that of the index and the portfolio's ESG score has to be at least as good as that of the index. We aim to outperform the index by selecting bonds with strong factor exposures, like attractive valuation and positive momentum, while controlling turnover. To decarbonize and harvest the factor premiums efficiently we control interest-rate risk, exposure to lower-rated countries, concentration risk, deviations from the index and liquidity risk. The results from this simulation are summarized in Table 4 below.

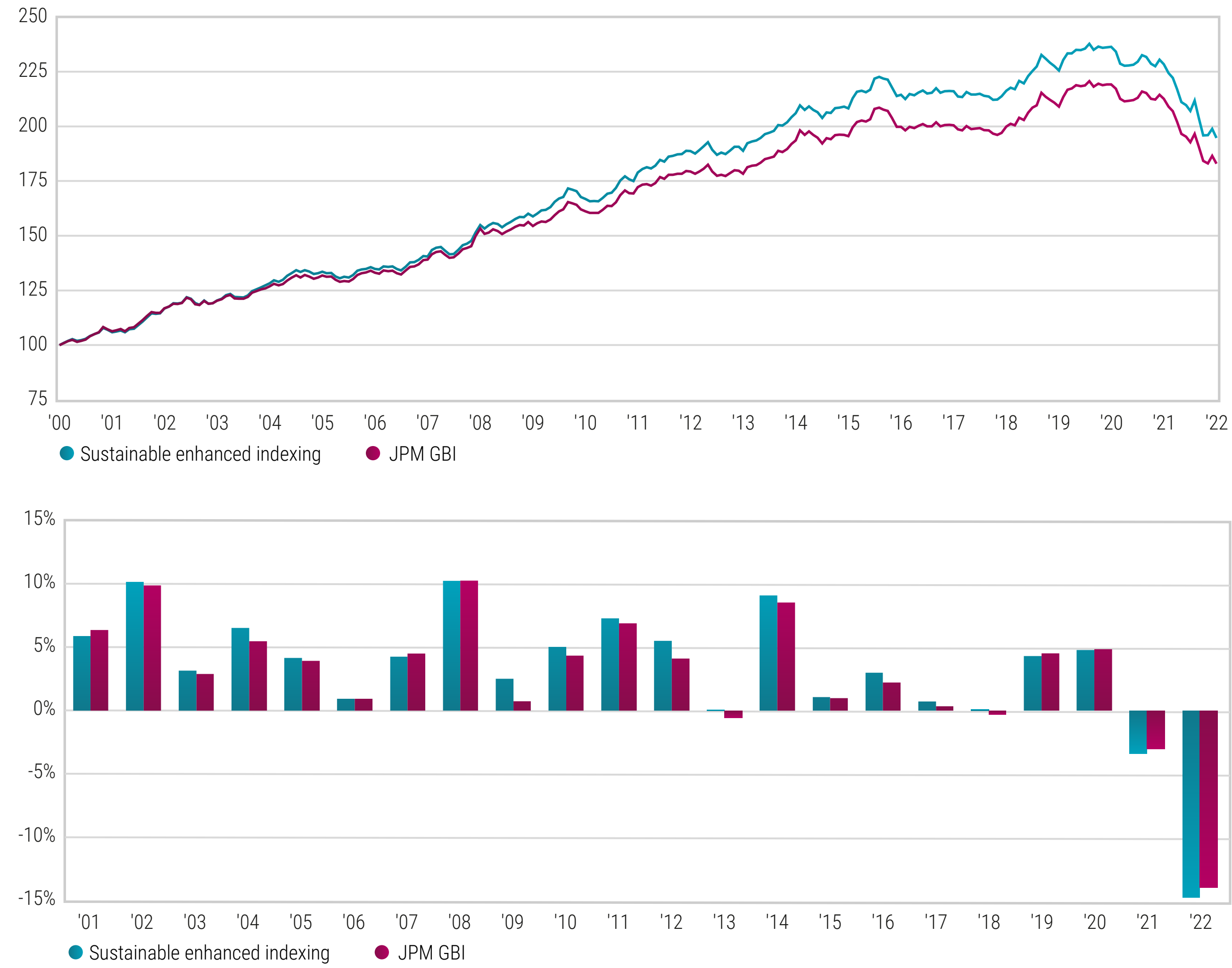
Table 4 | Simulated results for sustainable enhanced index portfolio, 2001-2022

	Sustainable enhanced index	**JPM index**
Return	3.10%	2.81%
Volatility	3.60%	3.52%
Sharpe	0.60	0.53
Outperformance	0.29%	-
Tracking Error	0.64%	-
Information Ratio	0.45	-
CO_2/capita	9.40	11.80
ESG score	7.71	7.64

Source: Robeco, EDGAR, JP Morgan

The sustainable enhanced index solution has indeed enhanced returns: in the simulation, it has produced somewhat higher returns with a similar volatility as the regular index and thus a modestly higher Sharpe ratio. At the same time the average CO_2/capita is reduced by at least 20% at any point in time as intended, and the average ESG score is maintained. This strategy thus efficiently reduces carbon emissions while it also enhances return.

Figure 10 | Sustainable enhanced index, simulation, 2001-2022; cumulative returns and annual returns



Source: Robeco, JP Morgan

Compared to the green beta solution discussed in the previous chapter, the tracking error produced by the sustainable enhanced index solution is not much higher. Both solutions deliver a similar carbon reduction. This shows that we do not need much extra tracking error to enhance returns; we can efficiently use the tracking error budget to decarbonize and simultaneously enhance returns. We should be aware that the alpha can be less consistent in periods where decarbonization impairs the factor exposure in comparison to an unconstrained multi-factor portfolio. This is reflected in the information ratio, which is decent, but lower than that of a multi-factor strategy without decarbonization.

Just like the green beta solution, the sustainable enhanced index solution can be used with various benchmarks as a starting point and then customized to a client's risk limits and desired levels of carbon reduction. We can show whether the desired reduction is possible within these risk limits and if so, how much room is left for return enhancement. When the carbon reduction target gets more ambitious, the number of potential solutions will decline and hence the room to add alpha or pursue other sustainability goals declines as well. Depending on the preferences of the client, the focus of the solution can shift towards sustainability or towards return enhancement.

Conclusion

We have discussed why and how to reduce carbon emissions in government bond portfolios. Our solutions avoid the pitfalls of the naïve decarbonization approach and result in efficient decarbonization, i.e. strong carbon reduction with limited tracking error. We present a solution with index-like risk and return and one that combines decarbonization with return enhancement.

Carbon reduction is gaining interest among investors. We propose decarbonization solutions for government bonds. Government bond investors face risks related to the climate transition. Investors can mitigate these risks by shifting their portfolios to bonds from countries with lower emissions. By doing so, they also might encourage governments to take climate action and provide funding for climate policies.

Reducing a portfolio's carbon intensity by reducing the weight of bonds from high-emissions countries and increasing the weight of bonds from countries with lower emissions is not trivial. A naïve decarbonization approach can have unintended consequences for the risk profile, like a higher duration, a weaker average credit rating and lower liquidity. It can also reduce a portfolio's yield and weaken the portfolio's ESG profile.

We propose two solutions that avoid these pitfalls. Our risk-controlled portfolio construction results in a more efficient decarbonization: we can reach the same reduction in average emissions with less risk than the naïve approach, or a stronger reduction than the naïve approach with the same risk budget. Both solutions also ensure that the ESG profile does not deteriorate.

- For investors looking for decarbonization without explicitly aiming for alpha, we propose our green beta solution. This approach aims to avoid overpaying for lower emissions. We show that this results in a portfolio with significantly lower emissions, while mimicking the risk and return profile of the regular index.
- For investors who want to combine carbon reduction with return enhancement, our sustainable enhanced index solution reduces a government bond portfolio's carbon intensity and enhances its returns through factor investing.

Both solutions can be used with various benchmarks as starting point and customized to client's risk limits and desired level of carbon reduction. We have shown results using production-based CO_2 emissions per capita as measure of country emissions, but we also discuss alternative measures. Our solutions can target these other measures as well.

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