

Gold and climate change

Decarbonising investment portfolios



This report was produced by the World Gold Council in collaboration with Urgentem, a leading climate risk analytics consultancy.

About the World Gold Council

The World Gold Council is the market development organisation for the gold industry. Our purpose is to stimulate and sustain demand for gold, provide industry leadership, and be the global authority on the gold market.

We develop gold-backed solutions, services and products, based on authoritative market insight and we work with a range of partners to put our ideas into action. As a result, we create structural shifts in demand for gold across key market sectors.

We provide insights into the international gold markets, helping people to understand the wealth preservation qualities of gold and its role in meeting the social and environmental needs of society.

Based in the UK, with operations in India, China, Singapore and the USA, the World Gold Council is an association whose members comprise the world's leading and most forward thinking gold mining companies.

About Urgentem

Urgentem is an award-winning, independent provider of transparent carbon emissions data and climate risk analytics to the finance industry. Its mission is to empower the financial sector to play a leadership role in the transition to a sustainable low carbon economy by providing climate risk data, analytical tools, investment services and products that are science aligned, transparent and collaborative.

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Executive Summary

Climate change is both a physical reality and a rapidly growing systemic and existential risk that all aspects of society are currently learning to address. It is now widely understood that greenhouse gas (GHG) emissions must therefore decrease very rapidly – ultimately, to ‘Net Zero’ – if we are to avoid potentially catastrophic consequences. The process of decarbonising the economy is such an urgent priority that it is now reshaping nearly all policy, business, and investment decisions.

And how investors evaluate and respond to the risks and opportunities inherent in this transition will inevitably influence how they build and manage their portfolios, particularly over the medium and long term.

To further explore the implications of the transition to Net Zero carbon for gold as a portfolio asset, we collaborated with specialist climate risk consultancy Urgentem. Specifically, we sought to quantify the impact of introducing gold as a strategic investment to a global multi-asset portfolio from a climate transition perspective, while mindful of its risk and return performance too.

Building blocks

This analysis builds on several strands of the World Gold Council’s previous work on gold and climate change which:

- Quantified gold’s carbon footprint in granular detail (that is, its Scope 1, 2 and 3 emissions)
- Outlined a potentially accessible and cost-effective decarbonisation pathway for gold
- Assessed the potential impacts of climate-related risks on asset return expectations.

These ‘building blocks’, along with Urgentem’s global climate database and analytical tools, allowed us to integrate gold into a portfolio and analyse its carbon footprint and climate target (Net Zero) alignment on a consistent basis, compatible with how other portfolio constituents were evaluated.

Although, in practice, holding physical gold (or a gold-backed investment product) will be associated with only minimal emissions, we adopted the assumption that an investor will inherit a substantial proportion of the ‘embedded’ carbon footprint associated with the

mining and production of gold. This enabled a forward-looking analysis of how gold’s carbon profile and future decarbonisation potential might affect a portfolio’s alignment with climate targets and, specifically, a Net Zero scenario.

Key findings

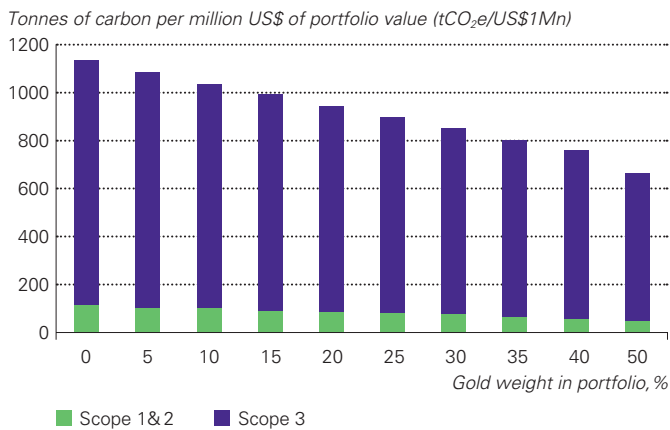
- The findings indicate that holding gold can contribute to portfolio alignment with climate targets and a Net Zero scenario. The benefits of gold allocations on a global multi-asset portfolio (of equities and corporate bonds) include:
 - Reducing the portfolio’s overall carbon footprint
 - Increasing portfolio alignment to climate decarbonisation – Net Zero – pathways
 - Reducing the vulnerability of the portfolio to climate transition risks and shocks, such as the introduction of a carbon tax
- A range of measures were used to quantify these impacts, showing a consistent trend.
- We also found that these positive climate impacts were achieved without adversely affecting the risk-return profile of the portfolio. In fact, there were strong indications that an allocation to gold would improve the performance and risk profile of the portfolio, in addition to its climate transition benefits.
- While the latter finding needs to be qualified, given the limited (five-year) time frame of the back-testing and gold’s relative outperformance during this period, longer-term testing found that the performance and risk profile impacts of gold allocations on the portfolio were similarly favourable, although to a lesser extent.

Portfolio performance and carbon footprint

The multi-asset portfolios, with data covering 5 years of weekly returns, were back-tested using different % allocations of assets to explore how the incorporation of gold at increasing weights might impact the portfolio's risk-return profile and its overall carbon footprint. (Historic carbon data for assets beyond 5 years is limited.)

The increased allocations to gold had a notable impact on the carbon footprint and emissions intensity of the market value of the overall portfolio. For a portfolio of 70% equities and 30% bonds, introducing a 10% allocation to gold (and reducing the other asset holdings by equal amounts) lowered the emissions intensity of portfolio value by 7%, and a 20% holding in gold lowered it by 17%.

Gold Allocations and Portfolio Carbon Intensity by Market Cap

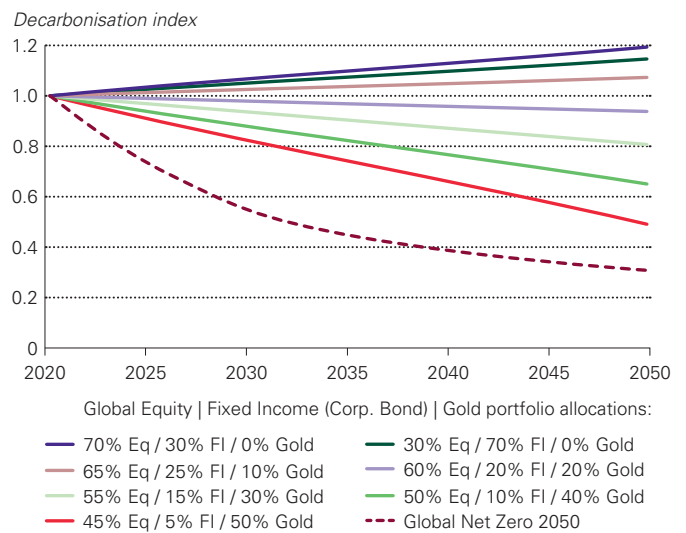


Source: Urgentem

Decarbonisation pathways

We then sought to measure the projected emissions trajectories of differently constituted portfolios against global scenario pathways and climate targets – specifically, Current Policies ('business as usual') and Net Zero 2050 scenarios. While no portfolio we examined was wholly aligned to a Net Zero carbon target, allocations to gold clearly had a positive impact on future alignment (as indicated in the chart below).

Portfolio decarbonisation trajectories versus Net Zero Scenario



Source: Urgentem

Portfolio temperatures

Many investors have been seeking to quantify the climate implications of investment holdings by using what is often referred to as the ‘temperature rating’ or ‘warming potential’ of a portfolio. This offers a high-level indication of what portfolio holdings imply for the global temperature projected to 2100. Our analysis of the impact of asset allocation on such temperature metrics again suggests gold might play a positive role in mitigating portfolio climate impacts. We calculated that a 50% allocation to gold causes the estimated temperature increase implied by portfolio holdings to fall 40%, by over 1°C, compared to an equity-heavy portfolio without gold; a 10% gold allocation results in a temperature fall of 0.21°C (a 7% drop).

Asset allocations and implied portfolio temperature, to 2100

Portfolio Weight Equities Fixed Income (Corp. Bonds) Gold	Portfolio Temp Increase, °C to 2100
70% Eq / 30% FI / 0% Gold	2.96
30% Eq / 70% FI / 0% Gold	2.85
65% Eq / 25% FI / 10% Gold	2.75
60% Eq / 20% FI / 20% Gold	2.53
55% Eq / 15% FI / 30% Gold	2.28
50% Eq / 10% FI / 40% Gold	2.01
45% Eq / 5% FI / 50% Gold	1.76

Source: Urgentem

Carbon costs and portfolio performance

One of the primary levers and policy responses to climate change, to accelerate the transition to a zero carbon economy, is generally perceived to be the imposition of a carbon price; putting an explicit price on GHG emissions which is then paid for by the emitter. A carbon price also offers investors a means by which they can analyse the potential impact of climate-focused policies and any associated business cost implications on their portfolios.

Our carbon pricing analysis suggests that adding gold or increasing the allocation in the portfolio minimises the annual value-at-risk. This is more substantial under the Net Zero 2050 scenario than the Current Policies scenario. This indicates that, should the policy environment move towards more aggressive positions, a gold allocation can lessen the inherent transition risk. We assume there will be little direct impact from a carbon price on gold but, even if there is, the impact will be minimal compared to that on the equity or bond markets.

Conclusions

This analysis lends credence to the suggestion that gold might contribute to portfolio resilience in the context of climate transition risks. Using a range of measures, we note that an allocation to gold can have a demonstrable impact on reducing the emissions profile of a portfolio and facilitate closer alignment of portfolios with Net Zero carbon scenarios.

Introduction

“Delivering emissions reductions of the magnitude envisaged by the Paris Agreement will require huge capital investment... it will require investors to accelerate the process of systematically aligning their core investment portfolios with the needs of the low-carbon economy.”

The Portfolio Decarbonisation Coalition /
UNEP FI, 2016¹

Climate change is both a physical reality and a rapidly growing risk – a *systemic* and *existential risk* – that all aspects of society are currently learning to address. It is now widely understood that greenhouse gas (GHG) emissions, resulting from human and commercial activity, are the primary cause of climate change, and emissions from these activities must therefore decrease very rapidly if we are to avoid the potentially catastrophic economic and environmental consequences.

Science very firmly predicts that a failure to curb emissions and the associated rise in the global average temperature will result in more extreme weather events of greater frequency and severity, with destructive impacts on ecosystems, biodiversity, resources, food security, cities, health and living standards.²

Radical changes and concerted actions are therefore urgently needed if we are to be able to reduce emissions at the scale required to limit the average global temperature rise to ‘well below’ 2°C – and, preferably, to 1.5°C – above pre-industrial levels. These were the climate targets set by the signatories of the Paris Agreement in 2015.³ To have a chance of achieving these targets will require reaching, by mid-century, a state of ‘net zero’

emissions in which the world’s total annual emissions do not contribute to any further accumulation of climate-warming gases. Any activity that produces emissions will be balanced by the commensurate reduction or removal of carbon⁴ elsewhere from the atmosphere.

The process of decarbonisation – of systematically reducing carbon emissions according to a defined strategy and targets – is now of such a pressing priority that it is increasingly reshaping nearly all policy, business and investment decisions. How governments and companies define and implement decarbonisation will have a profound effect on the economic landscape and market risks and opportunities. And how investors come to understand, evaluate and respond to these risks and opportunities will increasingly influence how they build and manage their portfolios, particularly over the medium and long term.

Climate change poses a very wide range of challenges and investors need to consider the potential financial impacts of both the transition to a net-zero economy and the physical impacts of a variety of possible climate change outcomes. These latter issues, of physical resilience and adaptation in the face of a warming planet, are undoubtedly becoming increasingly pressing. But the immediate priority for many investors is to arrive at a better understanding of the portfolio impacts and nearer term risks associated with a range of climate scenarios and possible decarbonisations pathways.

It is now widely acknowledged that the transition, to decouple economic growth from fossil fuels and shift to low carbon energy sources, will need to accelerate and expand rapidly over the next decade – and preferably sooner – if it is to be effective. Redirecting investment strategies to reflect and drive decarbonisation initiatives and processes has therefore become an urgent priority. However, there is still considerable work to be done to define the analytical frameworks, reference points and metrics required to support these decisions.

1 *Investment Portfolios in a Carbon Constrained World; Annual Report 2016* (2016), Portfolio Decarbonisation Coalition / UNEP FI

2 The clarity and certainty of scientific consensus on climate change was reasserted in the IPCCs Sixth Assessment Review (2021)

3 www.un.org/en/climatechange/paris-agreement

4 The term ‘carbon’ is here used to signify CO₂ and all CO₂ equivalents (CO₂e) – the set of greenhouse gases identified under the Kyoto Protocol as associated with global warming.

This report therefore seeks to address some of these investor needs by looking at the implications of expanding traditional measures of asset and portfolio performance with additional metrics to capture the carbon footprint of investment portfolio holdings and estimate how that might change over time to allow portfolio alignment with climate targets. These factors are examined as they apply to mainstream (equity and bond⁵) portfolios, with an assessment of how allocations to gold might impact the expected risk-return performance, carbon profile and climate trajectories of those portfolios.

GHG Protocol Scope Emissions

Scope 1 Direct Emissions

GHG emissions directly from operations that are owned or controlled by the reporting company

Scope 2 Indirect Emissions

Indirect GHG emissions from the generation of purchased or acquired electricity, steam, heating, or cooling consumed by the reporting company

Scope 3 Indirect Emissions

All indirect emissions (not included in Scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions



⁵ Consideration of fixed income assets was restricted to corporate bonds, due to data and methodological constraints although some of the implications of the carbon impacts of sovereign bonds in portfolios is discussed briefly.

Climate-related risks, measurement and metrics

“The first step that investors can take toward decarbonisation is to determine the aggregate level of emissions currently generated... within their portfolio. Investors can then use this figure as a benchmark to measure their progress toward achieving a ‘net zero’ portfolio over time.”

Morgan Stanley Institute for Sustainable Investing, 2020⁶

Although the need to integrate climate change risks into asset allocation models and portfolio construction decisions has been a growing concern for some years, relatively little attention had been devoted, until recently, to analysing carbon risk from an investment perspective. Existing methods for managing such risks have tended to focus on divestment from emission-heavy industries, with some compensatory shifts towards investment in ‘greener’ instruments.

But in the last few years we have seen a range of initiatives, driven by climate-conscious investors, seeking to embed a more holistic perspective on carbon risk within their asset allocation strategies. The resulting analytical frameworks have progressed rapidly, although are very much still in development, not least as they have had to apply methodologies that are often driven by the available data and, specifically, what can be more readily measured. Wider disclosure on climate-related risks – galvanised by the broad acceptance of the recommendations of the Taskforce on Climate-related Financial Disclosures (TCFD)⁷ – has contributed to substantial progress on the quantification of emissions and the monitoring of progress, but reporting and measurement has primarily been focused on the position and status of individual companies and their associated sectors. While understandable, this can impose some significant challenges when it comes to evaluating the carbon implications of assets beyond the corporate equity and debt markets.

World Gold Council gold and climate change research ‘building blocks’

This research builds on previous analysis undertaken by the World Gold Council, in collaboration with third party specialists, and key steps in the methodology refer to findings from these previous works. The key reports and the findings relevant to this study are:

Gold and climate change; an introduction (2018)

- Initial estimates of gold’s global carbon footprint drawn from a survey of academic estimates of the carbon intensity of production
- Exploration of the portfolio implications of the limited emissions from bullion on the annualised carbon footprint of a gold and equity portfolio.

Gold and climate change; current and future impacts (2019)

- Detailed summary of the total carbon footprint of the gold supply chain, broken down into sources of emissions, categorised by Scope 1, 2 and 3 definitions.
- An exploration of the various means open to gold mining to implement decarbonisation, with an identified high-level Paris-aligned pathway for the gold mining sector to move towards net zero carbon.
- An examination of the potential impacts of different climate risks and scenarios – their probability and magnitude – on the return sensitivity of different asset classes, including gold.

Gold and climate change; the energy transition (2020)

- Detailed analysis of the emissions from gold mining’s generation and consumption power of, with an evaluation of the impacts of current and projected actions to decarbonise power on sectoral climate target alignment.

6 *Climate Transition in a Portfolio Context: What Matters and What to Measure* (2020), Morgan Stanley Institute for Sustainable Investing.

7 www.tcfhub.org



One of the key challenges in seeking to embed consideration of climate-related risks into traditional financial models is that climate-related risks differ substantially from other investment risks. They are non-linear, with little relationship to historical data or past performance. They are deeply uncertain, and likely shaped by a complex interconnection of tipping points and domino effects. They are long-term and forward looking. And they are potentially characterised by endogeneity and circularity – rendering cause-and-effect based evaluations inappropriate and unproductive.⁸

Previous analysis and qualitative risk assessment models

In our earlier examination of climate-related investment risks, in collaboration with global sustainability consultancy Anthesis, we shaped our basic methodology around that defined and refined in a series of works from leading investment consultancy Mercer⁹ but which can broadly

be perceived as based on an ‘Integrated Assessment Model’ approach. Our analysis utilised established climate scenarios, based on different emissions action pathways and their potential economic and physical impacts as derived from integrated assessment models (considering a range of possible policy and macro-economic responses, and transition and physical risks). This then allowed us to arrive at a high-level numeric estimate of asset class and sector return sensitivities to each set of risk factors, as weighted by probability and magnitude, over three timeframes (to 2030, to 2050 and to 2100).¹⁰

A key benefit of such an approach is that it takes a forward-looking perspective. This can be used to supplement traditional asset allocation models which typically rely primarily on historical data and are therefore not adept at capturing the future potential investment impacts of the transition to a low-carbon economy or the projected – but diverse and chaotic – physical impacts of climate change.

⁸ See *Climate risks and financial stability* (2021), S. Battistion et al, Journal of Financial Stability (Volume 54).

⁹ *Climate Change Scenarios – Implications for Strategic Asset Allocation* (2011); *Investing in a Time of Climate Change* (2015); *Preparing for Transformation: Assessing the Prospective Investment Impacts of Low Carbon Economic Transition* (2017); *Investing in a Time of Climate Change; The Sequel* (2019), all Mercer.

¹⁰ For a more detailed description of the methodology previously used by the World Gold Council and Anthesis in *Gold and climate change: current and future impacts* (2019), please refer to *Gold and climate change: current and future impacts | Appendices – Appendix 3 – Gold as an investment and climate-related risks*.

But we should also acknowledge the approach has a number of weaknesses, including the following:

- Asset class and sector sensitivities are assessed based on qualitative judgments as inputs, which is a common feature of many existing methodologies for managing climate-related investment risks but may undermine the reliability of quantitative outputs.
- More specifically, the very long-term scenario projections – out to 2100, for example – are based on very a broad range of often interconnected risks, assumptions and uncertainties. This means estimates of specific asset performance or return sensitivities, beyond a certain point in time, can probably only be approached with a limited degree of confidence.
- Extrapolating from ‘current evidence’ and ‘baseline’ conditions is problematic if particular prevailing factors are dominant but may also be transitory. Volatile political factors and specific policy decisions, for example, may render a range of key assumptions redundant¹¹ which may then undermine the basis upon which wider return expectations are made.

This suggests that, although the application of qualitative evaluations on a range of risk factors and scenarios will likely remain a valuable part of the toolset used to inform climate-focused portfolio risk management perspectives, longer-term projections might be better viewed as a set of hypotheses which need to be revisited and revised regularly in line with shifting scenario expectations.¹²

Our focus here, in reconsidering some of our previous findings but adopting a different perspective, has been to utilise a more quantitative methodology, developed and applied by climate risk consultancy Urgentem,¹³ to examine the impacts of asset allocation decisions on portfolio transition and decarbonisation, as aligned with Paris Agreement climate targets.

It is important to note that this report does not seek to analyse the likely performance profiles of assets in response to climate-related shocks, from either a disorderly transition or extreme physical impacts. However, as stated above, we have previously offered a summary of the potential sensitivities of a range of mainstream asset classes, including gold, to a wide spectrum of climate-related risks. That said, the initial back-testing part of our analysis does offer a clear indication of how gold can benefit the balance of risk and return in a portfolio, which has direct implications for considerations of portfolio resilience or vulnerability in the face of climate-induced market risks.

¹¹ For example, the substantial change in policy expectations following the 2020 US election required many models to be revised with a new set of input assumptions and projections.

¹² Mercer have also recently acknowledged the need for the frequent review and possible recalibration of their scenario models by suggesting the implementation of a regular ‘scenario signpost monitoring’ and annual review process.

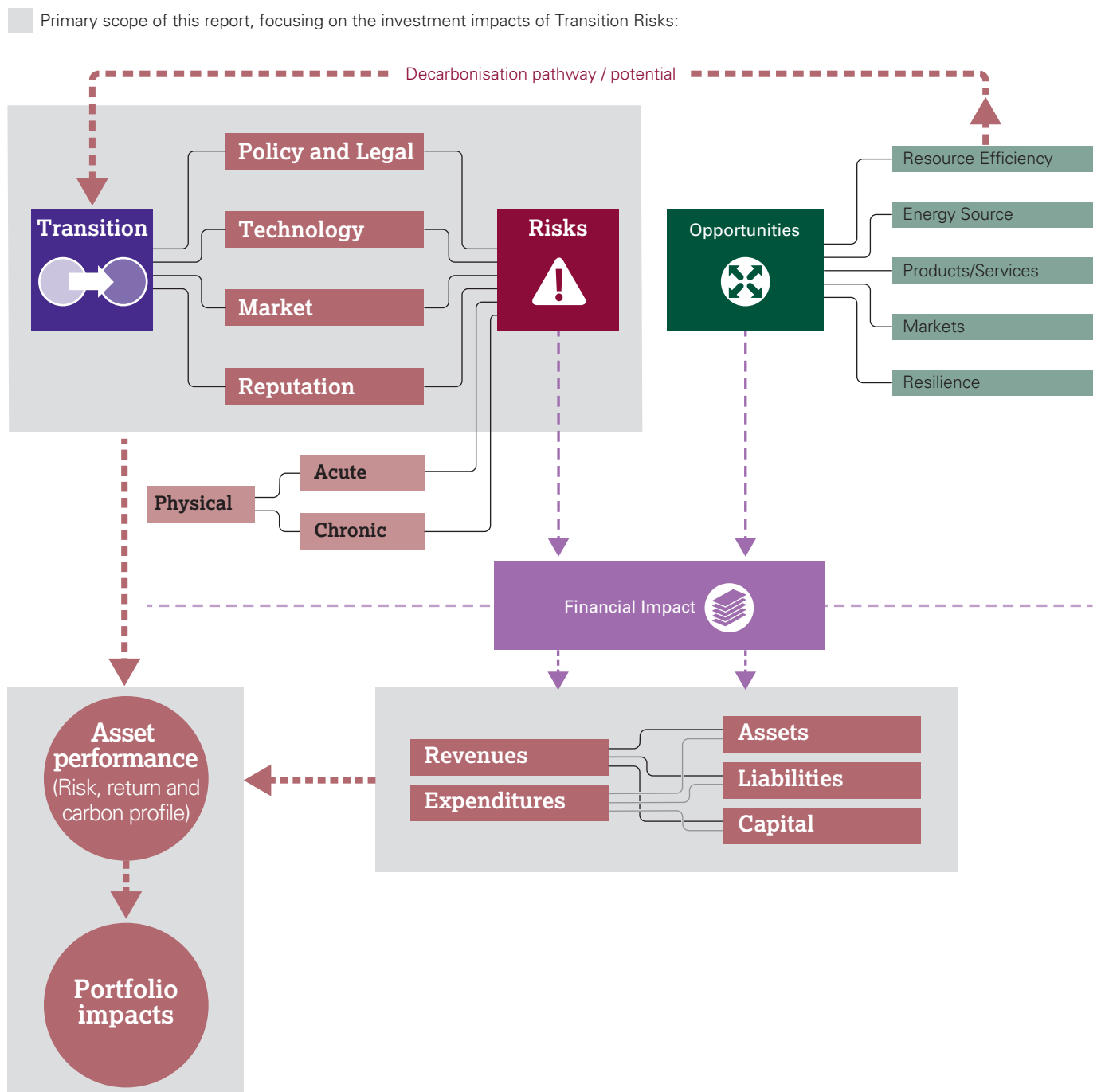
¹³ www.urgentem.net/

Transition risks and climate targets

Climate transition risks typically refer to the likely impacts on asset values or returns that might be associated with a swift and substantial transition to a low-carbon economy. These could include major and sudden shifts in policy and regulation, technological advancements, reputational and legal challenges, and changing consumer and societal

demands. Specifically, the introduction of carbon pricing or taxes, a rise in litigation as individuals or organisations seek compensation for climate-related losses or damage, or a sharp swing in consumption patterns towards low carbon consumer goods and products, are all factors that may need to be incorporated into investor thinking.

Figure 1. Climate-related risks, opportunities, and financial impacts; report scope



Source: Adapted from *Recommendations of the Task Force on Climate-related Financial Disclosures* (2017)



Many investors, however, are likely to start approaching the task of integrating climate-related risks into their strategies by first seeking to understand the emissions profile of their portfolios. More specifically, they will need to evaluate what portfolio constituents might contribute to future emissions reduction, contrasted against which of their holdings might prove an obstacle to progress as a possible concentrated source of further future emissions.

This is the approach adopted by this research. Once an estimate of the current carbon footprint and the future emissions reduction pathway of individual investment

holdings was established, we then examined the potential contribution different asset allocations make to a reduction in the overall carbon footprint *and* intensity of a portfolio. Looking forward, we then evaluated how the different weightings of assets can impact the potential future alignment of a portfolio with climate targets.

We also considered one further test of gold's possible contribution to the management of climate-related portfolio risk via an examination of the potential impacts on asset performance of the application of carbon pricing policies and associated costs.

Analysis summary

The key components of the analysis can be summarised as follows:

i. Portfolio Footprint Analysis (Back-testing)

- Estimating gold's impacts – from a risk, return and carbon perspective – on portfolio performance.
- Calculating the carbon intensity and total emissions – on a market capitalisation / enterprise value basis – of portfolios of equities, (corporate) bonds, and gold, with different weights (allocations) of each asset class.
- Regional and sector footprint analysis – breaking down the footprint into country and sectoral emissions – facilitating gold's integration into the portfolio in a consistent manner with other constituent assets.

ii. Forward-Looking Alignment Analysis

Projecting the carbon profile of the differently weighted portfolios from what is known of recent trends, current actions, targets and commitments,¹⁴ to describe the **carbon trajectory** and **estimated temperature** increase of each portfolio.

– Current Policies

The future carbon profile of the portfolios measured against a current 'business as usual' scenario.

– Net-Zero 2050

The future carbon profile of the portfolios measured against a Net-Zero transition pathway.

(Climate scenarios are defined using the recently published NGFS technical descriptions.¹⁵)

iii. Carbon Price (Cost) Analysis

Calculating the impact of a carbon cost on each portfolio, in the context of global Current Policy and Net Zero Scenarios. With a measure of the portfolio risk implications of transitioning from Current to Net Zero scenarios.

The rationale and methodologies behind each step in the analysis are described in the Appendices.

¹⁴ The Urgentem database of asset carbon profiles captures the historical trend and stated future targets of each company

¹⁵ NGFS *Climate Scenarios Database – Technical Documentation v2.2* (2021), Network for Greening the Financial System (NGFS). See also <https://data.ene.iiasa.ac.at/ngfs>

Methodology

The ‘decarbonising portfolio’ has two meanings: first, that the portfolio reduces its exposure to carbon risk and aligns with a low-carbon future; and second, that the portfolio proactively contributes to decarbonising the economy”

Credit Suisse, 2021¹⁶

For a fuller description of the methodology used in this report and all definitions, assumptions and calculations please refer to the **Appendices: Methodology notes.**

Gold’s carbon footprint

The World Gold Council has, in previous research, analysed the gold supply chain to arrive at granular estimates for gold’s emissions profile and its potential decarbonisation pathway. In our 2019 work, *Gold and climate change; current and future impacts*, we included emissions estimates scaled up from formal production and refining emissions intensity figures to include all annual gold flows, both upstream and downstream. This allowed a comprehensive view of the likely total carbon footprint of gold – with estimates for Scope 1, 2 and 3 emissions. It also confirmed that nearly all the emissions from the gold supply chain are generated by gold mining operations and processes, and the vast majority (80% or more) of those emissions are related to the consumption or on-site generation of electricity.

In our subsequent work (*Gold and climate change; the energy transition*) a year later, we focused primarily on quantifying emissions from the mine site in order to map out detailed decarbonisation scenarios for gold mining, measured against potential alignment with Paris

Agreement climate targets (specifically, <2°C and 1.5°C). While not representative of all annual global gold market flows and associated emissions, the findings of this research offered perhaps the most accurate granular data covering gold mining’s Scope 1 and 2 emissions – the bulk of annual gold supply chain emissions – and their potential for reduction.

The analysis summarised in this report revisits the process of estimating gold’s carbon footprint, to ensure it is aligned and compatible with the carbon emissions metrics for other assets and at a portfolio level. This estimation process made extensive reference to the earlier World Gold Council research and translates those findings¹⁷ into a carbon profile for gold as an investment asset.

‘Embedded’ emissions

To arrive at a carbon footprint of gold from an investment perspective, we use the working assumption that the gold holding within a portfolio is sourced from a combination of newly mined gold, therefore ‘inheriting’ a substantial portion of the carbon footprint associated with the mining and refining processes, and recycled gold, which has a far lower level of ‘embedded’ emissions. The proportionate split of embedded emissions from newly mined and recycled gold was roughly 70:30, respectively, in keeping with the typical structure of annual supply.¹⁸

The assumption of an investment in bullion derived solely from newly mined sources equates to the measurement of the “worst case” scenario for gold’s carbon footprint. However, even the above approach, which makes an allowance for the lower level of emissions associated with recycled gold, is likely to overstate the embedded emissions that an investor is likely to inherit in practice, given that annual new supply – whether from mine production or recycled sources – is only a very small percentage around 2.4% of the total above ground stocks of gold from which, conceptually at least, bullion and bullion-backed investment products may be drawn.

¹⁶ *The decarbonizing portfolio: A sustainable investment strategy for a low-carbon future* (2021), Credit Suisse.

¹⁷ Scope 1 and 2 GHG emissions and the decarbonisation pathway for gold were derived from ‘*Gold and climate change: the energy transition*’ (2020); the quantification of gold’s downstream Scope 3 emissions references ‘*Gold and climate change: current and future impacts transition*’ (2019), with primary research undertaken by, respectively, Wood Mackenzie and Anthesis.

¹⁸ See www.gold.org/goldhub/data/gold-supply-and-demand-statistics

Scope emissions

To allow a comparison with other assets, the carbon footprint of gold was further broken down into Scope 1, 2 and 3 emissions, with variance given to the regional differences of emissions sources. Scope 1 emissions have been adjusted for regional emissions intensities associated with local (on-site) power sources, while Scope 2 emissions have been adjusted for regional grid intensities.¹⁹ This is based on an assumption that each unit of investible gold embeds the aggregate global emissions profile, as discussed above, primarily from mine production and recycled supply.

Integrating gold into a portfolio footprint

One of the primary challenges of integrating gold into the portfolio on a consistent basis with other assets is to adopt an approach that allows analysis of gold's impact on the overall portfolio from both a climate *and* a financial performance perspective.

As a starting point, we calculate the volume of carbon per tonne of gold investment based on the footprint methodology discussed above. Where available the total amount (volume) of gold held should be used for an apportioned approach. In the case where this is not available, the gold price should be used to calculate the volume of gold owned in the portfolio based on the approximate value of the physical gold holding when purchased.

Once incorporated into the portfolio and assigned a weighting (a portfolio allocation expressed as a % of value), the carbon emissions for the gold holding can be calculated for Scopes 1, 2 & 3. Using the market capitalisation approach, a calculation of the carbon intensity for gold and other assets in the portfolio can be made on a comparable basis, allowing for carbon footprint and climate alignment analysis across the portfolio.

To produce a carbon footprint for a portfolio containing Gold, Equity and Corporate Bond (CB) assets, two calculation methods were applied to arrive at estimates for carbon intensity per unit of portfolio value and a portfolio's total emissions.²⁰ Note, however, that due to asset-specific data constraints the total emissions estimates were used primarily to validate the trends identified in estimating changes in carbon intensity.

Portfolio construction

To represent a global, balanced portfolio, we assembled indexes consisting of equities and corporate bonds, and then added gold.

Five regional equity indices covering both Developed and Emerging Markets were created as follows:

- North America DM Equity Index
- Latin America EM Equity Index
- Europe DM & EM Equity Index
- Africa EM & FM Equity Index
- Asia-Pacific DM & EM Equity Index

Constituent assets were screened for liquidity from each region. The top 200 companies were selected and weighted on the basis of market capitalisation. For each year (of the 5-year series), the step was repeated to select and rebalance the constituents (by market capitalisation) and the aggregate total index return was then calculated for inclusion in the portfolio.

A similar approach was applied to construct a global developed market investment grade corporate bond index.²¹ For each ultimate issuer of the bond, the weights were capped at 3% to limit concentration risk.

We acknowledge that the focus on corporate assets as portfolio constituents probably does not represent an optimal diversification strategy but this was largely driven by lack of data availability and consistency.²²

19 As described and quantified in *Gold and climate change; the energy transition* (2020), World Gold Council.

20 That is, the *Weighted Average Carbon Intensity of Market Value and the Apportioned Carbon Emissions (Total Emissions)* – see the **Appendix 2** for further details.

21 Emerging Market (EM) bond data is insufficient, lacking the same coverage and depth of emissions data to be consistent and comparable with other portfolio constituents, and is therefore excluded.

22 For further comments on this issue see *A note on asset class omissions* in *Appendix 3 – Portfolio construction and performance metrics*.



Back testing

The multi-asset portfolio, with data covering 5 years of weekly returns, was then back tested. Different weights – % allocations – were applied to the indices and gold to produce performance metrics and a snapshot of overall emissions. Specifically, this highlighted how the different allocations and the incorporation of gold at different weight²³ might impact the portfolio's risk-return profile and its overall carbon footprint.

Forward-looking projections and pathways

The portfolio alignment analysis uses a bottom-up approach to construct portfolio-specific decarbonisation benchmarks based on sector exposure, corporate emissions, and a range of climate scenarios. These portfolio-specific benchmarks are compared to global decarbonisation pathways and the portfolio's calculated emissions trajectory, which incorporates company targets and historical trends. The analysis demonstrates the alignment of the portfolio to the chosen scenario and can be used to generate a temperature alignment score. This analysis is used to demonstrate how the inclusion of gold into a portfolio can affect the alignment of the portfolio to a decarbonisation target.

Carbon price impacts

We extended the analysis to measure how the introduction of a climate transition shock in the form of carbon pricing (carbon costs) would affect investment portfolio performance. We have assumed that a carbon cost is introduced at a company level, proportional to the emissions (carbon footprint) of the company. We here use a shadow carbon price, taking into account both explicit (carbon tax, cap and trade, etc.) and implicit (policy changes, abatement costs, etc) costs. We assume these costs directly impact the earnings of the company.

Then the relationship between the company's earnings change and portfolio return is estimated for both the equity and corporate bond holdings within the portfolio. A carbon cost (assumed to be a negative earnings change) is then applied to calculate the final impact on portfolio returns.

This approach is applied to two climate policy scenarios (with different carbon price expectations): Current Policies ('business as usual') and Net Zero 2050, allowing for an exploration of the portfolio risk implications – value loss and value-at-risk (VaR) – of the difference between them.

²³ The starting weights for the portfolio constituents are 70%, 30% and 0% for equities, bonds, and gold, respectively. Gold is then added at 5% increments, while the weights of equities and bonds are reduced equally.

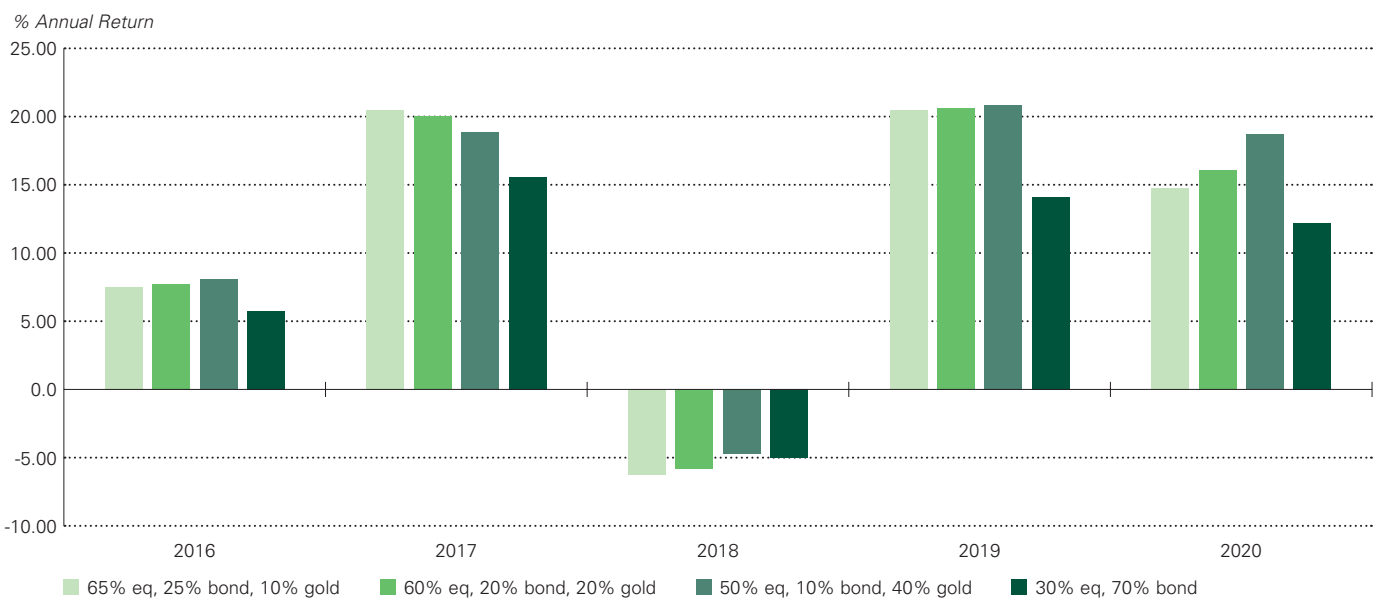
Findings

Portfolio performance – risk, return and carbon

The findings below strongly demonstrate gold’s ability to contribute to the optimal risk-return balance of a portfolio, moderating downside volatility, and compensating for return weakness elsewhere in the portfolio.²⁴

While the portfolio performance estimates need to be qualified, given the limited (five-year) time frame of the back-testing data, and gold’s relative outperformance during this period, longer-term testing found that the performance and risk profile impacts of gold allocations on the portfolio were similarly favourable, although to a lesser extent.

Chart 1: Annual returns of portfolios with various compositions



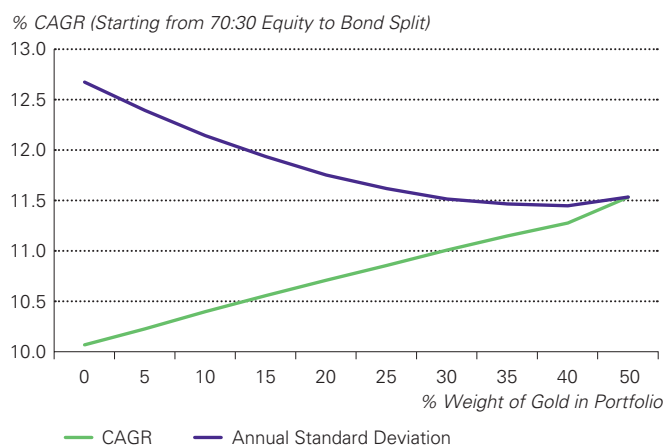
24 For a full set of portfolio performance indicators, see the [Portfolio metrics table \(table 9\)](#) in Appendix 3: Portfolio construction and performance metrics.

The illustration of gold’s contribution to an optimal risk return balance in portfolios is highlighted very clearly in **Chart 2** below. Commencing from a portfolio comprised of 70% equities and 30% bonds but then introducing and increasing the allocation to gold by % increments, we can see how the CAGR (Compound Annual Growth Rate) of the portfolio increases, and the volatility (standard deviation) decreases as the weighting of gold in the portfolio increases. However, the starting weights can have a significant impact on the point at which an optimal point of balance is reached. When repeated, with starting weights of 60% equities 40% bonds, the incremental increase in the weight of gold’s allocation still improves returns while moderating volatility, but the results suggest a lower optimal gold weighing of around 35% (see **Chart 2b**).

Portfolio Value-at-Risk

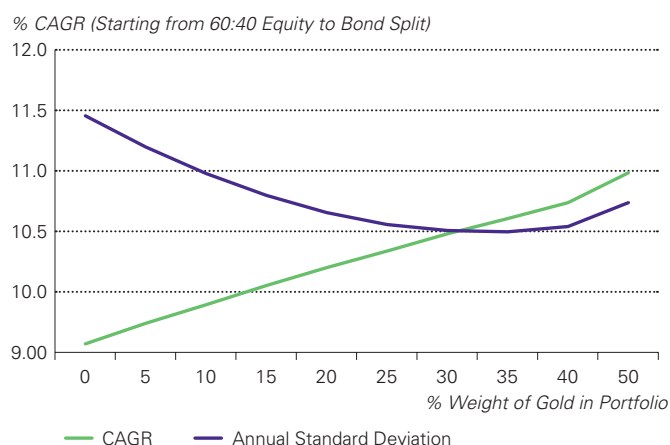
To further validate these findings, we also examined how allocations to gold might impact estimates of portfolio Value-at Risk.²⁵ The 6-month value-at-risk of an equity heavy portfolio with 10% gold is reduced by 7% if the weighing of gold in the portfolio is increased to 40%. Alternatively, if the concentration of the portfolio is switched heavily towards bonds (70%) then the 6-month value at risk is reduced by 32%. However, this greatly reduces the return by 22%, whereas increasing the weight of gold increases the return by 13%, which reinforces the evidence of the increased risk-reward ratio from gold (as indicated in **Charts 2 and 2b** below).

Chart 2: Portfolio CAGR and volatility vs weight (%) of gold



Source: Urgentem. Price data: Refinitiv

Chart 2b: Portfolio CAGR and volatility vs weight (%) of gold



25 The parametric VaR at the 95% confidence level was calculated based on a portfolio value of one million USD.

Correlations

The correlation matrix of the asset indexes and gold (**Table 1**) below is supportive of the perception of gold being, over the medium or long term, broadly uncorrelated to mainstream assets. For the five-year period in focus, gold and the equity market display a weak positive relationship, while gold's correlation with the global investment grade corporate bond market is a little more positive. Overall, gold was the least correlated of the portfolio constituents.

Short- and long-term back-testing

The time frame for back-testing was largely driven by data availability – specifically, the availability of suitably detailed carbon data for all portfolio constituents. But gold's performance over this five-year period (2016-2020) has been particularly strong and, it can be argued, perhaps atypically so, compared to its longer-term performance profile.

However, a longer-term, cross-cyclical view of gold's risk-return performance suggests that this contribution to enhancing the risk-reward ratio of a basket of assets is an enduring characteristic of gold as a portfolio constituent. This was evident when the above analysis was applied to portfolio data extending from 1999 to 2020, with, for example, a notable increase in the Sharpe Ratio with higher allocations to gold. While a 20-year data view suggests a more moderate long-term return expectation for gold, it also offers further evidence of gold's persistent diversification attributes. For example, the 5-year correlation of 0.17 for gold and North American equities drops to 0.04 when the period of analysis is extended over two decades (see **Table 1b**, below²⁶).

Table 1: Correlations, 5-year

5-Year Correlations – Weekly Returns

	Global DM IGI Bond Index	Africa EM and FM Equity Index	N America DM Equity Index	Asia Pacific DM and EM Equity Index	Europe DM and EM Equity Index	L America EM Equity Index	Gold
Global bonds Index	1.00	0.48	0.37	0.48	0.46	0.49	0.61
Africa Equity Index	0.48	1.00	0.61	0.73	0.73	0.75	0.34
N America Equity Index	0.37	0.61	1.00	0.73	0.78	0.64	0.17
Asia-Pacific Equity Index	0.48	0.73	0.73	1.00	0.87	0.73	0.22
Europe Equity Index	0.46	0.73	0.78	0.87	1.00	0.72	0.22
L America Equity Index	0.49	0.75	0.64	0.73	0.72	1.00	0.28
Gold	0.61	0.34	0.17	0.22	0.22	0.28	1.00

High Correlation	Mid-point (0.5)	Low Correlation
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Source: Urgentem. Price data: Refinitiv

Table 1b: Correlations, 20-year

20-Year Correlations – Monthly Returns

	Global DM IGI Bond Index	N America DM Equity Index	Ex US DM Equity	EM Equity	Global Equities Ex US	Gold
Global bonds Index	1.00	0.05	0.21	0.22	0.22	0.46
N America Equity Index	0.05	1.00	0.88	0.78	0.88	0.04
Ex US DM Equity	0.21	0.88	1.00	0.87	0.99	0.15
EM Equity	0.22	0.78	0.87	1.00	0.97	0.28
Global Equities ex US	0.22	0.88	0.99	0.92	1.00	0.20
Gold	0.46	0.04	0.15	0.28	0.20	1.00

26 Asset indexes for 5-year and 20-year correlations differ due to data history availability.

Gold and extreme market risk

These findings drawn are therefore very consistent with a wider body of work which has repeatedly demonstrated that gold can contribute to the optimal risk-return balance in a portfolios, comprised of a range of equities and bonds.²⁷

It is, perhaps, of some relevance that the recent 5-year period of the sample data set for this aspect of our analysis included the substantial and severe economic and market impacts from the COVID-19 pandemic. There is, of course, no direct relationship between the damage inflicted on many sectors and assets from the pandemic-induced lockdowns and the prospect of future market disruption and possible value destruction threatened by climate-related risks on the horizon. But this recent period of market stress should serve to remind us of the enduring relevance to portfolio construction of assets that may represent a robust store of value, relatively uncorrelated to prevailing market trends and conditions.

Gold's relative resilience and diversification potential is particularly evident when mainstream asset classes are subject to market volatility or shocks and underperforming. Gold's outperformance during these times has been well documented.²⁸ It also, to a large extent, formed the basis for the qualitative assumptions underpinning the projections of gold's relatively robust performance in the World Gold Council's earlier work on asset sensitivities in the context of climate scenarios.²⁹

Asset weights, emissions intensity and total emissions

The increased allocations to gold have a notable impact on the carbon footprint and emissions intensity of the market value of the overall portfolio, as indicated in **Table 2**, below.

Table 2: Gold allocations and portfolio carbon intensity

Gold Portfolio Weight (% allocation)	Weighted Average Carbon Intensity / Market Cap (tCO ₂ e/\$1m)d			Total Emissions tCO ₂ e/EVIC \$1bn		
	Scope 1 and 2	Scope 3	Scope 1, 2 and 3	Scope 1 and 2	Scope 3	Scope 1, 2 and 3
	% change	% change	% change	% change	% change	% change
0	0%	0%	0%	0%	0%	0%
5	-6%	-4%	-4%	-5%	-1%	-2%
10	-11%	-8%	-8%	-11%	-2%	-3%
15	-17%	-12%	-13%	-16%	-3%	-5%
20	-23%	-16%	-17%	-22%	-4%	-6%
25	-28%	-20%	-21%	-27%	-5%	-8%
30	-34%	-24%	-25%	-33%	-6%	-9%
35	-39%	-28%	-29%	-38%	-7%	-11%
40	-45%	-32%	-33%	-43%	-8%	-12%
50	-56%	-40%	-42%	-54%	-10%	-15%

²⁷ See, for example, www.gold.org/goldhub/research/relevance-of-gold-as-a-strategic-asset-2021

²⁸ WGC strategic case and risk mitigation research.

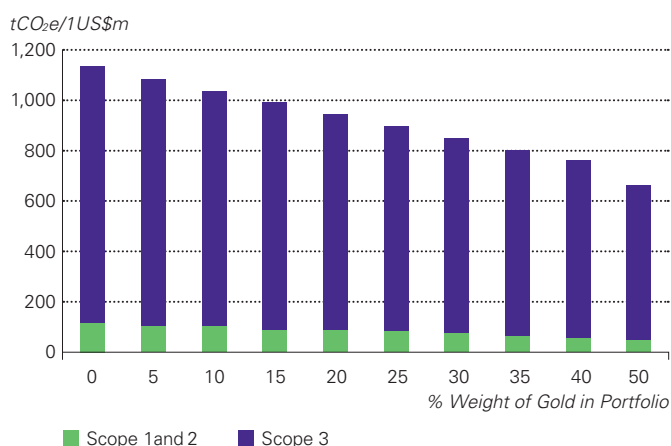
²⁹ *Gold as an investment and climate-related risks* section in [Gold and climate change: Current and future impacts](#).

Combining Scope 1, 2 and 3 emissions, we note a reduction of over 40% in the emissions intensity of the value of a portfolio comprised of 50% gold, 45% equities and 5% bonds, compared to a portfolio of 70% equities and 30% bonds with no allocation to gold. We acknowledge that such a sizeable allocation to gold may be unrealistic for most mainstream investors, but all allocations to gold have an material impact on emissions reduction, as indicated in **Chart 3**. A 10% holding in gold (with 65% in equities and 25% in bonds) results in an estimated fall in portfolio emissions intensity of 7%, and a 20% holding in gold lowers the emissions intensity of the portfolio by 17%.

In addition to examining the impact of including a location to gold on the carbon intensity of portfolio value, we also looked at the impact of differently weighted portfolios on their *total emissions*. The scale of Scope 3 emissions from the other assets in the portfolio means that the total emissions associated with a portfolio are far less impacted by the introduction and increased weights of gold, although an emissions reduction impact is still evident (as indicated in **Chart 3b**).

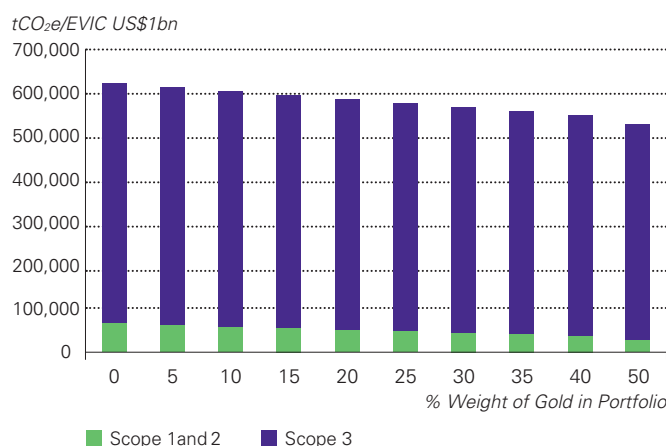
Due to data coverage and consistency issues, these metrics were not a primary focus of the report, but we are confident that the overall trend held; that is, with more substantial gold holdings we witnessed notable corresponding reductions in total portfolio emissions.

Chart 3: Weighted average carbon intensity of portfolio market capitalisation



Source: Urgentem

Chart 3b: Total emissions of portfolio enterprise value



Asset and sectoral carbon footprints

If we look closer at the various portfolio constituents and their contribution to the portfolio’s overall carbon profile, we note gold’s impact only becomes material when it is given a higher weighting, and even then, for example with a 40% allocation to gold (see **Chart 4** below), gold’s share of emissions is small.

Back-testing findings summary

Our analysis firmly indicates that gold can be used as a strategic asset to diversify the risk in a portfolio and to improve overall performance, while reducing the carbon footprint of the portfolio. However, a stronger performance and greater risk mitigation characteristics were evident in the shorter five-year period, when the recent COVID-19 pandemic and stressed markets may have supported gold’s outperformance of other assets.

Focusing on the five-year frame, for which more comprehensive carbon data is available, we note that a portfolio’s carbon footprint decreases with an increased weight of gold in the portfolio. There is a more significant reduction in the scale of Scope 1 and 2 emissions. This is not surprising given gold’s Scope 3 emissions are relatively inconsequential.

Looking at gold’s current carbon footprint and its likely performance profile, our findings provide strong evidence to indicate that incorporating gold into a portfolio can have favourable impact on the risk-reward performance of investment holdings while helping reduce their carbon footprint.

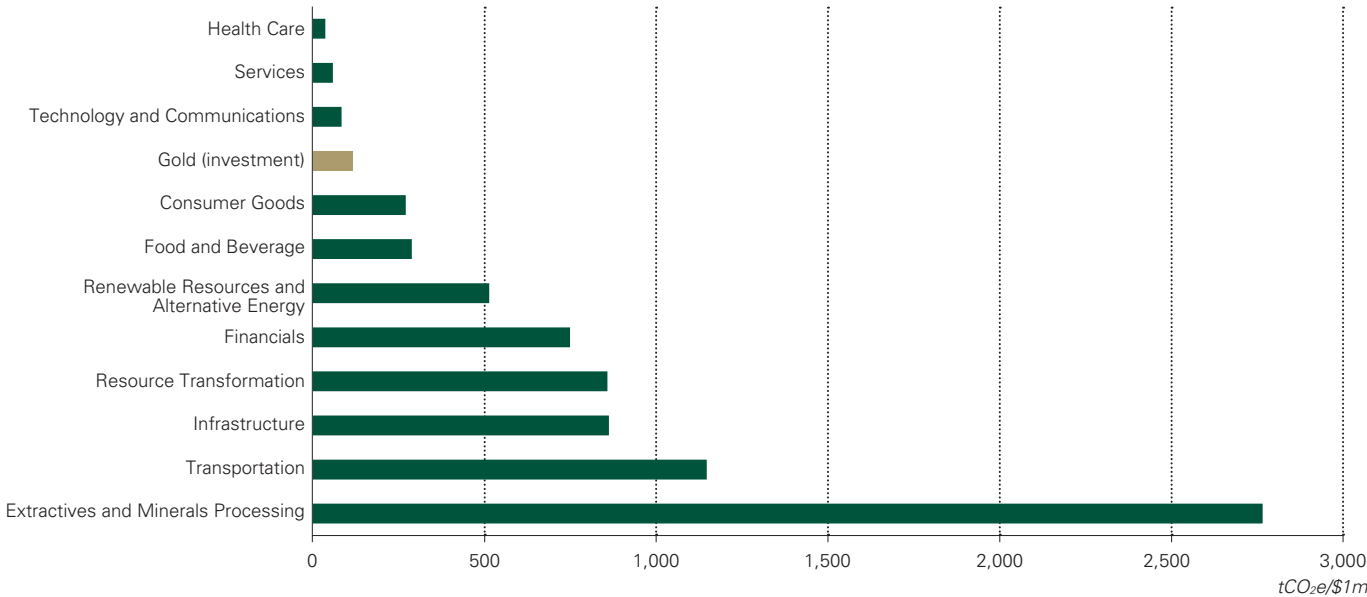
Both the performance and footprinting analyses indicate that gold as an investment can have favourable risk-reward performance impacts when incorporated into a portfolio to minimise the carbon footprint.

The forward view – portfolio decarbonisation and scenario alignment

While establishing the immediate impact of asset allocation decisions on the carbon footprint of portfolio holdings is a vital first stage in minimising exposure to carbon risks, a forward view is also required to determine how those holdings will contribute to longer term climate scenarios and targets.

In this analysis, decarbonisation pathways are calculated using a bottom-up methodology, moving from the asset to the portfolio level, to define the emissions trajectories of the differently weighted portfolios. Projected portfolio emissions trajectories are then measured against global scenario pathways.

Chart 4: Sector carbon intensity by market capitalisation (Scope 1,2 and 3)



Source: Urgentem

For a fuller description of the methodology used in the forward-looking analysis please refer to **Appendix 3: Portfolio alignment methodology**.

The chart below (**Chart 5**) shows the range of different portfolio compositions and how increased allocations to gold have a positive impact on more closely aligning the portfolio carbon trajectory with the global Net Zero emissions pathway. No portfolio comprised of these assets, given what we currently know of their current or projected future carbon profiles, is wholly aligned to a Net Zero 2050 carbon target, but allocations to gold clearly have a positive impact on future alignment.

An alternative view of gold’s potential contribution to closer climate target alignment is offered by **Chart 6** which shows the accumulated carbon associated with the differently weighted portfolios, as indexed against the benchmark allowance for global accumulated emissions under a Net Zero scenario to achieve a 1.5°C climate target. The measure of a portfolio’s cumulative emissions is often taken as a good indicator of its climate impacts, and also forms the basis of how we estimate the implied ‘temperature’ of the portfolio, as discussed below.

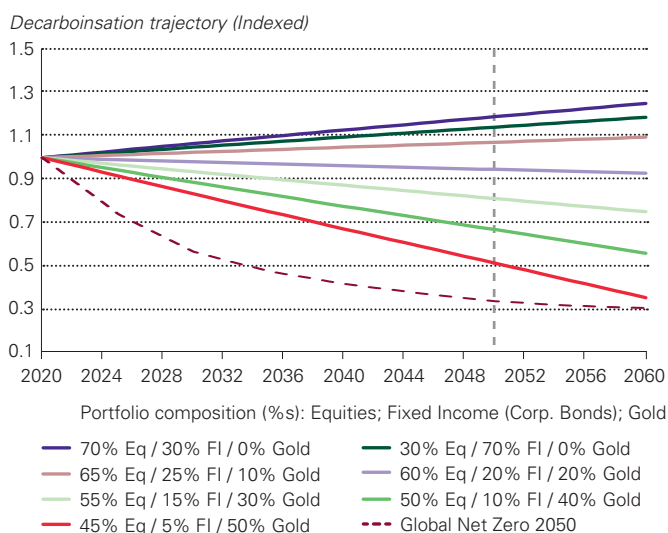
Portfolio ‘temperatures’

In seeking to better capture the climate change impacts of a portfolio, there has been a recent trend to seek to quantify the temperature implications of investment

No portfolio comprised of these assets, given what we currently know of their carbon profiles, is wholly aligned to a Net Zero 2050 carbon target, but allocations to gold clearly have a positive impact on future alignment.

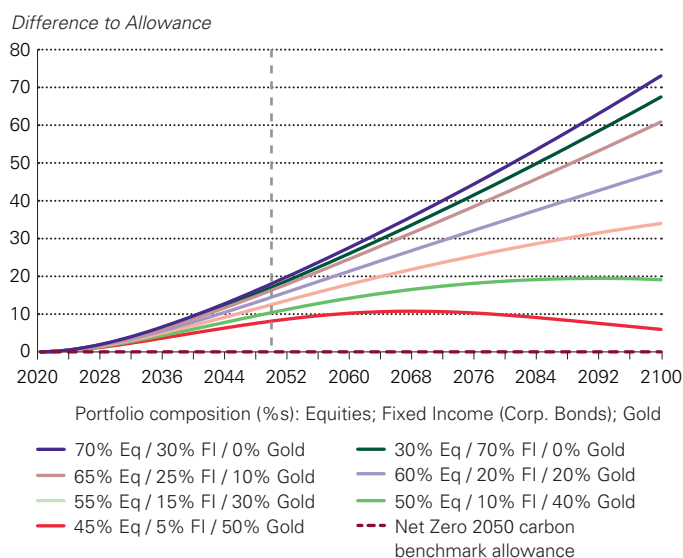
holdings – to arrive at what is often referred to as the ‘temperature rating’ or ‘warming potential’ of a portfolio.³⁰ The apparent simplicity of such a metric is very appealing, as was recognised by Mark Carney, the former Governor of the Bank of England, who stated, “Such a forward-looking measure can help asset owners and asset managers understand the transition pathways of their investments.”³¹ But there have also been some questions raised regarding whether such metrics might obscure important factors within a portfolio, foster complacency, or direct attention away from ‘real world’ climate risks and impacts.³²

Chart 5: Portfolio decarbonisation trajectories – Net Zero 2050 scenario



Source: Urgentem

Chart 6: Cumulative difference to Benchmark Allowance – Net Zero



30 That is, the increase in °C of the global temperature above the pre-industrial average, indicating how the climate could respond if the global emissions followed the trajectory of the portfolio.

31 Remarks given at a panel to launch the third annual America’s Pledge report, at the 25th Annual Conference of the Parties (2019), Mark Carney, Bank of England. www.bankofengland.co.uk/-/media/boe/files/speech/2019/remarks-by-mark-carney-at-the-us-climate-action-centre-madrid.pdf

32 *How warm is your portfolio? Our take on the temperature rating of portfolios* (2020), Thinking Ahead Institute (1.5°C investing working group).

That said, if used in combination with a range of other measures and detailed consideration of future decarbonisation pathways, portfolio temperature metrics can provide a useful concise indicator of potential exposure and progress. This can also simplify comparison of the relative climate performance of different portfolios. Our analysis of the impact of portfolio composition on the ‘warming potential’ within portfolios (see **Table 3** below) calculates an implied temperature increase, projected to 2100, based on the estimated cumulative carbon emissions produced by the differently weighted portfolios (as plotted in **Chart 6**, page 22).³³ Our findings again suggest that gold might play a positive role in mitigating the climate impacts of investment holdings. We note that a 50% allocation to gold causes the estimated temperature increase implied by portfolio holdings to fall by over 1°C compared to portfolios without gold; a 20% gold weighting results in temperature fall of 0.44°C.

Annualised emissions

These findings can also be taken as offering additional support for the position outlined in the World Gold Council’s initial examination of these factors, prompted by research from Baur & Oll,³⁴ which analysed how the carbon footprint of gold might, over time, help balance the higher carbon impacts concentrated in other portfolio assets – specifically, the S&P500.³⁵ That work

also adopted the concept of ‘embedded emissions’ for gold, assuming the investor inherits the full emissions from gold mining – what might be termed ‘the worst case’ assumption. In practice, this might result in double-counting of emissions from a carbon accounting perspective, but it allows investors some understanding of the forward implications of gold holdings on portfolio emissions. Although that analysis did not specifically reference gold mining’s downstream (Scope 3) emissions as the basis for capturing the carbon footprint of gold as an asset, it did consider how the minimal emissions associated with holding gold might, looking forward, impact a portfolio’s carbon footprint on an annualised basis. It concluded that incorporating gold could potentially compensate for the further accumulation of emissions from other portfolio constituents, and that gold’s role in the portfolio as a ‘balancing’, low carbon asset would be more impactful with time.

While that perspective is not incorporated into the analysis in this report, if it were overlaid onto the findings here it would likely amplify the portfolio emissions reduction impacts of a gold allocation.

Table 3: Asset allocations and implied portfolio temperature, to 2100

Portfolio Weight Equities Fixed Income (Corp. Bonds) Gold	Portfolio Temp Increase, °C to 2100
70% Eq / 30% FI / 0% Gold	2.96
30% Eq / 70% FI / 0% Gold	2.85
65% Eq / 25% FI / 10% Gold	2.75
60% Eq / 20% FI / 20% Gold	2.53
55% Eq / 15% FI / 30% Gold	2.28
50% Eq / 10% FI / 40% Gold	2.01
45% Eq / 5% FI / 50% Gold	1.76

Source: Urgentem

33 To measure portfolio impact, an implied temperature increase is calculated using the transient climate response to cumulative carbon emissions (TCRE) methodology, as recommended by the TCFD for use in scenario analysis. See **Appendix 3** for more details.

34 *The Role of Gold and the VIX in Investment Portfolios – A Financial and Sustainability Perspective*, 2017. Baur & Oll. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3069283

35 The investment case for gold in a climate-change impacted world section in *Gold and climate change: An introduction*, *ibid.*



Forward-looking alignment analysis findings summary

Our analysis has found that there are scenario alignment benefits to introducing gold as a strategic investment to a global balanced portfolio. Increasing the weighting of gold within the portfolio has the effect of increasing the portfolio's alignment to the benchmark allowance under the Net Zero 2050 scenario.³⁶ In addition, the cumulative emissions difference to the benchmark is minimised in the portfolios containing more gold. This has an impact of lowering the implied temperature increase metric. Taken together, these findings offer strong evidence that the inclusion of gold in a portfolio has a positive impact on its alignment with climate targets and could help to minimise portfolio climate impacts while decreasing the exposure to transition risks.

Carbon costs and portfolio performance

One of the primary levers and policy responses to climate change and accelerate the transition to a zero carbon economy is generally perceived to be the imposition of a carbon price – typically, putting an explicit price, expressed as a value per ton of carbon dioxide equivalent (tCO₂e), on GHG emissions, which is then paid for by the emitter. In practice, this price may take many forms, including flexible pricing via an Emissions Trading System or a mandatory carbon tax with fixed tariffs.

But the overall objectives are broadly the same – to dissuade emitters and incentive the shift to clean renewable power sources – and there is broad consensus around the urgent needs for more efficient pricing mechanisms and policies commensurate with the scale of climate change risks and impacts.

A carbon price also offers investors a means by which they can analyse the potential impact of climate-focused policies and any associated business cost implications on their portfolios.

³⁶ NGFS Climate Scenarios Database – Technical Documentation v2.2 (2021), Network for Greening the Financial System (NGFS). See also <https://data.ene.iiasa.ac.at/ngfs>

With this in mind, we have chosen to consider the implications of applying a rising carbon price on the differently weighted portfolios analysed above. A carbon price is here defined in a broad sense, to include the potential theoretical application of a global carbon tax on emissions, but also to acknowledge additional cost implications for particular sectors and companies.

(For a more detailed description of the methodology used to calculate the impact of carbon pricing, see [Appendix 4: Carbon pricing methodology.](#))

Our carbon pricing analysis suggests that adding gold or increasing the allocation in the portfolio minimises the annual value-at-risk. This is more substantial under the Net Zero 2050 scenario than the current policies scenario. This indicates that should the policy environment move towards more aggressive positions, then gold as an alternative asset can lessen the transition risk, since we assume there is no direct impact of carbon price on gold or, even if there is, the impact will be minimal compared to that on the equity or bond markets.

Looking at the general impact of carbon pricing policies on portfolio value over time,³⁷ our analysis suggests that the Net Zero 2050 scenario will have a stronger negative impact on growth than is projected under the current policies ('business as usual') scenario, as the higher carbon price constrains returns from both the equities and fixed income markets. If we look at the difference

in portfolio returns between the scenarios – that is, the fall in portfolio value imposed by the transition to stricter Net Zero 2050 policies and higher carbon costs – we again note that gold can play a role in minimising negative impacts (as indicated in [Chart 7](#)). Our analysis showed that expected portfolio loss is minimised by increasing the weight of gold in a portfolio; comparing a portfolio with no gold to one with 50% allocation to gold, the loss of portfolio value is reduced by 5%.

Looking at the value-at-risk (VaR) implications of the shift from current to more stringent Net Zero 2050 policies, we find further evidence of gold's potential to moderate risk exposure, with a reduction in VaR associated with an increased weight of gold in a portfolio (as indicated in [Chart 8](#) below). This is highly significant under the Net Zero 2050 scenario where the annual value-at-risk is 2.12% compared to 3.31%, when the gold weighting is increased to 50% (from 0%). This is around a 36% reduction in annual value-at-risk at the 99% confidence level. A smaller gold allocation still has a notable impact on VaR reduction, with a 10% gold holding resulting in a 7% fall to a 3.07% VaR level. This leads us to conclude that having larger allocations of equities or corporate bonds in a portfolio will expose it to a higher degree of transition risk. Conversely, allocating a substantial proportion of a portfolio to carbon-risk neutral assets or assets that are unlikely to be negatively impacted by a rising carbon price, such as gold, should help reduce portfolio transition risk.

Chart 7: Potential loss in portfolio value from a shift to Net Zero policies, by % of gold holdings

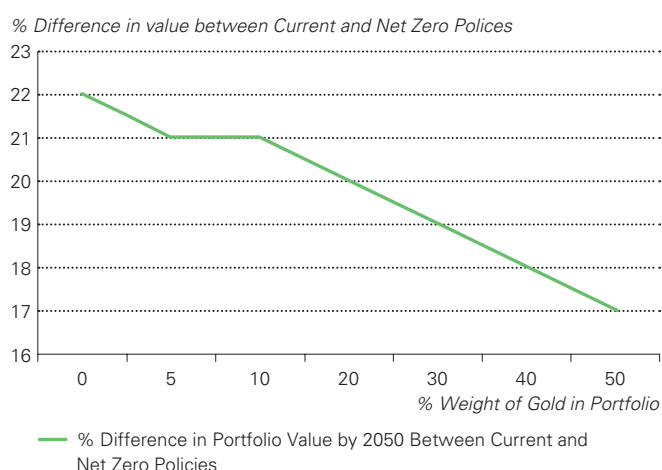
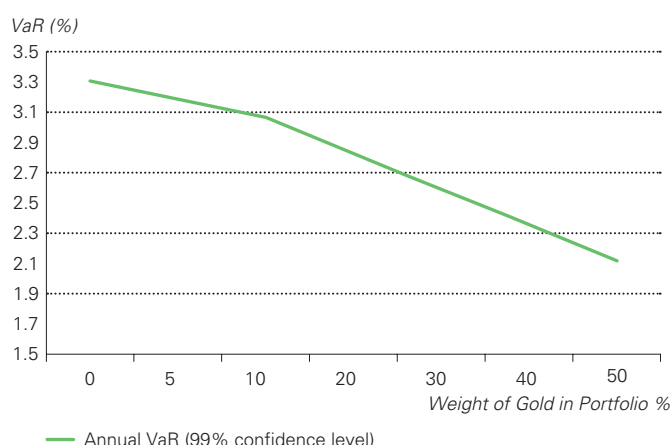


Chart 8: Portfolio VaR for various % of gold holdings – Net Zero Scenario



³⁷ For methodological reasons, asset and portfolio values are here based on an assumption of long-term linear growth rates. In practice, policy responses – and other transition risks – will likely have a range of connected or compound impacts that will have a non-linear effect on asset and portfolio values.

Conclusions



This analysis lends credence to the suggestion that gold might contribute to portfolio resilience in the context of climate transitions risks.

Our earlier research³⁸ had established a set of hypotheses, with some statistical evidence to support them, regarding gold's potential ability to contribute to the management of climate-related risks in investment portfolios. This research sheds further light on a number of our previous findings regarding gold's potential contribution to reducing portfolio emissions by adopting a methodology that allows for a quantitative assessment of gold that is compatible with the way the carbon implications of other assets are modelled within a portfolio context.

Given the urgency of adapting our asset selection and allocation strategies to better reflect and support the transition to a net zero economy and the importance of implementing change within the next few decades, we mainly focused on scenarios and targets out to 2050.

Using a range of measures, we note that an allocation to gold can have a demonstrable impact on reducing the emissions profile of a portfolio and lower its implied temperature. This allows closer alignment of portfolios with Net Zero carbon scenarios and 1.5°C climate targets. Currently, few mainstream global portfolios can demonstrate full alignment with Paris Agreement targets, and there is a compelling case for including gold as a strategic asset to contribute to closer alignment while also protecting value and moderating risk.

This analysis lends credence to the suggestion that gold might contribute to portfolio resilience in the context of climate transitions risks. It has a potential role to play in reducing the carbon impacts of a portfolio, while also being relatively impervious to the impacts of a rising carbon price, which is widely perceived as likely needed to accelerate the transition to a low carbon economy.

Much of this is, of course, based on the assumption that gold mining, and the energy landscape in which it operates, will continue to decarbonise as initial trends and research suggests. We have documented elsewhere that gold mining is well placed to both contribute to the global energy transition and also to benefit from it, with a clear and concentrated opportunity for the sector to pursue decarbonisation, as aligned to Paris Agreement targets. And, given that the mine production process is responsible for nearly all gold supply chain emissions, decarbonising that production effectively decarbonises gold as an asset.

³⁸ *Gold and climate change: An introduction* (2018), *Gold and climate change: Current and future impacts* (2019), *Gold and climate change: The energy transition* (2020), all World Gold Council.

However, we have to acknowledge that this is still a forward view dependent on further substantial actions from the gold mining sector. If gold mining were not to decarbonise as we project and, specifically, little progress was to be made in moving away from fossil fuels to drive on-site operations, and gold production at higher emission mines was not reduced, then the significant impacts a gold holding can have on reducing the carbon footprint of an investment portfolio would be diminished, although not entirely negated.

That said, it is perhaps worth restating that the analysis summarised here is based on the assumption of a 'worst case scenario' with regards the level of emissions an investor accepts as embedded in the asset they purchase. In reality, the minimal emissions associated with a gold

holding and the plentiful above-ground stocks from which investments will likely be drawn, suggest the practical implications on a portfolio's carbon profile of holding gold may, in some aspects, be even more positive than this analysis suggests.

The primary focus of this report is on the emissions implications of portfolio holdings, and it does not seek to estimate the sensitivity or response of gold or other asset classes to the full spectrum of climate-related risks. However, it can be interpreted as offering strong supporting evidence for our previous hypotheses that gold might play a significant role as a climate risk mitigation asset and make a substantial contribution to robust investment portfolio performance as the global economy is transformed by climate change.

Appendices – methodology notes

The following notes are a summary of the key methodological issues addressed by Urgentem, as described by its research team, in undertaking the analysis summarised in the main body of the *Gold and climate change: transition risk and portfolio impacts* report.

Appendix I: Gold footprint methodology

The overall approach taken by the Urgentem research team was to extend the existing methodology for carbon footprinting gold with the objective of increasing the alignment of gold's carbon footprint to the carbon emissions of other assets, including equities and bonds. Urgentem has built on the existing methodology as set out in previous World Gold Council research – specifically, *Gold and climate change: current and future impacts* (2019) and *Gold and climate change: the energy transition* (2020). This approach more accurately measures the carbon footprint of gold from an investment perspective allowing for a consistent approach at a portfolio level.

With a comparable carbon footprinting methodology in place, gold can then be incorporated into a portfolio for broader climate impact analysis. Calculation of the carbon intensity of gold and the other assets in the portfolio on a comparable basis allows for a robust approach to portfolio level carbon footprinting and forward-looking climate alignment analysis.

To create a carbon footprint of gold from an investment perspective (Investment Gold), we have used the working assumption that the gold investment within the portfolio comes from a mix of newly mined gold, inheriting a proportion of the carbon footprint associated with the mining and production of gold, and recycled gold.

The weights for the different types of gold (newly mined and recycled) are calculated from the structure of average annual supply flows, as estimated by the World Gold Council. Taking just newly mined gold in isolation would also allow for the measurement of the “worst case” scenario of gold's footprint and could prove useful for analytical purposes.

Several adjustments need to be made when considering gold from an investor's perspective.

The emissions from gold mining need to be translated into the emission of gold bullion as an

investment. Gold mining Scope 1 & 2 emissions are translated into the upstream Scope 3 emissions for a gold investor, while downstream Scope 3 emissions from gold miners (identified as 'investment gold') become the Scope 1 & 2 emissions for the investor.

We have also given consideration to the inclusion of a greater level of detailed regional grid intensity analysis for both mined and recycled gold given this accounts for a large portion of the emissions intensity of gold. This involves making adjustments to both Scope 1 and Scope 2 emissions for gold on a regional basis.

Regional footprint adjustments

To make the regional adjustments for energy use, both Scope 1 and 2 emissions have to be taken into consideration. Scope 1 emissions need to be adjusted for local power, while scope 2 emissions have to be adjusted for regional grid intensities. For this analysis we have included a regional factor to account for the differences in Scope 1 and 2 emissions using regional/country level data as provided by the World Gold Council (specifically, the *Gold and climate change: the energy transition* (2020) data book from Wood Mackenzie and the World Gold Council). We incorporated the percentage of power taken from the grid in the various different mining regions against the power generated locally. Utilising regional/country level grid intensities we are able to make regional intensity adjustments which can then be incorporated into a final calculation of gold's overall carbon footprint.

Scope 1 adjustment

Here we adjust the WGCs global estimate for gold's Scope 1 carbon emissions based on regional factors.

For calculating the proportion of global gold mining Scope 1 emissions that come from electricity generation we used an estimate that 50% of Scope 1 emissions are the result of electricity generation and the other 50% from other mining activities.

These estimates are based on the average proportion of mining electricity that comes from the grid versus locally generated electricity. We assume that Scope 1 emissions from non-power generation activities are similar between regions.

For each region we calculated a Scope 1 adjustment factor. This takes into account the local off-grid intensity of electricity generation based on the regional proportion of off-grid electricity generated from each source and the tCO₂e/MWh intensity per generation type

(Data source: *Gold and climate change: the energy transition* (2020) data book, Wood Mackenzie, World Gold Council)

The data inputs for the Scope 1 adjustment process are as follows:

$\text{Adjustment_Factor} = (1 - \text{Grid_Pct_Electricity}) * (\text{Off_Grid_Intensity} / \text{Off_Grid_Intensity_Average})$

$\text{Grid_Pct_Electricity}$ = Regional proportion of electricity from grid.

$\text{Off_Grid_Intensity}$ = Regional tCO₂e/MWh intensity of off-grid electricity generation

$\text{Off_Grid_Intensity_Average}$ = Weighted Average tCO₂e/MWh intensity of off-grid electricity generation (Weighted by gold production).

To calculate the adjusted Scope 1 emissions, we adjusted only the proportion of Scope 1 coming from off-grid power generation, as follows:

$\text{Adjusted Scope 1} = (\text{Adjustment_Factor} * \text{S1_Pwr_Gen}) + \text{S1_Non_Pwr_Gen}$

$\text{S1_Pwr_Gen} = 0.5 * \text{Global estimate for Scope 1 emissions per tonne of gold}$ (Source: *Gold and Climate Change: Current and Future Impacts* (2019), World Gold Council). This is the proportion of the Scope 1 estimated to have come from power generation, on average.

$\text{S1_Non_Pwr_Gen} = 0.5 * \text{Global estimate for Scope 1 emissions per tonne of gold}$ (Source: *Gold and Climate Change: Current and Future Impacts*). This is the proportion of the Scope 1 estimated to have come from non-power generation, on average.

Scope 2 adjustment

For the adjustments to Scope 2, we adjusted for regional power grid intensities. The regional power grid usage for gold production was examined across 31 gold producing countries using data from the WGC Databook (Share of Gold Production by Power Source, 2019), the IEA and ETP.

The regional adjustment factor for Scope 2 emissions for gold can then be calculated as follows:

$\text{Adjustment_Factor} = \text{Grid_Pct_Electricity} * (\text{Reg_Grid_Intensity} / \text{Grid_Intensity_Avg})$

$\text{Grid_Pct_Electricity}$ = Regional percent of electricity supplied from grid.

$\text{Reg_Grid_Intensity}$ = Regional grid intensity.

$\text{Grid_Intensity_Avg}$ = Average global grid intensity.

$\text{Scope 2 Adjusted} = \text{Adjustment_Factor} * \text{Scope_2_Global}$

Scope_2_Global = Global estimate for Scope 2 emissions per tonne of gold (Source: *Gold and Climate Change: Current and Future Impacts*).

This greater analysis of emissions from power usage is warranted given this is an area of focus for decarbonisation within the mining industry with a move towards using renewables instead of high emissions energy. This could be largely driven by the move from fossil fuel extraction towards using electric machinery and vehicles.

We have analysed the impact of power usage across the major gold producing countries and regions, focusing on the top 10 producing countries, excluding China and Uzbekistan where data is limited.

Country grid emissions factors were obtained from the IEA. Country gold mining intensity values are sourced from the WGC report: *“Gold and climate change: The energy transition”*

Translating Adjusted Scope 1+2 Footprints into Investor Footprint

Since our analysis is being carried out from the gold investors' point-of-view, the emissions from gold mining need to be translated into the emission for gold bullion as an investment. The Scope 1 and 2 emissions from gold mining companies then become the upstream Scope 3 emissions from the investors point of view. The downstream Scope 3 emissions from gold miners (investment) become the Scope 1 & 2 emissions for the investor. For the Scope 3 analysis we used the Scope 3 estimate from the WGC report: *Gold and Climate Change: Current and Future Impacts*.

Further, to account for the fact that some gold in circulation comes from newly mined gold but can also be sourced from recycled gold, we adjust the emissions based on the percent of newly mined versus recycled gold in circulation. We have also used the estimates for the relative amounts of types of gold in circulation – i.e. as reflected in annual supply and demand flows from the WGC data hub (www.gold.org/goldhub/data/gold-supply-and-demand-statistics).

While we feel that the adjustments made provide a very good representation of gold's carbon footprint from an investors' perspective, we would note that the Scope 3 footprint does not take into account transportation or other downstream categories. However, the estimated footprint does reflect the most material categories in the gold supply chain.

Table 4: Gold’s Scope 1, 2 and 3 absolute emissions from investors’ perspective – mix of new mined and recycled gold (emissions (tCO₂e) per tonne of gold)

Country	Scope 1, 2 & 3 absolute emissions per tonne gold	Scope 1 & 2 absolute per tonne gold	Scope 3 absolute per tonne gold
Russian Federation	14421.452	3.62	14417.832
Australia	16449.134	3.62	16445.514
United states	15031.408	3.62	15027.788
Canada	9795.123	3.62	9791.503
Peru	10267.679	3.62	10264.059
Ghana	13332.731	3.62	13329.111
South Africa	23710.158	3.62	23706.538
Mexico	17210.603	3.62	17206.983
Brazil	6451.849	3.62	6448.229
Kazakhstan	12510.717	3.62	12507.097

Source: Urgentem. Emissions (tCO₂e)per tonne of gold

Table 5:Regional footprint of gold (newly mined and recycled)

Country	Scope 1, 2 & 3 intensity of market cap	Scope 1 & 2 intensity of market cap	Scope 3 intensity of market cap
Russian Federation	296.127	0.074	296.052
Australia	337.762	0.074	337.688
United states	308.651	0.074	308.577
Canada	201.131	0.074	201.056
Peru	210.834	0.074	210.760
Ghana	273.771	0.074	273.697
South Africa	486.859	0.074	486.784
Mexico	353.398	0.074	353.324
Brazil	132.481	0.074	132.406
Kazakhstan	256.892	0.074	256.818

Source: Urgentem. tCO₂e\$USD Million

Table 6: Gold carbon footprint from global investor perspective

Gold investor – investment gold	Scope 1, 2 & 3 tCO ₂ e per tonne gold	Scope 1 & 2 tCO ₂ e per tonne gold	Scope 3 tCO ₂ e per tonne gold
Newly mined and recycled	21059.85	3.62	21056.23
Newly mined only	32692.62	3.62	32689.00

Source: Urgentem. tCO₂e per tonne of gold

Appendix II: Integrating gold into portfolio carbon footprints

To produce a carbon footprint for a portfolio containing Gold, Equity and Corporate Bond (CB) assets, two calculation methods were applied: the Apportioned Emissions (Total Emissions) and the Weighted Average Intensity of Market Value:

The Apportioned Emissions (Total Emissions)

$$\text{Total Emissions Equity \& CB} = \sum \frac{\text{Weight} \times \text{portfolio Value}}{\text{EVIC}} \times \text{Corporate Emissions}$$

$$\text{Total Emissions Gold Bullion} = \sum \text{Gold Owned (kg)} \times \text{Emissions per kg}$$

$$\text{Total Emissions Portfolio} = \text{Total Emissions Equity \& CB} + \text{Total Emissions Gold Bullion}$$

The Weighted Average Intensity of Market Value approach:

$$\text{Intensity} = \sum (\text{Weight} \times \text{Emissions per } \$\text{USD million value}),$$

Where,

$$\text{Emissions per } \$\text{USD million value (Gold)} = \frac{\text{Gold Owned (kg)} \cdot \text{Emissions per kg}}{\text{Market Value of Gold}}$$

$$\text{Emissions per } \$\text{USD million value (Corporate)} = \frac{\text{Corporate Emissions}}{\text{FY Market Capitalisation}}$$

Weight = weight in portfolio,

Portfolio Value = Sum of all positions in portfolio in \$USD,

Corporate Emissions = Either Scope 1+2 or Scope 1+2+3 emissions,

EVIC = Enterprise Value Including Cash (Following PCAF),

Gold Owned (kg) = Either known kgs of gold in holding or calculated as gold holding / gold price per kg,

Emissions per kg = per kg emissions estimate based on WGC research,

Market Value of Gold = Value of Gold per kg

Table 7: Portfolio carbon footprint with varying weights of gold (newly mined mold)

Gold portfolio weight %	Weighted average intensity market cap (tCO ₂ e/\$1m)		Total emissions tCO ₂ e EVIC \$1bn	
	Scope 1 & 2	Scope 3	Scope 1 & 2	Scope 3
0	114.58	1025.04	69144.64	558060.91
5	108.12	991.77	65390.45	564235.08
10	101.67	958.50	61636.27	570409.25
15	95.21	925.23	57882.08	576583.41
20	88.75	891.96	54127.90	582757.58
25	82.29	858.68	50373.71	588931.74
30	75.84	825.41	46619.53	595105.91
35	69.38	792.14	42865.34	601208.08
40	62.92	758.87	39111.15	607454.24
50	50.01	692.33	31602.78	619802.57

Source: Urgentem. New mined and recycled gold (investment gold) intergrated into Urgentem’s Global Balance Multi-Asset Portfolio (see 4.0 – Portfolio Construction and Backtesting)

Table 8: Portfolio carbon footprint with varying weights of gold (newly mined and recycled gold)

Gold portfolio weight %	Weighted average intensity market cap (tCO ₂ e/\$1m)		Total emissions tCO ₂ e EVIC \$1bn	
	Scope 1 & 2	Scope 3	Scope 1 & 2	Scope 3
0	114.58	1025.04	69144.64	558060.91
5	108.12	983.88	65390.45	552292.86
10	101.67	942.72	61636.27	546522.80
15	95.21	901.56	57882.08	540753.75
20	88.75	860.40	54127.90	534984.69
25	82.29	819.24	50373.71	529215.64
30	75.84	778.08	46619.53	523446.58
35	69.38	736.92	42865.34	517677.52
40	62.92	695.76	39111.15	511908.47
50	50.01	613.45	31602.78	500370.36

Source: Urgentem. New mined and recycled gold (investment gold) intergrated into Urgentem’s Global Balance Multi-Asset Portfolio (see 4.0 – Portfolio Construction and Backtesting)

Importance of Scope 3 Emissions

Analysis by Urgentem has found that, on average, 86% of a company's total carbon emissions come from Scope 3 emissions, highlighting the importance of including Scope 3 in our analysis here. Indeed, this is especially important when it comes to analysing a portfolio's exposure and vulnerability to climate transition risks. Excluding Scope 3 emissions from this analysis would fail to provide an accurate picture of a portfolio's exposure to such risks.

The role of Scope 3 emissions also takes on further significance when considering Investment Gold. As discussed above, Scope 1 and 2 emissions of gold mining companies form part of the Scope 3 emissions of Investment Gold, while aspects of Scope 3 emissions from the gold mining companies are embedded in the Scope 1 and 2 emissions of Investment Gold and inherited by the investor.

This again highlights the importance of carrying out the detailed analysis of Scope 3 emissions across all 15 categories to provide a more complete picture of the carbon emissions for our portfolio and the influence that gold can have on the carbon footprint of the portfolio.

Portfolio construction

To represent a global, balanced portfolio, we assembled indexes consisting of equities and bonds, and then added gold.

Five regional equity indices covering both Developed and Emerging Markets were created as follows:

- North America DM Equity Index
- Latin America EM Equity Index
- Europe DM & EM Equity Index
- Africa EM & FM Equity Index
- Asia-Pacific DM & EM Equity Index

Constituent assets were screened for liquidity from each region. The top 200 companies were selected and weighted on the basis of market capitalisation. For each year (of the 5-year series), the step was repeated to select and rebalance the constituents (by market capitalisation) and the aggregate total index return was then calculated for inclusion in the portfolio.

A similar approach was applied to construct a global developed market investment grade corporate bond index.³⁹ For each ultimate issuer of the bond, the weights were capped at 3% to limit concentration risk.

The region of the equity was defined by the country of incorporation or the primary listing of the security. Each company and its securities must be classified in only one region to be considered. Within each region countries from developed, emerging, and/or frontier markets were selected as listed below.

Regions:

- North America – includes developed markets only
- Latin America – includes emerging markets only
- Asia-Pacific – includes emerging and developed markets
- Europe – includes developed markets only
- Africa – includes emerging and frontier markets

Selection criteria for investable equity universe

1. When defining the eligible bond universe only fixed rate coupon bonds were considered for simplicity.
2. Credit rating – only investment grade bonds were included (Moody's rating Aaa – Baa3).
3. Issuer Country of Domicile – the securities must belong to issuers domiciled in the developed markets listed below.

Australia	France	Japan	Singapore
Austria	Germany	Luxembourg	Spain
Belgium	Hong Kong	Netherlands	Sweden
Canada	Ireland	New Zealand	Switzerland
Denmark	Israel	Norway	United Kingdom
Finland	Italy	Portugal	USA

4. Maturity – Each index constituent must have a maturity of greater than 1 year from the date of constituents' selection. That is, if the selection is done in Dec of 2015 for the year of 2016, each security maturity should be greater than Jan 2017. This is to avoid a lot of cash being carried forward if bonds mature within the holding period.

³⁹ Emerging Market (EM) bond index data is insufficient to be consistent and comparable with other portfolio constituents and is therefore excluded.

5. Liquidity – The liquidity of the bonds were measured using indirect measures, due to lack of direct measures such as bid-ask spread and trading volume.
 - a: Issue amount – The amount issued should be greater than USD 1bn.
 - b: Issue date – must be less than 5 years on the date of the constituent’s selection. The older a bond becomes, an increasing percentage of its issued amount is absorbed into buy-and-hold portfolios, and it becomes less liquid.
6. Weighting – market-value-weighted index. Index weights were based on the outstanding par amounts for bonds on the month of the constituent selection. That is at the end of December 2015 for the year of 2016. Weights were capped at 3% per issuer to limit concentration risk.
7. Similar to the equity sub-indices, the global bond index was used to generate a total returns index.

Unlike the equity indices, Emerging market and Frontier market corporate bonds were not included in the final bond indices for a number of reasons. Firstly, this category of the corporate bond market tended to fail our liquidity and other selection requirements for inclusion.

Secondly, financial and fundamental data were not insufficient to be consistent and comparable with other portfolio constituents. Hence, the decision was taken to exclude these categories of the corporate bond market from our portfolio selection process.

Multi-Asset Portfolio Construction

A series of multi asset portfolios were constructed from the Equity and Bond indices with varying weights for equities, bonds and gold. For the shorter term benchmark analysis, a portfolio of 60% MSCI ACWI and 40% iShares iBoxx Investment grade corporate bonds were used.

For the longer-term backtesting period, given the lack of available data for many of the assets included in our shorter term backtest portfolio, we constructed a multi asset portfolio consisting of Gold, MSCI US Total Return Index, MSCI EAFE Total Return Index, Bloomberg Barclays US Credit Index, Bloomberg US Treasury Index and Bloomberg Global Ex US Treasury Index. With the longer term backtesting we followed a similar approach to the portfolio construction used for the shorter period, using the starting weights of 70%, 30% and 0% (equities, bonds and gold). The weighting of gold was slowly increased at 5% increments and the corresponding weights were equally reduced in equities and bonds.

Table 9: Portfolio metrics

Portfolio composition (equities, corp bonds, gold)	Alpha	Annualised mean return	Arithmetic mean (weekly)	Arithmetic sharpe ratio	Beta	CAGR	Calmar ratio	Conditional VaR (5%)*	Excess kurtosis*	Gain/loss ratio*
30%_70%_0%	2.50%	8.29%	0.15%	91.39%	0.55	7.96%	43.20%	-2.26%	20.60	1.40
45%_5%_50%	4.72%	12.23%	0.22%	99.62%	0.69	11.54%	47.79%	-3.12%	10.49	1.34
50%_10%_40%	4.08%	11.95%	0.22%	97.88%	0.73	11.28%	44.95%	-3.10%	11.93	1.38
52.5%_12.5%_35%	3.76%	11.79%	0.22%	96.41%	0.75	11.15%	43.62%	-3.11%	12.45	1.40
55%_15%_30%	3.43%	11.64%	0.21%	94.56%	0.77	11.01%	42.34%	-3.14%	12.81	1.50
57.5%_17.5%_25%	3.09%	11.47%	0.21%	92.37%	0.78	10.86%	41.10%	-3.17%	12.99	1.47
60%_20%_20%	2.75%	11.31%	0.21%	89.87%	0.80	10.71%	39.91%	-3.22%	13.01	1.50
62.5%_22.5%_15%	2.40%	11.14%	0.20%	87.11%	0.82	10.56%	38.52%	-3.27%	12.86	1.47
65%_25%_10%	2.05%	10.96%	0.20%	84.13%	0.84	10.40%	37.11%	-3.34%	12.58	1.43
67.5%_27.5%_5%	1.69%	10.78%	0.20%	80.99%	0.86	10.23%	35.67%	-3.41%	12.19	1.36
70%_30%_0%	1.33%	10.59%	0.19%	77.74%	0.88	10.07%	34.30%	-3.50%	11.70	1.36

*based on weekly data

Benchmarks used for comparative analysis: 60% MSCI ACWI, 40% iShare iBoxx Corporate bonds

Table 10: Portfolio metrics continued

Portfolio composition (equities, corp bonds, gold)	Geometric sharpe ratio	Historical VaR (5%)*	Information ratio	Maximum drawdown	Parametric VaR (5%)*	R-squared	Skewness*	Sortino ratio	Standard deviation
30%_70%_0%	87.12%	-1.06%	35.85%	-19.18%	-1.77%	82.81%	-2.00	93.83%	8.28%
45%_5%_50%	93.88%	-1.67%	74.66%	-25.60%	-2.44%	67.35%	-0.65	120.41%	11.53%
50%_10%_40%	92.21%	-1.59%	60.46%	-26.57%	-2.43%	76.04%	-0.84	114.03%	11.45%
52.5%_12.5%_35%	90.82%	-1.68%	54.93%	-27.04%	-2.44%	79.76%	-0.93	110.24%	11.47%
55%_15%_30%	89.08%	-1.65%	50.01%	-27.48%	-2.46%	82.98%	-1.01	105.48%	11.52%
57.5%_17.5%_25%	87.02%	-1.58%	45.46%	-27.92%	-2.49%	85.63%	-1.07	101.91%	11.62%
60%_20%_20%	84.67%	-1.63%	41.03%	-28.34%	-2.53%	87.70%	-1.13	97.87%	11.76%
62.5%_22.5%_15%	82.09%	-1.71%	36.42%	-28.91%	-2.57%	89.18%	-1.18	94.46%	11.94%
65%_25%_10%	79.31%	-1.81%	31.20%	-29.53%	-2.62%	90.10%	-1.21	91.14%	12.15%
67.5%_27.5%_5%	76.38%	-1.88%	24.62%	-30.21%	-2.68%	90.50%	-1.23	88.00%	12.40%
70%_30%_0%	73.35%	-2.03%	15.01%	-30.87%	-2.75%	90.43%	-1.25	84.16%	12.68%

Portfolio composition (equities, corp bonds, gold)	Absolute emissions Scope1&2 1bn	Absolute emissions Scope3 1bn	Absolute emissions Scope12&3 1bn	Treynor ratio (%)	Weighted average intensity market cap Scope1&2	Weighted average intensity market cap Scope3
30%_70%_0%	81171.45	537428.25	618599.70	13.73%	143.86	1192.77
45%_5%_50%	31602.78	619802.57	651405.36	16.71%	50.01	613.45
50%_10%_40%	39111.15	607454.24	646565.40	15.42%	62.92	695.76
52.5%_12.5%_35%	42865.34	601280.08	644145.42	14.82%	69.38	736.92
55%_15%_30%	46619.53	595105.91	641725.44	14.24%	75.84	778.08
57.5%_17.5%_25%	50373.71	588931.74	639305.46	13.69%	82.29	819.24
60%_20%_20%	54127.90	582757.58	636885.48	13.15%	88.75	860.40
62.5%_22.5%_15%	57882.08	576583.41	634465.50	12.63%	95.21	901.56
65%_25%_10%	61636.27	570409.25	632045.52	12.13%	101.67	942.72
67.5%_27.5%_5%	65390.45	564235.08	629625.53	11.65%	108.12	983.88
70%_30%_0%	69144.64	558060.91	627205.55	11.18%	114.58	1025.04

*based on weekly data

Benchmarks used for comparative analysis: 60% MSCI ACWI, 40% iShare iBoxx Corporate bonds

Back-testing limitations

Both the shorter and the longer backtesting period between 2016-2020 and 1999-2020 have been impacted by extreme market stress events and this has favoured gold's performance during these periods.

The global bond index constructed in the shorter period analysis and for portfolio footprinting is composed of constituents selected from the developed countries only.

Further, only liquid investment grade fixed coupon bonds were selected. Therefore, it does not fully reflect the performance of the global bond universe.

The global equity universe consists of the Top 200 companies by market capitalization from each region, in total about 1000 companies. Therefore, the performance of the global equity index does not fully reflect the global equities universe.

Appendix III: Portfolio alignment methodology

The analysis has three components:

1. The Global Emissions Index

This component illustrates the relative change in global GHG emissions under the chosen scenario. This index is calculated based on the overall global GHG emissions output under the scenario and is adjusted for any negative emissions (CCS or LUC) in the scenario.

2. The Benchmark Emissions Index

This component illustrates the emissions trajectory the portfolio should take in order to be completely aligned to the decarbonisation scenario. This index can be compared alongside the global emissions index to understand how the portfolio's decarbonisation rate compares to the global rate. The difference is impacted by the exposure of the portfolio to different sectors and asset classes.

This component is calculated using a bottom up aggregated approach. First, each company or asset in the portfolio is analysed based on its industry and the ideal emissions pathway for its Scope 1, 2, and upstream and downstream Scope 3 emissions are calculated. These pathways come from the outputs of the NGFS models and a mapping between the NGFS model outputs and each scope for each industry. Negative emissions from CCS and land use change are accounted for in the analysis. Second, we aggregate the emissions pathways to a portfolio level pathway. This is done based on apportioned Scope 1, 2 and 3 emissions.

3. Portfolio Trajectory Index

This component represents a calculated trajectory for the portfolio. The analysis uses the past 3 years worth of Scope 1, 2 and 3 emissions data for corporations

to calculate a trajectory for emissions. Additionally, if corporations have disclosed any public decarbonisation targets, these are incorporated. For gold, we calculated a decarbonisation rate based on the changes in gold mining power emissions from the WGC's data book for the Gold and climate change: the energy transition report. Again, we use an apportioned emissions approach to aggregate the trajectories of each holding in the portfolio to a portfolio level trajectory index. This component is used to assess the degree of alignment of each portfolio to the benchmark and to each other portfolio in the analysis.

For this analysis Urgentem's company level Scope 1, 2 and 3 carbon emissions data were used, while the latest NGFS Net Zero 2050 and Current Policies scenarios were used to construct the benchmark. The Current Policies scenario was chosen as a business as usual (BAU) scenario that would reflect a bad-case warming impact. The Net Zero 2050 scenario reflects a much more ambitious scenario with a more desirable climate outcome but with much greater transition impacts.

Implied portfolio temperature methodology

To measure portfolio impact, an implied temperature increase is calculated using the transient climate response to cumulative carbon emissions (TCRE) methodology. This methodology is recommended by the TCFD for use in scenario analysis. This methodology looks at the cumulative carbon emissions produced at a global level under each scenario and the related climate response (temperature increase). Based on our estimate of the cumulative carbon emissions produced by a portfolio, we can calculate its TCRE temperature increase.

Appendix IV: Carbon pricing methodology

Carbon pricing methodology for corporate bonds

For each firm in the portfolio we calculate the earnings change at time t, using the formula below.

$$Earnings_change = \frac{Earnings_t - Earnings_{t-4}}{Earnings_{t-4}}$$

Then we use the formula below to construct a portfolio level earnings change.

$$Earnings_change_portfolio_{j,t} = \sum_{i=1}^n Weight_{i,j,t} * Earnings_change_{i,t}$$

We now have a time-series portfolio return and a time-series earnings change matched by date. Next we select an estimation window (5 year) to run Linear Least Squares Regression to obtain an earnings beta.

$$Portfolio_return = Intercept + Earnings_Beta * Earnings_change_portfolio_{j,t}$$

Carbon cost calculation for companies

For each firm in the portfolio, we calculate the carbon cost at time t using the formula below.

$$Carbon_cost_per_t = Carbon_emissions_t * Carbon_price_t$$

We then convert the carbon cost into a percentage of earnings.

$$Carbon_per_earnings_t = Carbon_cost_t / Earnings_t$$

Then we use the formula below to construct portfolio level carbon cost

$$Carbon_per_earnings_portfolio_{j,t} = \sum_{i=1}^n Weight_{i,j,t} * Carbon_per_earnings_{i,t}$$

The impact of carbon cost on portfolio return can be calculated using the formula below.

$$Carbon_portfolio_return_{t+1} = Carbon_per_earnings_portfolio_{j,t} * Earnings_beta_t$$

The carbon adjusted returns can then be converted into portfolio price.

$$Carbon_adj_price_{t+1} = base_price_t * (1 + Carbon_portfolio_return_{t+1})$$

Carbon pricing methodology for corporate bonds

The approach used for forecasting and giving targets for share prices was similar to that used by equities analysts.

The P/E ratio was used to provide a valuation framework. The approach used was to forecast the earnings of the individual companies and the potential for earnings growth over the coming years. This allowed for a P/E ratio to be assigned based on a company's peer group/sector as well as global valuations. This could be adjusted if it was felt that a particular company had a relatively better/worse earnings profile going forward. With the estimated earnings profile and prospective P/E ratio, a price target could be assigned to individual companies.

Using this framework, if the extent to which future earnings could be impacted by a Carbon Cost are known, the share price at which the current or a certain P/E ratio is maintained can be obtained. One push back to this approach could be that companies that are likely to be impacted more significantly by a carbon tax are likely to move to a lower P/E ratio in anticipation.

Calculation

$$EPS = (Net\ Income - Preferred\ Dividends) / Weighted\ Average\ Shares\ Outstanding$$

$$P/E = Price/EPS$$

$$Carbon\ Cost = Carbon\ Price \times Absolute\ Emissions$$

$$Carbon\ Adjusted\ EPS = (Net\ Income - Preferred\ Dividends - Carbon\ Cost) / Weighted\ Average\ Shares\ Outstanding$$

$$Carbon\ Adjusted\ Price = Carbon\ Adjusted\ EPS \times P/E$$

$$Carbon\ effect = (Share\ price - Carbon\ Adjusted\ Price) / Share\ price$$

Forecasting returns

The carbon effect calculated for each individual company is used as a proxy to measure the impact it will have on the EPS growth of the company. The forecasted Carbon Adjusted EPS is used to calculate the estimated price of a share at a given time.

The formula to calculate the EPS is as follows:

$$Carbon_adjusted_EPS_{t+1} = (EPS_t * (1 - Carbon_effect_{t+1})) * (EPS\ Growth\ Rate + 1)_{t+1}$$

$$Estimated_carbon_adjusted_price_{t+1} = Carbon_adjusted_EPS_{t+1} * (P/E)_t$$

* The EPS growth rate used in the calculation is the average long-term annual EPS growth rate of S&P 500.

Carbon pricing assumptions and limitations

To carry out this analysis we assume that the relation between earnings and portfolio returns are linear. The model can be adjusted to non-linear regression based on the type of asset in the portfolio.

Earnings before tax have been used for this analysis, but the ideal proxy is "Earnings before extraordinary items". Earnings in the same quarter of the previous year are used to calculate earnings change to control seasonal effects.

More control variables could also be added to the regression model, for example to explain the market return, which is likely to explain a significant portion of the variation in the portfolio returns.

The Fama French Three factor model could also be used to explain most of the asset returns.

A longer sample period to estimate earnings beta would also further add to the robustness of the beta.

Valuations and return assumptions/limitations

The EPS growth rate used in the model is a generic value of 5.6% per year obtained from the last 150 years EPS growth rate of the S&P 500. Thus, this does not reflect performance of an individual company as its EPS growth rate may vary. Furthermore, an EPS growth rate does not directly measure the future growth of the share price nor dictate the returns from an investment. However, using the individual long-term average EPS growth rate of each company would improve the robustness of the model.

We assumed an expected constant compounded growth rate of 2.9% for Gold for the 30-year projections. However, there are reasons to think this assumption, based on historical long-term performance, may be an under-estimate, particularly if stricter climate policy changes and the impact of higher carbon costs erode earnings from other assets, rendering gold more attractive and competitive as an asset, and supporting a more buoyant price.

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