Demystifying Climate Transition Scenarios

July 2022

Introduction

This report is a collaboration between PwC UK and WBCSD presenting some of the learnings from the project management team for the WBCSD Climate Scenario Analysis Reference Approach project. The Climate Reference Scenarios Project focused on developing an approach to climate transition scenario analysis for use by companies in the energy system. This included the development of an online Climate Scenario Catalogue, a platform that contains information from selected public scenarios and additional business relevant scenarios. The Catalogue allows users to explore the scenarios and variables within it and allows for comparison and analysis across time horizons.

This document is intended to provide introductory information and educational material about climate transition scenarios which all individuals can read. While some readers will have used the scenario Catalogue, familiarity with the Catalogue is not necessary to understand this document.

This work builds on the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD). For more information about these processes, please see:

- Task Force on Climate-related Financial Disclosures[1]
- TCFD: The Use of Scenario Analysis in Disclosure of Climate-related Risks and Opportunities[2]
- TCFD: Guidance on Scenario Analysis for Non-Financial Companies[3]
- WBCSD Climate Scenario Analysis Reference Approach for Companies in the Energy System[4]

This document aims to provide:

- An overview of the process through which climate scenarios are quantified using models.
- The tools to be able to interpret the assumptions and modeling methods that form standard climate scenarios.
- Foundation level of knowledge on climate transition scenarios, which readers can build upon through further reading and research.

This document highlights some of the key aspects of climate models that can affect the results:

- The underlying assumptions of the climate scenarios that characterise pathways to a temperature target (page 4).
- The core modeling methodology used to quantify the climate scenarios (page 9-10).
- How a combination of these factors can describe the same temperature outcome but show a different trend (page 16-17).

Further information around climate scenarios and modeling can be found below:

- Carbon Brief, Q&A: how IAMs are used to study climate change
- Carbon Brief, Explainer: how SSPs explore future climate change
- Cicero & UNEP FI, Pathways to Paris: a practical guide to climate transition scenarios for financial professionals
- Climate Analytics, IAMs: what are they and how do they arrive at their conclusions?

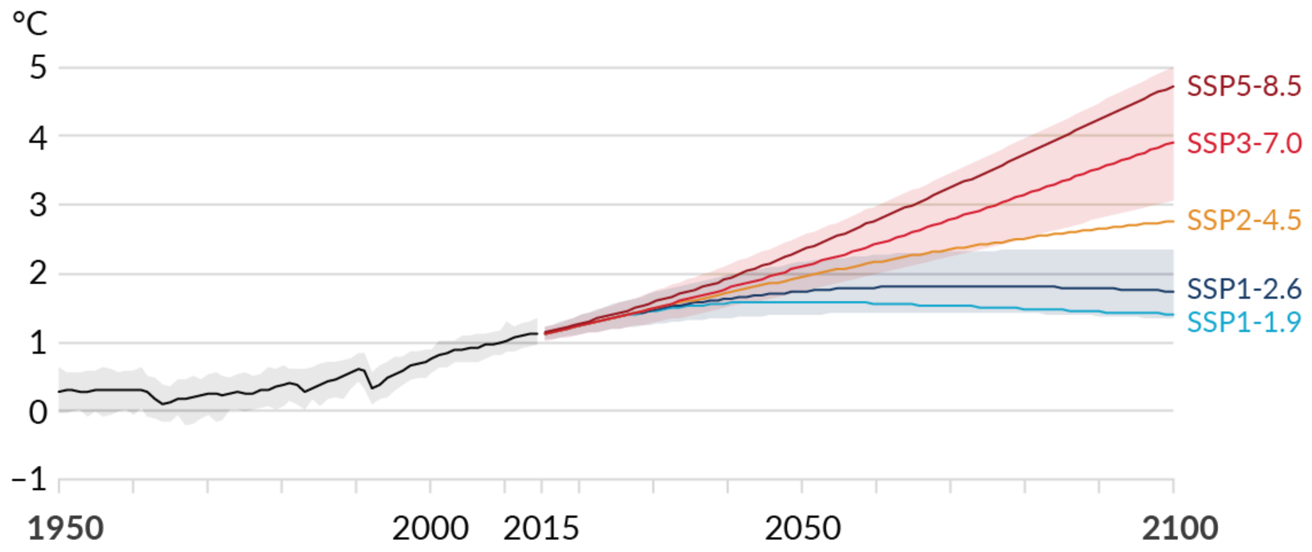
What are climate scenarios?

TCFD definition: "A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships."

A climate scenario can be seen as a narrative that describes a potential pathway the future could take towards a certain climate outcome. For example, the figure to the right shows the differing temperature pathways across the IPCC's climate scenarios.

Climate scenarios are a plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g. rate of technological change, prices) and relationships. They allow users to analyze a diverse range of possibilities in order to assess possible actions, decisions, strategies, and investments. Climate scenarios assess the consequences of different levels of climate policy, technological and societal action at different speeds, and impacts of short and long time horizons. There are many factors incorporated into climate scenario development and many to consider when analysing their outputs.

The users of climate scenarios can be businesses, investors, researchers, policy-makers, regulators and many more, each of whom will have different goals for what they are hoping to gain from the scenario analysis process. Further detail on how climate scenarios can be used appears later in this document.



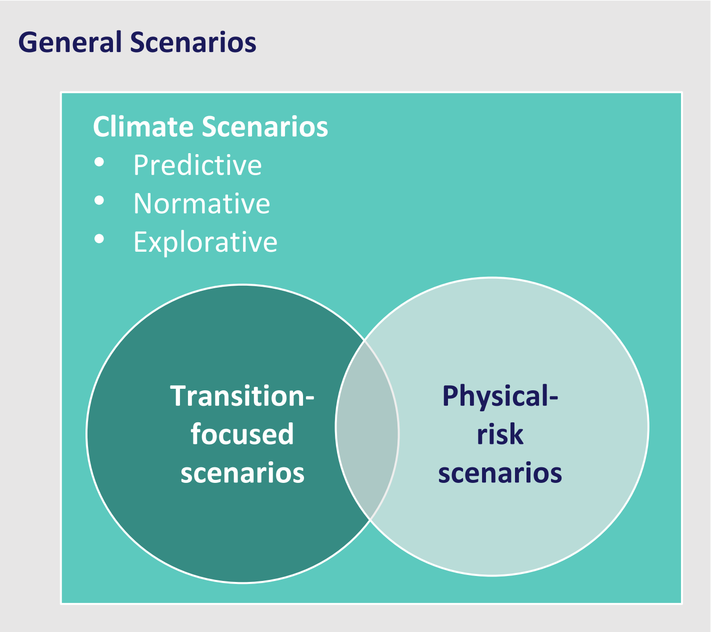
Source: Sixth Assessment Report of IPCC Working Group I, 2021[5]

What are climate scenarios?

When analyzing climate scenarios, transition risks and opportunities are usually considered separately from physical risks. This document focuses on transition scenarios.

- **Transition-focused scenarios** look at the technological, political, legal, market and economic changes required to reach a certain pathway, and the associated risks and opportunities. Hence, these scenarios can aid in the analysis of the impacts which may arise from a transition, such as to a low carbon economy.
- **Physical-risk scenarios** are focused on the physical impacts due to climate change such as extreme weather events.

Certain scenario providers will provide scenarios for both physical and transition risk and opportunity analysis; hence there can be overlap between the two in some cases (e.g. IPCC, NGFS, and IEA provide both physical and transition scenarios).



Climate scenarios are a subset of scenarios in general (subsets include economic scenarios, policy scenarios and others) of which there are many different types. These **different types of scenarios** allow us to focus on different elements of scenario analysis.

- Some scenarios aim to predict what the most likely outcome will be (**"Predictive"** scenarios), using modeling and trend analysis to make assumptions about the future. An example of this within climate scenarios would be a scenario forecasting policy decisions going forward or those based on current or pledged policies.
- Other scenarios work around how a specific objective could be achieved (sometimes called **"Normative"** scenarios), such as any scenarios looking at how we can limit warming to 1.5°C or achieve net zero by a certain date.
- Finally, some scenarios explore how certain external factors may impact the future (**"Explorative"** scenarios), such as limiting the use of certain technologies and seeing what would happen as a result.

Reference: "Scenario types and techniques: Towards a User's Guide" Futures 38 (2006) Lena Borjeson, Mattias Hojer, Karl-Henrik Dreborg, Tomas Ekvall, Goran Finnveden[6]

What are common climate scenario storylines?

There are a growing number of organizations that are producing climate scenarios. These scenarios provide a range of storylines, each with certain characteristics.

Some of the most commonly referenced scenarios were developed by IPCC as part of their assessment reports. However, these scenarios only represent a fraction of the universe of scenarios that have been developed in recent years. Scenarios are developed by many institutions (including businesses, academics, think tanks, and many more) for a wide variety of reasons. However, the majority of scenarios follow broadly similar storylines.

A summary of some common storylines used by scenario developers is shown in the table across. Each of these scenarios will have a different emphasis, different assumptions, and different outcomes representing a range of possible futures.

Story Summary	Paris Ambitious Action	Delayed Action	Current National Commitments	Business as Usual
Transition Story Emphasis	Paris Agreement aligned, with steep, sustained annual emissions reductions	Limited climate action for a decade and a half then steep decarbonization trajectory following crisis	Decarbonization trends based on pledged national commitments and international policies	Follows existing trends & activities, current policies type
Socio-economic assumptions	International effort to align to Paris Agreement	Social turmoil, late action in society	Some societal shift toward decarbonization	No significant societal or economic changes to activity
Temperature Outcome by 2100	1.5°C	Can hit 2°C but often including high use of negative emissions tech	Approximately 2-3°C	Often 3°C rise or above

What are the different purposes of climate scenarios?

There are many climate scenarios available, each with a different purpose in mind by the developer.

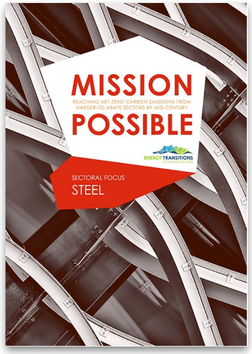
For many climate scenarios, the purpose of their development was to inform policy decisions at a global level. These scenarios were often developed by academics (e.g. within the IPCC), to provide potential outcomes and pathways for policymakers and other academics. The granularity of climate scenarios has improved with time into providing more sector-specific and regional granularity. However, one scenario cannot answer all of questions that each user may have. Therefore, different scenario developers can develop scenarios with other purposes in mind.

For example, some models quantifying climate scenario storylines are designed to inform decision makers about the optimal pathways for specific aspects of decarbonization, such as technology development. Others may look to inform decision making with company objectives in mind such as internal scenarios developed by business for their own analysis.

Depending on the focus of the scenarios being used, models will differ in their level of complexity. For example, scenarios focusing primarily on the energy system will need to be applied to models that have a complex energy module within them and may have a simpler representation of land use. This balancing of the complexity of the modules is often based on the amount of computing power needed to run the model, with a trade-off found between the necessary detail and granularity and the running time.

Some scenarios choose not to produce a global-scale scenario in order to focus on a particular sector or region. These scenarios are often developed from a bottom-up rather than a top-down perspective, considering what may be feasible within a certain sector or region. These sector specific scenarios and regionally specific scenarios can be used to supplement analysis alongside scenarios with a more global perspective. In this report we will not provide additional insight into sector specific and regionally specific scenarios, but some examples of regionally specific and sector specific scenarios are given across.

National Grid's Future Energy Scenarios have a regional focus on the UK[5]



Mission Possible's Sectoral focus on Steel[6]

How are climate scenarios used by business?

Climate scenarios can be used by businesses for both internal and external purposes.

Through scenario analysis, businesses can assess their business models and strategies against different possible futures and therefore better judge where work might be needed to improve business resilience. Scenario analysis is also important to meet disclosure requirements, such as the TCFD recommendations. With climate disclosures becoming mandatory in some jurisdictions, and financial market regulators introducing stress tests, scenarios are becoming more widely adopted. It is therefore important for users to understand how scenarios are developed and how to interpret their outputs based on the assumptions made by the scenario developers.

External uses of climate scenarios

- To meet disclosure requirements such as TCFD.
- To meet regulatory requirements such from the FCA, PRA and ECB.
- To meet investor needs and conversations regarding strategy and portfolio resiliency.
- To enable engagement and communication to stakeholders of how the business can evolve over time.

Internal uses of climate scenarios

- To understand strategic business resilience.
- To understand how the business could align itself to a certain goal such as to a 1.5°C pathway, to inform business decisions.
- To understand the business case for certain strategic decisions.
- To conduct sensitivity analysis to changing conditions over time.
- To manage risks and opportunities to feed into Enterprise Risk Management (ERM) frameworks.

How are climate models applied to scenarios?

The majority of climate models are produced by Integrated Assessment Models, quantifying the pathways of climate scenarios, with other modeling types also used.

Climate scenarios are the detailed narrative of assumptions, key factors, developments and pathways that define a plausible future. Climate scenario models are the quantification of these pathways and are developed using computer models that are able to analyze multiple factors, and interactions between them, that might affect the future according to the objective of or rationale behind the model and scenario. Within this development process, macroeconomic assumptions, such as population growth and GDP, combined with climate limits, such as the need to hit a 1.5°C target, are described by the climate scenario. The climate model then quantifies these assumptions and pathways (and other assumptions introduced by the modellers) to produce a modelled set of outputs. An example of a set of macroeconomic assumptions often used are the IPCC's Shared Socioeconomic Pathways (SSPs), as described to the right. The IPCC's Representative Concentration Pathways (RCPs) can serve as climate limits into models, if the aim of the model is to quantify a scenario along an RCP's greenhouse gas (GHG) emission pathway.

The majority of these models will be an Integrated Assessment Model (IAM). These are detailed models calculating energy and economic system transformation pathways. They usually provide the least-cost pathway to reaching a certain level of warming, known as cost-effectiveness IAMs.

In some cases, other modeling types are used, such as the IEA's World Energy Model (WEM) which is a techno-economic large-scale simulation model with a focus on the energy system. Energy models often use a higher level of detail to examine transition impacts on the energy system. Energy system models (often in simplified forms) can also be found within an IAM interlinked with other models.

A Spotlight on the IPCC's scenarios:

Readers may have heard reference to scenarios and tools used by the IPCC in their scenario development processes, including the **SSPs (Shared Socioeconomic Pathways)** and **RCPs (Representative Concentration Pathways).** SSPs and RCPs are critical inputs into climate models, outlining different potential macroeconomic assumptions or GHG emissions pathways. Further detail on each input is included below.

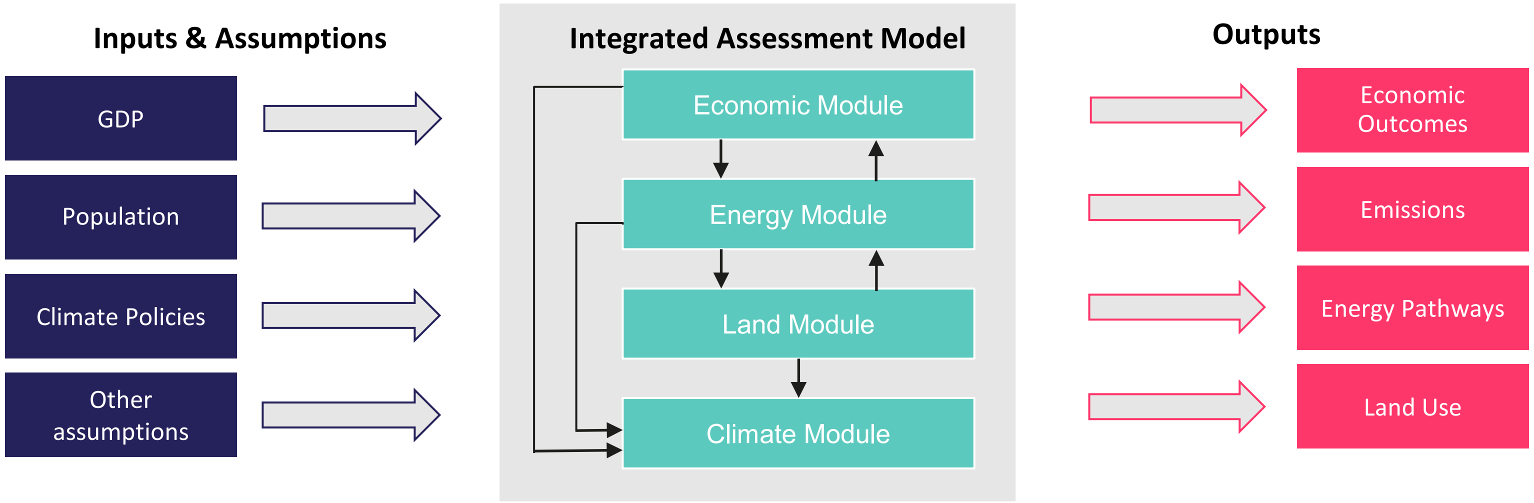
- **SSPs** explore different pathways of how society, demographics and the economy could change over the next century. Pathways include "SSP1: Sustainability" where the world transitions to a more inclusive, sustainable future, whereas in "SSP3: Regional rivalry" is dominated by nationalism and a focus on domestic issues. These pathways are subsequently input into climate models to explore how societal choices impact emissions pathways.
- **RCPs** are GHG emissions pathways that describe different futures based on the volume of GHGs emitted. Each RCP is aligned with a specific temperature outcome. For example, RCP2.6 is considered to be consistent with a temperature rise of below 2°C.

RCPs and SSPs are used in combination with each other in climate scenario models to understand how different temperature outcomes and socioeconomic futures could occur under certain conditions.

References: How SSPs explore future climate change[9], Sixth Assessment Report of IPCC Working Group I, 2021[5], IEA World Energy Model[10]

How are IAMs developed and used?

IAMs are made up of multiple modules, each modeling an aspect of the overall system.



Source: How SSPs explore future climate change[9], IPCC AR6 physical climate[5]

How IAMs are used:

IAMs are usually used to ask "what if?" questions to the model and produce a pathway answering the question, such as:

- What if the carbon budget were X and we can only emit that much more until 2100?
- What if climate policy implementation is highly fragmented across regions?

These questions are posed to IAMs, often in combination with one another, through the assumptions and limits applied to the model.

This diagram depicts how an IAM can have a number of inputs running through multiple modules and producing a number of outputs. An example of a set of inputs and assumptions are the IPCC's SSPs.

Each of the modules within an IAM represent one aspect of the overall IAM. These modules will normally include a climate module, a land module, an energy system module, and a module representing the economic system.

IAMs may specialize in or emphasize a particular aspect of integration, e.g., climate-economic, or climate-land use.

The outputs from the IAM will depend on how the developer chooses to run the model. In this example, the outputs might be economic outcomes, emissions and energy pathways resulting from activities within the scenario and land-use outputs.

References: Pathways to Paris: a practical guide to climate transition scenarios for financial professionals[12], How IAMs are used to study climate change[13], Climate scenarios demystified: a climate scenario guide for investors[14], IAMs: what are they and how do they arrive at their conclusions?[15], General Equilibrium Theory Definition[16]

What are some IAM modeling methodologies?

Different types of IAM modeling can be used in order to "tell the story" of each climate scenario.

Modellers can use different methodologies to explore different possibilities within a scenario's storyline and purpose. These different IAM modeling methodologies may be described in technical scenario documentation. They can be applied on a module-by-module basis; therefore, an IAM can have combinations of methodologies.

Methodologies for supply and demand interactions within the economy:

General equilibrium model: These models analyze the economy as a whole, showing how supply and demand interact and balance in an economy of multiple markets working simultaneously. All policy action would therefore be applied to the economy as a whole, **e.g. The IEA scenario WEM net zero energy 2050 scenario** uses a general equilibrium model for all modules (see page 16).

Partial equilibrium model: These models only analyze the impact of policy action on those markets that would be directly affected by the policy. This allows breakdown into single markets and the method calculates supply and demand of more than one market to stabilize at their equilibrium levels, **e.g. The NGFS GCAM5.3_NGFS Net Zero scenario** uses a partial equilibrium model for the energy and land sectors (see page 16).

How the model makes decisions over time:

Perfect foresight: Models with perfect foresight take into account all future decision-making choices to search for the most efficient pathway, however these models don't assume any uncertainty in future pathways. They then minimize costs in every time period across the entire pathway. This may mean implementing a more expensive technological choice at one time because over the span of 10 years it would prove to be cheaper overall, **e.g. The NGFS REMIND-MAgPIE 2.1-4.2 Net Zero scenario** considers the energy sector and macroeconomy under perfect foresight (see page 16).

Myopic: Myopic models make each decision individually, not considering future decision making. These models are often used to explore pathways with delayed action to climate change, with non-optimal choices made earlier on in the pathway due to cost and therefore locking higher emissions in, **e.g. The NGFS GCAM5.3_NGFS Net Zero scenario** models the energy and land sector assuming myopic consumers and producers (see page 16).

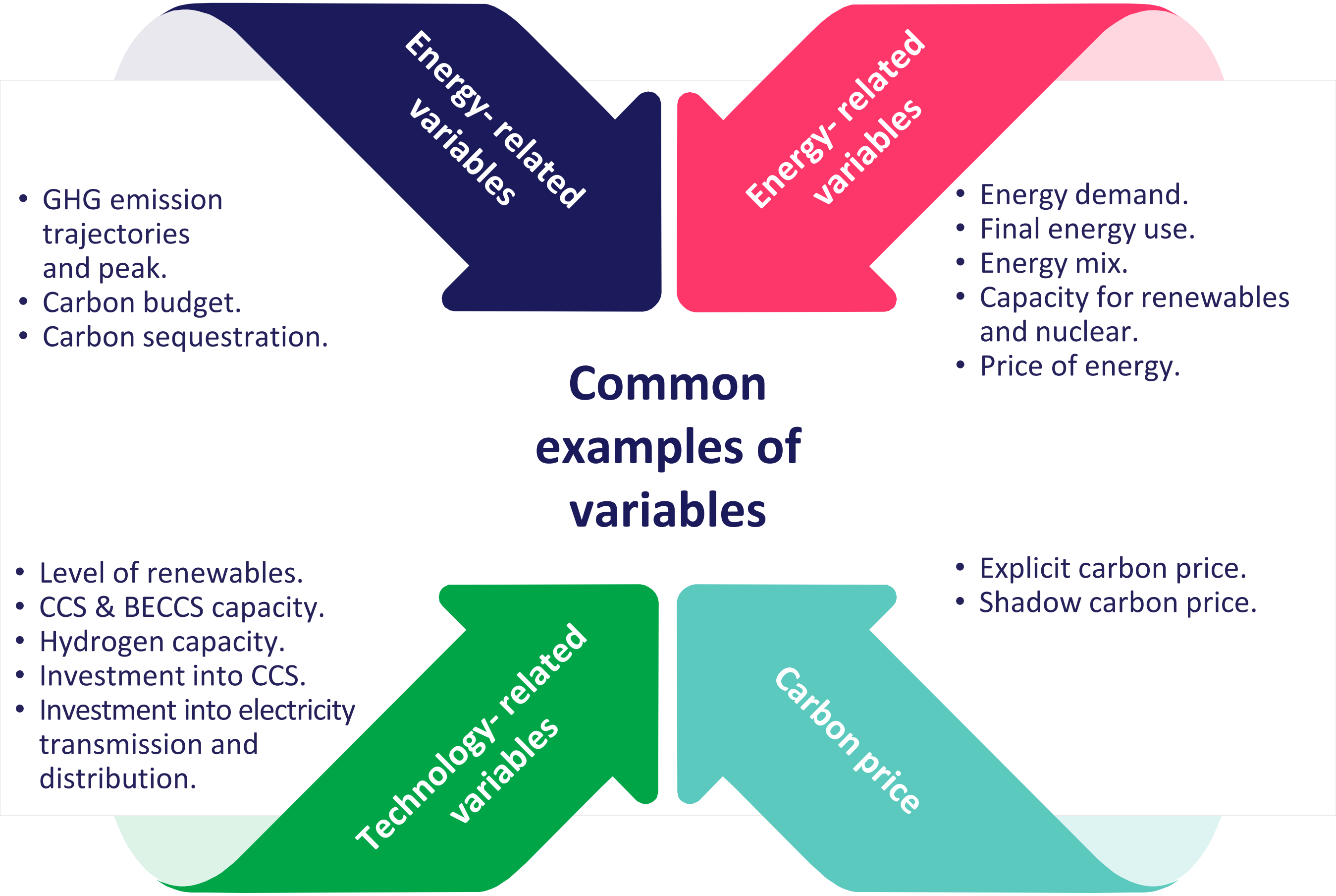
References: NGFS Climate Scenarios for central banks and supervisors[17], Vivid Economics Technical Documentation: Climate Scenario Catalogue[18]

What are the outputs of IAM climate scenario models?

Outputs from IAM climate scenario models are time-dependent variables which can be compared, adapted, and calibrated according to the needs of the user.

When an IAM runs, it will run through the interlinkages between the modules, producing outputs in the form of time-dependent variables. Other model types will also produce output variables in a similar manner. These variables provide you with a view of what may need to happen in various situations in order to hit a certain temperature goal, such as what the energy mix in a particular region would need to be to limit warming to 1.5°C. The variables can then be used as inputs into the user's own analysis, or adapted and calibrated as necessary for specific analyses. For example, one may adapt a global variable to apply it to a particular region.

The number and types of outputs produced will vary depending on the scenario being modelled, but the following are some common examples of variables (with many more available for each of the scenarios available currently).



Common examples of variables

- GHG emission trajectories and peak.
- Carbon budget.
- Carbon sequestration.

- Energy demand.
- Final energy use.
- Energy mix.
- Capacity for renewables and nuclear.
- Price of energy.

- Level of renewables.
- CCS & BECCS capacity.
- Hydrogen capacity.
- Investment into CCS.
- Investment into electricity transmission and distribution.

- Explicit carbon price.
- Shadow carbon price.

An example use case for climate scenario model outputs

The output variables can be the starting point for describing how transition and physical risks and opportunities can link to financial impacts.

Identified risks and opportunities in company risk statement	Risk impact area	Output variable from climate model	Impact on company strategy and plans	Financial impact of a risk/ opportunity manifesting
Identify material risk and opportunities	Link to a climatic risk impact area	Use a climate modeling output to identify a relevant climate scenario variable	Understand how this risk or opportunity could impact company strategy, operations, supply chain	Using the selection of climate scenario variables, quantify the impact of this risk/ opportunity manifesting

Climate scenario outputs can be used as a tool for understanding potential changes to impacts on the balance sheet and market opportunities. This can be done through a 5-step process:

1. Develop an impact pathway linking risk and opportunities to an impact on the balance sheet.
2. Apply normative and explorative scenarios to assess material risks and to set climate related targets.
3. Identify a relevant climate scenario variable.
4. Analyze how a variations in demand, supply, price etc. under different scenarios might affect key parts of the business and its performance.
5. Perform sensitivity analysis on drivers of transition risk, to assess impacts on revenue, costs and profitability. Drivers of transition risk can include policy and legal (e.g. compliance costs and emission pricing), market and economic (e.g. company and asset valuation,) etc.

What are the key considerations and limitations of IAMs?

As the old saying goes: “all models are wrong but some are useful.”

Modeling assumptions and the granularity of interlinkages built between modules - along with many other factors - will influence outputs from scenarios used by IAMs. The combination of the assumptions and inputs used for the quantification and modeling of scenarios are highly unlikely to replicate what will happen in reality; therefore, these models cannot and should not be used as if they are predictions of the future. We have highlighted some of the key considerations and limitations worth noting when using IAMs. Understanding these factors will help scenarios users understand the range of uncertainty in model outputs.

Using scenarios from multiple sources can reduce uncertainty

The IPCC’s Coupled Model Intercomparison Project for the AR6 report (CMIP-6 project) allows the IPCC to take the outputs from many different IAMs. The project aims to capture most aspects of observed climate change well through the averaging of results across multiple models.

After providing the necessary inputs for modeling, the IPCC takes an average of the results for each of the outputs. This helps to reduce some of the uncertainty that would arise if only one model was used to develop scenarios. Therefore, extending this concept to business-use of climate scenarios, it is important to consider scenarios from multiple sources and perspectives to reduce the uncertainty introduced by the assumptions made by each model and scenario provider.

Not all scenario providers use the same macroeconomic assumptions

Macroeconomic variables such as population growth and economic trends such as GDP are major determinants of emission pathways within scenarios. These are also inputs into models rather than factors which IAMs determine for themselves.

The SSPs are an example of how the IPCC aims to standardize some of these macroeconomic assumptions. For example, NGFS use SSP2 (Middle of the Road: Medium challenges to mitigation and adaptation) as the macroeconomic assumptions within their climate scenarios. However, not all scenario providers use the SSP assumptions. For example, the IEA uses their own macroeconomic assumptions and it is worth noting this when determining scenarios to be used in analysis.

References: IAMs: what are they and how do they arrive at their conclusions?[15], NGFS Climate Scenarios for central banks and supervisors[17]

What are the key considerations and limitations of IAMs?

Further considerations and limitations are often connected to the how technology is represented within the IAM.

Technology

IAMs cannot capture rapid technological changes. IAMs are designed to model the gradual trends of well-established technologies, taking a conservative view of the potential for technological breakthroughs. Therefore, IAMs are unable to forecast any transformational changes such as those already seen in the development of Solar Photovoltaic (PV) or Electric Vehicle (EV) technologies for example. Hence, real-life technological developments tend to differ from scenario pathways.

Carbon capture and storage

IAMs will more readily forecast a scale up of a current technology over the development of a new technology. For example, scenarios have tended to prefer to scale up carbon capture and storage connected to existing current fossil fuel plants over the scale up of renewable technologies. In reality, we have seen renewables rapidly become a more feasible option for decarbonization.

This feature of IAMs has implications for those using these scenarios for decision making. It has been found that as renewable sources of power increase in scale, the utilization rate of natural gas power plants decreases, making the addition of CCS an even more expensive proposition. Therefore, there can be an over-reliance on CCS within scenarios due to the manner in which models handle technological development.

Bioenergy

Another area in which IAMs struggle to produce consistent results is that of the **capacity of bioenergy and the role of bioenergy with carbon capture and storage** (BECCS). BECCS is a commonly used negative emissions technology modelled within scenarios. IAMs often focus on the most cost-effective way to hit a certain target but other considerations, such as food security or biodiversity, must also be accounted for.

Many IAMs do constrain mitigation options based on other policy goals, such as placing a limit on bioenergy produced within the system. However, some IAMs have very few bioenergy constraints due to the complexity of introducing supplementary analysis of bioenergy implications into models. A commonly accepted filtering criteria can be used to eliminate the use of any scenario suggesting more than 100EJ in bioenergy worldwide (based on academic consensus that 100EJ is likely the maximum feasible).

Reference: IAMs: what are they and how do they arrive at their conclusions?[15]

How is carbon pricing modelled?

Another important consideration is how carbon pricing is modelled for climate scenarios as this will impact how carbon pricing variables are used in analysis.

Many models introduce an economy-wide carbon price as a proxy for climate policy however this can be a great oversimplification and tends to discount other policy methods such as mandates around low carbon power and energy efficiency as policy tools. The use of a carbon price to represent levels of ambition in climate policy can also exaggerate the use of CCS when compared with models which explicitly model climate policies. Real world policies, using a variety of policy instruments, will likely result in different outcomes when compared to a single economy-wide carbon price. Therefore, when selecting scenarios for analysis, users should explore how carbon prices are used within the models.

To demonstrate how different scenario providers model carbon pricing, we have directly compared the approach of the IEA against that of NGFS:

IEA Scenarios

The IEA uses an explicit carbon price; this means the models can apply consideration on a sector by sector basis, analyzing the amount of emissions in each sector to calculate a tax or price. Carbon prices are introduced as inputs by the IEA, projecting a certain carbon price per sector which can be interpreted as a direct tax on emissions.

NGFS Scenarios

NGFS scenarios use a shadow carbon price, which is treated as the marginal cost of abatement (the price required for a certain transition to occur). Hence, the carbon prices are very high within NGFS scenarios as they are not intended to be interpreted as a tax. NGFS takes the cumulative global carbon emissions from all sectors and constrains them at different levels, using a carbon price to reach the desired level of cooling or warming for the climate limit applied for the scenario. The resulting carbon price is therefore a tool that is used to control the emissions within the scenario.

Guidance on using NGFS carbon price variable: Within scenario analysis, care should be taken when analyzing the impact of a tax-like carbon price on a business when the carbon price variable is similar to that of NGFS (a shadow carbon price). This NGFS carbon price variable is not optimal to use in analyzing carbon price impacts on sectors or businesses because it is a tool to control the whole system's emissions within the scenario.

References: NGFS climate scenario technical documentation[19], Sognnaes et al "A multi-modal analysis of long-term emissions and warming implications of current mitigation efforts"[20]

Understanding how a variable evolves over time

How to apply knowledge of IAMs to understanding how variables evolve.

An area of scenario analysis that often causes confusion are the differences found between seemingly similar scenarios. To demonstrate how variable trends may differ between scenarios, an example has been provided from the Climate Scenario Catalogue on page 17 of this report. This example shows two graphs, the capital expenditure investment in CCS (right), compared with the total CCS across all fuels and technologies (left). Each of the scenarios shown are Paris Ambitious 1.5°C scenarios.

NGFS GCAM5.3_NGFS Net Zero	**Orderly** transition, **partial equilibrium model** of energy and land sector assuming **myopic** consumers and producers.
NGFS GCAM5.3_NGFS Divergent Net Zero	**Disorderly** transition, **partial equilibrium model** of energy and land sector assuming **myopic** consumers and producers.
NGFS REMIND-MAgPIE 2.1-4.2 Net Zero	**Orderly** transition, **general equilibrium model** on energy sector and macroeconomy under **perfect foresight**. Partial equilibrium model for land sector with myopic behavior.
NGFS REMIND-MAgPIE 2.1-4.2 Divergent Net Zero	**Disorderly** transition, **general equilibrium model** on energy sector and macroeconomy under **perfect foresight**. Partial equilibrium model for land sector with myopic behavior.
The IEA scenario WEM net zero energy 2050 scenario	**Orderly** transition, with all models being **partial equilibrium models**.

Orderly Transition: assumes climate policies are introduced early and gradually become more stringent to allow for a gradual, lower risk transition.

Disorderly Transition: assumes climate policies are delayed in their introduction and therefore emissions reduction need to be rapid in order to meet the required temperature target, resulting in higher transition risks, often spread out over geographies.

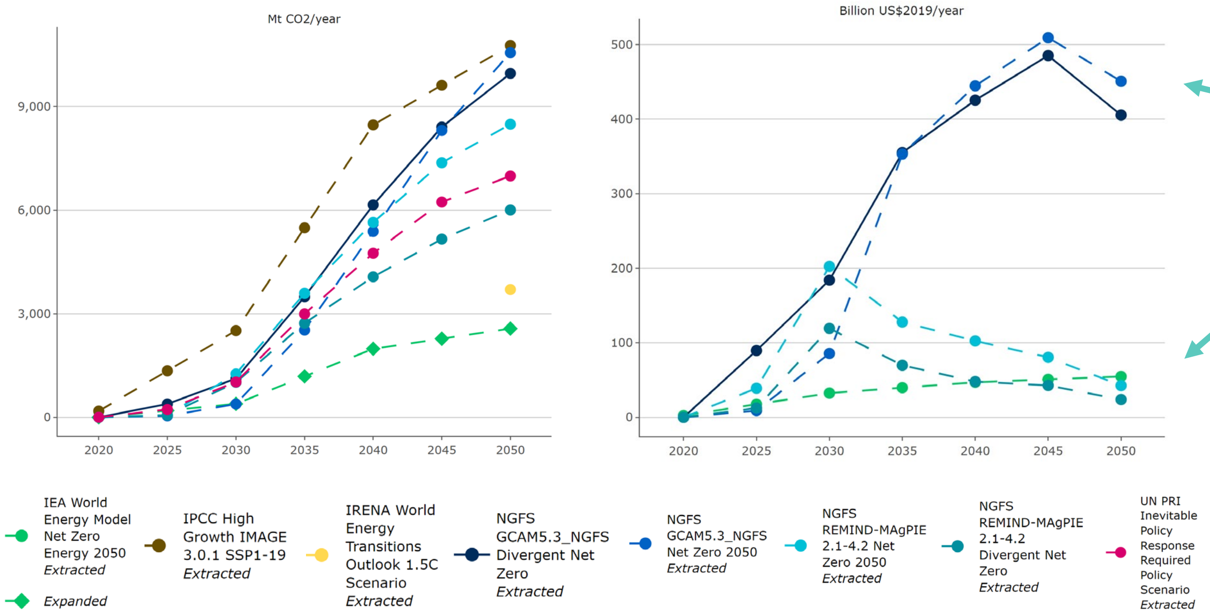
References: NGFS climate scenario technical documentation[19], IEA World Energy Outlooks Scenarios "Understanding WEO Scenarios"[21]

Understanding how a variable evolves over time

Under the same 1.5°C Paris Ambitious scenario family, the trends in CCS investment and volume of CCS differ across scenarios due to the underlying assumptions and methodology.

CCS for all fuels and technologies with CCS (Mt CO2/year)

CCS investment (Bn US$/year)



Source: Climate Scenario Catalogue

The chart on the right describes CCS investment up to 2050, across several Paris Ambitious 1.5°C scenarios. Using the description of each scenario on page 16, it would be expected that there are more similarities in investment into CCS according to whether the scenario is based on an orderly or disorderly transition.

- However, the two scenarios with higher annual investment closer to 2050 are both from the NGFS GCAM model, which includes both an orderly and disorderly transition scenario.
- Similarly, the other scenarios with lower investment include both orderly and disorderly transitions, from two NGFS ReMind models and the IEA WEM scenario.

This suggests that scenario outcomes are driven primarily by myopic nature of the GCAM models or the perfect foresight of the ReMIND models, rather than by the type of transition. This demonstrates how the modeling methodology can impact the output variable, with the myopic models resulting in higher annual CCS investment closer to 2050.

The left chart shows total CCS for the energy sector, all scenarios show an upwards trend on total CCS in the energy sector but some clear differences in ranges, notably the IEA Net Zero Scenario which includes no new investments into unabated coal power plants and new oil and gas fields or coal mines from 2021 onwards, as well as the phase-out of unabated coal power globally by 2030. This illustrates how different assumptions influence outputs as described on the next page.

How to interpret differences between scenario outputs

Outputs can differ between scenarios due to the underlying assumptions or worldviews determined by the modeller

Differences between scenario outputs can be due to the modeling methodology used, but also can be due to different assumptions fed into the model itself. There are a number of output variables across climate scenarios that show a relative degree of convergence in a scenario family. Some of these areas of convergence are summarised across. However, for areas of specific detail or topics which lack a clear consensus on the future pathway, assumptions tend to diverge between scenarios such as in the examples given across.

Convergence across many scenarios is present in areas such as:

- Electrification across end-use sectors increasing.
- Fossil fuel demand decreasing and renewable power generation increasing as the world transitions.
- The emissions pathways which lead to a certain global temperature change, for example, the emissions pathways for 1.5°C scenarios tend to have a fair amount of agreement between them.

Assumptions tend to diverge between scenarios in areas such as:

- The energy mix (proportions of each energy source or fuel type within the energy system).
- Role of bioenergy within the energy system.
- Role of hydrogen within the energy system.
- Role of negative emission technologies in reaching net zero emissions.

By identifying areas in which scenarios differ, scenario analysis can focus on key potential decisions. The differences between scenarios can often be traced back to the input assumptions. For example, the role of bioenergy will greatly depend on whether the model sets limits on bioenergy based on land-use and other policy goals. Similarly, the price of technologies, such as hydrogen technologies, within the model will impact the role that hydrogen plays within the output scenarios. Feedback loops and interlinkages can also be less straightforward, as highlighted earlier in the relationship between how carbon price is used as proxy for climate policies and the impact this has on the reliance of the scenario on CCS.

Therefore, by understanding the assumptions made by scenario providers, users can understand why certain variables show the trends they do within the outputs.

Reference: Gielen et al "18 energy transition scenarios to watch: where they agree and disagree"[22]

Understanding how to apply climate scenario models

Scenario models are a useful tool to support strategic resilience assessments. However, it is important to understand their limitations and the different factors that influence outputs.

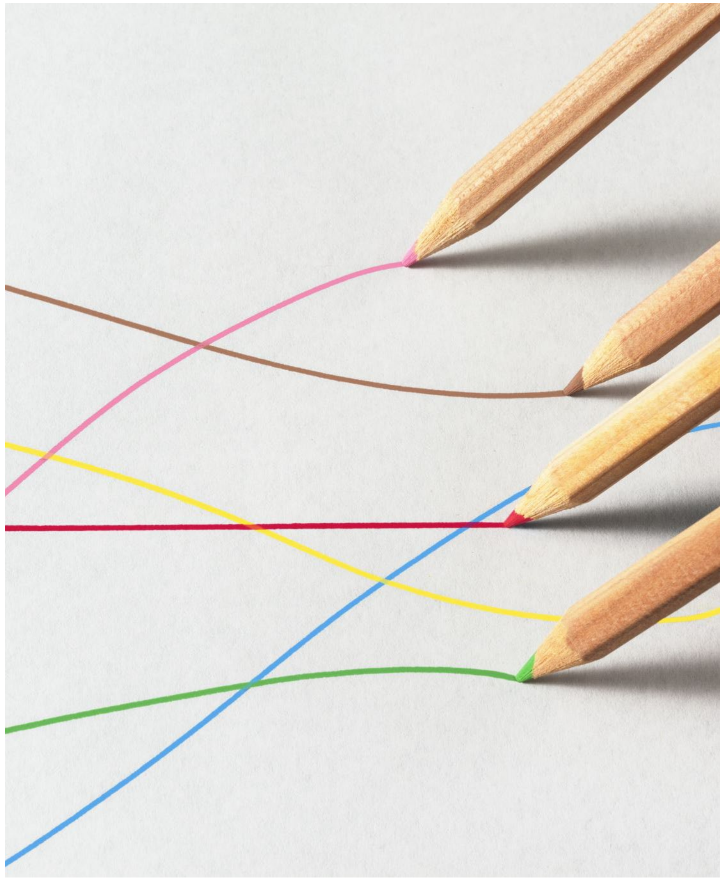
This report has addressed key questions surrounding climate transition scenarios. Climate scenario models are used to quantify the set of assumptions and pathways described by the scenarios to produce business-relevant outputs. Limitations have been identified and examples given to help a user understand how a variable can be analyzed across different scenarios.

Climate scenarios and models are complicated processes that are a product of assumptions, methodological choices, and a compromise between complexity and computation time. Due to these complexities, climate scenario model outputs are not meant to be taken "out of the box" and lifted into internal models or disclosures. Users should understand what is driving the outputs of the quantified scenarios before applying it themselves.

This document offers some helpful tips to assessing what makes an output behave the way it does, highlighting some of the key aspects of climate scenario models that can affect the results:

- The underlying assumptions of the climate scenarios that characterise pathways to a temperature target (page 4).
- The core modeling methodology used to quantify the climate scenarios (page 9-10).
- How a combination of these factors can describe the same temperature outcome but show a different trend (page 16-17).

For further reading on climate scenarios, please refer to the references provided throughout and to the guidance by scenario providers and the TCFD.



References

1. TCFD (2017) Recommendations of the Task Force on Climate-related Financial Disclosures https://www.fsb-tcfd.org/
2. TCFD (2017) The Use of Scenario Analysis in Disclosure of Climate-Related Risks and Opportunities https://assets.bbhub.io/company/sites/60/2020/10/FINAL-TCFD-Technical-Supplement-062917.pdf
3. TCFD (2020) Guidance on Scenario Analysis for Non-Financial Companies https://assets.bbhub.io/company/sites/60/2020/09/2020-TCFD_Guidance-Scenario-Analysis-Guidance.pdf
4. WBCSD (2022) Climate Scenario Analysis Reference Approach for Companies in the Energy System https://www.wbcsd.org/CSARA
5. IPCC (2021) Sixth Assessment Report of IPCC Working Group I https://www.ipcc.ch/assessment-report/ar6/
6. Lena Borjeson, Mattias Hojer, Karl-Henrik Dreborg, Tomas Ekvall, Goran Finnveden (2006) "Scenario types and techniques: Towards a User's Guide" Futures 38
7. National Grid (2021) ESO Future Energy Scenarios https://www.nationalgrideso.com/future-energy/future-energy-scenarios
8. MPP (2021) Mission Possible Partnership Net Zero Steel Initiative https://missionpossiblepartnership.org/wp-content/uploads/2021/10/MPP-Steel_Transition-Strategy-Oct19-2021.pdf
9. Carbon Brief (2018) Explainer: How 'Shared Socioeconomic Pathways' explore future climate change https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change
10. IEA (2021) World Energy Model https://www.iea.org/reports/world-energy-model
11. UNFCCC Energy Models https://unfccc.int/topics/mitigation/workstreams/response-measures/modelling-tools-to-assess-the-impact-of-the-implementation-of-response-measures/energy-models#eq-10
12. Cicero & UNEP FI (2021) Pathways to Paris: a practical guide to climate transition scenarios for financial professionals https://www.unepfi.org/wordpress/wp-content/uploads/2021/02/UNEP-FI-Pathways-to-Paris.pdf
13. Carbon Brief (2018) Q&A: how IAMs are used to study climate change https://www.carbonbrief.org/qa-how-integrated-assessment-models-are-used-to-study-climate-change
14. Cicero (2018) Climate scenarios demystified: a climate scenario guide for investors https://pub.cicero.oslo.no/cicero-xmlui/bitstream/handle/11250/2481124/Climate%20scenario%20guide-final.pdf?sequence=1
15. Climate Analytics (2018) IAMs: what are they and how do they arrive at their conclusions? https://climateanalytics.org/media/climate_analytics_iams_briefing_oct2018.pdf
16. Investopedia (2021) General Equilibrium Theory Definition https://www.investopedia.com/terms/g/general-equilibrium-theory.asp
17. NGFS (2021) NGFS Climate Scenarios for central banks and supervisors https://www.ngfs.net/sites/default/files/media/2021/08/27/ngfs_climate_scenarios_phase2_june2021.pdf
18. Vivid Economics (2022) The Catalogue Technical Documentation. http://climatescenariocatalogue.org/
19. NGFS (2020) NGFS climate scenario technical documentation https://www.ngfs.net/sites/default/files/ngfs_climate_scenario_technical_documentation_final.pdf
20. Sognnaes et al (2021) A multi-modal analysis of long-term emissions and warming implications of current mitigation efforts https://www.nature.com/articles/s41558-021-01206-3
21. IEA World Energy Outlooks Scenarios Understanding WEO Scenarios https://www.iea.org/reports/world-energy-model/understanding-weo-scenarios
22. Gielen et al (2021) 18 energy transition scenarios to watch: where they agree and disagree https://energypost.eu/18-energy-transition-scenarios-to-watch-where-they-agree-and-disagree/

Glossary

Bioenergy with Carbon Capture & Storage (BECCS)	A negative emissions technology achieved through extracting bioenergy from biomass, capturing the carbon dioxide released and storing it to remove it from the atmosphere.
Carbon Capture & Storage (CCS)	The process of capturing carbon dioxide and then transporting and storing it for sequestration.
Climate Scenarios	A climate scenario can be seen as a narrative that describes a potential pathway the future could take towards a certain climate outcome.
Cost-Effectiveness IAMs	Detailed models calculating energy and economic system transformation pathways, providing the least-cost pathway to reach a certain level of warming.
Disorderly Transition	Assumes climate policies are delayed in their introduction and therefore emissions reduction need to be rapid, resulting in higher transition risks.
Explicit carbon pricing	Applies consideration on a sector by sector basis, analyzing the amount of emissions in each sector to calculate a tax or price.
General Equilibrium Model	Analyzes the economy as a whole, showing how supply and demand interact and balance in an economy of multiple markets working simultaneously.
Integrated Assessment Model (IAM)	A type of scientific modeling aiming to link features of society and economy with the biosphere and atmosphere.
IAM modules	The interlinked component models that make up an IAM, for example there is likely to be an energy module, a land module, a climate module and an economic module.
Intergovernmental Panel on Climate Change (IPCC)	The IPCC is the United Nations body for assessing the science related to climate change.
International Energy Agency (IEA)	Autonomous intergovernmental organization working to shape energy policies for a secure and sustainable future.
Myopic	Myopic models make each decision independently of all other decisions, not considering future decision making.

Network for Greening the Financial System (NGFS)	Network of central banks and financial supervisors aiming to accelerate the scaling up of green finance.
Orderly Transition	Assumes climate policies are introduced early and gradually become more stringent to allow for a gradual, lower risk transition.
Paris Agreement	An international treaty on climate change with the goal to limit global warming to well below 2, preferably to 1.5 °C, compared to pre-industrial levels.
Partial Equilibrium Model	Only analyzes the impact of policy action on those markets that would be directly affected by the policy.
Perfect foresight	Models with perfect foresight take into account all future decision-making choices to search for the most efficient pathway.
Physical climate impacts	The physical risks (and limited opportunities) arising from climate change, including chronic risks like extreme heat, drought, and water access as well as acute risks like wildfires, hurricanes, and flooding.
Representative Concentration Pathways (RCP)	Greenhouse gas concentration pathways developed by the IPCC.
Shadow carbon pricing	The notional value that is chosen to be attached to carbon emissions from business activities and used as an internal management tool to support decision making.
Shared Socioeconomic Pathways (SSP)	"Pathways" that examine how global society, demographics and economics might change over the next century.
Task Force on Climate-related Financial Disclosures (TCFD)	The TCFD is an industry-lead group established with the support of the Financial Stability Board to develop voluntary recommendations for more effective climate-related disclosures.
Transition climate impacts	The risks and opportunities arising from technological, political, legal, market and economic changes required to reach a certain pathway.

Acknowledgements

WBCSD would like to thank PwC UK as lead author of this report, WBCSD member companies engaged in TCFD Readiness & Scenario projects for insights, the TCFD Secretariat for feedback and Bloomberg Philanthropies for support.

Authors

Josh Fettes – PwC UK, Sustainability

Alice Melvin – PwC UK, Sustainability

Matt Gilbert – PwC UK, Sustainability

Luke Blower – WBCSD, Redefining Value

Disclaimer

About the World Business Council for Sustainable Development (WBCSD)

WBCSD is the premier global, CEO-led community of over 200 of the world's leading sustainable businesses working collectively to accelerate the system transformations needed for a net zero, nature positive, and more equitable future.

We do this by engaging executives and sustainability leaders from business and elsewhere to share practical insights on the obstacles and opportunities we currently face in tackling the integrated climate, nature and inequality sustainability challenge; by co-developing "how-to" CEO-guides from these insights; by providing science-based target guidance including standards and protocols; and by developing tools and platforms to help leading businesses in sustainability drive integrated actions to tackle climate, nature and inequality challenges across sectors and geographical regions.

Our member companies come from all business sectors and all major economies, representing a combined revenue of more than USD $8.5 trillion and 19 million employees. Our global network of almost 70 national business councils gives our members unparalleled reach across the globe. Since 1995, WBCSD has been uniquely positioned to work with member companies along and across value chains to deliver impactful business solutions to the most challenging sustainability issues.

Together, we are the leading voice of business for sustainability, united by our vision of a world in which 9+ billion people are living well, within planetary boundaries, by mid-century.

www.wbcsd.org

Follow us on Twitter and LinkedIn