Climate scenarios

What they are, why they are important, and how they are applied to investment portfolios

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In brief

- Climate analytics initially focused on carbon emissions metrics[1] such as carbon footprint and carbon intensity. While carbon emissions metrics can help understand where a company currently stands on its emissions profile, these backward-looking metrics that are often lagged by one to two years provide only limited insights into a company's exposures to climate risks. To understand a company's exposures to climate risks, climate scenario analysis can provide further insights.
- Given the multitude of climate scenarios that are available, it is crucial that investors understand how scenarios are constructed, the uncertainties that are inherent in climate model design, and the associated implications for the results of a climate scenario analysis.

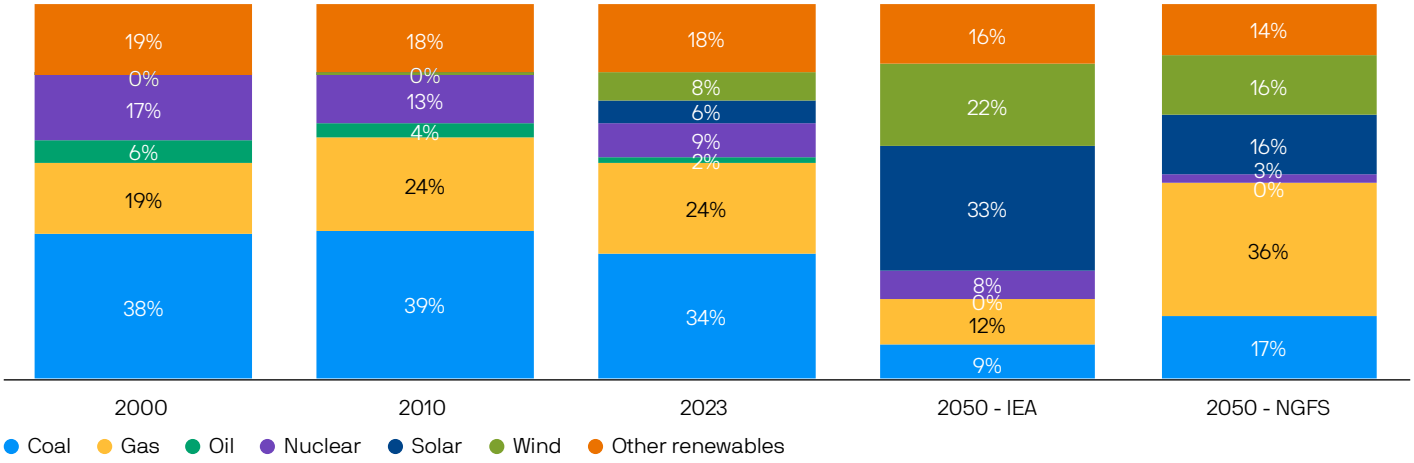
What are Climate Scenarios?

Climate scenario analysis is a process to help organizations consider how the future might look if certain trends continue or certain conditions are met with respect to the climate.[2] Climate scenarios analysis is generally done by running simulations of plausible climate futures, based on a set of assumptions on the economy and its interaction with the climate. These simulations produce climate and economic outputs such as global GHG emissions, GDP and energy demand given specific assumptions. (**Exhibit 1**) gives an example of electricity generation fuel mix at 2050 under two different climate scenarios.

Scenario analysis has been used for planning purposes for decades by companies and researchers. Climate scenarios were initially developed by the energy sector and NGOs such as the IEA amid the oil price shocks of the 1970s to test business plans against different climate 'futures'. The academic world developed their own climate models to assess climate change impacts through institutions such as the IPCC in 1988. In the financial sector, climate scenarios were first popularized in 2017 with the TCFD framework.

[1] "Understanding Carbon Metrics", J.P. Morgan (June 2023).
[2] https://www.fsb-tcfd.org/recommendations/

Exhibit 1: Electricity generation fuel mix in 'stated policy' climate scenarios

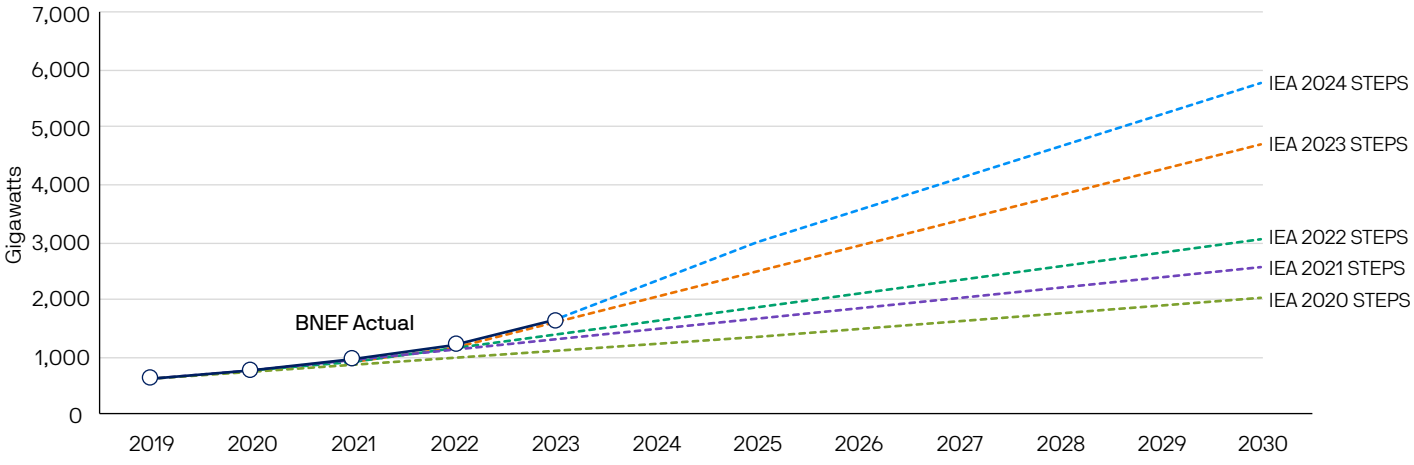


Source: BNEF, Internation Energy Agency (STEPS), Network for Greening the Financial System State Policies

Are climate scenarios forecasts?

While climate scenarios provide a view of possible futures, they are not forecasts. Forecasts are focused on what will likely happen, with some level of confidence and shorter forecast horizons. Climate scenarios on the other hand explore a range of plausible climate outcomes without assigning probabilities to each scenario. Climate scenarios generally have much longer forecast horizons, often focused on modelling out to 2050 or 2100, and have a much higher level of uncertainty. Technologies and policy are continuously evolving, and as such climate scenarios often face criticism for underestimating trends, such as the rapidly increasing solar power capacity additions over time as seen in (**Exhibit 2**). The most recent IEA 2024 STEPS scenarios notably made a significant upward revision from their prior solar power pathways projecting 5800 GW of installed solar capacity by 2030, compared to the IEA 2022 STEPS scenario which had significantly less solar capacity of 3000 GW by 2030.

Exhibit 2: IEA has historically underestimated the speed of growth for solar power in its climate scenarios

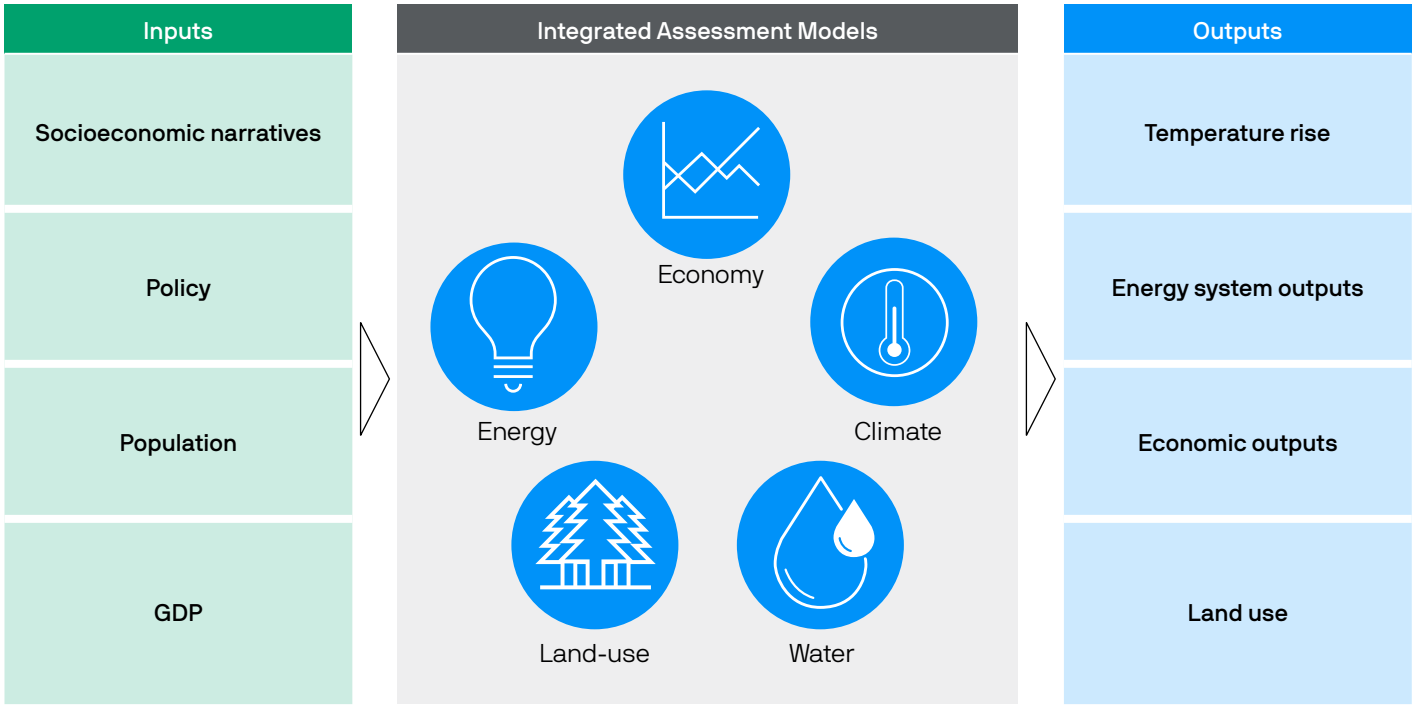


Source: IEA, BNEF.

How are climate scenarios structured?

Climate scenarios are typically developed using a variety of specialized models, representing different elements of social, economic and natural systems. These models can be combined into integrated assessment models (IAMs) that analyze how different socioeconomic trends may interact with climate factors over time. Integrated assessment models require a set of socioeconomic inputs and narrative assumptions in order to generate pathways for climate and economic scenario variables, as shown in (**Exhibit 3**) below.

Exhibit 3: Integrated Assessment Models combine models from different disciplines into a cohesive framework



Source: J.P. Morgan Asset Management.

While IAMs vary in their exact design, they tend to rely on two common inputs: Shared Socioeconomic Pathways and Representative Concentration Pathways.

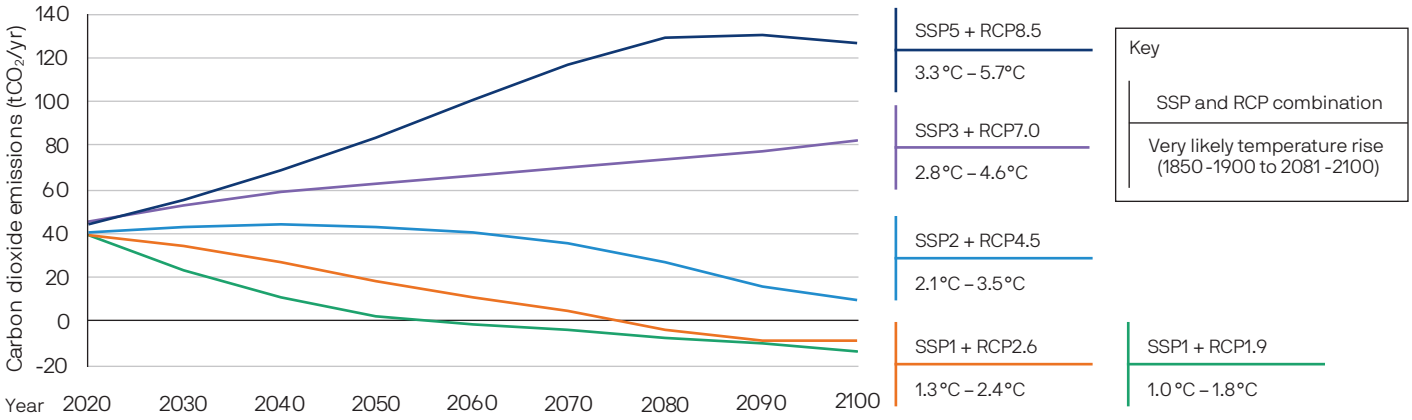
Representative Concentration Pathways (RCP) model possible greenhouse gas (GHG) concentration trajectories and ultimately their warming over the course of the 21st century (**Exhibit 4**). RCP pathways purposefully do not include any socioeconomic narratives.

Shared Socioeconomic Pathways (SSPs), on the other hand, describe the future in terms of broad economic, demographic and policy trends to enable easy comparison.[3] They set the socioeconomic narrative to complement the GHG concentration trajectories of the RCPs. In total, there are five commonly used SSPs, with the sustainable and inclusive pathway (SSP1) and fossil-fuel development pathway (SSP5) as two extremes (**Exhibit 4**).

[3] Riahi et al., The Shared Socioeconomic Pathways and Their Energy, Land Use, and Greenhouse Gas Emissions Implications: An Overview, Global Environmental Change, 42, pp. 153-168, 2017.

Exhibit 4: Summary of SSP storylines, RCP emissions trends and temperature outcomes

	Name	Description
SSP1	Sustainable pathway	A gradual transition to an environmentally friendly future with an emphasis on inclusive development
SSP2	Middle of the road	A continuation of current trends where environmental concerns are addressed at a slow pace and progress towards achieving wider Sustainable Development Goals is limited
SSP3	Regional rivalry	A world where both mitigation and adaptation challenges are high
SSP4	Inequality areas	A world with highly unequal investments and economic opportunity, with a focus on local issues in higher income
SSP5	Fossil fuel development	Continued use of fossil fuels and resource intensive lifestyles with a focus on the ability for competitive markets and innovation to address sustainable development
	Emissions trend	
RCP1.9	Emissions decrease immediately and become negative by the middle of the century	
RCP2.6	Emissions reduce from ~2020 and usually become negative after 2080	
RCP4.5	Emissions start declining from the middle of the century and tend to stabilise from 2080	
RCP8.5	Emissions increase rapidly until around 2080 when they level off	



Source: J.P. Morgan Asset Management, IPCC.

(**Exhibit 4**) above shows the SSP and RCP combinations that are commonly used to provide a set of comparable outputs. The range in temperatures results from the different temperature outcomes from the many IAMs used to run each combination.[4,5,6,7]

How are climate scenarios applied across key stakeholders?

Climate scenarios are key inputs into models that seek to answer two broad questions around the double materiality of climate change.

1) Financial materiality: what is the financial impact of climate change on a company? How much would it cost a company to decarbonize its operations? Is the company poised to benefit from increased demand from low-carbon products? From a physical risks perspective, how will the company be impacted by losses during extreme climate events?

2) Impact materiality: what is the company's impact on climate change? And how can we assess a company's ambition to mitigate their impact on the climate?

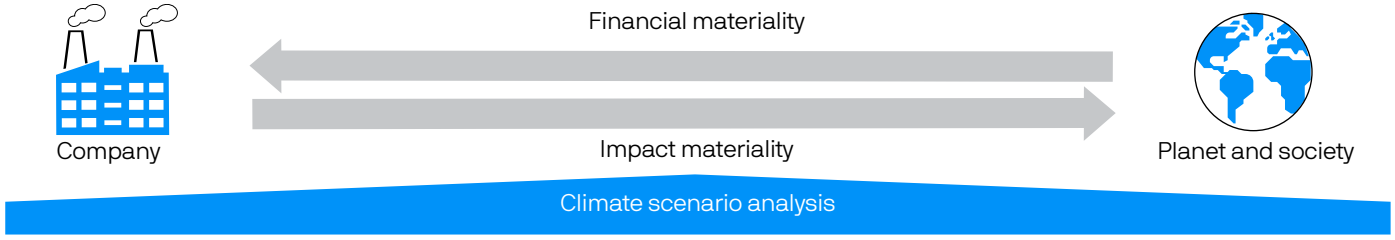
[4] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

[5] van Vuuren, D.P., Edmonds, J., Kainuma, M. et al. The Representative Concentration Pathways: An Overview. Climatic Change 109, 5 (2011). https://doi.org/10.1007/s10584-011-0148-z

[6] Lee, J.-Y et al. 2021: Future Global Climate: Scenario-Based Projections and Near-Term Information. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 553–672, doi:10.1017/9781009157896.006.

[7] Data from IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press.

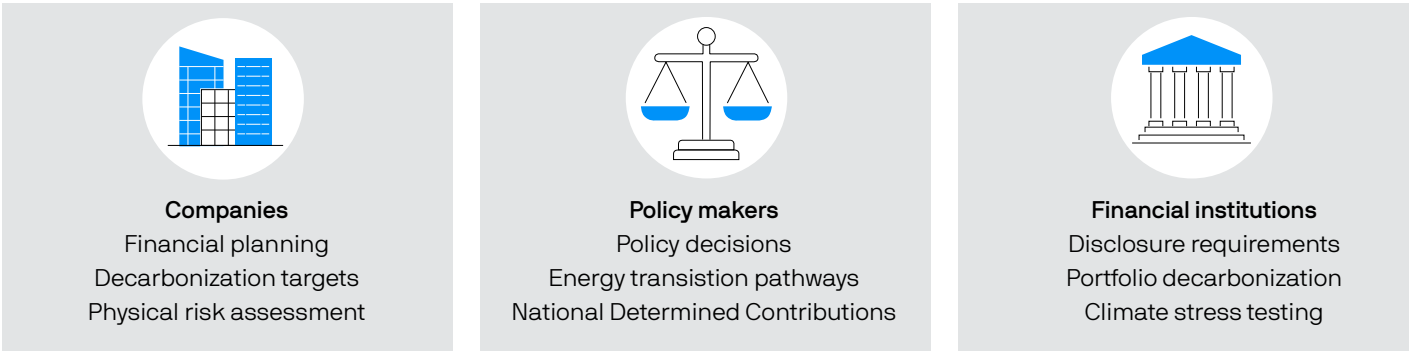
Exhibit 5: The double materiality of climate change



Source: J.P. Morgan Asset Management

Climate scenarios can be applied across several use cases. For instance, corporates may use climate scenarios for business planning or physical risk assessments. Policymakers may use climate scenarios to inform policy decisions, and set national decarbonization objectives. Financial institutions use them to comply with disclosure requirements, as well as stress testing and portfolio alignment objectives.

Exhibit 6: Climate scenario use-cases by key stakeholder groups



Source: Network for Greening the Financial System, BNEF, J.P. Morgan Asset Management.

Regulation also increasingly mandates the disclosure of climate-related financial risks and opportunities. For instance, the EU's Corporate Sustainable Reporting Directive (CSRD) and IFRS S2 standards will require certain companies to disclose on climate-related risks and opportunities. In addition, CSRD requires additional disclosures of the impact that a company is expected to have on the climate. In the UK, the scope of companies subject to climate-related financial disclosures is also increasing and covers, among others, large companies, listed companies and FCA regulated entities, including asset managers. Similar climate disclosure requirements exist from Hong Kong's Securities and Futures Commission (SFC). These disclosure rules may contain provisions on or encourage the disclosure of climate-scenario analysis information. As regulators increasingly require companies and asset managers to disclose climate-related risks and climate impacts, we can expect increased focus on this area.

Which climate scenarios are most popular among financial institutions?

A multitude of climate scenarios have been developed by different organizations over the years.[8] Among the most widely used by the financial sector are the climate scenarios published by the Network for Greening the Financial System (NGFS), the International Energy Agency (IEA) and the Intergovernmental Panel for Climate Change (IPCC) as shown in (**Exhibit 7**) below.

[8] The Intergovernmental Panel on Climate Change (IPCC), led by its Working Group III, has undertaken an extensive effort to review and compile a database of over 3,000 quantitative climate scenarios. AR6 Scenario Explorer and Scenarios Database hosted by IIASA, accessible here: https://data.ene.iiasa.ac.at/ar6

Exhibit 7: Comparison of key climate scenario providers

		IEA	NGFS	IPCC
Scenarios	> 3°C	–	• Current Policies	• SSP5-8.5
	2-3°C	• Stated Economic Policies Scenario (STEPS) • Announced Pledges Scenario (APS)	• National Determined Contributions	• SSP2-4.5
	< 2°C	• Net Zero Emissions by 2050	• Net Zero 2050 • Below 2c • Delayed Transition	• SSP1-2.6
Key users		• Companies • Investors	• Central banks • Banking and insurance sector	• Policymakers • Academic institutions
Granularity		• Focus on emissions from energy systems	• Covers emissions from all sources including land-use	
Most recent update		World Energy Outlook (2024)	Phase V scenarios (2024)	Assessment Report 6 (2023)

Source: IEA, NGFS, IPCC.

NGFS scenarios are particularly popular with central banks to stress test the banking sector's lending portfolios. The NGFS has developed different groups of scenarios that describe a range of potential futures. For example, the NGFS orderly scenarios assume a timely and coordinated introduction of climate policies that consequently limit both climate-related physical risks and transition risks, such as the need for stringent climate policies and regulations later in the century. On the other hand, the NGFS disorderly scenarios assume that there is delayed or uncoordinated policy action across sectors and/or regions. For example, the delayed transition scenario considers the impact of waiting to implement policies required to mitigate climate change to well below 2°C until around 2030, resulting in overall higher stringency – for example, of carbon prices – over the following decades.

The IEA publishes several climate scenarios as part of its annual World Energy Outlook, which are widely used by both companies and investors. The IEA scenarios vary in their ambition and stringency, from business as usual under the current policy landscape in the Stated Policies Scenario (STEPS), to a net zero world under the Net Zero Emissions (NZE) scenario.

The scenarios provided by the NGFS and IEA can be roughly mapped to one another, but investors undertaking climate scenario analysis will likely choose one scenario group over the other, based on the needs of their analysis. The IEA scenarios have been developed with qualitative storylines in mind, making it easier for investors to understand how and why changes occur, and to interpret results. Many asset managers have used IEA scenarios for their own analysis, meaning that outputs may be more comparable among peers. The IEA scenarios are also regularly updated, which may be preferred by users interested in better understanding the changes in the implementation and ambition gap for current policy and technology rollouts.

On the other hand, NGFS scenarios cover GHG emissions from all sources, while most IEA scenarios currently consider only CO_2 emissions from energy systems, and therefore exclude land use and other GHGs. There are also more scenarios and more models within the NGFS group, making them more useful for exploring uncertainty. Additionally, technical model documentation is freely available for the NGFS scenarios, and the models are mostly open source, allowing users to run them with bespoke inputs.

What drives uncertainty in climate scenarios?

While differences in the results are expected, as climate scenarios do not necessarily aim to give an answer about the most likely future, understanding what drives their outputs could be helpful in forming an opinion, albeit subjective, on the possibility of different outcomes. There are two key factors that can drive the divergence of climate scenario outputs: (1) the assumptions made in the scenario; and, to a lesser extent, (2) the climate scenario model type used.

1. The assumptions made in the climate scenario

As stylized versions of the future, climate scenarios make a number of assumptions about how the next few decades may play out, including around technology advancements and costs, and policy choices.

The realization that the assumptions underpinning climate scenarios can considerably affect their results is important for embracing the differences and uncertainty around the outputs these models generate. For example, scenarios might differ in the importance they attribute to specific technology solutions that are yet to be proven at scale, such as carbon capture and storage (CCS), and bioenergy with carbon capture and storage (BECCS). As a result, the climate scenarios that rely less on nascent technologies and more on the solutions that already exist could be considered by some users more likely.

Climate scenarios can also vary in their assumptions around the acceptability of a reliance on nuclear power or natural gas[9] – again, something that could be considered less or more probable by some users, given their beliefs about how the future might play out. As an illustration, the IEA's Net Zero Emissions Scenario differs from the scenarios included in the IPCC's Special Report, "Global Warming of 1.5°C", across multiple fronts, including, lower use of fossil fuels and limited reliance on CCS.

Furthermore, scenarios can vary substantially in their assumptions about the overall timing and ambition of a climate action, and the resulting peaks and reductions in emissions across geographies and sectors. Typically, the models that focus on a long-term end-century temperature and emissions target, without imposing a medium-term cap on emissions, see an emissions overshoot in the meantime, and therefore tend to rely more heavily on carbon dioxide removal solutions later in the century.[10] At the same time, the scenarios that include an explicit global warming cap throughout the century might be better at managing inter-generational trade-offs.

2. The climate scenario model type used

The other key factor that can affect the results of climate scenario outputs, even under similar assumptions, is the type of model used in the analysis (its structure and algorithm). Climate models vary across a number of characteristics,[11] ranging from optimization to simulation models, from myopic to perfect foresight models, and from general to partial equilibrium. That said, the differences stemming from the choice of a climate model could arguably be smaller compared to the impact of using divergent model assumptions.[12]

How can investors use climate scenarios to assess a company's impact on the climate?

To assess a company's impact on the climate, one can apply climate scenarios using methodologies such as Implied Temperature Rise (ITR). ITR metrics are a type of portfolio alignment tool that provides a simplified output to ease the comparison of policy outcomes. These metrics can help answer questions on company and portfolio alignment, such as: "are these company's emissions within their boundaries for a given climate scenario?". This is an example metric that is often reported for the UK's FCA climate disclosure requirements.

[9] Weber, C. et al. Mitigation Scenarios Must Cater to New Users, Nature Climate Change, 8(10), pp. 845–848 (2018) doi: 1038/s41558-018-0293-8. Thimet, P. J. and Mavromatidis, G. Review of Model-Based Electricity System Transition Scenarios: An Analysis for Switzerland, Germany, France, and Italy, Renewable and Sustainable Energy Reviews, 159 (2022).

[10] Rogelj, J. et al. A New Scenario Logic for the Paris Agreement Long-Term Temperature Goal, Nature 573(7774), pp.357–363 (2019) doi: 10.1038/s41586-019-1541-4.

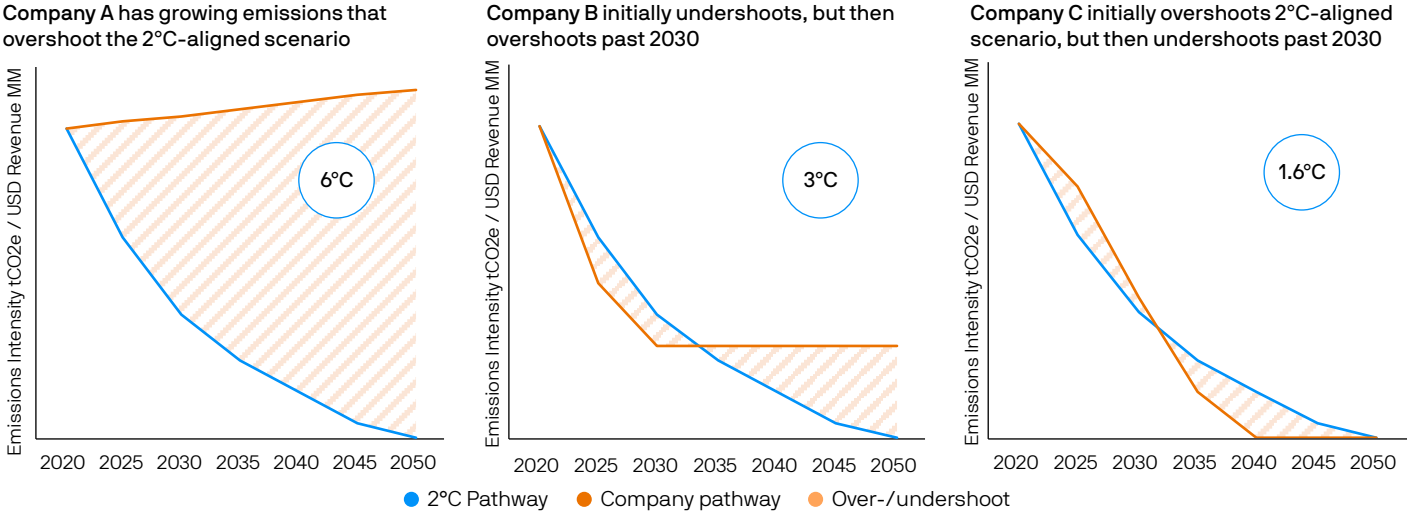
[11] IPCC Sixth Assessment Report, Mitigation of Climate Change, 2022.

[12] Pindyck, R. S. The Use and Misuse of Models for Climate Policy, Review of Environmental Economics and Policy, 11(1), pp. 100–114 (2017) doi: 10.1093/reep/rew012.

A company-level ITR is typically calculated by considering how much the total emissions of a company overshoot or undershoot the total emissions that the company is allowed to emit under a particular scenario, such as a 1.5°C net zero pathway. This emissions allowance pathway is usually referred to as the benchmark. Tools will often include company-level emissions reduction targets, and they will usually make the assumption that these targets are met. For companies without emissions reduction targets, methodologies tend to use either a default value based on an expectation of current policy outcomes (for example, 2.7°C) or an emissions projection based on historical trends.

Exhibit 8 below provides an illustrative example of the ITR metric for three example companies.

Exhibit 8: Illustrative example of an ITR estimate for three companies



Source: J.P. Morgan Asset Management. For illustrative purposes only.

In (**Exhibit 8**) above, company A has no decarbonization targets in place, and is expected to grow their emissions in line with their growing production. Their emissions pathway overshoots the 2°C-aligned pathway, resulting in a high ITR. Company B, on the other hand, has an ambitious decarbonization plan in place up until 2030, whereby it undershoots the 2°C-aligned pathway. However company B has no long-term targets in place, and is expected to hold emissions relatively flat, leading to an overall overshoot and an ITR that is not aligned with a below 2C scenario. Company C initially overshoots its 2°C-aligned pathway, but then accelerates its pace of decarbonization leading to an undershoot post 2030, and an ITR that is below 2°C.

How can investors measure the financial impact of climate change on a company using climate scenarios?

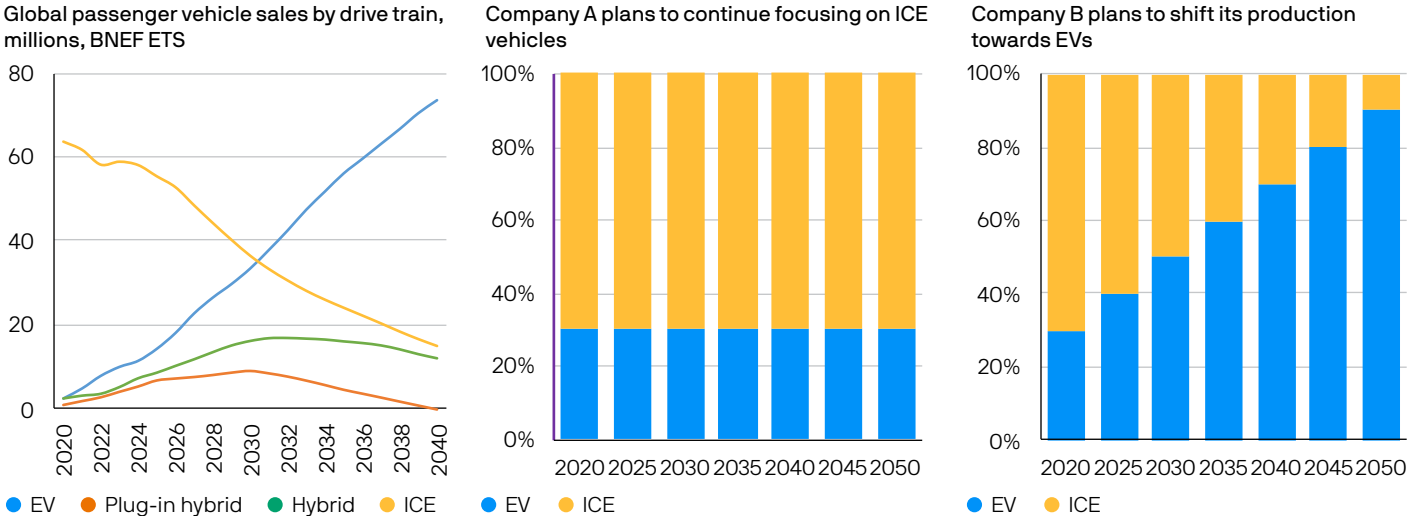
Similar to financial scenario analysis, climate scenario analysis can help give ranges of how the market value of a portfolio, and the companies within it, may change over time under a given climate scenario. Climate risk analysis combine financial models with climate scenarios to produce forward-looking estimates. The output from different scenarios can be compared to develop an understanding of how companies could fare under different assumptions. The output for a scenario may be provided relative to the present day or to a baseline where there are no further changes in climate-related policies or physical risk.

Users often consider a set of scenarios that focus on high physical risk, high transition risk and what they deem to be the most likely scenario. This multi-scenario approach can help users to better understand the range in uncertainty within the models and the scenarios, as well as identify emerging trends in climate-related risks or opportunities.

(**Exhibit 8**) illustrates some of the inputs that may be used in climate risk analysis. The left panel shows climate scenarios for the passenger vehicle industry out to 2050 using BNEF's Economic Transition Scenario (ETS). The right two panels present company-level business plans for two illustrative companies. Company A's strategy is to continue manufacturing internal combustion engine vehicles (ICE) in the same proportion going forward, while company B intends to increase its production mix of electric vehicles.

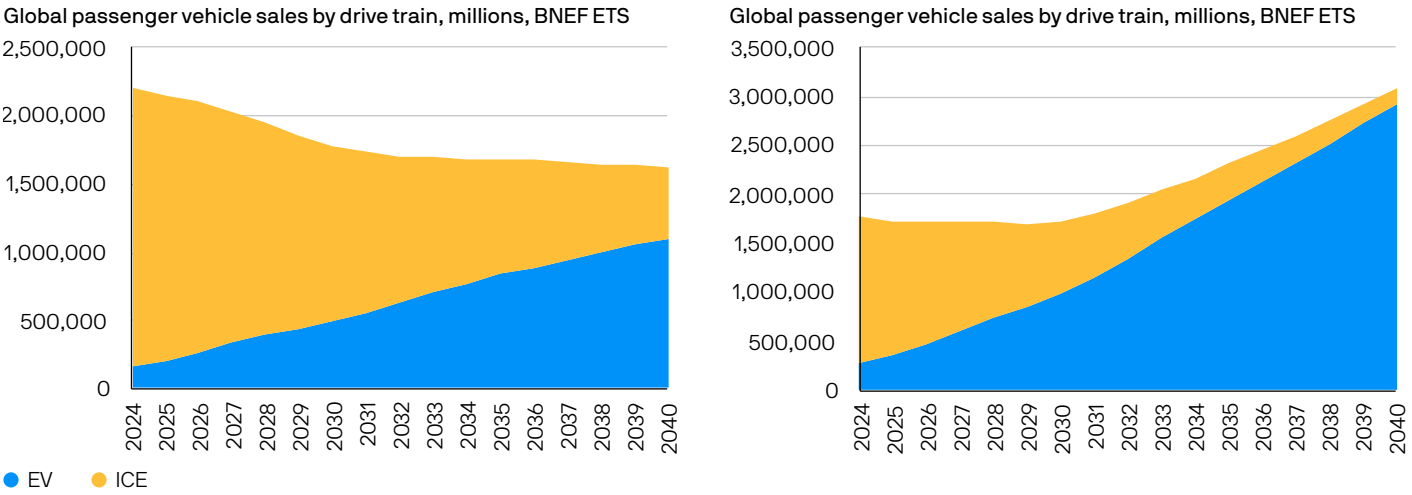
Assuming company A and B's market shared for each market (EV market share, ICE market share) remain constant, this could imply that sales for ICE vehicles for company A would fall more significantly as a proportion of overall revenues, compared to company B. And company A would be less well positioned to benefit from the surge in EV demand than company B as can be seen in (**Exhibit 9**) below.

Exhibit 9: Climate scenarios for passenger vehicle market



Source: BNEF, J. P, Morgan Asset Management, for illustration only.

Exhibit 10: Company A's business plans capture a larger sales volume due to growth in EV market under BNEF ETS scenario



Source: J.P. Morgan Asset Management, for illustration only.

What are the key challenges for investors looking to use climate scenarios?

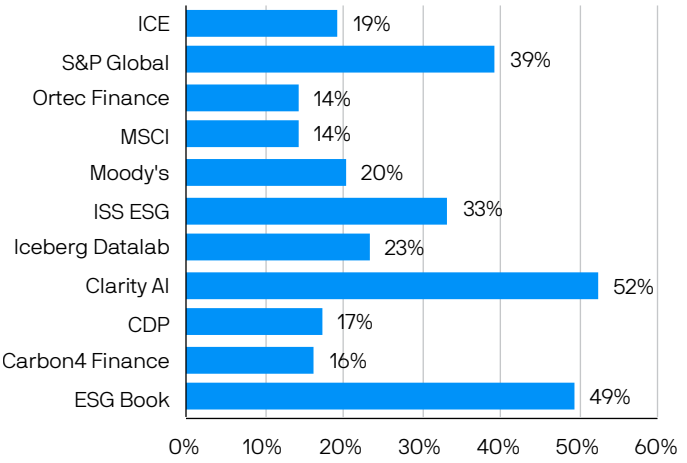
Because climate scenario models were originally designed with the policy and planning communities in mind, the scenarios require adjustments to serve the needs of business use cases.[13] One of the key challenges is the fact that policy makers and the private sector operate at different time horizons. While climate scenario models project temperature trajectories decades into the future, investment cycles are significantly shorter.

The "off-the-shelf" climate scenarios might also not always offer the granularity needed for investment decisions (for example, at the sector, market or issuer level). There is often additional work involved for climate scenario users to refine the assumptions made by the readily available scenarios and to break down the scenario outputs to a level required for decision making.

There is a lack of consistency in climate scenario data among vendors. While climate scenarios from data vendors can be useful, the proprietary methodologies used can lack consistency and transparency across providers. A study of climate scenarios vendors conducted by the IIGCC in 2022 found a wide range of estimates for the same portfolio, indicating a lack of consistency across vendors, shown in (**Exhibit 11**).

However, by developing a good understanding of the assumptions, limitations and uncertainties of the underlying scenarios, and the metric and data estimation methodologies applied, users can be better equipped to understand, interpret and use the outputs.

Exhibit 11. IIGCC found a lack in conformity of vendor's assessment of companies' conformance with Paris-Aligned climate scenarios in sample portfolio



Source: IIGCC.

Conclusion

Regulators have increasingly been requiring climate risk disclosures for companies and financial institutions. A range of scenarios and tools have been developed for the specific purpose of better quantifying the interaction between climate change and companies. Having a good understanding of the assumptions used in climate models, including their limitations and uncertainties, is important when interpreting outputs from these types of analyses. Over time, the available tools and data are expected to increase in both quality and quantity. By starting to use the existing tools, users can be best positioned to enhance their capabilities and incorporate these new developments.

[13] The Task Force on Climate-Related Financial Disclosures outlines the journey of developing scenario analysis capabilities: https://www.tcfdhub.org/scenario-analysis/

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