DISCUSSION PAPER SERIES

DP17944

A BESPOKE, PROBABILISTIC APPROACH TO CLIMATE SCENARIO ANALYSIS

Jeremy Lawson, Anna Moss, Alexandre Popa, Eva Cairns and Craig Mackenzie

OCCASIONAL PAPERS

ISSN 0265-8003

A BESPOKE, PROBABILISTIC APPROACH TO CLIMATE SCENARIO ANALYSIS

Jeremy Lawson, Anna Moss, Alexandre Popa, Eva Cairns and Craig Mackenzie

Discussion Paper DP17944
Published 28 February 2023
Submitted 27 February 2023

Centre for Economic Policy Research
33 Great Sutton Street, London EC1V 0DX, UK
Tel: +44 (0)20 7183 8801
www.cepr.org

A BESPOKE, PROBABILISTIC APPROACH TO CLIMATE SCENARIO ANALYSIS

Abstract

We develop a new approach to designing climate scenarios and assessing the impact of physical and transition climate risks on companies and markets that is better tailored for financial and investment decision making. Our main innovations are that we: (i) allow for more plausible policy variation across sectors and regions to construct 'bespoke' scenarios that are more realistic than typical 'off-the-shelf' reference scenarios, (ii) develop a baseline scenario benchmarked against what is priced into the market to better identify potential asset price misalignments, (iii) assign probabilities to scenarios and aggregate them to analyse how the long-term fair valuation of asset prices relates to a probability-weighted mean outcome. Our main results indicate that while the transition to a lower-carbon global economy is highly likely to continue, the world is unlikely to converge on a Paris-aligned trajectory - our probability-weighted mean scenario points to a 2.3°C warming by 2100. While transition effects on corporate equities and bonds at the index level is modest, we find large variations at the asset level and within sectors, implying that climate risks and opportunities are largely a micro investing phenomenon. We also find that the choice of scenario as well as our regional, sectoral and technological choices can greatly affect asset and sector valuation. Lastly, incorporating and assessing the credibility of companies' transition plans into the model can significantly modify their valuation. We believe that our probabilistic bespoke climate scenario approach provides unique insights for capital allocation by constructing a realistic assessment of scenario pathways. Different users can make different choices depending on their beliefs and objectives, they can dynamically update their assumptions with new information

JEL Classification: C68, D78, F55, G17, G18, H23, L70, L90, Q20, Q30, Q40, Q50

Keywords: Climate change, Energy transition, Climate scenario analysis, Credibility Assessments, Asset valuation

Jeremy Lawson - jeremy.lawson@aberdeenstandard.com
abrdn Research Institute and CEPR

Anna Moss - anna.moss@abrdn.com
abrdn Research Institute

Alexandre Popa - alexandre.popa@abrdn.com
abrdn Research Institute

Eva Cairns - eva.cairns@abrdn.com
abrdn Research Institute

Craig Mackenzie - craig.mackenzie@abrdn.com

abrdn Research Institute

A BESPOKE, PROBABILISTIC APPROACH TO CLIMATE SCENARIO ANALYSIS

Jeremy Lawson[1], Anna Moss[2], Alexandre Popa[3], Eva Cairns[4], and Craig Mackenzie[5]

XXXX 202X

Abstract

We develop a new approach to designing climate scenarios and assessing the impact of physical and transition climate risks on companies and markets that is better tailored for financial and investment decision making. Our main innovations are that we: (i) allow for more plausible policy variation across sectors and regions to construct 'bespoke' scenarios that are more realistic than typical 'off-the-shelf' reference scenarios, (ii) develop a baseline scenario benchmarked against what is priced into the market to better identify potential asset price misalignments, (iii) assign probabilities to scenarios and aggregate them to analyse how the long-term fair valuation of asset prices relates to a probability-weighted mean outcome. Our main results indicate that while the transition to a lower-carbon global economy is highly likely to continue, the world is unlikely to converge on a Paris-aligned trajectory - our probability-weighted mean scenario points to a 2.3°C warming by 2100. While transition effects on corporate equities and bonds at the index level is modest, we find large variations at the asset level and within sectors, implying that climate risks and opportunities are largely a micro investing phenomenon. We also find that the choice of scenario as well as our regional, sectoral and technological choices can greatly affect asset and sector valuation. Lastly, incorporating and assessing the credibility of companies' transition plans into the model can significantly modify their valuation. We believe that our probabilistic bespoke climate scenario approach provides unique insights for capital allocation by constructing a realistic assessment of scenario pathways. Different users can make different choices depending on their beliefs and objectives, they can dynamically update their assumptions with new information.

JEL classification: CE54, C68, D78, F55, G17, G18, H23, L70, L90, Q20, Q30, Q40, Q50

Keywords: Climate Change, Energy Transition, Climate Scenario Analysis, Credibility Assessments, Asset Valuation

[1] Chief Economist and Head of abrdn Research Institute, abrdn Research Institute, 6 St Andrew Square, Edinburgh, EH2 2BD. E-mail: jeremy.lawson@abrdn.com
[2] Senior Sustainability Analyst, abrdn Research Institute, 6 St Andrew Square, Edinburgh, EH2 2BD. E-mail: anna.moss@abrdn.com
[3] Macro ESG Researcher, abrdn Research Institute, 6 St Andrew Square, Edinburgh, EH2 2BD. E-mail: alexandre.popa@abrdn.com
[4] Head of Sustainability Insights & Climate Strategy abrdn, 6 St Andrew Square, Edinburgh, EH2 2BD. E-mail: eva.cairns@abrdn.com
[5] Head of SAA Research abrdn, 6 St Andrew Square, Edinburgh, EH2 2BD. E-mail: craig.mackenzie@abrdn.com

1 Background and literature review

The Task Force for Financial Disclosures (TCFD) describes scenario analysis as "…a process for identifying and assessing the potential implications of a range of plausible future states under conditions of uncertainty" (TCFD, 2017, p. 25). The effects of climate change occur over long time horizons, with high degrees of uncertainty regarding the associated policy, technology, energy usage, economic and physical impact pathways. Standard risk assessment methods don't fully capture these high uncertainties, as they often rely on an unchanged structure of the economy and financial system, have a narrow approach and focus on backward trends. Climate scenario analysis can help overcome those challenges by considering a wide range of future pathways, helping decision-makers understand how climate risks could evolve.

Methodology and design

Whilst the design of climate scenario analysis exercises share common features, there is considerable flexibility in the approach that can be taken. Some of the main design choices involve: the scenarios to include (e.g. the degree, and timing, of policy action); climate risks considered (transition, physical, or both); granularity (low granularity to explore the impact on the macroeconomy, high granularity to assess the impact on individual firms and securities); and time horizon. The choice of underlying Integrated Assessment Models (IAMs) may also differ. IAMs model the interaction between different "modules" such as economics, energy systems, land use and emissions. They return transition pathways (e.g. temperature evolution, carbon price) that are used for climate scenarios.

As a result, whilst climate scenarios share common features such as interactions with IAMs and the use of hypothetical future trajectories to understand climate risk implications, the high degree of flexibility means that climate scenarios can be used in a variety of applications to explore the effects of multiple plausible futures.

Major use cases

On the public side, climate scenarios are increasingly being used to measure potential risks and capital adequacy of financial institutions (micro-prudential policy), or assess financial system-wide climate risks, including the size and distribution of shocks, and the transmission channels (macroprudential policy) (NGFS, 2020). Climate scenarios have been incorporated into stress testing exercises to understand how regulated financial institutions and the financial system might be affected under different climate pathways. This helps policy makers supervise the financial system's resilience to potential climate shocks through micro (individual capital requirements) and macro (sectoral systemic risk buffer) measures. For central banks, climate scenarios are relevant for macroeconomic forecasts (e.g. long-term growth, inflation, employment) and for analysing structural changes under multiple climate pathways.

On the private side, financial institutions and non-financial corporations increasingly employ scenario analysis to assess the resilience of their business and investment strategies to a range of plausible future pathways and adapt accordingly. Climate scenarios particularly help financial institutions to analyse the performance of their investments under different pathways, build portfolios that are resilient to the different dimensions of climate change, and engage with companies to better manage their vulnerabilities to climate-related risks. Financial institutions also increasingly need scenario-analysis to meet regulatory requirements. In the UK, the Prudential Regulation Authority published a supervisory statement in 2019 making the requirement for climate-scenario analysis mandatory for banks and insurers, we expect regulators in other regions with high climate ambitions to follow.

Major scenario initiatives

The climate scenarios that have been developed by the Intergovernmental Panel on Climate Change (IPCC), the International Energy Agency (IEA), and the Network of Central Banks and Supervisors for Greening the Financial System (NGFS), are currently the most often utilised "off-the-shelf" or reference scenarios, though other 'families' of scenarios are also available.

The IPCC provides Representative Concentration Pathways (RCPs) that describe future greenhouse gas concentrations and the resulting amount of warming that could occur, as well as Shared Socioeconomic Pathways (SSPs) that explore hypothetical socioeconomic trends. IAMs use SPPs as inputs to model transition pathways (IPCC, 2021). The IEA has built three scenarios that rely on the Global Energy and Climate Model. The annual World Energy Outlook applies those scenarios to analyse future energy trends and their implications on energy security, environmental protection, and economic development (IEA, 2021). The NGFS scenarios have been developed to provide a common starting point for analysing climate risks to the economy and financial system (NGFS, 2022), enabling the comparison of results across institutions and jurisdictions. They serve as a reference for many central banks and supervisors and financial institutions. The NGFS has designed 6 scenarios. associated with different levels and aspects of transition and physical risks. The scenarios are produced via 3 IAMs (GCAM, MESSAGEix-GLOBIOM and REMIND-MAgPIE) to consider a wider range of policy and technological assumptions, generating 18 transition pathways. The NGFS applies Global Macroeconomic Models to assess macro-financial impacts. Table 1 provides an overview of the main existing climate scenarios.

Table 1: overview of the main climate scenarios

Provider	**Scenario**	**Temperature increase by 2100***	**Description**
IPCC	SSP1-1.9	1.4 °C	Global CO2 emissions are cut to net zero around 2050. Societies switch to more sustainable practices.
	SSP1-2.6	1.8 °C	Global CO2 emissions are cut severely, but not as fast, reaching net-zero after 2050. Societies switch to more sustainable practices.
	SSP2-4.5	2.7°C	CO2 emissions hover around current levels before starting to fall mid-century, but do not reach net-zero by 2100. Socioeconomic factors follow their historic trends, progress towards sustainability is slow.
	SSP3-7.0	3.6°C	Emissions and temperatures rise steadily and CO2 emissions roughly double from current levels by 2100. Countries become more competitive with one another.
	SSP5-8.5	4.4°C	Current CO2 emissions levels roughly double by 2050. The global economy grows quickly and is fuelled by exploiting fossil fuels and energy-intensive lifestyles.
IEA	Net Zero Emissions by 2050	1.5°C	It sets a narrow but achievable pathway for the global energy sector to achieve net zero CO2 emissions by 2050. It doesn't rely on emissions reductions from outside the energy sector to achieve its goals.
	Announced Pledges	1.7°C	It assumes that all climate commitments made by governments around the world, including Nationally Determined Contributions (NDCs) and longer-term net zero targets, will be met in full and on time.
	Stated Policies	2.5°C	It reflects current policy settings based on a sector-by-sector and country-by-country assessment of the specific policies that are in place, as well as those that have been announced by governments around the world.

NGFS	Net Zero 2050	1.4°C	Orderly scenario. It limits global warming to 1.5 °C through stringent climate policies and innovation. Climate policies are introduced immediately. Physical risks are relatively low but transition risks are high.
	Divergent Net Zero	1.4°C	Disorderly scenario. Net-zero reached by 2050 with higher costs due to divergent policies introduced across sectors and a quicker phase out of fossil fuels. Climate policies are more stringent in the transportation and buildings sectors, decarbonisation of energy supply and industry is less stringent. Higher transition risks than in Net Zero 2050, physical risks are relatively low.
	Below 2°C	1.6°C	Orderly scenario. Climate policies are introduced immediately and become gradually more stringent though not as high as in Net Zero 2050. Net-zero CO_2 emissions are achieved after 2070. Physical and transition risks are relatively low.
	Delayed Transition	1.6°C	Disorderly scenario. Global annual emissions do not decrease until 2030. Strong policies are then needed to limit warming to below 2 °C. The level of action differs across countries and regions based on currently implemented policies. This leads to both higher transition and physical risks than the Net Zero 2050 and Below 2 °C scenarios.
	Nationally Determined Contributions (NDCs)	2.6°C	Hot house world scenario. NDCs includes all pledged policies even if not yet implemented. It assumes that the moderate and heterogeneous climate ambition reflected in the conditional NDCs at the beginning of 2021 continues over the 21st century. Moderate to severe physical risks. Transition risks are relatively low.
	Current Policies	>3°C	Hot house world scenario. Only currently implemented policies are preserved, leading to high physical risks. Emissions grow until 2080 leading to severe physical risks.

*estimates, temperature increases are compared to pre-industrial levels.

A number of major initiatives have been undertaken by central banks and supervisors.

- De Nederlandsche Bank analysed the potential financial stability impact of a disruptive energy transition for the financial sector via a stress test. The exercise used detailed data on the debt and equity holdings of Dutch banks, insurers and pension funds, and analysed four severe but plausible energy transition scenarios revolving around government policy and technological developments. The findings suggest that a disruptive energy transition could imply sizeable but manageable losses for financial institutions, and that taking energy transition risks into account can mitigate the risks for their portfolios (Vermeulen, et al., 2018).
- The Banque de France and the ACPR developed an analytical framework to quantify the impacts on economic and financial variables necessary for financial risk assessment. The modelling infrastructure builds on a suite of models, including a multi-country macroeconomic model, a sectoral model, various financial market modules and an infra-sectoral risk assessment framework. Allen, et al., (2020) provides an application of the framework to two disorderly transition narratives with a focus on transition risks. It shows substantial impacts on the sectors exposed to the transition policies, and that sectoral heterogeneity is also found at infra-sectoral levels. The results highlight that financial stability risks are potentially more pronounced than macroeconomic and financial market expectations imply.
- The Bank of England (BoE) Climate Biennial Exploratory Scenario (CBES) exercise explores the financial risks posed by climate change for the largest UK banks and insurers. Participants made granular assessments of their largest counterparties

with an emphasis on evaluating the net-zero transition plans of their corporate counterparties. The BoE designed three climate scenarios (early action, late action, and no additional action) based on the work of the NGFS.

- Other major initiatives include the ECB climate stress test (Alogoskoufis, et al., 2021), the EU-wide pilot climate exercise from the European Banking Authority (European Banking Authority;, 2021), and Bank of Canada climate analysis (Ens & Johnston, 2020).

Projections made by banks and insurers suggest overall costs will be lowest with early, well-managed action to reduce greenhouse gas emissions and so limit climate change (Bank of England, 2021).

On the private side, the United Nations Environment Programme Finance Initiative (UNEP FI) collaborates with actors from the banking industry to implement the recommendations of the TCFD in order to better manage and disclose climate risks. The programme includes "modules" where participants explore climate risk topics, including climate scenario analysis. The Changing Course Guide (UNEP FI, 2019) provides an overview of approaches and tools available to investors. It details the methodologies piloted by 20 investors and summarises key findings.

Under a 1.5°C scenario, transition risks could significantly affect the overall portfolio value, with risks more apparent at the sector level. Investors would face more pronounced risks if governments act late. The Pathway to Paris project (UNEP FI; CICERO, 2021) guides financial practitioners to understand and apply climate scenarios, including the assumptions, benefits, and limitations. Some of the limitations come from the fact that IAMs were designed to inform climate policy making, often with a global focus in mind, rather than financial risk analysis. The guide provides areas of improvement for the use of climate scenarios in financial risk analysis.

The Economic Impacts of Climate Change report (UNEP FI; NIESR, 2022) explores 3 short term scenarios ((i) sudden rise in carbon price, (ii) spike in oil price and, (iii) trade war) to provide insights of more immediate risks. Each of these scenarios entails decreased GDP growth, higher inflation rates, and greater volatility in other macroeconomic indicators that demonstrate the potential for climate-related events to cause economic and thereby financial market disruption. The publications also include case studies from financial institutions. In the UK, the Climate Financial Risk Forum (CFRF) is an industry forum jointly convened by the PRA and FCA to build capacity and share best practice. Its scenario analysis guide aims to promote understanding, consistency, and comparability by providing guidance on how to use scenario analysis to assess financial impacts and inform strategy and business decisions (CFRF, 2021).

Limitations of climate scenario initiatives

While the number of initiatives is quickly expanding, we observe some limitations that restrain the use of climate scenarios for financial and investment decision making.

First, off-the-shelf scenarios present some restrictions in their design. The NGFS scenarios mainly focus on what we would describe as tail risks: on the one side the orderly and disorderly NGFS scenarios return global warming below 1.6°C compared to pre-industrial levels, on the other side NDCs and current policy scenarios result in increases above 2.6°C and 3.0°C respectively. None of the scenarios assesses the "intermediate" and arguably most likely outcome of strengthened but insufficient policy actions to meet the Paris objectives, leading to global warming between 2°C and 2.5°C. The Announced Pledges and Stated Policies IEA scenarios cover intermediate outcomes but they rely on a unique model, which makes it difficult to assess how different technological pathways would alter the results.

Critically, this class of reference scenarios is limited by the typical, unrealistic assumption of policy uniformity across sectors and regions. Off-the-shelf scenarios are usually 'closed' by a de facto global carbon price applied to all sectors and regions. But the real world is characterised by hundreds of different regulated, voluntary, and shadow carbon prices that depend on the political economy of climate and energy policymaking in different countries, as well as the varying degrees of technology readiness of the energy transition in different sectors. This heterogeneity is likely to remain a feature of the policy environment over the coming decades, dominates the market pricing of climate risks and must be taken into account to more accurately estimate financial exposures.

Second, most climate scenario exercises include a baseline scenario that is not predicated on what is priced into assets. The baseline scenario is used to compare the output of alternative scenarios and is a key element to assess the implications of hypothetical future pathways. In most cases the baseline is either aligned to net-zero scenarios (Alogoskoufis, et al., 2021) (Allen, et al., 2020), or to a scenario with a continuation of current policies (Ens & Johnston, 2020) (Vermeulen, et al., 2018) (UNEP FI, 2019). However, those scenarios don't reflect what is valued by the financial industry, as capital flows are neither aligned with a net-zero world nor with a world without any additional policy action.

Third, climate scenario exercises don't adequately think about the outlook probabilistically. As a result, scenarios with low relative likelihoods are implicitly given equal weight in analysis to more realistic scenarios, while also leaving investors without a mean, expected outcome to consider. Finally, it is rare for scenario exercises to incorporate the credible, dynamic transition plans of individual firms, leading to either under or over-estimation of long-term climate-related exposures.

These limitations are especially relevant for the financial industry that attaches more importance to the most plausible pathways. A key aim of the industry is to evaluate the future value of investment portfolios to make appropriate investment decisions consistent with fiduciary duties. The standard approach, that relies on assumptions about the energy transition across geographies and sectors that is unlikely to materialise, can lead to biased estimates of financial exposures, misallocations of capital, and poor investment performance.

2 Bespoke climate-scenario methodology

2.1. Approach and rationale for building bespoke scenarios and assigning probabilities

Our approach to climate-scenario analysis is motivated by the view that a rigorous and transparent methodology is essential for making sound investment decisions. We found our approach to construct bespoke scenarios on three core beliefs:

(i) The political economy and economics of climate change mitigation will continue to vary across geographies and sectors.

(ii) Climate-related policy and low-carbon technology pathways are difficult to forecast over long horizons. Accordingly, there are a wide variety of plausible ways in which energy-usage patterns might evolve.

(iii) Given the two prior statements, **any approach that assumes uniformity of policy across geographies and sectors, or is based on a single fixed view of future technological change, will generate misleading results.**

Our bespoke architecture relaxes the restricted assumptions of the off-the-shelf scenarios, and allows us to consider differentiated views across regions, sectors and technological developments to generate more plausible scenarios that help better inform the assessment of climate risks and opportunities. The bespoke method facilitates the construction of scenarios whose outcome lies between the "net-zero" and "no action" tail events, and a baseline scenario based on what we believe is priced in to the market.

Bespoke scenarios are more flexible. Unlike off-the-shelf scenarios, we can estimate investment implications from altering a specific regional or sectoral policy while maintaining the other blocks unchanged. Therefore, bespoke scenarios can more easily adapt to political, policy, economic and technological developments. We can also assess the "What if?" investment implications in the case of hypothetical developments.

We complement the bespoke methodology with a probabilistic approach. It enables us to take into account the likelihood of different pathways when analysing the financial implications. We also generate probability-weighted summaries that underpin the estimates for financial-security impairments and consider the distribution of risks around that mean. Finally, we can easily adjust the probabilities as the underlying political, policy and technology drivers of the different scenarios change.

We detail in the rest of the section the modelling of our scenario analysis as well as our decisions behind the design of our bespoke scenarios and assigned probabilities**. The main innovation is contained in the probabilistic bespoke scenario approach rather than in the choices that we have made.** Other users can apply our methodology while making different decisions about how to allocate probabilities and rank the sectors and regions in terms of likelihood of transitioning rapidly, it would return unique but enhanced insights compared to the traditional approach.

2.2. Modelling asset pricing and financial exposure

We have collaborated with our modelling partner Planetrics[6] to develop our bespoke climate-scenario approach. Our scenario analysis is built around a four-step framework (Figure 1):

(i) Identify and design the bespoke climate scenarios relevant for assessing the different dimensions of climate risks and opportunities.

(ii) Translate these scenarios into a series of economic shocks within an energy systems model. These shocks incorporate direct impacts like carbon taxes or physical damages to infrastructure, and indirect impacts such as changes to commodity prices and the evolution of demand for different types of energy.

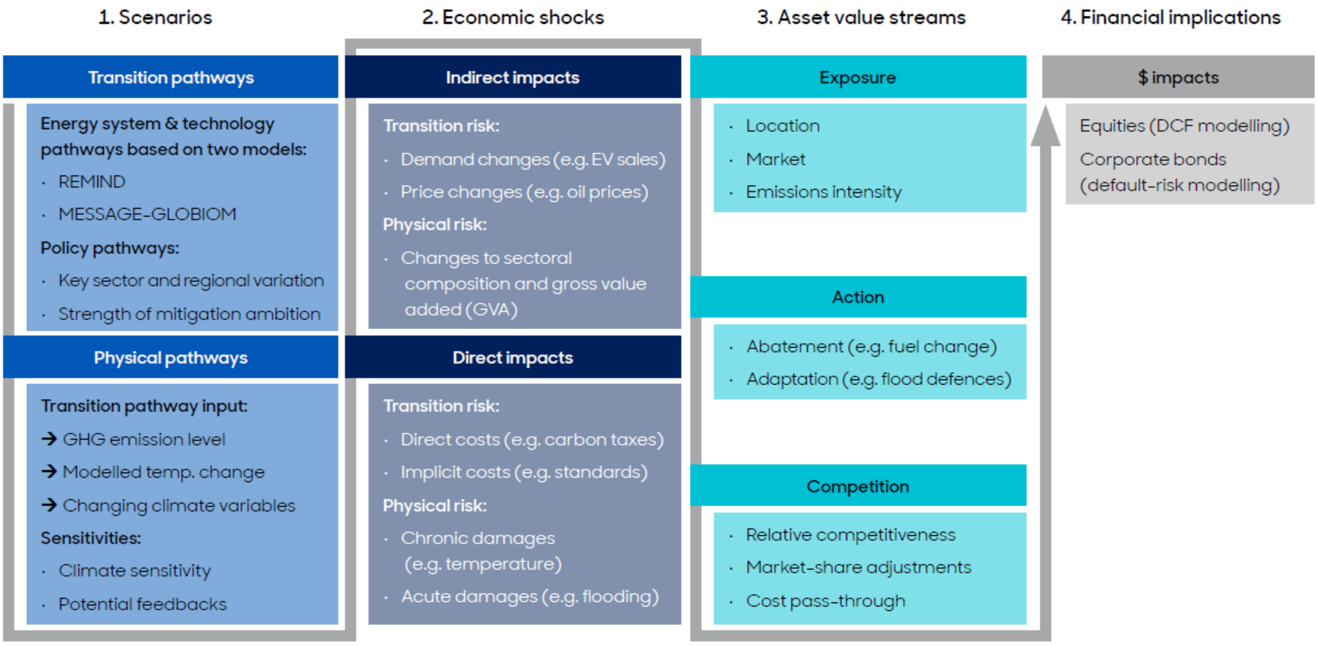
(iii) Estimate the effect of these shocks on asset value streams, taking into account the nature of assets' exposure to different types of shock, capacity to adapt or mitigate, and the nature of competition within an industry.

(iv) Convert these asset-value-stream projections into 'fair value' impairment estimates, based on standard capital-asset-pricing frameworks. All changes in earnings and value are calculated as deviations from our baseline scenario representing what the market is pricing in.

We can illustrate the framework by considering a simplistic scenario limiting climate change to 1.5°C by 2050, and a baseline where the market prices in a scaling up of policies but insufficient to limit temperature increases to 1.5°C. In this scenario, countries take broad-based, rapid and stringent policy and regulatory steps to curtail emissions. The model assumes that countries implement least-cost abatement measures, implying the introduction of high carbon prices across all sectors and geographies. These, the changes in patterns of demand, and the prices of inputs and outputs, are the key economic shocks (step 2 in our framework). In this scenario, fossil fuel intensive companies underperform relative to the baseline, they are subject to larger direct and indirect cost shocks and cannot fully pass them to end-users because they compete for market share with cleaner firms. Conversely, renewable energy companies benefit from rising final prices for end-users without having to absorb any additional costs, and their market share rises over time. Fossil fuel firms would need to mitigate the impact of direct carbon pricing by investing in capital projects such as carbon capture and storage (CCS) technology or increase the renewable share of their portfolio to reduce direct carbon costs through abatement (step 3). Under this scenario, the future expected earnings of a fossil fuel firm are much lower than for a renewable competitor with a high risk of stranded assets. This justifies a lower valuation relative to the baseline we assume is priced into assets (step 4).

[6] Findings within this paper have been created by abrdn drawing on selected data provided by Planetrics Ltd (which does not include investment advice). Any data within this paper represents abrdn's own selection of applicable scenarios selection and/or and its own portfolio data. abrdn is solely responsible for all assumptions underlying these scenarios, and all resulting findings, and conclusions and decisions. Planetrics Ltd. is not an investment adviser and has not provided any investment advice.

Figure 1: The building blocks of climate-scenario analysis



Source: based on Planetrics framework, January 2021.

The outcome is reversed under a scenario in which current climate policies are maintained, leading to warming in excess of 3°C by the end of the century. No action is taken to limit emissions and carbon prices remain low. As a result, fossil fuel companies do not face a cost shock or policy incentives to decarbonise their business. Future expected earnings are stronger than in the baseline, justifying a higher valuation than under the previous example. By contrast, the fair value of the renewable businesses declines, because their market value was predicated on policy actions scaling up over time. However, as warming is significant in this scenario, both chronic and acute physical climate impacts could weaken the productive capacity of both firms dependent on the location and vulnerability of their assets.

We put emphasis on the identification and design of the bespoke climate-scenarios (step 1) that distinguishes our approach from other climate scenario exercises. The first step plays a critical role in estimating fair value impairments.

Estimating the effect of climate-scenarios on securities

The climate scenario framework uses two key components that simplify the exercise:

(i) We estimate the impact of a given scenario relative to the baseline scenario. This might, for example, produce an estimate of earnings growth for a fossil fuel firm that is half as much under a scenario leading to a 1.5°C warming than under the baseline that considers limited policy action.

(ii) We assume that the growth rate for earnings in the baseline is accurately reflected in current market prices.

Applying the second assumption, we estimate the earnings growth associated with the baseline scenario for each company rather than forecasting numerous company specific long-term earnings. We reorganise the standard discounted cash-flow equation

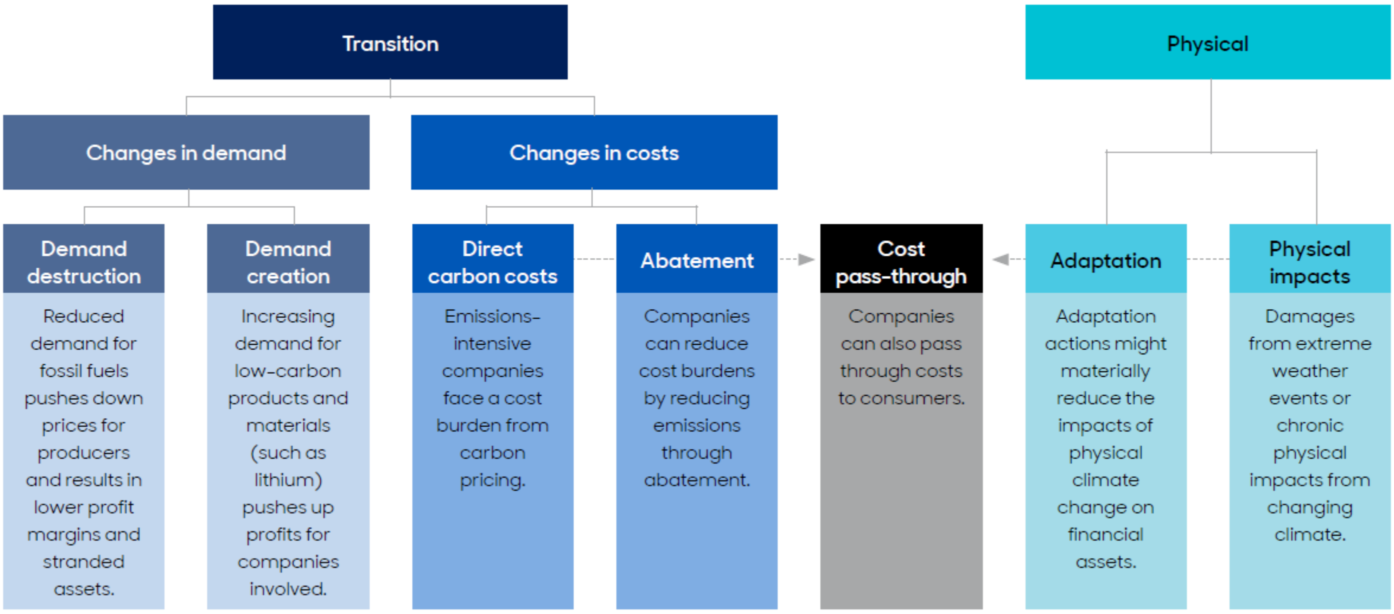
$P = D/(r - g)$ to $g = r - (\frac{D}{P})$.

The share price (P) is the market price at the point the baseline scenario is defined. The discount rate (r) is sourced from consensus estimates of sector discount rates; and the dividend level (D) is generated from sector earnings data and plausible assumptions about pay-out ratios. Therefore, we can evaluate the earnings growth rate for any company in any scenario.

Expanding the previous example, if the fossil fuel company has a current growth rate of 6%, the stringent policy scenario would return a 3% growth rate. With this technique, we can estimate the fair-value price in any scenario by arranging the equation. This approach is used for equities and equity-like assets. For corporate bonds, changes in equity valuations are translated into changes in bond-default risk using standard techniques. In addition, standard bond valuation techniques are then used to translate changes in default probabilities into change in bond valuation.

Figure 2 summarises the multiple factors which impact asset value streams. In addition to the overall impact on asset value we are able to drill down to these seven distinct impact channels, allowing us to interpret the factors that underpin the asset-level change.

Figure 2: The seven impact channels of climate-scenario analysis



Source: Planetrics, October 2022

2.3. Bespoke scenario building blocks

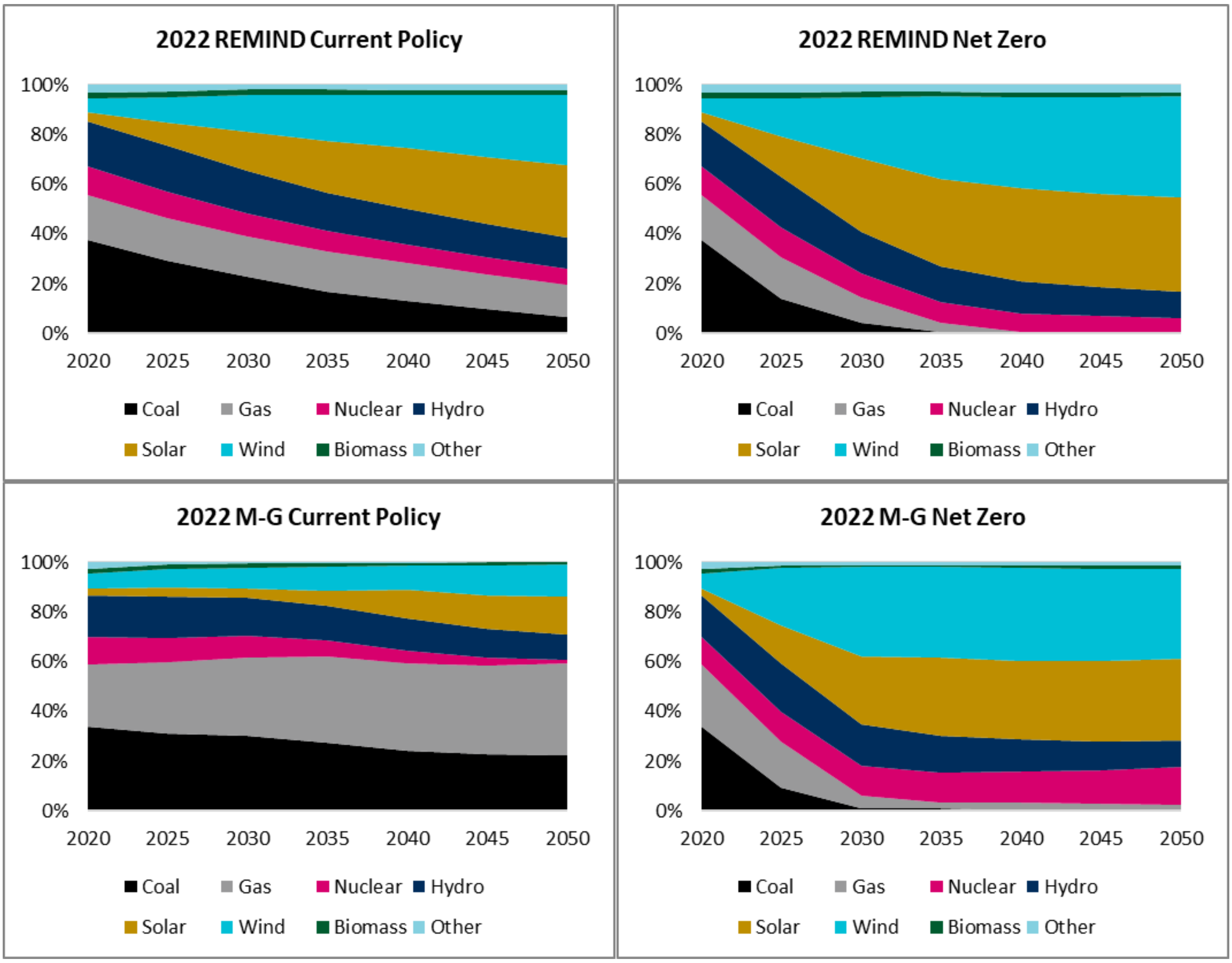
Energy-systems models and technology pathways

Modelling climate risk requires the use of integrated assessment models (IAMs) that embed different assumptions about energy systems in different countries and sectors, as well as technology pathways. We selected the REMIND-MAgPIE (REMIND) and MESSAGEix-GLOBIOM (M-G) models as the foundations for our analysis. We chose different models to take into account how technological uncertainties would affect our results. These models were most consistent with the observed take-up of different energy technologies over the past decade, as well as with our views of the most likely evolution of low-carbon technologies in the future.

The REMIND model projects the relative price of renewables to decline rapidly, it permits the comparatively cheap decarbonisation of the global power sector without any significant negative effects on energy demand. The rapid decarbonisation reduces the need for natural gas to act as a transition fuel. We chose a second model to shape an alternative energy evolution pathway. The M-G model is more pessimistic about the future relative share of renewables. Figure 3 illustrates how gas plays a larger role in scenarios with the continuation of current policies, with nuclear taking a more prominent role in the net-zero pathway compared to the REMIND model. An important caveat is that none of the models available to us were able to fully capture technologies like hydrogen energy that have not already been deployed at scale.

While the M-G model considers a larger share for gas than in the REMIND model in most scenarios, natural gas can only play a limited role in scenarios with a rapid transition. Figure 3 illustrates the evolution of energy-technology shares in the power sector between now and 2050 in the current policy and net-zero scenarios for both models. Despite the role of gas in the M-G model, the non-fossil share is above 90% by 2030 in the rapid action scenarios.

Figure 3: Power generation mix for the REMIND and M-G models in the current policy and net-zero scenarios.



Source: Planetrics/NGFS (2022)

Applying both the REMIND and M-G models to the same policy pathways within our scenarios also allows us to isolate the extent to which the estimated impairment on a given security is driven by the technology-pathway assumptions.

Policy pathways

We wanted a policy-set choice wide enough to allow for plausible and consequential differences, but also small enough for the analysis to remain tractable. We decided on the following three parameter categories: Objectives, sectors, regions.

Sectors: Policy is allowed to vary across the four main market-relevant energy-use and carbon-emitting sectors: power, transportation, industry, and buildings.

Regions: Policy is allowed to vary across five countries or regions – the US, the EU (including the UK), the other developed economies as a group, China, and the other emerging economies as a group.

<u>Objectives</u>: Policy in each sector and region can vary across the six different mitigation objectives defined by the NGFS – Net Zero 2050, Below 2 °C, Divergent Net Zero, Delayed Transition, NDCs, Current Policies – as well as hybrids of 'neighbouring' reference scenarios; i.e. Delayed Transition/NDC.

<u>Framework to assess policy pathways</u>

We use a framework to evaluate the geographies and regions that are more likely to follow faster decarbonisation pathways. The framework helps us to design and update bespoke scenarios, as well as to attribute probabilities to the different scenarios.

We look at the political backdrop and policy action in order to assess policy pathways. Political backdrop is important as political dynamics shape environmental policy, whereas policy action evaluates the concrete policy agenda.

Table 2 details the policy indicators and the elements considered to evaluate political backdrop and policy action.

Table 2: Framework to assess policy pathways

<table>
<tr><td rowspan="4">Political backdrop</td><td>Party politics and ideology</td><td>Are political parties divided on climate change?
Does voter polling and action signal concern regarding climate change?
Political commitments are more credible under closely aligned political parties and strong voter interest regarding climate change, a change in government can reverse climate commitments.</td></tr>
<tr><td>Institutional stability and transparency</td><td>How stable and transparent are the judicial, legislative and executive institutions in the country?
Stable and transparent institutions provide greater visibility of the political agenda</td></tr>
<tr><td>Policy coordination and distribution</td><td>Where do environmental policy powers reside across local, state and federal authorities?
Are these authorities coordinated in climate action?
In federal systems, for example, the powers to determine and influence climate and energy policy are usually shared between central, state (provincial or regional), and local government authorities. This raises coordination challenges, particularly when climate mitigation is contested politically</td></tr>
<tr><td>Private actors in political space</td><td>What sector/business lobbying, if any, is affecting policy choices in this space?
Corporate lobbying pressure can alter the political agenda</td></tr>
<tr><td rowspan="3">Policy action</td><td>Carbon pricing</td><td>Does the government formally price carbon?
Carbon taxes or an emission trading system (ETS) signal substantive support for the energy transition. Carbon pricing regimes have the advantage of being a market mechanism that helps ensure climate change mitigation and greenhouse gas abatement occur at the lowest possible cost to the economy. We pay attention to the implied level of the price and how widely the price is applied. A narrow ETS affecting only one industry or sub-industry with generous allowances may struggle to move the dial on climate change</td></tr>
<tr><td>Binding commitments</td><td>Are environmental goals legally binding or aspirational?
Is regulation in place and is it stringently applied and monitored? Are there regulatory quotas on emissions for particular sectors?
Such commitments signal climate policy is considered a long-term issue rather than a short-term political strategy</td></tr>
<tr><td>Smart climate policy</td><td>Is climate policy integrated with other policy areas?
Does climate policy tackle major sector challenges and physical risks?</td></tr>
</table>

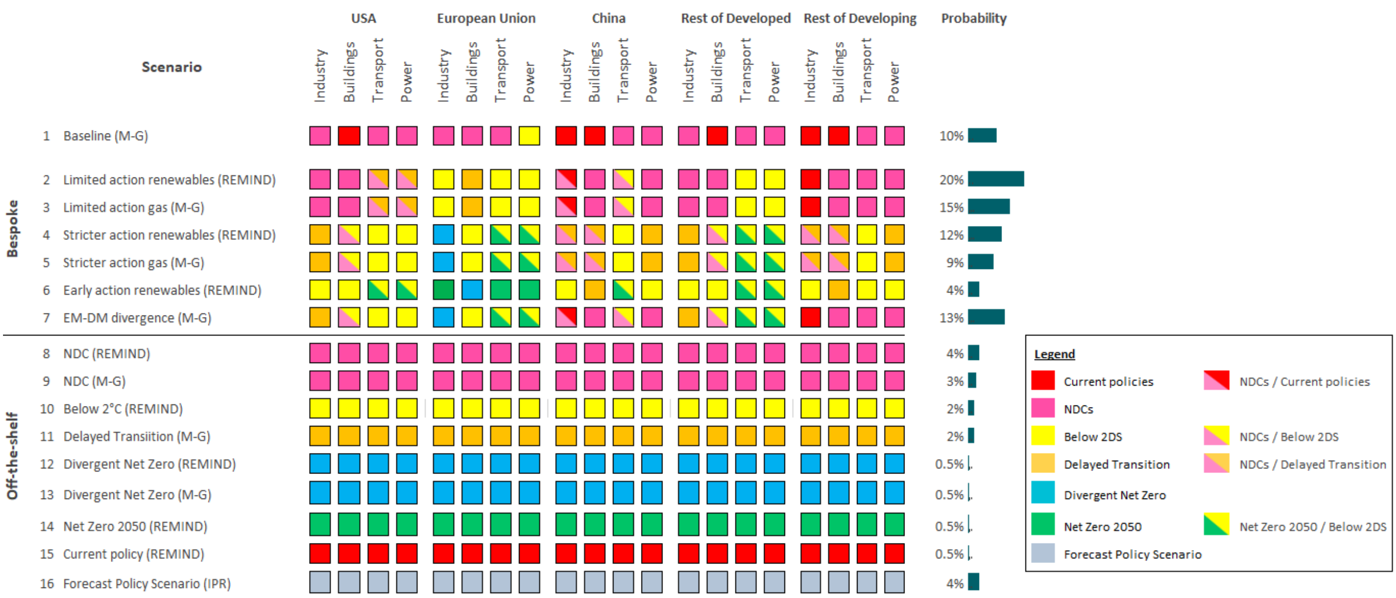
		• Does government consult or collaborate with business on climate issues? This addresses the importance of embedding environmental policy into policy decisions, targeting the sectors contributing most to CO_2 emissions and intensity, and engaging with business to design policy solutions that smooth the transition path.
	Incentives	• What incentives exist to encourage lower CO_2 emissions for firms? Incentives, such as tax credits, subsidies or tax breaks for R&D, feed-in tariffs, and investment in cleaner energy production and use all encourage good behaviours

2.4. Rationale for our scenario choices

We produce 18 scenarios in total. This includes 9 off-the-shelf scenarios based mostly on the NGFS scenario suite in addition to 7 bespoke scenarios and two probability-weighted scenarios- our 'mean' scenario based on the probabilities we assign to each of the individual scenarios, and a 'Paris-aligned' probability-weighted scenario based on the probabilities of the 8 scenarios consistent with keeping warming below 2°C.

Figure 4 displays the matrix of policy variation that we applied to produce the scenarios. The rows indicate our range of scenarios, the columns specify the sectors and geographies. The colour of the boxes represents the level of policy ambition utilising the scenario language of the NGFS scenarios. Some scenarios have identical narratives but diverge through their energy-system models. The table also illustrates the separate approach between off-the-shelf and bespoke scenarios. Off-the-shelf scenarios have identically coloured boxes because they usually do not allow for policy variation across geographies and sectors.

Figure 4: Policy variation across sectors and regions in our scenarios and assigned probabilities



Source: abrdn, Planetrics, October 2022

<u>Baseline scenario</u>

We first design the baseline scenario, with all security impairment estimates being expressed relative to that baseline. We use inputs from abrdn's investment and research teams to estimate what is priced in the market. For our latest analysis, September 2022 valuations were the starting point.

Our analysis suggests that financial markets place relatively little weight on climate-policy changes due to occur beyond a 10-year horizon except under two conditions:

(i) policy changes are already clearly and credibly signalled or;

(ii) technology take-up and pricing trends are already pointing very strongly in a particular direction.

We concluded that markets were mostly pricing in only a moderate scaling up of existing policies in most sectors and regions.

Looking at the sectors, we determined that slower decarbonisation would occur for the industrial and buildings sectors, where there is less existing policy limiting emissions and mitigation costs are currently highest due to less mature low and zero carbon technology options. We therefore determined that the market was pricing in the maintenance of current policies in the buildings sector, with the exception of Europe where greater ambition was being factored in to reflect committed policy pledges and concrete legislation (NDCs). For the industrial sector the baseline reflects the maintenance of current policies in developing markets and China, and NDCs for developed markets.

In contrast, we factor in the greatest policy change for the power sector in all regions. This sector has presented the greatest reduction in carbon intensity over the past decade. It is backed by ETS and carbon taxes in some countries that would be scaled up over time by legislation, as well as by established zero and low-carbon substitution solutions. We assume that the market prices in the largest amount of abatement in the European power sector, given the scope and legislative credibility of its ETS, and the additional carbon taxes in place in many countries. Hence the baseline considers the market is pricing in Paris-aligned policy for Europe, and the implementation of NDCs elsewhere.

We place the transportation outlook closer to the power than industrial and buildings sectors. It benefits from a tightening regulation and falling relative production costs for electrical alternatives, albeit the barriers to decarbonisation are generally higher than in the power sector. Our belief is that all the regions are pricing in agreement with NDC policies.

We select the gas-leaning M-G model as our baseline energy-system. The relative pricing of utilities companies with a heavy tilt towards renewables was not compatible with the optimistic solar projections of the REMIND model at the starting point of our exercise. We can, however, change the model baseline in the future as market expectations evolve.

Bespoke scenario narratives and choices

Developing bespoke scenarios allows the creation of pathways that we consider to be more plausible than those presented by 'off the shelf' scenarios. Our bespoke scenarios are able to provide similar global pathways to the NGFS scenarios, but are built upon underlying, more realistic variability across geographies and sectors.

In addition to the baseline, the bespoke scenario narratives are:

- Limited action. Scenario with limited policy action, resulting in temperature increase above 2.5°C by 2100.
- Stricter action. Stricter but delayed policy action that mainly occurs after 2030. This scenario implies a disruptive transition and weak Paris alignment, with an increase of 1.9°C.
- Early action. Ambitious and immediate policy action, resulting in a less disruptive transition and an increase of 1.7°C.
- EM-DM divergence. Large split between developed economies that pursue ambitious policies, and emerging economies. Temperature change of 2.5°C.

Similar to the baseline scenario, most bespoke scenarios are predicated on the view of stronger policy and actions in Europe than in most other developed markets, with the US generally lagging behind the smaller non-European economies as well. We also assume that most emerging economies – including China – will lag behind the developed world, though we also expect China to decarbonise faster than emerging economies (ex-China) as a whole. This is because political economy considerations favour near-term growth goals over long-term environmental considerations in most developing countries, though there are important variations to be aware of. The exceptions are the early and stricter action bespoke scenarios. They cannot be achieved without very large emissions reductions also occurring in the emerging world, and thus a convergence of global policy across geographies and sectors.

We maintain the views underpinning the baseline scenario at the sector level. Policy action, low-carbon technological changes, and renewable energy penetration related to the power and transport sectors are likely to be stronger than those in the industrial sector, which in turn is likely to be stronger than those in the buildings sector.

Technology transfer across borders is more likely in the transportation sector than in the industrial and buildings sectors thanks to the greater supply-chain and market integration. Technological barriers to lowering industrial emissions are more diffuse, while the larger potential for carbon leakage represents a politico-economic barrier to stronger action in the industrial sector. The extended life cycle of buildings is a major barrier to progress without an extensive and expensive retrofitting regime in place.

2.5 Rationale for assigning probabilities to scenarios

We interpret the off-the-shelf scenarios as more implausible with regards to the existing geographic and sector policy variations. We therefore assign a low combined-probability weight of 17% to the off-the-shelf scenarios in our analysis (Figure 4). In an approach that we mimic in the bespoke assignment, scenarios implying either no change to climate policies from the status quo, or radical, rapid and broad-based change to the status quo, receive lower weights. We primarily use the off-the-shelf scenarios to benchmark our analysis against those most commonly modelled by regulators and other users of climate scenarios. We attribute a cumulative probability of 3% to the tail-risk scenarios commonly used by central banks – net-zero 2050, current policies and delayed net zero transition.

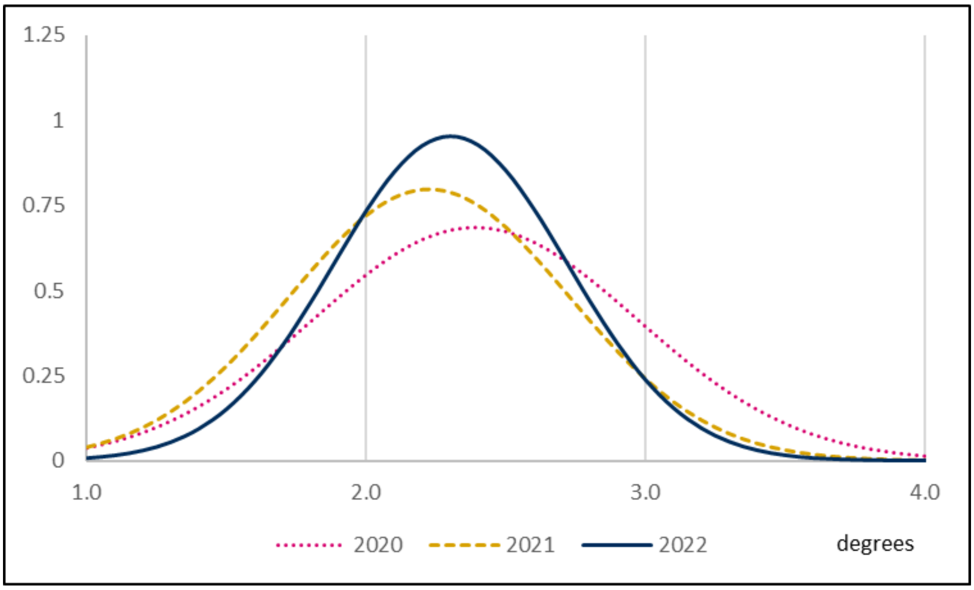
The baseline scenario is an approximation of what we think is currently priced into assets, but it is not our modal scenario. We consider that policy is more likely than not to become more ambitious with regards to what was priced into the market in September 2022. While the pace of the energy transition is only moderate for now, we suppose policy action and technological progress will speed decarbonisation in the medium term. Against the baseline's 10% probability, we therefore assign more weight to the limited-action REMIND model (20%), limited action M-G model (15%), stricter action REMIND model (12%) and emerging-market–developed-market (EM–DM) divergence (13%) scenarios. These scenarios imply a lower temperature change than in the baseline. Our choices also infer that the bulk of our probability lies above 2°C warming.

The world is likely not to meet the objectives set out in the Paris Climate agreement. We assign a 34.5% probability to emissions being reduced enough to limit global warming to below 2°C (a weakly Paris-aligned outcome), though only 3.5% to a 1.5°C outcome (strong Paris alignment). Indeed, net-zero 2050 objectives require unprecedented rapid and broad-based decarbonisation as the world would have used up its entire carbon budget for a 1.5°C world within a decade. Similarly, achieving the below 2°C target necessitates global emission reductions equivalent to around 3% per annum, which will be difficult without a significant global acceleration in the decarbonisation of the power sector, an electrification of all other sectors, significant changes to agricultural and forest management practices, and the coordinated policy action to match.

These scenarios appear difficult to reach given that absolute emissions from emerging countries are rising and that various countries present important gaps in their policy commitments. China has undertaken massive investments on renewables and 2060 net-zero target, but the country is also still investing in coal-fired power stations, and the national ETS that is central to curb emissions has a narrow coverage. In the US, climate change remains subject to partisan disagreement. Meeting the objectives of the Paris Agreement requires consistent efforts over very long time horizons, but periods of slowing change or even reversal are likely during periods in which Republicans hold the reins of power. Figure 5 represents the distribution of our probabilities with regards to the temperature change associated with the scenarios.

We don’t want our analysis to be dependent on any one model’s assumptions about technology given the uncertainties, the REMIND and M-G-model-based scenarios have roughly equal combined weights in our analysis. The probabilities are modestly tilted towards the more renewable-friendly REMIND model when the baseline model is excluded. That tilt relates to the observed technological changes over the past decade and our reading of the evidence related to future developments.

Figure 5: Temperature change probability distribution of our climate scenarios



Normal distribution. Source: abrdn, Planetrics, October 2022

Approach to updating scenarios and probabilities

The choice and design of the scenarios, and assignment of probabilities are made on the basis of our best current evidence-based judgement about the political economy of global climate policy, and feasible technological pathways. As with any scenario-analysis framework, however, **scenario design and probability assignments must be revisable against transparent criteria as new information comes to light**. We revise the scenario design and probabilities annually.

The waymarks for changes to our scenario construction and associated probability weights fall into four categories:

(i) Concrete, credible, durable, and significant climate-mitigation-related policy or regulatory changes at the sub-national, national and international level. Such as the scaling up of an ambitious ETS in a region whose emissions have a significant impact on the potential to meet global climate objectives.

(ii) Changes in political leadership and public attitudes that are likely to translate into the changes denoted in the first criterion. Such as the election of a government with a greater commitment to mitigating climate change, coupled to a credible policy agenda supporting implementation.

(iii) Sustained behavioural changes among consumers, corporations and investors that are likely to significantly alter climate relevant patterns of energy demand and supply. Such as a significant increase in the emissions weighted proportion of companies scaling up their individual emissions-reduction targets.

(iv) Revealed changes in aggregate, regional and sectoral investment decisions or low-carbon technological progress that alter the economics and timescales for abatement. Such as reduction in the installation of coal-fired power plants in emerging economies.

Only significant changes relative to what is factored into our scenario construction and existing probability assignment lead to revisions. We pay a close attention to the credibility of the commitments. For instance, increases in emission reduction or other climate related targets that are not accompanied by binding, credible supporting mechanisms. Similarly, when new governments with climate policies that differ significantly from the previous government are elected, the stability of those governments and the breadth of support for their climate ambitions will influence the extent of probability changes.

3 Results

We first present the implications of our bespoke and probabilistic climate scenarios on climate pathways (future of emissions, temperature projections, energy usage and carbon prices). Second, we analyse the impairment estimates at the index, sector, and firm level. We mainly look through equity securities, the asset class for which the estimated effects are greatest. In the next step we comment on the results drawn from considering different technological pathways. We then expand on how bespoke scenarios generate additional insights across regions. Finally, we comment on the main changes between our three years of analysis, and on how it has affected impairment estimates. We show in this section that the bespoke approach is able to generate more plausible insights than standard climate scenario approaches.

3.1. Future of emissions, temperatures, energy usage and carbon prices

Table 3 provides an overview of the projected outcomes for the baseline as well as the probability-weighted scenarios. The difference between the mean and baseline scenarios provides our estimate of the likely scale of the key elements of the energy transition that have not been priced in. The differential between the mean and Paris aligned scenarios highlights the remaining efforts needed to achieve the Paris targets.

Table 3: Projected energy demand, renewable energy share, and carbon price under different scenarios

Category	***Measure***	***Mean***	***Baseline***	***Paris-aligned mean***
Temperature change	*2100, compared to pre-industrial levels (current 3.2°C)*	*2.3°C*	*2.7°C*	*1.8°C*
Share of non-fossil power generation	*Share in 2050 (current 79%)*	*82%*	*59%*	*97%*
Coal demand	*Annual growth 2020-2050 (current 0.82%)*	*-2.65%*	*-1.95%*	*-5.85%*
Gas demand	*Annual growth 2020-2050 (current 0.77%)*	*0.52%*	*1.98%*	*-1.43%*
Oil demand	*Annual growth 2020-2050 (current -0.98%)*	*-0.97%*	*-0.08%*	*-2.03%*
Electricity demand	*Annual growth 2020-2050 (current 2.44%)*	*2.66%*	*2.38%*	*3%*
EV sales	*EV share of new vehicle sales in 2050 (current 73%)*	*86%*	*80%*	*96%*
Carbon price	*$/tCO2 in 2050*	*316$*	*49$*	*656$*

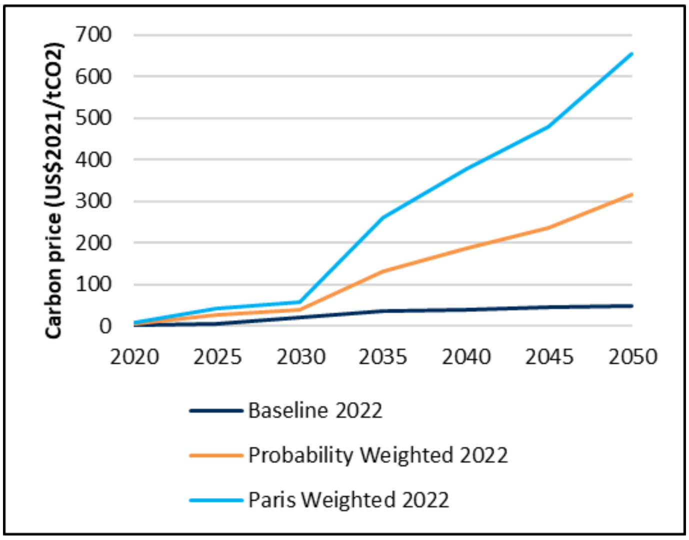
Source: abrdn, Planetrics, October 2022

We find that the market is pricing in an outcome with limited climate action, far from Paris alignment. The baseline projects a temperature increase of 2.7°C by 2100, which is more ambitious than our current policies scenario (3.2°C increase) but falls short of NDC policies (2.3-2.4°C increase). We also find that a stricter policy environment would likely manifest than that which is currently priced in the baseline. However, the policy scale up won't be sufficient to respect the Paris Agreement, with the mean scenario pointing to a warming of 2.3°C.

The global share of non-fossil fuel power generation increases to 82% by 2050 in the mean scenario. We observe that the power sector is likely to be the epicentre of a significant energy transition, even if global policy does not align behind the objectives of the Paris Agreement. We project coal usage to decline by 55% in our mean scenario from today's levels, versus 45% in the baseline, and to be almost removed in Paris-aligned pathways. Natural gas remains relatively stable in the mean scenario as it remains a transition fuel in moderate action scenarios, but natural gas usage falls by 35% in the Paris-aligned scenario. The energy-mix projections with the Paris-aligned scenario underscore how the energy transition would accelerate and its implications. Coal, oil, and auto companies producing conventional internal-combustion-engine (ICE) vehicles are penalised as global coal and gas demand declines and the share of electric vehicles sales rises close to 100% in 2050.

We observe a large differential in the global carbon price between our baseline and probability-weighted scenarios. We estimate a carbon price of $49 per ton of CO2 in the baseline[7], whereas our mean scenario implies a price above $300 with a strong increase after 2030 (Figure 6). Carbon price is an important component that influences investments in carbon intensive projects, the gap between the baseline and mean scenarios suggests that financial markets underestimate this metrics, with repercussions on investment decisions. Carbon prices rise above $2000 in the delayed transition scenario by 2050 as a disorderly transition involves larger efforts to decarbonise. There will of course be considerable regional and sectoral variation in future carbon pricing. In the appendix we illustrate how our bespoke scenarios generate more carbon price flexibility across regions and sectors compared to the off-the-shelf scenarios (Figure A1). We also indicate the projected global temperature rise, energy demand, renewable energy share, and carbon price under each scenario (Table A1).

Figure 6: Our mean scenario implies a higher carbon price than in the baseline



Source: abrdn, Planetrics, October 2022

The outcomes highlight the ways our bespoke probabilistic approach generates insights into the future of energy demand patterns that differ from what we could obtain from anchoring on a narrow set of policy and technology pathways.

3.2. Index level exposures

We present the results hierarchically, beginning with index-level effects, then sectors, sub-sectors and regions, before ending with security-level impairment estimates. Most of the analysis is focused on impacts on the fair value of equity securities in the MSCI

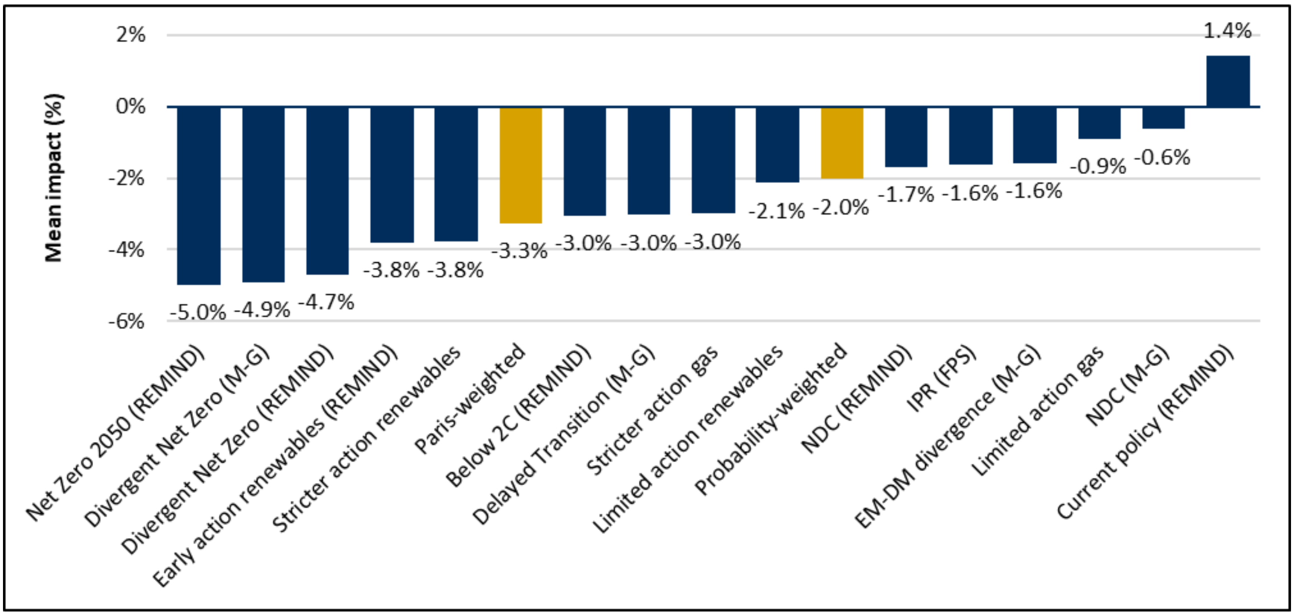
[7] These prices can include implicit costs imposed through regulation and other policies, as well as carbon taxation.

ACWI index weighted by market capitalisation, the asset class for which the estimated effects are greatest. All impacts are expressed as a percentage deviation in fair value compared with the baseline scenario, with the financial impact modelled up to 2050.

We find that the energy transition would moderately impair companies from an aggregate financial perspective. All except our current policy scenarios generate impairment on listed equites. However, differences across scenarios are relatively small, even in the tail scenarios associated with the strongest climate-mitigation action and the largest changes in the energy mix compared with the baseline. The large negative effects on many individual securities are largely offset by positive effects on others in what are mostly diversified equity indices. This is also consistent with the most credible economic analyses implying that even a net zero transition by 2050 would be associated with modest aggregate cumulative negative economic effects.

Figure 7 shows the impact of each scenario on the MSCI ACWI Index. The mean scenario would generate an average impact of -2% in our latest analysis. The impairment is less pronounced than in most scenarios because we attributed larger probabilities to the Limited action and EM-DM divergence scenarios that show limited impacts.

Figure 7: Climate scenario impact on global equity valuations



Source: abrdn, October 2022

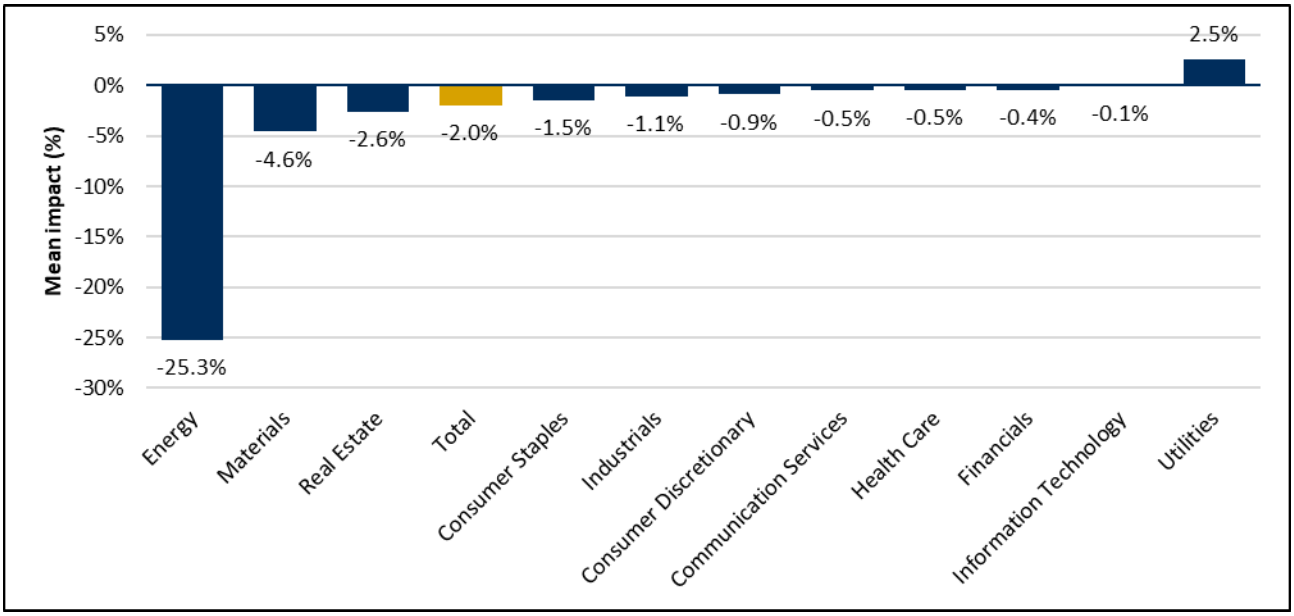
Paris-aligned scenarios have larger negative effects, due to greater demand destruction and higher carbon costs for fossil-fuel-intensive sectors and firms. On the opposite side, the current policy scenario generates positive aggregate effects, as the current activities of many firms do not face higher costs or weaker demand from the energy transition. However, physical risks would be the highest in the current policy scenario. The financial impacts of such risks are modest out to 2050 – the end of our modelling period - but would be much larger in the second half of the century. Physical risk estimates are also attenuated by the assumption of relatively high market discount rates for individual securities. We also note that out of the three bespoke scenarios in line with net-zero, delayed action scenarios result in larger impairments than immediate action scenarios, in line with the literature.

The generally small index-level impact does not indicate that climate risk has low materiality. These 'world-level' results hide large fluctuations between sectors, sub-sectors and the firms within those sectors that we explore in the next sections.

3.3. Sector level exposures

We find larger variations at the sector level, with the impact of the energy transition concentrated in a small number of sectors. Figure 8 shows sector impairments in our mean scenario. We find the strongest effects on the energy sector that would be negatively impaired (-25.3%), in contrast the utilities sector would enjoy a modest uplift (+2.5%). Whilst the Materials sector would be negatively impaired by over 4%, the remaining sectors would face very minor aggregate fair value impairments.

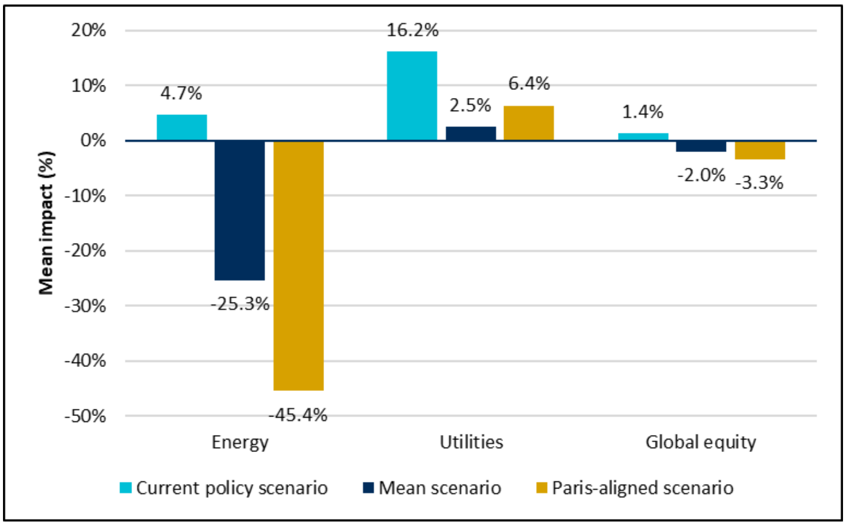
Figure 8: Valuation impact across sectors in the mean scenario



Source: abrdn, October 2022

The more aggressive Paris-aligned scenario amplifies the effects of the mean scenario. Energy firms would be impaired by -45% on average as higher carbon costs and demand destruction would particularly affect emission intensive companies. The utilities sector would display a larger uplift of 6% (Figure 9). Lastly, we find that utilities companies would be positively impacted in most scenarios, the average positive uplift goes up to 62% in the delayed transition scenario on the back of elevated carbon price. Whereas the energy sector is negatively impacted in all except the current policy scenario. Note that as Scope 3 emissions data becomes more comprehensive and able to be incorporated into our analysis, estimated impacts on sectors like finance have the potential to increase substantially.

Figure 9: Utilities and energy sector impact



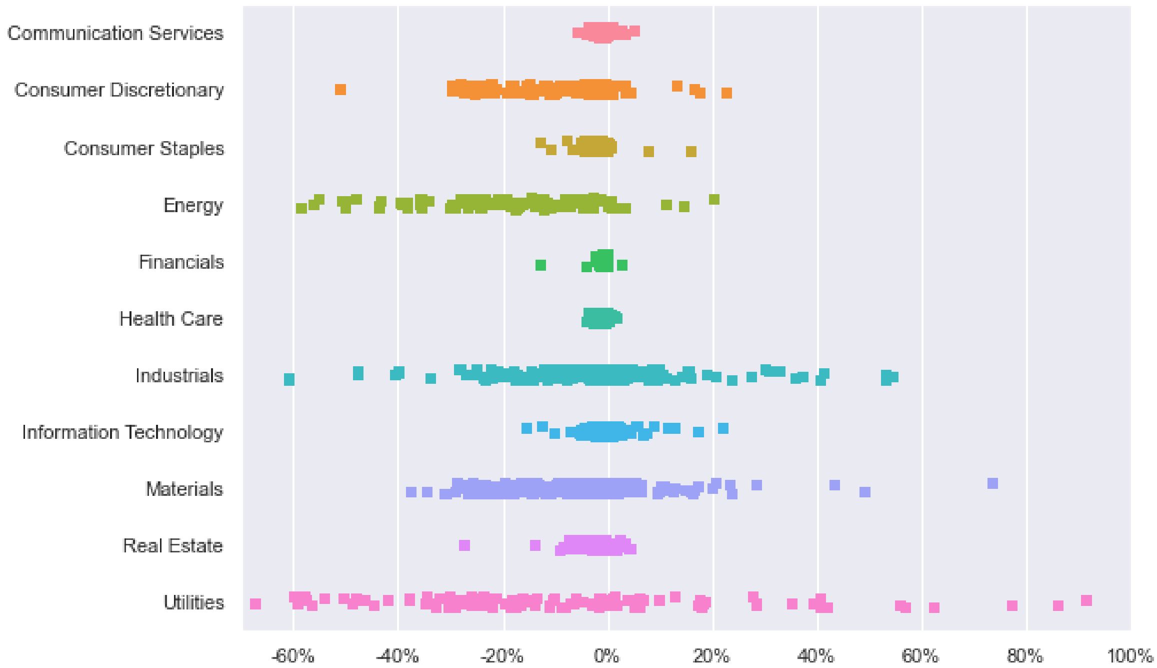
Source: abrdn, October 2022

3.4. Sub sector and firm level exposures

Figure 10 shows the dispersion of net impairment estimates across all the firms in the MSCI ACWI index, under our mean scenario, for each aggregate sector. **We find much greater dispersion of potential valuation effects across firms within each sector.**

Sector averages do not describe how individual firms would likely be impacted under a given scenario. Many companies are negatively impaired in sectors that are on average positively affected, and vice versa. Despite an average positive effect in our mean scenario, some firms in the utilities sector experience negative impairments of greater than -40%, as well as many others showing uplift greater than 40%. Within an aggregate sector, business models – and thus exposure to the different drivers of impairment – vary enormously.

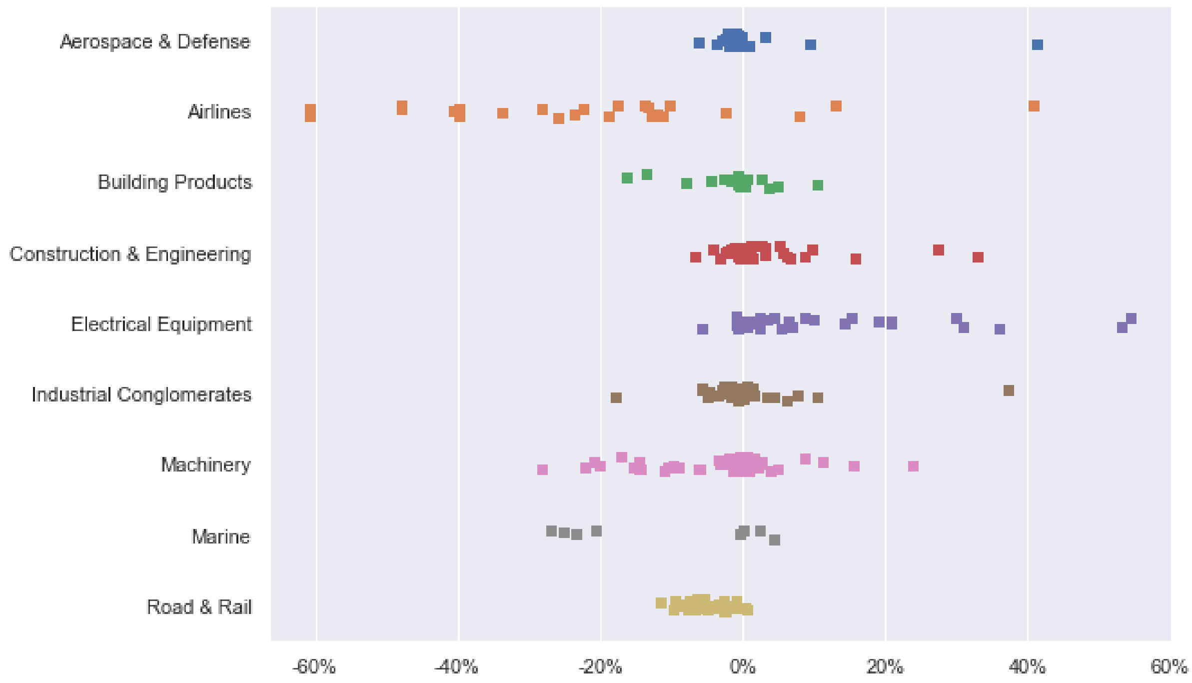
Figure 10: Estimated impairments are highly dispersed within sectors



Probability weighted mean scenario. Source: abrdn, October 2022
Firms whose valuation uplift is above 100% aren't displayed

We better understand the high dispersion by splitting sectors into sub-sectors. In general, most of the differences are accounted for in the sub-sectors' levels of reliance on revenues derived from fossil fuels. As carbon prices rise and the relative cost of renewable technologies fall (particularly in our more stringent policy-action scenarios) fossil-fuel-reliant firms suffer more. Within the Industrial sector, for example (Figure 11), the air and marine transportation sub-sectors are particularly negatively impaired in most scenarios. These firms are subject to some of the highest carbon costs in climate-action scenarios, suffer from significant demand destruction and have many fewer abatement opportunities. Interestingly, we find within the energy sector that many coal mining firms would be only slightly impaired in the mean scenario. Coal firms face large downturns in most scenarios, but the large uplifts experienced in the low or no additional action scenarios offset most of the impairment within the mean.

Figure 11: High variation across Industrial sub-sectors



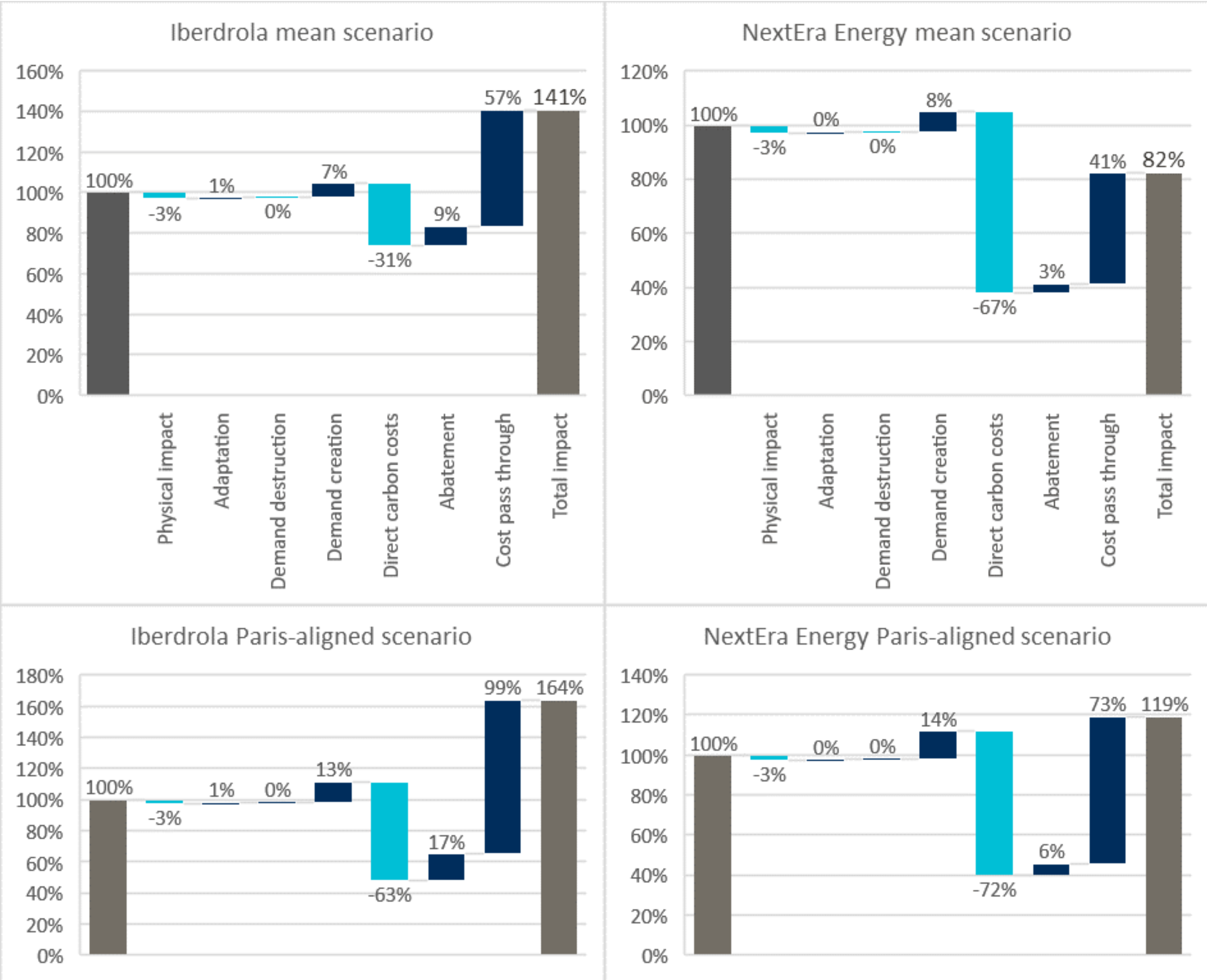
Subset of Industrial subsectors. Source: abrdn, October 2022

We can decompose the valuation impacts by drivers to derive why results differ across different sector levels and between companies (Figure A.2 in the appendix shows the impairment drivers for the energy, materials and automobile sectors). Figure 12 shows the channels for two large renewable companies in the mean and Paris-aligned scenarios. NextEra Energy is a high carbon utilities company as it also operates oil and gas plants. Compared to the low intensity utility firm Iberdrola, NextEra Energy faces larger direct carbon costs. It has less ability to pass on its higher costs to end-users because it is competing with less carbon-intensive utilities. Consequently, Iberdrola experiences an uplift of over 40% in the mean scenario while NextEra Energy is negatively impaired by 18%.

The drivers change across our scenarios. In the Paris-aligned scenario, utilities firms can more than offset higher carbon costs thanks to greater electricity demand creation, the cost benefit of abatement options, and larger competitive advantage relative to more fossil fuel intensive companies.

In light of those observations we conclude that climate-related risks and opportunities are largely a micro-phenomenon.

Figure 12: Impact of scenarios on different utilities varies considerably



Source: abrdn,, October 2022

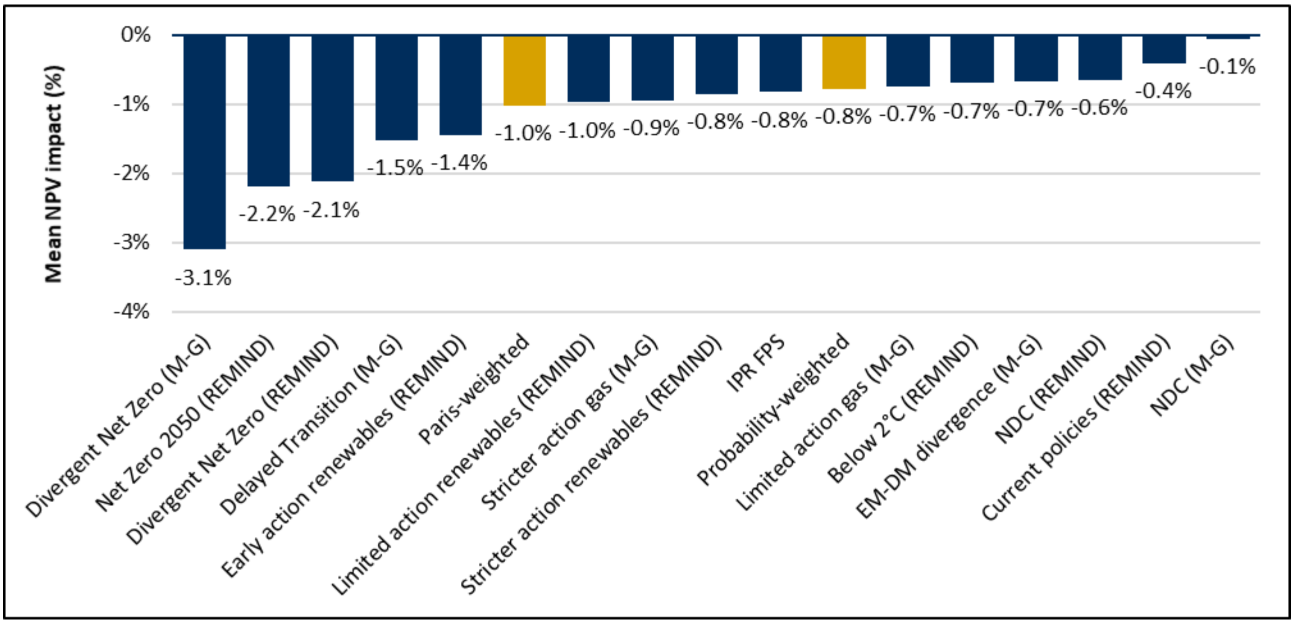
3.5. Credit results

Overall, we find similar observations between listed credit securities and equities with a few notable differences. **First, corporate credit effects are generally lower than equity effects.** Debt has a higher position than equity in the capital structure as well as a time-limited horizon which makes current investments less subject to climate risks that are expected to augment over time. That said, **the sign of the effects for credit securities is more likely to be negative than listed equity securities.** Risks matter more than opportunities, there is a larger effective cap on the valuation uplifts in a credit portfolio as implied default rates cannot fall below zero. These elements limit both the upside and downside impairment for fixed income.

<u>Credit results – index level exposures</u>

We use the iShares Global Corp Bond UCITS ETF as a proxy of a global Fixed Income Portfolio. Listed corporate credit valuation estimates mirror those for listed equities on a smaller scale. We find a slight negative impairment in the mean scenario (-0.8% versus -2.0% for equities), and that more ambitious scenarios generate larger portfolio impacts. As for equity, credit impairment estimates are derived from changes to future earnings pathways relative to the baseline. In contrast to equity, fixed income is negatively impaired under every scenario (Figure 13).

Figure 13: Corporate bond impact across scenarios

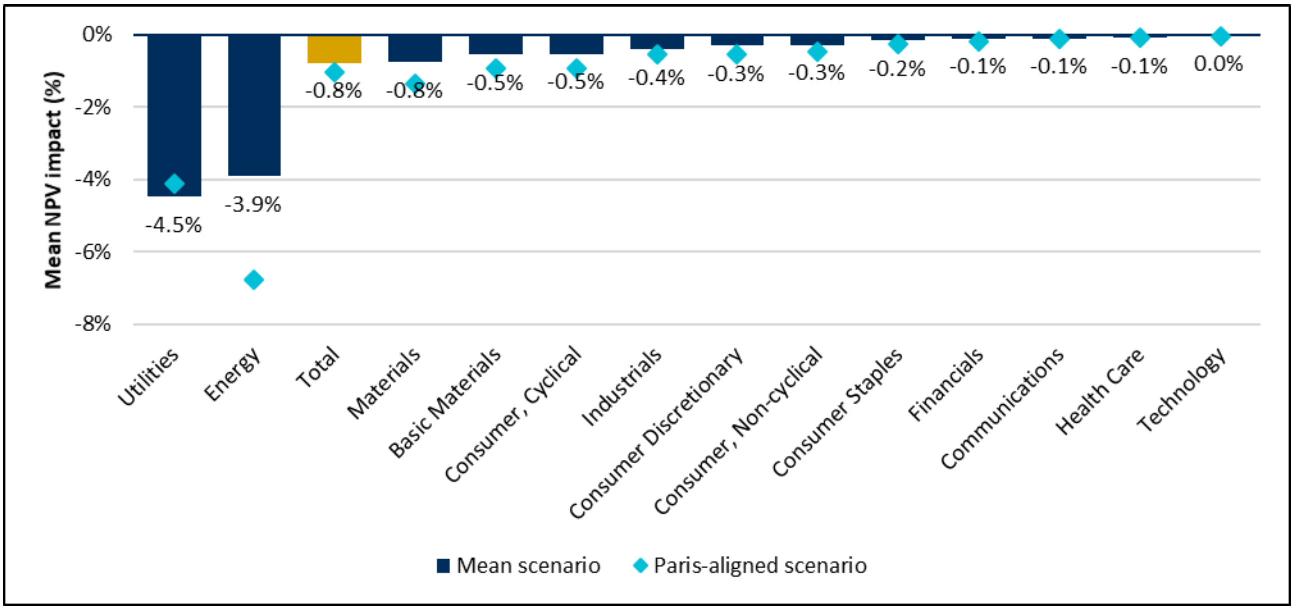


Source: abrdn,, October 2022

Credit results – sector level exposures

As with equities, the energy sector is significantly impaired. However, in contrast to equities, the utilities sector is negatively impaired, as there is further room for a fossil-fuel intensive generator to fall than there is for a low-carbon generator to rise (Figure 14).

Figure 14: Corporate bond impact across sectors in the mean scenarios

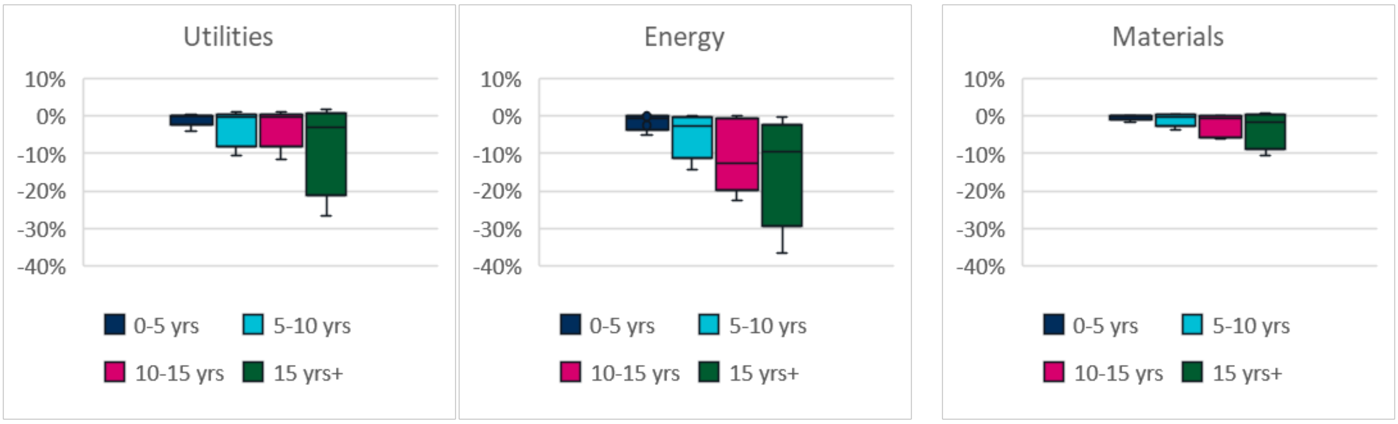


Source: abrdn, October 2022

Credit results – firm level exposures

We find larger impairments on longer duration bonds as climate shocks become more severe over time. Figure 15 shows that the impact on long term bonds is far more tangible within some sectors. More than a quarter of the energy and utilities credit securities with a maturity over 15 years face a negative impairment larger than 20% in the Paris-aligned scenario. We find larger impact for firms with weak credit ratings too. Companies with higher quality starting credit rating can tolerate higher shocks before their probability of default is impacted.

Figure 15: Longer duration bonds experience larger impacts



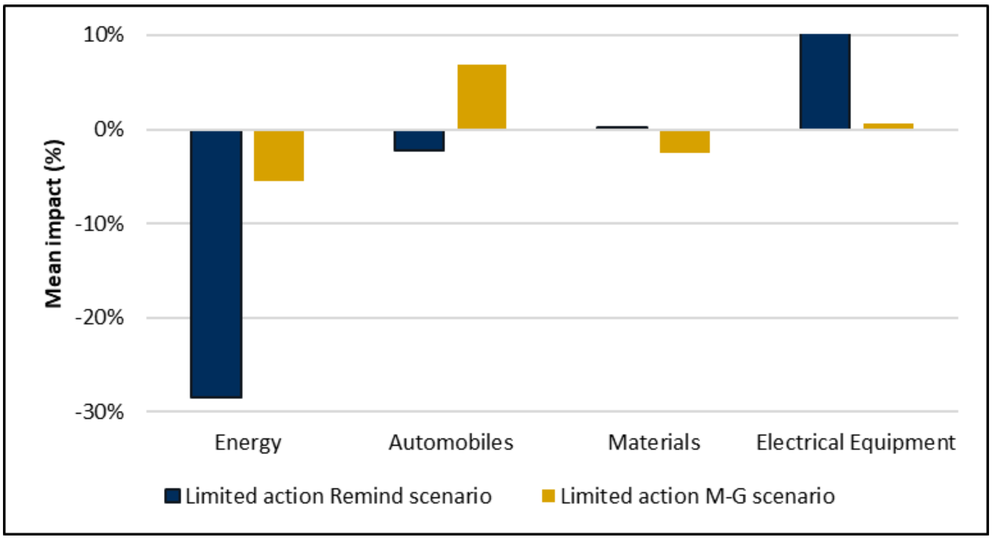
Change in valuation under the Paris-aligned scenario relative to current policy baseline

Source: abrdn, October 2022

3.5. Technology pathways

We find that the technology pathway considerably influences the valuation estimates at the sector and firm level. Figure 16 shows the average valuation impairment for a selection of key sectors and sub-sectors in the limited action renewables (REMIND model) and limited action gas (M-G model) scenarios. The two scenarios differ only through the IAM applied. We observe that energy firms and automobile manufacturers would be more negatively impacted in the REMIND model while Materials and Electrical Equipment would enjoy greater uplifts. This REMIND model forecasts a faster oil demand reduction as well as more demand for renewables energies that rely on raw materials and electrical components.

Figure 16: The IAM can affect the average valuation impact



Mean scenario. Source: abrdn, October 2022

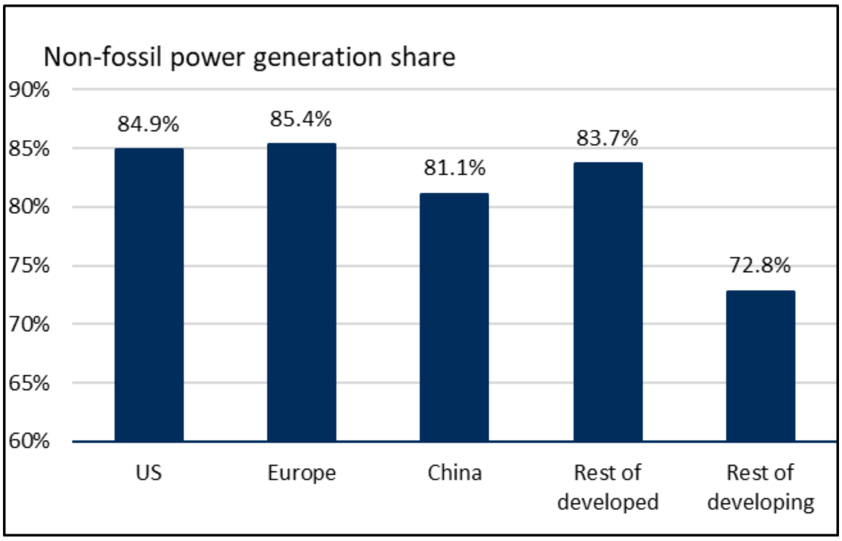
The results indicate that incorporating different technology pathways should be an important component of the climate scenario design. The future of technology over large timeframes is uncertain, we recommend climate scenario users to take this uncertainty into account.

3.6. Insights across regions

We find that our bespoke approach - allowing climate policy to vary across regions and the major energy-usage sectors within those region – generates different insights across geographies than the off-the-shelf approach.

At the region-level, we find larger variations of the non-fossil fuel energy shares in power generation across regions. In our mean scenario, the European non-fossil fuel energy share in the power sector mix reaches 85% in 2050, compared to 81% in China and less than 75% in the rest of the emerging markets (Figure 17).

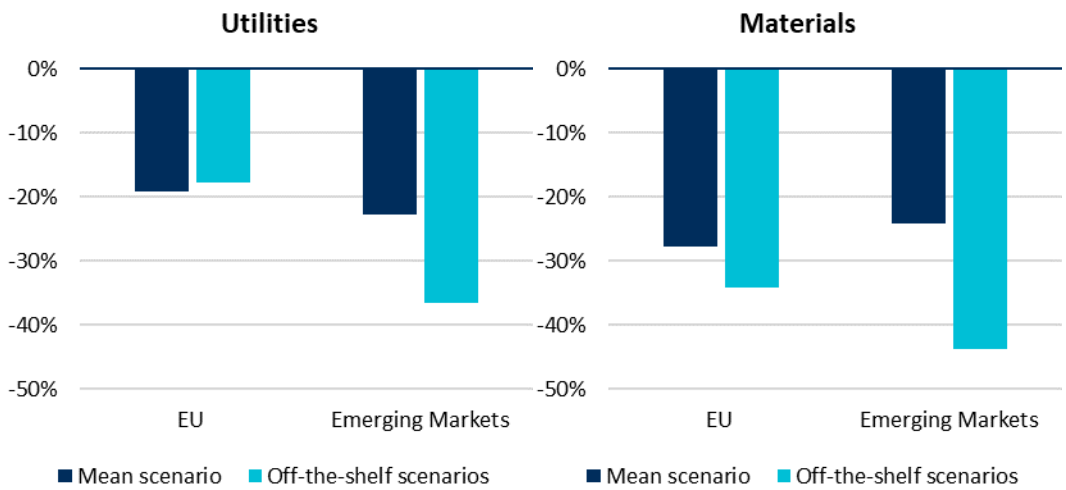
Figure 17: Power sector decarbonisation is likely to be highest in the developed markets



Mean scenario. Source: Planetrics, abrdn, October 2022

We also observe differences at the sector and firm-level. Figure 18 compares the mean direct carbon cost on European and emerging market firms between our mean scenario and an average of the eight NGFS off-the-shelf scenarios. We consider that policy action would become more stringent in Europe than in developing economies. While carbon costs remain relatively unchanged in Europe, for emerging markets they are much reduced in the mean scenario compared to the average off-the-shelf scenario. These changes in carbon costs are then reflected in valuation impacts. Figure A1 in the appendix illustrates that the bespoke approach creates more carbon price variation across regions which largely drives these impairments.

Figure 18: Larger regional variations in carbon costs affect the valuation impact



Comparison of mean direct carbon cost impact (weighted by market cap) for selected regions and sectors; mean scenario and mean of the NGFS off-the-shelf scenarios. Source: abrdn, Planetrics, October 2022

3.7. Updates between our three years of analysis

Adaptability to new information is an essential feature of our climate scenario framework that is much harder to incorporate into non-probabilistic exercises drawing only on off-the-shelf scenarios. We detail in this section how we have modified the design of our bespoke climate scenarios between our 2020, 2021 and 2022 exercise in response to economic, policy and technological backdrop.

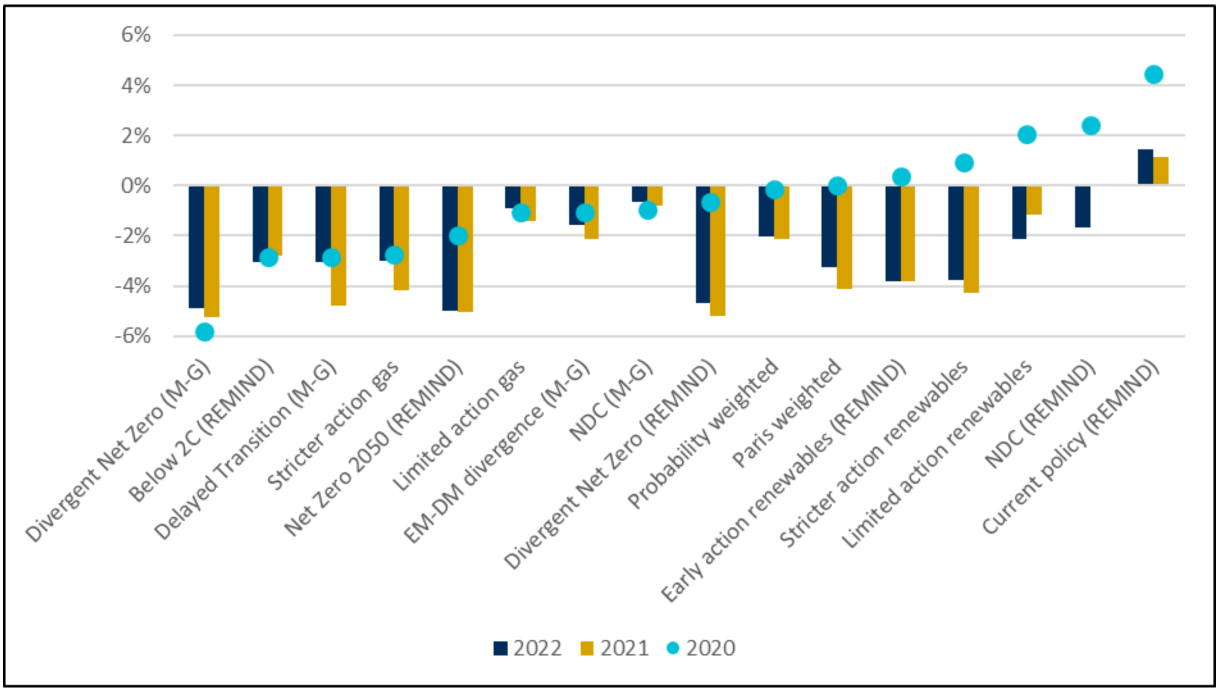
Overall, we have incorporated increased policy ambition into our choice of probabilities and bespoke scenarios. It has contributed to higher carbon prices in our mean scenario, and to downward revisions to long-term fair valuations for most companies. We have also considered a more ambitious baseline (in part due to the M-G model update), reducing the upside of demand creation**. There have been major changes to the macroeconomic, technology and policy landscape.** Firstly, NGFS scenarios were updated to incorporate new IMF projections for long-term global economic growth. Those revisions affect cumulative economic growth and the forecast size of the energy market. Post-Covid downward revisions to cumulative economic growth shifted the entire profile of oil consumption down and reduced the scale of the future electricity demand increase in the 2021 exercise. More recent forecasts revised GDP up and therefore increased energy demand in our 2022 exercise. Second, the M-G model has become more optimistic about solar PV usage and more pessimistic about natural gas and nuclear usage. This reflects faster than expected increases in solar's market penetration, the expectation that these trends will continue, and a less favourable outlook for carbon capture and storage technologies. The REMIND model has attributed similar weights to solar and wind sources, whereas it was relatively more optimistic on solar than wind in 2020. Third, policies have become more ambitious in some countries.

We have assessed that the market was pricing in a faster energy transition in 2021 and 2022 than in 2020 and have updated our baseline scenario accordingly. We have also updated the bespoke scenarios to reflect positive developments in the transportation sector at the sector level, and in the US and China at the region level (Table A2 appendix).

We have attached higher probabilities to stronger action scenarios that limit temperature increase to below 2°C (Figures 5). The scenario revisions have also manifested more modest levels of global warming (Figure A3 appendix). Consequently, the mean scenario results in a temperature rise 0.2°C lower than in our 2020 exercise (from 2.5°C to 2.3°C).

We provide further details of the bespoke scenario and probability updates in the appendix. **At the aggregate level, there has been a marked downward shift in the valuation estimates for the MSCI ACWI global index in almost every scenario after 2020 (Figure 19).** The principal drivers were: (i) increased demand destruction from lower economic growth projections; (ii) higher carbon costs (Figure A4 appendix), partly resulting from heightened policy actions that we have attributed to certain regions; (iii) a more ambitious baseline, pricing in a faster energy transition, reducing the demand creation effect. Changes were more modest between 2021 and 2022. Lower carbon costs from cheaper decarbonisation, updated policy pledges and targets, and the inclusion of 'blended' pathways have affected some scenarios (Figure A5 appendix).

Figure 19: Valuation estimates have declined after 2020



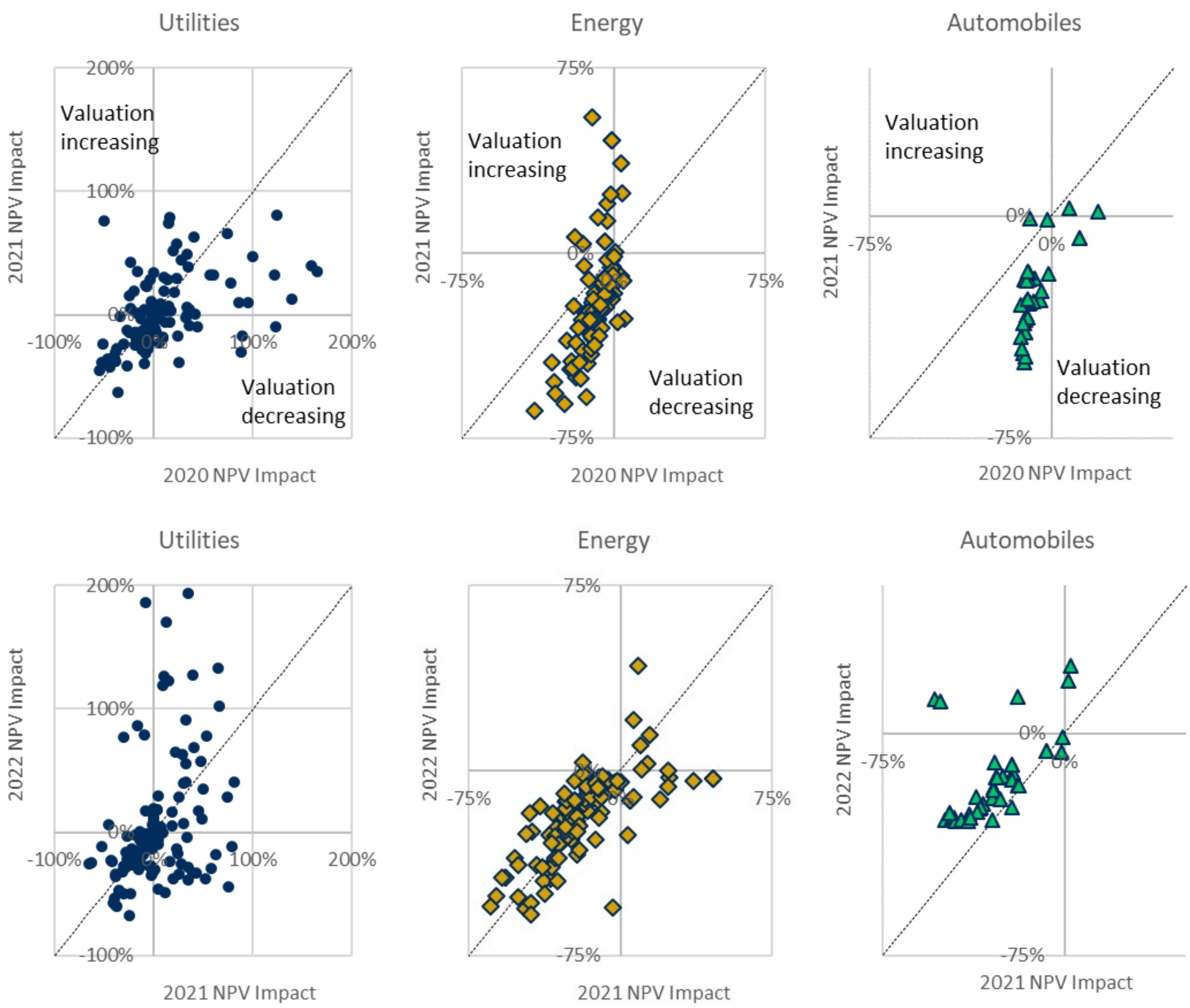
Source: Planetrics, abrdn,, October 2022

At the sector level, the size of the utilities uplift has become smaller because of reduced demand creation relative to the baseline. The use of 'blended' scenarios in the US, for example, results in increased carbon price before 2030, penalising heavy utilities, but has reduced the level that carbon prices reach after 2030, reducing the upside for low carbon utilities.

Energy and auto manufacturing (consumer discretionary) companies estimated impairments were larger in the 2021 than 2020 exercise, mostly attributed to the greater amount of demand destruction from more ambitious policies and a quicker phase out of oil in the transportation sector. The materials sector was also affected by larger carbon costs. Their valuation impairments have moved in the 2022 exercise. Energy and materials companies had lower market implied growth rates that reduced the weight of the future, where carbon prices are higher, relative to the short term. As a result the negative impact of direct carbon costs has reduced. For auto manufacturers, updated EV sales forecasts limited demand destruction and increased demand creation. The magnitude of the average uplifts for sub-sectors like green minerals, renewable utilities and renewable equipment manufacturers has also been revised downwards.

At firm level, the previous exercises also concluded that climate risk and opportunity was mostly a micro phenomenon. However, the same drivers changing our aggregate global and sector specific results, have also altered the nature of the dispersion within sectors. For example, because renewable utilities experienced a smaller estimated valuation uplift, the right-hand tail of the utility sector distribution became smaller between 2020 and 2021 (Figure 20).

Figure 20: Valuation impact for utilities, energy, and automobile companies across years in the mean scenario



Source: abrdn, October 2022

4. Dynamic Corporate Transition Plans

Our standard approach assesses transition risk impacts from current company emissions and revenue shares. This approach (like most climate scenario analysis exercises) does not incorporate future company targets, plans and strategies. For example, estimates of future demand creation are based on existing green revenues, not whether the company is altering its strategy to benefit from those changes in demand. **It is essential to quantify transition plans to determine whether companies would mitigate climate risks and understand the extent to which they could benefit from changing their business model.** We collaborated with our modelling partner Planetrics to develop the capability to take corporate transition strategies into account in the analysis.

As with government policy assessments, corporate transition plans should be complemented with a credibility assessment. A robust assessment of credibility enhances the efficacy of utilising corporate carbon and revenue targets in scenario analysis and alignment measures and reduces the risk of overestimating the likelihood of targets being achieved. When we consider the technologies and supportive policy environment required to achieve the necessary decarbonisation to get the global economy to net-zero, we see high risks of a credibility gap.

In response to this limitation, we complement our climate scenario approach by incorporating company transition plans, along with a credibility framework within which these plans can be assessed. We obtain a more realistic view on the financial implications of different climate scenarios on corporates and to what extent their targets can mitigate some of the impacts identified. Investing in companies with ambitious and credible transition plans also provides support to accelerate the green transition.

Transition plans

The company target approach utilises the emission reduction and revenue share targets set out in company climate strategies (to 2050) to identify transition parameters for inclusion in the modelling. Emissions reduction targets take the form of intensity or absolute targets. Intensity targets (tCO2/m$) are turned into a GHG intensity pathway, assuming a linear decline in intensity, while absolute targets are interpreted as intensity targets and turned into a linear reduction pathway. A smaller proportion of companies set revenue share targets that shift their product mix away from high-carbon products such as electric vehicle sales targets from auto manufacturers; or energy companies shifting their fuel mix in favour of low-carbon alternatives. This allows revenue share shifts to expand beyond the 'organic' growth of the standard modelling approach.

Our initial exploration of this approach includes researched company targets from approximately 2000 companies with information compiled from public data sources such as company sustainability reports. For these companies, the modelling process was re-run using the resulting company climate transition parameters. The results from the two approaches can then be compared to identify the potential benefit (or otherwise) to valuation, assuming targets are achieved. The model is used to assess individual companies– in this initial analysis returning the valuation impact where the individual company achieves its transition targets while other companies do not transition.

Credibility assessment

Table 4 details our framework for assessing the credibility of company targets and plans. The framework was partly inspired by the Institutional Investors Group of Climate Change (IIGCC) Net Zero Investment Framework (IIGCC, 2021), and the Glasgow Financial Alliance for Net Zero (GFANZ) guidance on portfolio alignment (GFANZ, 2022). We give a score to each category; we then aggregate the scores to return the credibility score. This outcome is used to discount the valuation uplift between the standard approach and the company target approach.

Table 4: framework for assessing credibility of targets and plans

Category	Reason	Details	Weight	Source
Emissions Target Design	Assess the various carbon targets set by companies by considering the approach in terms of scope, emissions metric type and progress against the target.	Place greater credibility on companies that: set targets against a greater coverage of their total emissions; encompass Scopes 1, 2 and 3; have absolute emissions reductions rather than intensity targets; are on track to meeting the targets they have set for themselves.	20%	MSCI
Emissions Performance	Assess if companies achieve emissions reductions.	Track year-on-year changes of emissions intensities, favouring higher levels of intensity reduction.	20%	Trucost
Technology Readiness	Achieving medium to long-term decarbonisation requires technologies that are not yet economically mature;	Use the International Energy Agencies Technology Readiness Level (IEA TRL)	20%	IEA TRL

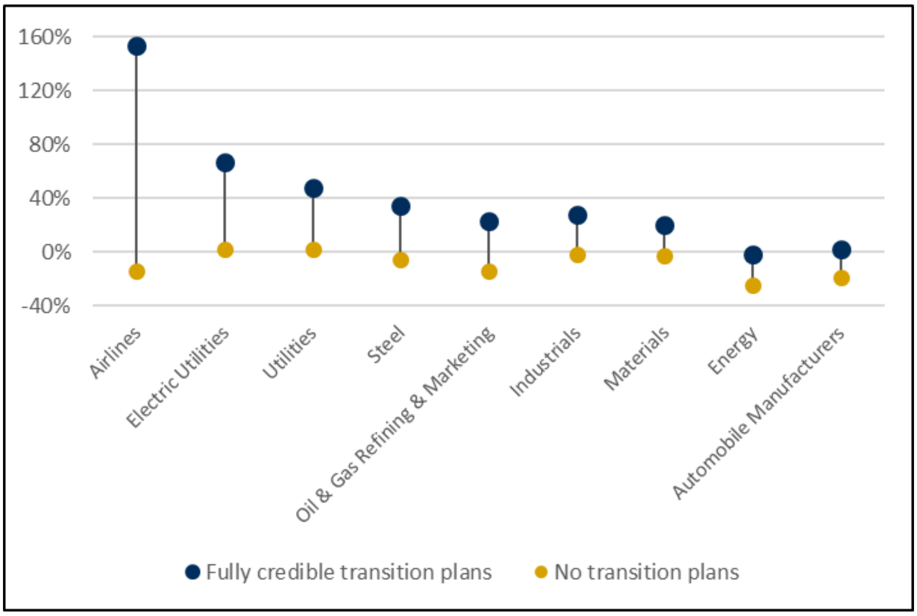
	incorporate a view of the technological readiness of a company.	framework. The IEA TRL score ranges from 0 to 11 in economic maturity.		
Policy Environment Supportiveness	Companies are affected by the political and policy environment in the countries in which they operate and generate revenues	Use company geographical revenues and abrdn's Research Institute Climate Policy Index (CPI). The CPI provides an assessment of the policy environment. Company geographical revenues are used to assess company exposure to the climate policy environments in which they operate, with the CPI scores weighted based on company exposure.	20%	abrdn; Factset
Green Market Penetration	Companies with higher green revenues have more technological competencies in the manufacturing and distribution of green products	Assess companies' ability to penetrate green markets. Look at the percentage of companies' green revenues.	10%	FTSE Russell
Climate Governance	Companies with strong governance frameworks in place are more likely to produce robust decarbonisation strategies and maintain board-level accountability to climate commitments.	Capture the supportiveness of a company's governance policies and frameworks. Use the Transition Pathways Initiatives (TPI) Management Quality score made up of 19 governance indicators.	10%	TPI

Results

The initial analysis shows that company targets meaningfully improve the valuation impact. The mean company impact increases by 16% in the mean scenario and 27% in the Paris-aligned scenario. Companies have lower exposure to transition risks such as carbon pricing and demand destruction, and greater exposure to transition opportunities such as demand creation and market impacts.

Figure 21 shows the extent to which transition plans impact subsectors valuation in the mean scenario. Most companies are negatively impaired in the standard modelling framework; when we incorporate the transition plans some of those firms enjoy a positive uplift of as much as 100%. The size of the uplift rises as companies include larger emission reduction targets and consider scope 3 emissions. We note that the size also depends on other factors such as the company's business model and the regions in which it operates. Similar results are observed for electricity companies, with higher uplifts for some companies already enjoying an uplift in the standard valuation model.

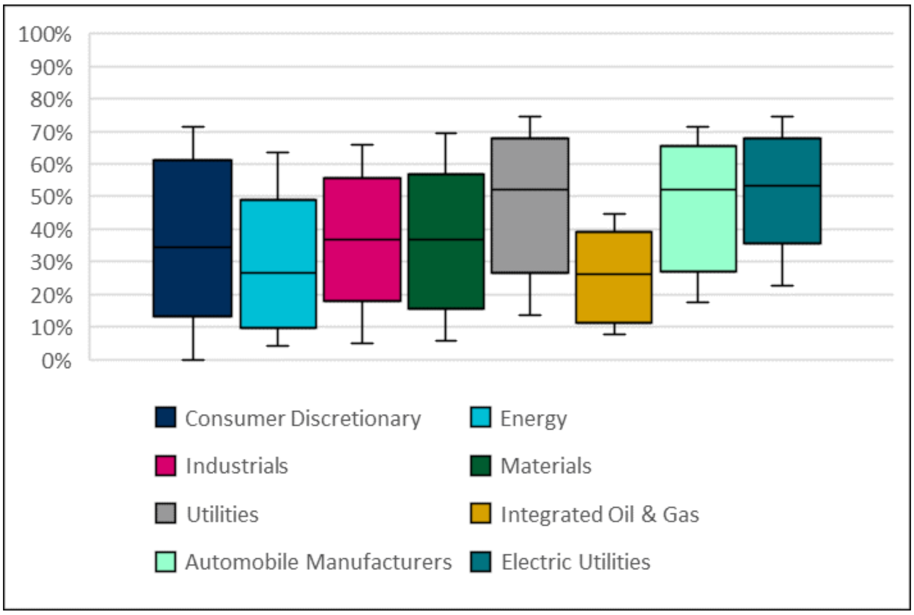
Figure 21: Companies within certain subsectors enjoy large uplifts when their targets are considered



Note: Company targets are analysed in isolation, and thus do not account for the way that other companies transition. As such, the chart shows the upper bound on the benefits individual companies can derive from dynamically transitioning.
Subset of firms, mean scenario. Source: abrdn, October 2022

Turning to the credibility aspect, we observe that the average firm has a large credibility gap, and that significant differences exist in the credibility scores across and within sectors. We find the average credibility score in the oil and gas sector is close to just 25% while it is above 50% for electricity utilities and automobiles companies. The difference is in part explained by increasing scope 1 and 2 emissions and a low share of green revenues in most oil and gas firms, whereas electricity companies have on average reduced their emissions and benefit from a larger share of green revenues. As a result, oil and gas firms are more negatively impacted by the credibility-adjustment than many electricity utility companies. Consequently, most energy firms have a negative credibility adjusted valuation. We also find that the credibility of company targets is heterogeneous from firm to firm (Figure 22). The results reinforce our view that by including company targets into our analysis and combining this with our credibility framework we can enhance the assessment of climate risks and opportunities.

Figure 22: Credibility score dispersion across sectors and sub-sectors



Source: abrdn, October 2022

5. Next steps

In this section we consider some of the limitations of our approach; as well as how we address some of those issues. We also provide recommendations on how the features of our probabilistic bespoke approach could benefit both the financial industry and policy making.

5.1 Limitations of our approach

We believe that our approach represents a significant advancement in the field of climate-scenario analysis, giving us greater confidence in the results and their applicability to real-world investing. However, it is important to be aware that, like any modelling exercise, our framework has some limitations. Some of the major drawbacks are:

- Our approach rests on the assumption that the baseline scenario is the one that the market is accurately pricing. This may not be the case. It is not clear how well market participants in aggregate understand the dynamics of the climate transition. It is also now widely accepted that markets may be inefficient in various ways, including the internal consistency of the pricing of transition risks across different firms. However, we believe that this simplifying assumption is a reasonable starting point, and it strongly simplifies what would otherwise be an intractable modelling problem.
- Climate scenarios do not capture the impact of firm births and non-climate drivers of firm deaths. Some companies incorporated into our analysis are likely to go out of business and new firms may come into existence. And some of these new firms may be the ones to harvest the benefits of the energy transition in the same way that certain technology companies were among the major beneficiaries of the internet revolution. Similarly, the modelling doesn't capture demand for nascent technologies as their growth is uncertain.
- The analysis relies on firm-level emissions-intensity data. While the consistency and quality of greenhouse gas-emission reporting is improving, neither disclosed emissions nor estimated emissions intensity data is yet available for some companies. For these companies, the analysis assumes that their emissions intensity is in line with the sector mean. That can lead to emissions being either significantly over- or under-estimated for these individual companies. Carbon-accounting rules are also not fully harmonised, even for listed companies. Furthermore, Scope 3 data are not incorporated due to insufficient data quality.
- Our analysis focuses on the energy system incorporating the power, transportation, industrial, and buildings sectors. We don't investigate agriculture, forestry and land use that account for 25% of global greenhouse-gas emissions. These sectors are less important from an investment perspective because they represent a small share of the investable universe.
- The modelling approach assumes that the supply side structure of the oil and gas market remains similar to today. The climate-scenario analysis focuses on changes in demand rather than supply. All sources of oil and gas available today are assumed to be available to 2050, including shale oil, oil sands, and Middle East oil and gas. Specifically removing any of these sources through either policy (e.g. fracking bans) or geopolitics (e.g. conflict or social unrest in the Middle East) could have a material impact on the balance of supply and demand, resulting in higher prices than expected and mitigating the transition impacts on producers.
- A smooth pricing of risk is assumed. However, impacts on market pricing may not occur linearly, For instance, tail physical impacts could result in abrupt pricing.
- Regarding our corporate credibility assessment framework:
  - Some data are only available for a subset of firms. For example, the TPI's MQ score, which is one input into our aggregate credibility score, is only available for 400 companies.
  - We currently look at companies' current green revenue share without considering future shares, we apply a high-level mapping approach to technology readiness and think the method could be improved.

- The analysis also considers targets in isolation, and thus does not account for the way that one company's transition can affect another, or the effect on overall sector and region emissions profiles. As a consequence, our current approach represents an upper bound on the benefits companies can derive from dynamically transitioning.
- Finally, the modelling currently assumes that companies can achieve their targets at no additional cost or loss of efficiency.
- We therefore use the framework to enhance the analysis of impairment estimates rather than to replace it.

- Finally, physical climate risk is incorporated into our analysis, but not deeply enough for us to be confident that we have appropriately captured all the relevant risks and channels of impact.

More generally, like any modelling exercise, ours is an approximation and simplification of the complexities of the real world. Though we think our financial exposure estimates are more robust than standard off-the-shelf or reference scenarios, important drivers of climate-related risk lie outside of the framework. Our results should therefore always only be complemented by other analysis before any financial decisions are made.

5.2 How are we beginning to address those limitations

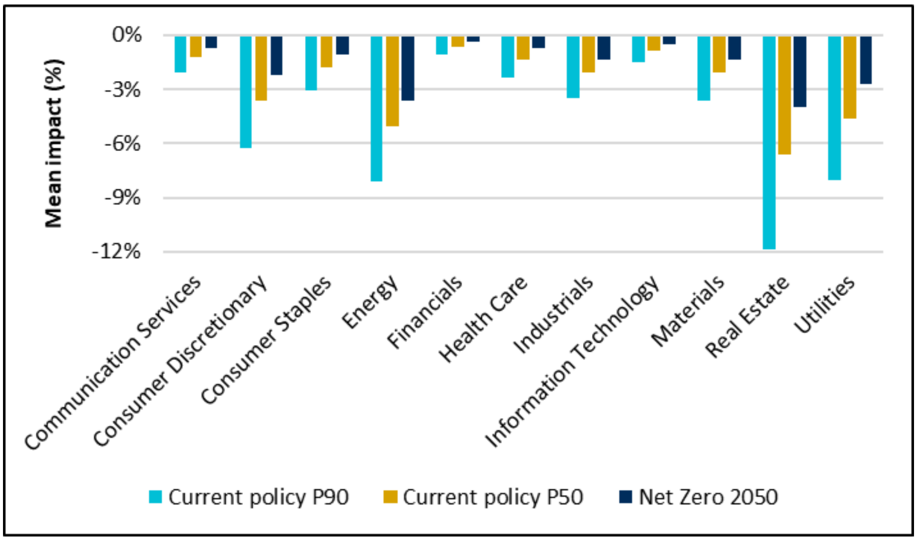
Transition plans and credibility assessment

The EU taxonomy will help include better capital expenditure data to assess future green revenues, albeit it will take time before the data are sufficiently widely available. We expect to use bottom-up company analysis to complement the IEA TRL framework, and better capture company-level technology competitive advantages. Finally, we intend to enhance the modelling to better assess the interactions between different companies' transition plans.

Physical risks

We deepened our analysis of the implications of physical climate change in our 2021 and 2022 exercise by adding an additional current policy scenario where security valuation estimates are dominated by physical effects. Instead of physical effects being taken from the mean of the potential distribution, in this scenario they are taken from the 90th percentile. We find that the 90th percentile effects generate almost twice as much negative impairment through the physical risk channel than the 50th percentile effects (Figure 23). We will better capture the implications as the modelling of physical risks is improving **(NGFS, 2022)**.

Figure 23: Physical risk impact by sector



Source: abrdn, October 2022

<u>Other asset classes</u>

We are extending our analysis to include building specific modelling of our real estate assets which is aligned with our scenario framework. We are also exploring how to best extend the insight obtained for public assets to cover private equities and credit.

5.3 Recommendations for industry change

We would recommend the financial industry places greater emphasis on utilising more realistic climate scenarios in order to deepen the understanding of transition and physical risks within their portfolios and business decisions. The industry could design climate scenarios better tailored to their needs by incorporating some features of our probability bespoke framework. First, to design more plausible scenarios by placing more emphasis on the importance of pathways between "net-zero" and "current policies", as well as by allowing for more variability across sectors, regions, and technological pathways. Second, to build a baseline scenario estimating what is priced by the market. Third, to consider the scenarios probabilistically to complement the analysis with a probability weighted mean scenario that describes the central tendency of the climate-risk distribution. We would also recommend to include and assess transition plans into the analysis.

Bespoke scenarios contain more flexibility. The analyses conducted in the previous sections highlight that the probability bespoke mechanism provides further insights and is more flexible than the traditional approach. A typical off-the-shelf scenario assumes that policy is applied uniformly across sectors and geographies. Policy sensitivity can therefore only be examined by altering assumptions for all sectors and geographies simultaneously. The bespoke architecture enables altering the policy ambition in a specific region and sector while maintaining the other blocks unchanged, and to evaluate the "What if?" implications. This approach also facilitates the design of additional scenarios, such as creating scenarios with a temperature increase that hasn't been projected in the off-the-shelf scenarios.

It would provide the financial industry with greater confidence in applying climate scenarios into decision making in order to estimate the valuation impairments under more plausible outcomes. Incorporating transition plans as well as evaluating their credibility would also provide additional insights at the firm-level. This would therefore improve the allocation of capital to generate better returns as well as to facilitate the energy transition.

Different features could be used depending on the case-study. For instance, integrating a baseline that estimates what is priced into assets would better fit an exercise looking at stock prices or at financial market shocks; developing bespoke scenarios with large variations across countries and regions could serve macroeconomic forecasting; including transition plans and credibility assessment could provide further insights into firm-level exercises.

Several observations drawn from our exercise can inform policymakers. First, we found that the baseline scenario is aligned with a "hot house world" scenario. Financial markets are currently far from pricing in (and therefore from allocating capital to) a Paris-aligned pathway- policymakers should take further actions to modify market perceptions and accelerate the transition. Second, the gap between the baseline and the Paris-aligned scenarios estimates the radical shift needed in the energy mix as well as how companies would be impacted, which could inform fiscal and monetary policy. Third, at the micro level many companies would effectively manage climate risks if their transition plans are fully implemented, however we find a large credibility gap meaning that efforts should be undertaken to reduce that gap.

In addition to the scenario design, we recommend to better capture macro dynamics to help enhance the use of climate scenarios. We take the example of the CBES process that extends climate scenarios into the sovereign-bond universe. We think that those scenarios have some limitations in how they consider the Bank rate and gilt yield paths. First, the Bank of England assumes that the policy rate in the Early Action scenario follows that of the baseline. That element is critical to interpret the results: while the baseline is not referred to as the scenario that is being priced in by the market nor is the Bank's view of the most likely long-run pathway for the economy, it does de facto play that role because the Bank provides no other reference scenarios as part of the exercise. The other two scenarios and their results are then expressed relative to that baseline. We regard this baseline scenario as a tail risk and would recommend to modify it to a more likely pathway in order to better assess the impact on macro indicators and on sovereign bond valuations. Second, we consider unlikely the assumption that the long-term neutral nominal and real interest rate is identical in the UK, Euro Area and US economies. Third, the pathway of the Bank of England rate in the Late Action scenario is hard to square with a typical central-bank reaction function. The increase in carbon prices is specified as a negative supply shock that pushes output down and inflation up, but the Bank is assumed to cut real interest rates aggressively and then take a decade to return the policy rate to its previous path.

6. Conclusion

Innovations and scope of our exercise

This paper contributes to the climate scenario analysis literature by addressing a number of the limitations identified above. Using a framework to evaluate policy action and the political backdrop within countries, we create bespoke scenarios that capture a wider range of outcomes than is typical, with more realistic assumption pathways that allow policy action to vary across regions and sectors. Drawing on regional and sectoral market expertise we also design a bespoke baseline scenario that better represents what is already priced into financial markets, enabling us to assess alternative scenarios to a more useful benchmark. In addition, we assign probabilities to our full suite of scenarios and use these to create a probability-weighted mean scenario that allows us to generate 'most likely' assessment of the inputs that underpin the estimates for financial-security impairments. Our innovation also extends to how we incorporate and evaluate the credibility of companies' transition plans into climate scenario analysis.

The results show that our bespoke probabilistic approach generates insights into the future of energy demand patterns that differ from what we could obtain from anchoring on the traditional off the shelf approach. Our baseline indicates that investors price a "hot house world" scenario associated with a temperature increase of 2.7°C by 2100. The probability-weighted scenario (or 'mean' scenario) points to a much faster transition and steepening carbon prices, but it falls short of the Paris objectives, with an increase of 2.3°C. The average valuation impact on companies is limited at the index level, but we find substantial dispersion at the sector and stock-level; energy firms are among the most at risk while many utilities firms would benefit from the climate transition; the choice of IAM also alters the results. By allowing for wider variations across regions we observe that many sectors in developed markets are more affected by carbon costs while the opposite occurs in developing economies. Lastly, the valuation impairment estimates are significantly impacted once we include transition plans and a credibility assessment into the scenario analysis.

Our climate scenario-analysis has been designed from an investment management perspective to estimate the impact on securities. Other actors can replicate the framework but make different assumptions and choices to create scenarios more adapted to their needs that would provide different insights. We find that this approach could also aid climate-scenario providers and policymakers and help enhance collaboration with the financial industry.

5. References

Allen, T. et al., 2020. Climate-Related Scenarios for Financial Stability Assessment: an Application to France. *Banque de France,* July.Issue 774.

Alogoskoufis, S. et al., 2021. ECB economy-wide climate stress test. *European Central Bank,* September.Issue 281.

Bank of England, 2021. Key elements of the 2021 Biennial Exploratory Scenario: Financial risks from climate change.

CFRF, 2021. Climate Financial Risk Forum guide 2021. Scenario Analysis. October.

Ens, E. & Johnston, C., 2020. Scenario Analysis and the Economic and Financial Risks from Climate Change. *Bank of Canada,* May.Issue Staff Discussion Paper/Document d'analyse du personnel — 2020-3.

European Banking Authority;, 2021. Mapping climate risk: Main findings from the EU-wide pilot exercise. May.Volume Report EBA/Rep/2021/11.

GFANZ, 2022. Measuring portfolio alignment: Enhancement, convergence, and adoption.

IEA, 2021. World Energy Model Documentation.

IIGCC, 2021. Net Zero Investment Framework Implementation Guide.

IPCC, 2021. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

NGFS, 2020. Guide to climate scenario analysis for central banks and supersivors.

NGFS, 2022. NGFS Scenarios for central banks and supervisors.

NGFS, 2022. Workstream "Scenario Design and Analysis" Mandate - April 2022 / April 2024.

TCFD, 2017. Final Report: Recommendations of the Task Force on Climate related Financial Disclosures.

UNEP FI; CICERO, 2021. Pathways to Paris: A practical guide to climate transition scenarios for financial professionals. February.

UNEP FI; NIESR, 2022. Economic Impacts of Climate Change: Exploring short-term climate related shocks for financial actors with macroeconomic models. May.

UNEP FI, 2019. Changing Course: A comprehensive investor guide to scenario-based methods for climate risk assessment, in response to the TCFD. October.

Vermeulen, R. et al., 2018. An energy transition risk stress test for the financial system of the Netherlands. *Occasional studies,* 16(7).

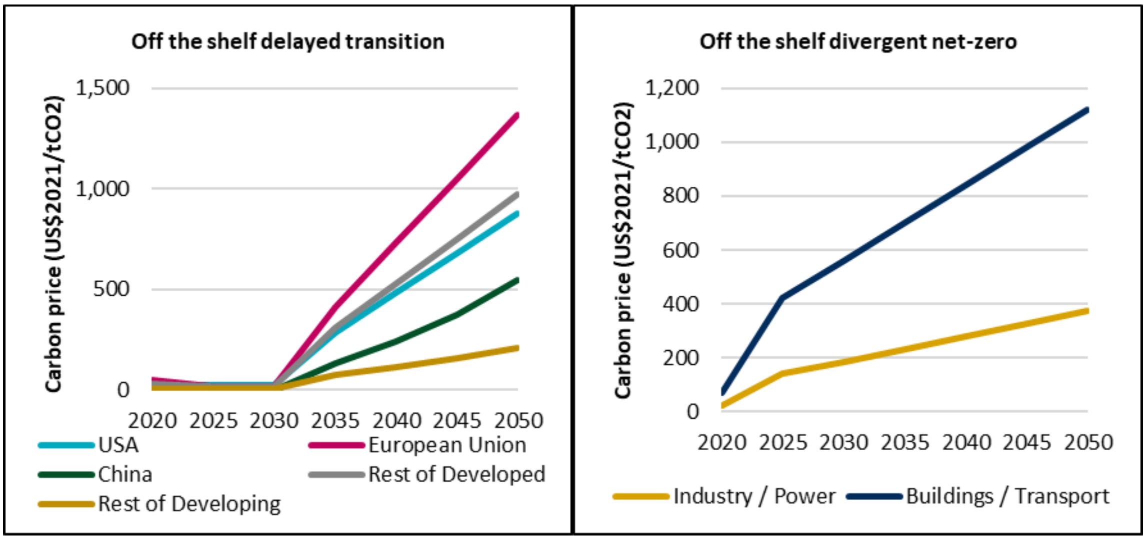
Appendix

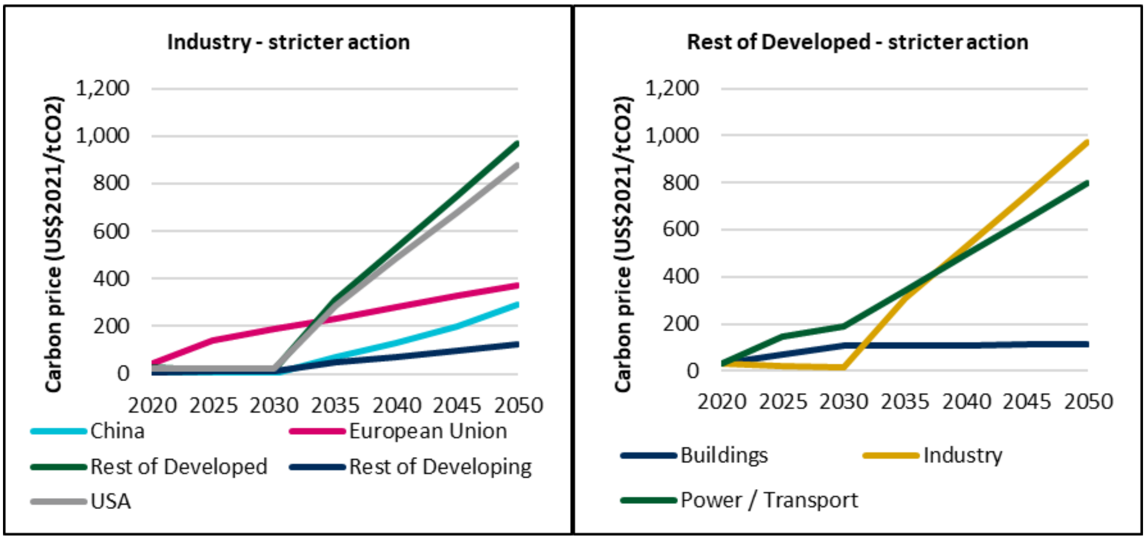
Carbon price variation across regions and sectors

To illustrate the observations we compare the off-the-shelf divergent net-zero scenario at the sector level and delayed transition at the region level with the stricter action bespoke scenario. We see that the divergent net-zero scenario returns different carbon prices but is limited, for instance it doesn't differentiate industry and power. Similarly the delayed transition scenario returns carbon prices for the regions but with a similar carbon price trajectory shape. It should also be noted that this comparison utilises the off the shelf scenarios with the largest differences across regions and sectors (the divergent net-zero is the only scenario returning different carbon prices), and that the delayed transition (divergent net-zero) scenario has a uniform carbon price pathway across sectors (regions).

By contrast, in our stricter action bespoke scenario, the stronger action from the EU (divergent net-zero policy) would exhibit a larger carbon price over the short term, and the US and other developed countries would face steep carbon price rise after 2030 to reach their net-zero objective. This contrasts with the rest of developing and China (NDCs / delayed policy). Similarly, we believe that the rest of developed would take different actions in the power and transport sectors (net-zero / below 2°C policy), than for industry (delayed policy) and buildings (NCDS / below 2°C policy). As a result our stricter action scenario would return more variability across sectors and regions. Other bespoke scenarios would return different and unique trajectories.

Figure A1 carbon price pathway under different scenarios (Remind model)





Source: NGFS (2022), aRI, Planetrics, October 2022

Table A1: Projected global temperature rise, energy demand, renewable energy share, and carbon price under each scenario

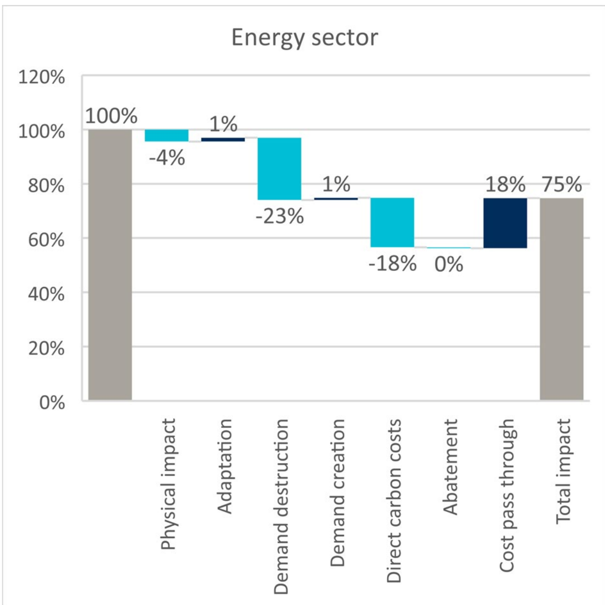
	Scenario	Temperature change		Oil demand			Coal demand		Gas demand	
		2050	2100	Peak oil (year)	2050 proj. (Mbbl/day) (2020 = 95.4)	Annual growth (2020-2050)	2050 proj. (Mtce/year) (2020 = 5393)	Annual growth (2020-2050)	2050 proj. (Bm3/year) (2020 = 3884)	Annual growth (2020-2050)
	Baseline (M-G)	1.8	2.7	2035	93	-0.08%	2984	-1.95%	6989	1.98%
Bespoke	Limited action renewables (REMIND)	1.8	2.6	2020	68	-1.11%	3966	-1.02%	3870	-0.01%
Bespoke	Limited action gas (M-G)	1.8	2.6	2035	89	-0.21%	2927	-2.02%	6619	1.79%
Bespoke	EM-DM divergence (M-G)	1.8	2.5	2030	86	-0.34%	2862	-2.09%	6271	1.61%
Bespoke	Stricter action renewables (REMIND)	1.7	1.9	2020	55	-1.83%	1199	-4.89%	2277	-1.76%
Bespoke	Stricter action gas (M-G)	1.7	1.9	2020	57	-1.72%	871	-5.90%	3876	-0.01%
Bespoke	Early action renewables (REMIND)	1.6	1.7	2020	54	-1.90%	230	-9.98%	1861	-2.42%
Off-the-shelf	NDC (REMIND)	1.9	2.4	2030	70	-1.05%	2441	-2.61%	3725	-0.14%
Off-the-shelf	NDC (M-G)	1.9	2.3	2035	92	-0.11%	2355	-2.72%	7171	2.07%
Off-the-shelf	Below 2˚C (REMIND)	1.7	1.6	2020	58	-1.67%	237	-9.89%	2107	-2.02%
Off-the-shelf	Delayed Transition (M-G)	1.7	1.4	2030	44	-2.55%	489	-7.69%	1858	-2.43%
Off-the-shelf	Divergent Net Zero (REMIND)	1.6	1.4	2020	30	-3.76%	92	-12.68%	1192	-3.86%
Off-the-shelf	Divergent Net Zero (M-G)	1.5	1.3	2020	32	-3.59%	104	-12.34%	1343	-3.48%
Off-the-shelf	Net Zero 2050 (REMIND)	1.6	1.4	2020	42	-2.69%	99	-12.49%	934	-4.64%
Off-the-shelf	Current policy (REMIND) (Med)	2.0	3.2	2030	71	-0.98%	6899	0.82%	4892	0.77%
Off-the-shelf	IPR (Forecast Policy Scenario)	1.8	1.8	2020	35	-3.25%	1437	-4.31%	1889	-2.37%
	Probability weighted mean**	1.8	2.3	2020	71	-0.97%	2410	-2.65%	4538	0.52%
	Paris Alignment (probability weighted)**	1.7	1.8	2020	52	-2.03%	884	-5.85%	2518	-1.43%

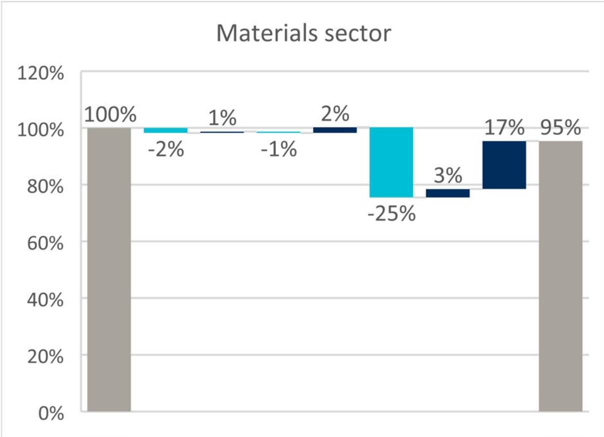
	Scenario	Electricity			2050 non-fossil fuel power generation share			Carbon prices* (US$2020/t CO_2)		
		2050 proj. demand (EJ/year)*	Annual growth (2020-2050)*	EV share 2050 (%) (2020 = 10%)	All	Wind*	Solar*	2020	2035	2050
	Baseline (M-G)	190	2.38%	80%	59%	21%	22%	2	36	49
Bespoke	Limited action renewables (REMIND)	198	2.59%	77%	93%	36%	35%	10	49	98
Bespoke	Limited action gas (M-G)	191	2.39%	79%	63%	22%	22%	2	84	195
Bespoke	EM-DM divergence (M-G)	207	2.67%	92%	66%	23%	23%	2	104	244
Bespoke	Stricter action renewables (REMIND)	209	2.77%	92%	100%	40%	38%	10	103	287
Bespoke	Stricter action gas (M-G)	250	3.32%	100%	94%	36%	32%	2	485	1221
Bespoke	Early action renewables (REMIND)	211	2.81%	94%	100%	40%	38%	11	114	274
Off-the-shelf	NDC (REMIND)	198	2.58%	75%	91%	36%	35%	10	45	62
Off-the-shelf	NDC (M-G)	182	2.22%	80%	59%	21%	22%	2	46	65
Off-the-shelf	Below 2°C (REMIND)	210	2.79%	92%	98%	40%	38%	10	72	160
Off-the-shelf	Delayed Transition (M-G)	254	3.37%	100%	97%	40%	33%	2	920	2381
Off-the-shelf	Divergent Net Zero (REMIND)	247	3.34%	100%	98%	41%	38%	18	266	585
Off-the-shelf	Divergent Net Zero (M-G)	279	3.70%	89%	99%	37%	32%	0	796	1732
Off-the-shelf	Net Zero 2050 (REMIND)	221	2.96%	100%	98%	41%	38%	10	209	562
Off-the-shelf	Current policy (REMIND) (Med)	190	2.44%	73%	79%	28%	29%	10	7	7
Off-the-shelf	IPR (Forecast Policy Scenario)			100%	91%			14	80	144
	Probability weighted mean	206	2.66%	86%	82%	30%	29%	6	133	316
	Paris Alignment (probability weighted)	227	3.01%	96%	97%	39%	36%	8	261	656

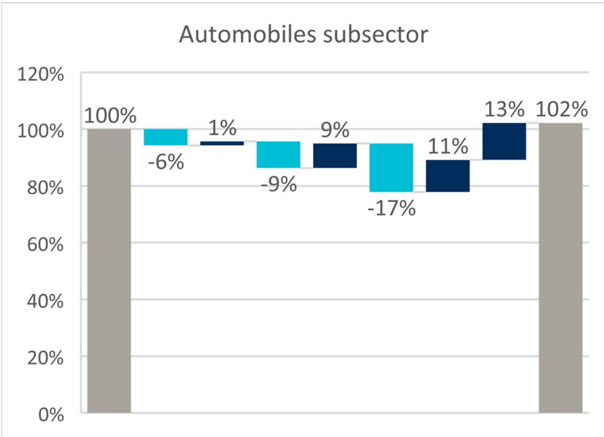
* The IPR scenario isn't included in the PW scenarios

Source: NGFS (2022), abrdn, Planetrics, October 2022

Figure A2: Valuation impacts by channel for the energy, materials and automobile sectors.







Mean scenario. Source: abrdn,, October 2022

The Energy sector is mainly affected by demand destruction, and by direct carbon costs. Non energy material sector impacts are driven primarily by carbon costs, most of the negative impairment is passed onto customers. The Automobiles subsector enjoys a positive uplift due to demand creation for EVs. There is also tangible abatement potential for transitioning to EVs.

Update to our bespoke scenarios and probabilities across time

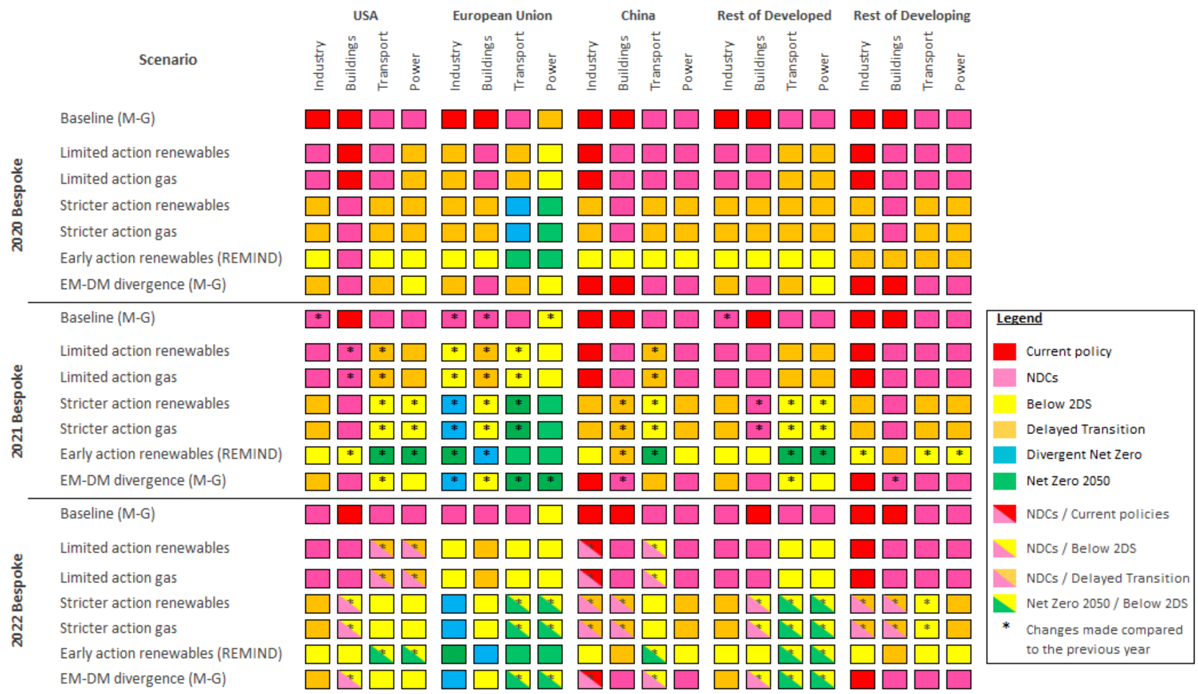
Baseline scenario: we have assessed that the market was pricing in a faster energy transition in 2021 than in 2020. We upgraded the industrial sector from current policy to NDCs for the US, the EU, and the rest of developed countries. We also raised the outlook for building and power sectors for the EU in the baseline scenario. This reflected the way that both energy system modellers, and markets themselves, re-appraised the outlook for renewable technologies.

Bespoke scenarios: In 2021, the ranking of sectors in terms of their likelihood of completing the zero-carbon energy transition was maintained. But the outlook for the transportation sector moved closer to the power sector than the industrial and buildings sectors. Renewable developments have shaped the transportation sector, our more optimistic assessment of how quickly the cost of EVs will fall below that of internal combustion engine (ICE)-powered vehicles leads to Electric vehicle (EV) penetration of 86% by 2050 in the mean scenario, 20ppts higher than in 2020. At the region level, we have considered that the US would no longer lag behind the other developed economies, and that China would decarbonise more quickly than other emerging markets (Table A.2)

Between 2021 and 2022 we moved most of the ambitious Net Zero 2050 policies to the blended Net Zero 2050 / Below 2DS, we considered less likely that governments would undertake the needed measures on the short term that would enable regions to reach net zero by 2050.

For the US, we moved from Delayed to the blended NDCs / Delayed pathway in the limited action transport and power sectors. It factors our view of more immediate policy in the short term, but that would become less stringent than in the delayed transition net-zero scenario over the longer term. For China we considered more ambitious policy for Industry.

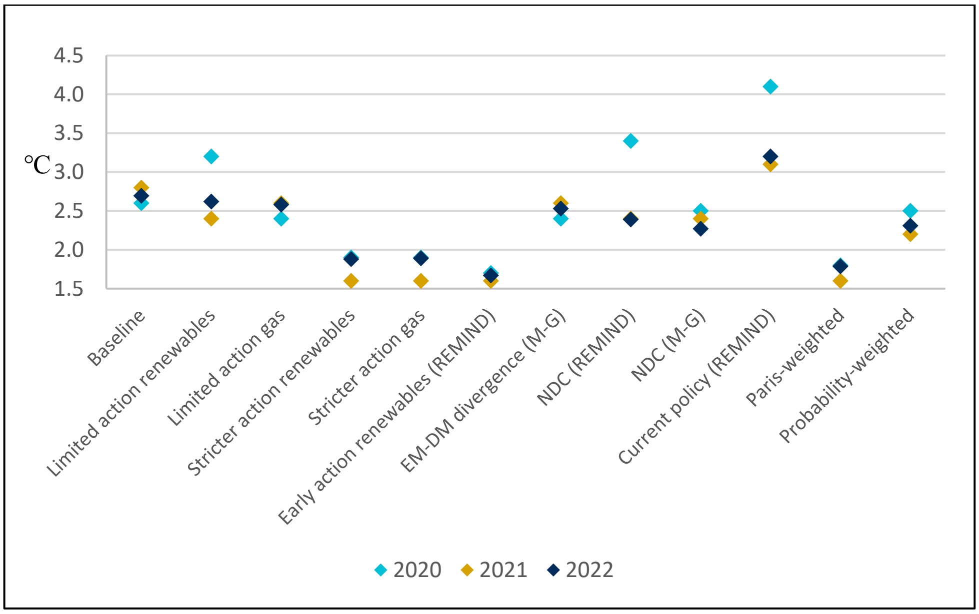
Table A2: Bespoke scenarios in our 2022, 2021 and 2022 exercises



Source: abrdn, Planetrics, October 2022

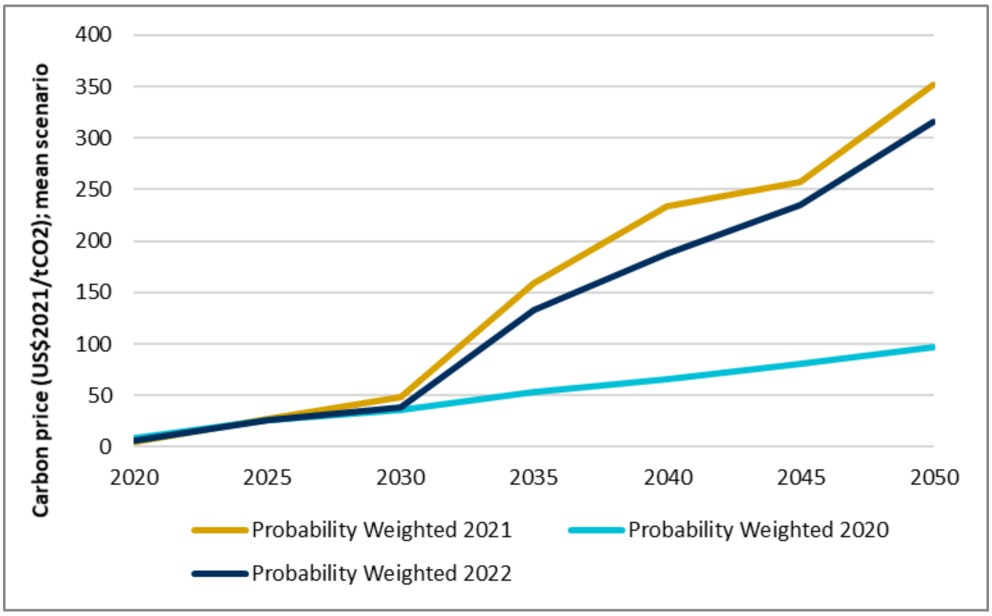
We have attached higher probabilities to stronger climate action scenarios that limit temperature increase to below 2°C (Figures 5). The scenario revisions have also manifested more modest levels of global warming after 2020 (Figure A.3). The tail-risk current policy scenario projected an increase of 4.1°C by 2100 in our 2020 analysis versus 3.2°C in 2022. The limited action renewables model scenario that assumed higher demand (especially on fossil fuels) in 2020 was predicted to reach 3.2°C, versus 2.6°C in 2022. The use of blended scenarios resulted in higher (but still aligned with the Paris Agreement) global warming in the 2022 stricter action scenarios. This element cascaded into higher warming in the probability-weighted scenario and contributed to concentrate the temperature change distribution (Figure 5).

Figure A3: Projected temperature increase associated with our climate scenarios



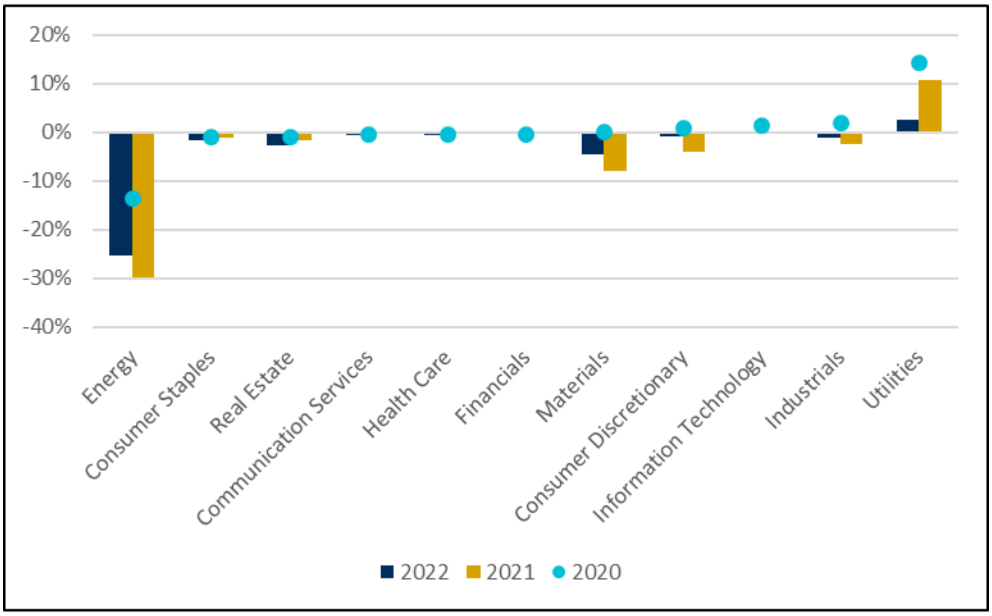
Source: abrdn, Planetrics. October 2022

Figure A4: Global carbon price projection across our exercises



Source: abrdn,, Planetrics. October 2022

Figure A5: Valuation impact by sector in the mean scenario across our exercises



Source: NGFS (2021), abrdn, October 2022