CFRF CLIMATE FINANCIAL RISK FORUM

CLIMATE FINANCIAL RISK FORUM GUIDE 2020

SCENARIO ANALYSIS CHAPTER

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Contents

This chapter represents the output from the cross-industry Scenario Analysis Working Group of the Climate Financial Risk Forum. The document aims to promote understanding, consistency and comparability by providing guidance on how to use scenario analysis to assess financial impact and inform strategy/business decisions.

This CFRF guide has been written by industry, for industry. The recommendations in this guide do not constitute financial or other professional advice and should not be relied upon as such. The PRA and FCA have convened and facilitated CFRF discussions but do not accept liability for the views expressed in this guide which do not necessarily represent the view of the regulators and in any case do not constitute regulatory guidance.

1 Introduction

Purpose

This climate change Scenario Analysis chapter provides practical guidance on how to use scenario analysis to assess climate-related financial risks to inform firms' strategy and business decisions. It was written by a cross-industry working group under the auspices of the Climate Financial Risk Forum.

This chapter is aimed at banks, asset managers and insurers of all sizes, and may be of interest to other institutions, such as pension schemes. It describes current industry good practices but is also designed to act as a guide for those firms who have yet to fully consider this topic.

Some of the information in this chapter may be more relevant for different firms depending on the nature of their business and their risk profile. Firms that responded to the PRA's Consultation Paper 23/18, indicated that scenario analysis is the one of the most challenging aspects of meeting supervisory expectations. Making a start with scenario analysis can be a bit daunting given the number of assumptions, data and decisions required. We have therefore, provided a practical 3-stage approach, at the end of this introduction, to help firms to get started quickly with their implementation of climate scenario analysis without having to delve into all the detail covered in sections 2-5 straight away.

We encourage firms to start work with urgency to develop an understanding of their vulnerabilities as well as the strategic and business opportunities including integration of ESG considerations where appropriate into investment processes, risk management and the product governance framework. As noted in the risk management chapter, a common approach is to perform a materiality assessment and initially focus on a small set of risks with scope and sophistication increasing over time. That advice holds true for scenario analysis, where it is sensible to start by identifying material exposures, considering simple 'what if?' scenarios, before introducing more complexity. It is for individual firms to determine the best approach for their own firm.

Whilst the scenario analysis chapter aligns well to regulation (including PRA Supervisory Statement 3/19), it should not in any way be viewed as either setting regulatory expectations or providing a set of standards that can be audited against. In 2019, the PRA published a discussion paper regarding the 2021 Biennial Exploratory Scenario (BES). The BES will focus on sizing risks to individual firms and the financial system. It will also allow the Bank of England to examine how major financial firms expect to adjust their business models. The Network for Greening the Financial System (NGFS) is publishing a set of reference scenarios, which firms may also find a useful reference.

The expectations and practices around climate risk are quickly evolving and hence the information and examples in the document, should be considered alongside current developments.

This chapter should be read in conjunction with the output from other cross-industry working groups of the Climate Financial Risk Forum, in particular the Risk Management and Disclosure chapters.

> **"Making a start with climate change scenario analysis can be daunting. We hope this practical guidance will motivate firms, if they haven't done so already, to take the plunge and get started."**

Angela Darlington (CEO of UK Life, Aviva and CFRF Scenario Analysis Working Group Chair)

Scope

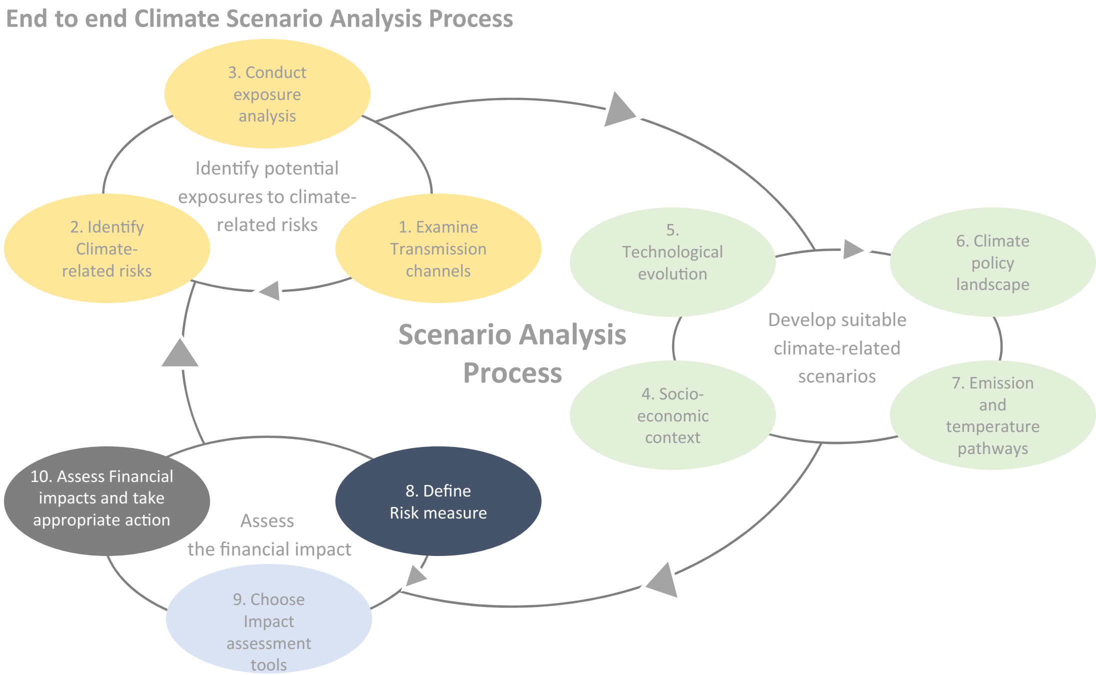
This chapter is organised into four main sections:

- **Section 2** focuses on the types of question that can be answered using scenario analysis and how firms can identify their potential exposures to climate-related financial risks.
- **Section 3** discusses how firms can identify and develop suitable climate-related scenarios, taking into account their potential exposures.
- **Section 4** focuses on the assessment of quantifiable risks and deals with how firms can then assess the financial impact of those scenarios on their business.
- **Section 5** highlights the key challenges and barriers facing the financial industry's use of scenario analysis.

The end-to-end climate scenario analysis process is iterative, as illustrated in Figure 1.

The first step is to identify potential exposures. The results of this can then inform the scenario development process. Some firms may want to start with various reference scenarios and alter them to be relevant to their own business models, rather than start from scratch. Another approach is to start with asking a set of 'what if?' questions, rather than launching into full blown scenario analysis: for example, what if there was a carbon price of $100? What if energy standards on homes were increased? The final stage is to assess the financial impacts of these scenarios and/or what if? questions. Insights gained from that financial impact analysis should in turn feed back into the refinement and identification of new risks and potential exposures, which will then inform the development of scenarios as well as supporting identification of potential new scenarios to be analysed.

Figure 1: End to end Climate Scenario Analysis Process



Climate change primer

This section provides a primer on the aspects of climate change that firms will need to understand before they embark on any aspects of scenario analysis. A library of further reading is provided in Section 6.

Climate change, mitigation and adaptation

Although the Earth's climate has changed significantly in the past, it is widely accepted that the increase in the Earth's temperature that we are currently witnessing is man-made (Intergovernmental Panel for Climate Change (IPCC)[1], 2014). This man-made climate change is caused by the release of greenhouse gases (GHG) into the atmosphere. The most prevalent of these gases is carbon dioxide (CO_2), associated with burning fossil fuels, industrial processes, agriculture, deforestation and other land uses, but other gases, such as methane (CH_4) and nitrous oxide (N_2O) are also contributing.

1 The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change. 195 countries are members.

The convention of using CO_2 equivalent emissions[2] to measure GHG emissions is used in this paper. There is a strong relationship between cumulative CO_2 emissions and global temperature change. Temperatures are estimated to already have risen by approximately 1ºC above pre-industrial levels. If emissions continue to rise as they have been doing, global temperatures will increase by far more than 2ºC. To keep global warming to less than 2ºC, mitigating actions will need to be taken so that only about 500 gigatonnes of carbon dioxide ($GtCO_2$) are emitted in the future. To put this in context, by the end of 2017 2200 $GtCO_2$ had been emitted since the pre-industrial period[3].

Therefore, to limit global warming to 2ºC, aggressive mitigating actions will need to be taken so that CO_2 annual emissions decrease rapidly. If carbon emissions do not decrease fast enough in the first half of the 21st century, then they will need to decrease even more rapidly in the latter part of the century. Requirements for mitigation include making changes to the energy system, the land system, industry, transport, and agriculture as well as influencing consumer behaviour (e.g. reducing food waste). These changes are designed to move human activity away from dependence on fossil fuels, result in greater efficiency of energy usage, change land system usage and reduce emissions in agriculture and industry. Changes in the climate are expected to give rise to both *acute* physical effects (such as increasing severity and frequency of extreme weather events e.g. heat waves, landslides, floods, wildfires and storms) as well as *chronic* effects, that are longer term progressive shifts of the climate (e.g. changes in precipitation, extreme weather variability, ocean acidification, rising sea levels and average temperatures).

Climate change raises distinctive challenges e.g.:

- **Far-reaching impact in breadth and magnitude:** climate change will affect all agents in the economy (households, businesses, governments), across all sectors and geographies. The risks will likely be correlated and, potentially aggravated by tipping points, in a non-linear fashion. This means the impacts could be much larger, and more widespread and diverse than those of other structural changes.
- **Foreseeable nature:** while the exact outcomes, time horizon and future pathway are uncertain, there is a high degree of certainty that some combination of increasing physical and transition risks will materialise in the future.
- **Irreversibility:** the impact of climate change is determined by the concentration of GHG in the atmosphere and there is currently no mature technology to reverse the process[4]. Above a certain threshold, scientists have shown with a high degree of confidence that climate change will have irreversible consequences on our planet, though uncertainty remains about the exact severity and time horizon.

2 CO_2 equivalent measures how much global warming a given type and amount of GHG causes, using the functionally equivalent amount or concentration of carbon dioxide.

3 See https://www.ipcc.ch/sr15/chapter/spm/ and www.globalcarbonproject.org/carbonbudget/19/highlights.htm

4 See https://royalsociety.org/news/2018/09/greenhouse-gas-removal/ for further discussion of the challenges of deploying technological solutions to remove greenhouse gases at the scale required.

- **Dependency on short-term actions:** the magnitude and nature of the future impacts will be determined by actions taken today which thus need to follow a credible and forward-looking policy path. This includes actions by governments, central banks and supervisors, financial market participants, firms and households.[5]

Paris Agreement[6]

Governments recognise the need to shift towards a low-carbon economy. In the 2015 Paris Agreement, national governments agreed to strengthen the global response to the threat of climate change through three main actions:

- Mitigation: holding the increase in average temperature to well below 2°C (degrees Celsius) above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5ºC.
- Adaptation: increasing the ability of countries to adapt to the adverse impacts of climate change.
- Finance: making financial flows consistent with a pathway to low GHG emissions and climate resilient development.

Nationally Determined Contributions (NDCs) are at the heart of the Paris Agreement and the achievement of these long-term goals. NDCs embody efforts by each country to reduce national emissions and adapt to the impacts of climate change. The Paris Agreement (Article 4, paragraph 2) requires each Party to prepare, communicate and maintain successive NDCs that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions. The European Union (EU) and its Member States (including the UK[7]) are committed to a binding target of at least 40% domestic reduction in GHG gas emissions by 2030 compared to 1990[8]. However, based on Climate Action Tracker[9], the EU needs to radically increase the emissions reduction goal in its Paris Agreement commitment to reflect not only the policies it has already adopted, but also what it can achieve by 2030.

Financial risks

Overall, while these targets and commitments provide an overarching framework in which to consider how economies will need to transition, there are a range of possible outcomes. Climate change combined with associated mitigation and adaptation measures present a number of risks and opportunities to the financial sector. The Taskforce for Climate-related Financial Disclosure (TCFD) recommends that organisations should seek to understand the impact of climate-related financial risks and opportunities and disclose the 'actual and potential impacts' of

5 Source: Network for Greening the Financial System (NGFS) First comprehensive report.
6 195 countries have signed up to the Paris Agreement (UN FCCC, 2016) and agreed to reduce their carbon emissions
7 This report was written on a pre-Brexit basis
8 SUBMISSION BY LATVIA AND THE EUROPEAN COMMISSION ON BEHALF OF THE EUROPEAN UNION AND ITS MEMBER STATES, Riga, 6 March 2015
9 https://climateactiontracker.org/

those risks and opportunities. Financial risks from climate change arise through two primary channels, or 'risk factors': physical and transition.

In general, transition risks are likely to materialise more rapidly[10] than the most extreme physical impacts from climate change. These risks manifest, for example, as increasing credit, market, operational, underwriting or reserving risk for firms. Please refer to the separate CFRF Risk Management chapter for more guidance on how to incorporate these considerations within firms' existing risk management frameworks.

Getting started quickly with climate scenario analysis

Making a start with scenario analysis can be a bit daunting given the vast number of assumptions, data and decisions required. We have therefore, developed a practical 3-stage approach to help firms to get started quickly with their implementation of climate scenario analysis (based on a case study by Aberdeen Standard Investments).

First and foremost, it is important to be clear what question/business decision the scenario analysis is intended to help the firm answer, before starting the scenario analysis.

Stage One: Firms should define:

- What is the objective of the scenario analysis? Key drivers could be the growing demand from their senior management, clients and regulators to understand the impact of climate-related financial risks and opportunities on their business under different scenarios. Scenario analysis can also be used to support strategic analysis, such as investigating new business opportunities which may prove more or less lucrative in different scenarios.
- What resources are needed and are available? What budget is available? Depending on the objective of the scenario analysis, firms may need dedicated resources (e.g. creation of a working group with internal and external subject-matter experts) that would be able to focus entirely on the scenario analysis.
- How climate change impacts their specific exposures? What their most material exposures are? Firms should conduct an analysis to understand their exposure in order to identify scenarios that are relevant and proportionate for their business. It is key for firms (in particular smaller ones) to focus their effort where it matters. Start with a clear view of their business profile and direct and indirect exposures across sectors and geographies, using some of the available screening tools.

10 Fast transition in some areas may be triggered by a change in social attitudes leading to changes in consumer behaviour (e.g. UK diesel car sales have halved in 2 years).

Stage Two: Firms should identify:

- What type of scenarios and risk metrics to be considered given their objectives and exposure? Firms should select appropriate Greenhouse gas emission and temperature pathways (see climate reference scenarios in annex 2) and define suitable risk metrics to assess the impact of climate–related risks and opportunities on (e.g. credit ratings or market valuations).
- Where firms (in particular smaller ones) opt to use an external provider many of these choices will be pre-determined. In that context the key focus of firms should be on getting potential vendors to clearly explain the choices they have made and why they consider these are (or are not) appropriate given the firm's specific exposure profile and the business decision(s) the scenario analysis is designed to support. Given no vendor model is likely to be a perfect fit, compromise will be required and firms will need to consider which choices matter most to them given their exposure profile and the objective of the scenario analysis.
- What data and tools to be used to conduct the scenario analysis (Internal or External)? Firms should select appropriate impact assessment tools that cover their objectives and exposure and take into consideration the available resources and budget. If it is decided to go external, to compare solution providers and select the one that most meets their needs, firms could use the following list of assessment questions that they can weight and score in line with their requirements:

Table 1: Assessment Questions for External Providers

Category	Assessment Questions
Breadth	What time horizons are available for the analysis (2030 or earlier vs 2050 or later [11])? What is the scope of the analysis? physical and transition risks? macro and micro? qualitative vs quantitative? supply chain impacts and markets? Which warming scenarios do you use?
Depth	What is the depth of the assessment for different asset classes, sectors and securities and is this proportionate with firm's size and risk profile? Exposure, sensitivity and adaptive capacity? How much focus is put on modelling in high emitting sectors? How granular is the data on demand? Pricing of energy at country level considered?
Rigour	How do you link micro and macro? What data sources are used?
Flexibility	How transparent are the inputs and assumptions? What is not visible? Is there the ability for us to change assumptions? We should be able to integrate climate scenarios into our own existing forward-looking models. Would that be possible?
Operating model	What is your operating model? This should include information on data/ownership/usability, turnaround times, resources on their side to provide support etc.
Cost	What is the charging model? What is the annual cost?

11 With respect to transition risks shorter time horizons are likely to be more relevant, whereas for physical risks longer time horizons will generally need to be considered.

An overview of example datasets and tools available in the market as at June 2020 has been published alongside the Risk Management chapter. The list is not exhaustive, and no endorsement is indicated by inclusion in the list.

Stage Three: Firms should define:

- How impacts are translated into financial metrics used in decision-making? Firms should translate these impacts into financial metrics used in decision-making (e.g. Profit & loss statement and Capital Ratios)
- What action should be taken? Firms should take appropriate action and conduct follow-up analysis if required. That said, given the relative immaturity of climate scenario analysis, and the challenges of conducting analysis over time horizons that are likely to reach beyond typical planning horizons, working out what action is 'appropriate' can itself be difficult. Outputs from scenario analysis are just one set of inputs into a broader set of strategic conversations that boards will increasingly need to engage with.

2 Climate scenarios for the financial services industry

What is scenario analysis?

In risk management, a range of tools are used for forward-looking assessment of risks and opportunities. Individual risk factors, or a specific combination, can be examined through sensitivity analysis[12] and stress tests[13]. However, for decision-making in the face of complex risks, scenario analysis is typically the most useful tool to deepen understanding of the potential impacts. A scenario is an alternative state of the world, typically centred on a narrative that brings it to life and helps to specify its inner logic. It is not a model, although model(s) may be used to determine some of its characteristics based on the central narrative as well to assess its impact on a firm's business. This is important given that it involves many interacting factors and potentially occurs over an extended time period.

A scenario is not a prediction, although it should be plausible whilst challenging business-as-usual assumptions. It cannot be comprehensive and needs to be selective, yet it should deal with the key factors of relevance to a firm. In the context of climate change, the TCFD recommends the use of climate scenario analysis to help firms to explore the potential range of climate-related outcomes and analyse the impact of these alternative states of the world on the business in a structured manner, as well as how the business may respond in these circumstances.

Climate-related questions to be answered by scenario analysis

It is important to be clear what question/business decision the scenario analysis is intended to help the firm answer, before beginning the process of developing and assessing the impact of climate-related financial risks and opportunities, as well as how the results will be used to take action. Climate scenario analysis can help firms better identify climate-related financial risks and opportunities, helping guide successful corporate strategies. It can provide useful information on how the company will perform under different future states. In addition, by better understanding the scenarios themselves, firms can better anticipate the macro-financial consequences of selected temperature and emission pathways. The PRA has outlined the following examples, for insurers that are broadly

12 Sensitivity analysis uses scenarios in which there is usually a relatively small change in risk factors or their likelihood of occurrence.

13 A stress test is a projection of the financial condition of a firm or economy under a specific set of severely adverse conditions. This may be the result of several risk factors over multiple periods of time.

applicable to other firms, of business decisions where scenario analysis could be appropriate and the likely associated time horizons (see Table 2 below).

Table 2: Example business decisions and the time horizons over which they are considered

Motivation to undertake climate change analysis	Time horizon
Disclosure: TCFD related	Long
Disclosure: Public reporting (e.g. shareholders)	Medium, Long
Disclosure: Public policy advocacy	Long
Business decision: Underwriting and pricing	Short
Business decision: Capital	Short
Business decision: Outwards risk transfer (e.g. reinsurance purchase)	Short
Business decision: Product development	Medium, Long
Business decision: Business Plan	Medium
Business decision: Risk management, including risk appetite setting	Medium, Long

- Short term: 1-5 years, which is the period during which boards typically operate to develop risk appetite, strategy and business plans.
- Medium term: 5-10 years, which is the period that the viability of new products would need to be tested against.
- Long term: 10-years or more.

Source: PRA 'A framework for assessing financial impacts of physical climate change' (2019)

There are many possible actions that a firm may decide to take as a result of undertaking scenario analysis. For example a firm might decide to reduce the exposure to assets which are particularly at risk and/or increase their exposure to those seen as benefitting should one of these scenarios unfold (via, e.g., exclusions or sector policies, tilts such as best in class approaches, or thematic investing strategies focused on climate change mitigation and adaptation solutions). Firms might choose to engage with invested organisations to help them enhance their disclosure on climate-related financial risks and bolster their strategy to cope with these risks (e.g., in the context of initiatives such as the Climate Action 100+ initiative or Carbon Disclosure Project (CDP) for corporates). Firms might also wish to engage with firms to help them on the transition, for example by supporting new capital expenditure to adapt their business models or to support adaptation to physical climate risks.

As well as undertaking scenario analysis to test how resilient a firm is to climate-related financial risks, scenario analysis can be used to test the alignment of a firm's business, investment portfolios or funds with a specific pathway – e.g. a 1.5°C or 2°C scenario. A number of external data providers now provide services looking at the alignment of companies or portfolios with the Paris Agreement goals. These metrics are though still very reliant on material assumptions which are often not that transparent and therefore the results need to be handled with care and further methodological development is likely required. These measures tend to be based on carbon foot-printing data, but they can also incorporate forward looking elements (e.g. transition pathways of companies) and different intensity measures can be mapped to a single alignment metric facilitating aggregation.

Beyond being a good proxy for transition risk, these alignment metrics are good communication tools and lend themselves to monitoring against organisations' high-level strategic climate-related goals, as long as they are suitably caveated with respect to the current level of methodological development.

A further use of scenario analysis is to see how much stress a firm can withstand before its business model fails. So-called 'reverse stress testing' is a risk management tool used to increase a firm's awareness of its business model vulnerabilities. For this type of analysis, a firm will design a scenario that tests its business plan to failure. Business plan failure is the point at which the market loses confidence in a firm and, as a result, the firm is no longer able to carry out its business activities. Typically, the time horizon for such a test would be three years.

For a climate-specific reverse stress test, firms might consider sources of transition and physical risks that will be particularly difficult for the firm to withstand. As an example of transition risks, how might an abrupt change in consumer preferences impact on a firm's profitability? Would this be enough to lead to failure or should it be coupled with other risks, such as weather-related disruption (e.g. severe flooding in data centers/supply chains)?

As noted in Table 2, and elaborated in the Risk Management chapter, firms may want to use scenario analysis to project various metrics that are part of its risk appetite (see Section 4 of the Risk Management chapter). Although, there is no common view of leading practice for factoring in long-term climate risk scenario analysis into risk appetite as yet, that chapter provides some initial ideas. For example, firms might aspire to a long-term qualitative statement such as 'being aligned with the Paris Agreement' or 'net zero by 2050'. Alternatively, they may develop metrics to monitor the proportion of a portfolio that has high transition risk ratings under various scenarios or is exposed to a specific peril in a particular region. That chapter also outlines how boards may want to use scenario analysis to help measure and embed climate risk, for example by asking some of the foundational questions such as: 'What countries, businesses, sectors, companies are most impacted in these scenarios? Are we comfortable with this exposure? Is our underlying collateral positively linked with climate-related probability of default?'

Identify potential exposures to climate change

The following figure illustrates the three steps required to identify potential exposures to climate-related financial risks and opportunities and assess their materiality.

Figure 2: Identify potential exposures to climate-related financial risks and opportunities

Examine both physical and transition transmission channels	Both transition and physical channels should be examined by firms when identifying climate-related financial risks. Transition channels relate to new climate policies, technology and usage in order to achieve lower emission pathways. Physical channels relate to acute (e.g. increases in extreme weather events) and chronic effects (e.g. increases in average temperatures and sea level rises). Physical and transition climate-related financial risks and opportunities do not act in isolation.
Identify climate-related financial risks and opportunities	To identify climate-related financial risks and opportunities, firms should either start from their business profile and risk register and consider whether existing risks are susceptible to climate-related effects or start with a future climate scenario and consider how macroeconomic variables used in existing financial risk assessments could be affected.
Conduct exposure analysis and assess materiality	Firms should conduct analysis to understand how the identified climate-related financial risks and opportunities will impact their specific exposures and what their most material exposures are in order to identify any hotspots and develop scenarios that are relevant and proportionate for their business.

Examine the transition and physical transmission channels

When identifying climate-related financial risks, firms should examine how both transition and physical channels could impact their business, currently and in the future. The impact will depend on a firm's business model as well as the composition of their balance sheet. The next couple of sections provides a bit more detail on how to think about the direct and indirect impacts from transition and physical risk channels.

Transition transmission channels

Transition risks and opportunities can operate through a number of transmission channels making this a broad area for firms to consider. The assessment of these channels may include key components that contribute to lower emission pathways and their economic consequences, for example, use of renewable energy sources, increased electrification, actions taken to reduce industrial emissions, increased energy efficiency and carbon capture mechanisms as well as consumer behaviour (e.g. less flying, less food waste, adjusted diets). The economic consequences are varied and range from changes in investment returns to effects on growth and employment.

- *Direct effects:* As climate policies penalise fossil fuel production as well as the production and use of emission-intensive goods and services, firms will face

direct risks from stranded assets, negative movements in bond and equity valuations, changes in cash flows and a deterioration in the credit risk profile of customers in affected sectors. At the same time, climate policies and technological development will promote firms involved in the production of goods and services that assist in reducing emissions. Firms need to assess these negative and positive direct transition impacts.
- *Indirect effects:* Climate policies will also have broader, indirect consequences by changing the prices of a broad basket of goods and services and affecting aggregate patterns of demand and supply.

Take the example of the introduction of a carbon tax. This will have a direct impact on a manufacturer that uses non-renewable energy resources, as the cost of its fuel inputs rises. But that manufacturer might be able to pass the costs on to consumers. Depending on factors such as the degree of competition, the market power of the manufacturer, the price sensitivity of consumers, there will be indirect effects on consumers and other competitors. If the carbon tax is fully passed through, then consumers will have to choose whether to carry on purchasing the goods, but have to pay the higher price, reducing the amount of income they have left for other purchases (an income effect); or consumers may choose to switch to other goods (the substitution effect).

More sophisticated analysis would aim to incorporate international factors, implied by global trade and financial linkages. For example, has the carbon tax also been applied overseas or are border carbon adjustments in place? If not, will overseas competitors be able to undercut local manufacturers? Will domestic production move overseas? Even thinking through some of these channels can be very helpful for firms trying to understand the potential for climate-related changes to impact on their portfolios. Considerations of timing, scale and fragmentation will influence broader macroeconomic outcomes and could also affect socio-political risks.

Physical transmission channels

Climate change is expected to lead to an increase in the frequency and severity of ‘acute’ weather-related events, such as floods and droughts, as well as longer-term ‘chronic’ shifts in climate, such as increases in average temperatures and sea level rise. The incidence and severity of both acute and chronic events will differ by region. While acute events are currently evident, absent mitigation, they are expected to increase in frequency, severity over time and may become more prolonged, compounding their impact. A continued rise in emissions will lead to higher average temperatures with significant socio-economic impacts expected above 2°C.

- *Direct effects:* Corporate balance sheets will be impacted by acute physical events, e.g. precipitation, flood, or wildfire; or by chronic physical effects, e.g. flood risk due to sea level rise. These direct economic impacts arise from factors such as loss of output and costs of repair.
- *Indirect effects:* Long-term chronic changes in climate patterns (e.g. sea level and mean temperature rises) as well as the broader impact of extreme events will impact aggregate demand and output. These broader economic costs may arise from spill-overs such as disruption to a supply chain or support and adaptation costs borne by the sovereign, which would then impact on inflation, interest rates and long-term productivity.

Take the example of a mortgage lender. It will be important for them to assess the flood vulnerability of the properties on which they have lent mortgages. Not only will location data be important, but also the availability of insurance. At what point might insurance become unavailable? What might happen to house prices in these scenarios? How might this impact on loss given default if the customer cannot repay their loan? If borrowers suffer from negative equity, what might happen to local consumption patterns? The case study below gives an example from a bank.

Case Study: JPMorgan Physical Risk Scenario Analysis

We looked at the impact on longer-dated mortgage exposures of a physical risk scenario where climate change has accelerated sea level rise in select coastal locations, rapidly driving residential property values lower.

The scenario considers a multi-year time horizon and assumes a certain annual percentage drop in the home-price-index. The scenario presumes that, as sea levels continue to rise, an increasing number of property owners begin to place their units on the market, driving prices down. This eventually results in an inflection point where property values drop below outstanding unpaid principal balance.

Losses arise as homeowners stop making payments given their falling property values. The scenario assumes that, as property values fall below outstanding principal balance, homeowners walk away from their properties. No new originations were projected and no amendments to amortisation and prepayment schedules, which are based on historical levels

There are several next steps we are considering, including expanding the scope to other perils (e.g. fires and drought) and to our own physical properties (i.e. branches, offices). These exercises could help in the identification and quantification of new physical risks.

Identify climate-related financial risks and opportunities

Risk identification is a process used by firms to identify, register and monitor risks that are relevant to their business model. Whilst there is inherent uncertainty over the climate future, firms should be including climate-related financial risks in the risk identification process. There are two complementary approaches that firms can take to start identifying climate-related financial risks:

- Start from the business profile and risk register of firms and question which business areas or risks are vulnerable to the physical effects of climate change or the transition to a low-carbon economy. For example, how might changes in carbon prices affect credit risk profiles of firms in the manufacturing sectors? Which firms are better placed to meet new environmental standards?

- Start with a future climate scenario and consider how macroeconomic variables (such as GDP and unemployment) used in existing financial risk assessments could be affected. This is more difficult for smaller firms, who might find it easier to rely on existing reference scenarios. But local knowledge and deep insights into specific sectors might make it sensible to alter these reference scenarios to local conditions.

"Scenario analysis can not only help firms to understand their vulnerabilities to climate change but also the strategic and business opportunities."

Angela Darlington (CEO of UK Life, Aviva and CFRF Scenario Analysis Working Group Chair)

Conduct exposure analysis and assess materiality

To assess how exposed firms are to material climate risks, firms will need to source relevant data about their exposures. For example, having data on the location of suppliers, facilities, customers and sales is important for transition and physical channels. Table 3 provides a few examples of the types of data sources needed for assessing physical and transition risk. An overview of example datasets and tools available in the market as at June 2020 has been published alongside the Risk Management chapter. The list is not exhaustive, and no endorsement is indicated by inclusion in the list.

Table 3: Exposure location data types.

Exposure location data type	Transition	Physical
Supply Chain	Location (carbon pricing[14]) of suppliers	Location of suppliers
Operations and Assets	Location (carbon pricing) of facilities	Location of facilities
Market	Location (carbon pricing) of customers	Location of sales

With respect to transition channels, firms could also source Scope 1, 2 and 3 GHG emissions data about their exposures, as an initial guide to the exposure of a firm to transition risk (see definitions below). In order to ensure a relevant and proportionate approach with respect to this data, firms may wish to focus on exposures with the highest carbon intensities and longer durations as well as examine the type of the financial relationship (e.g. a lending commitment, bond underwriting or other).

14 Carbon pricing regimes will differ from jurisdiction to jurisdiction meaning that a firm's exposure to changes in carbon prices will depend on its market, operation and supply chain geographical footprints.

Definition of Scope 1, 2 and 3 GHG emissions

Scope 1: "Direct GHG emissions that are from sources owned or controlled by the reporting entity."

Scope 2: "Indirect GHG emissions associated with the production of electricity, heat or steam purchased by the reporting entity."

Scope 3: "All other indirect emissions, i.e., emissions associated with the extraction and production of purchased materials, fuels, and services, including transport in vehicles not owned or controlled by the reporting entity, outsourced activities, waste disposal, etc."
Source: IPCC Fourth Assessment Report (2007)

Case Study: AIG – Overview of climate change scenario in PRA's GIST

This case study provides an overview of the PRA General Insurance Stress Test (GIST) and how the climate change scenario is being used to better understand climate-related financial risk and shape risk assessment frameworks. Insurance companies perform scenario analyses in a number of different formats to support an array of business operations. These include Natural Catastrophe modelling to aid internal model development; Emerging risk scenario assessments, as part of ongoing 'horizon scanning' to review potential future threats to the business; and Regulator-defined stress testing programmes. The PRA GIST is an example of a biennial regulatory stress test, targeted at general insurers.

The GIST consists of eight separate stress tests, covering market, reserving, natural catastrophe and man-made catastrophe risk events. The PRA has also included a climate change related test which comprises three scenarios covering both physical and transition risks with a potential impact out to 2100:

- **Scenario A:** A sudden transition, ensuing from rapid global action takes place which leads to a sudden, disorderly transition towards carbon and GHG neutrality. This results in a temperature increase below 2°C (relative to pre-industrial levels) but only following a disorderly transition. Transition Risk is maximised as part of this scenario. The scenario is based on the type of disorderly transitions highlighted the IPCC Fifth Assessment Report (2014). Shock parameters are illustrative of potential impact in 2022.
- **Scenario B:** A long term, orderly transition takes place, in line with the Paris Agreement. Temperature increase is kept well below 2°C (relative to pre-industrial levels) with the economy transitioning in the next three decades to achieve carbon neutrality by 2050 and greenhouse-gas neutrality in the decades thereafter. The underlying assumptions for this Scenario are based on the scenarios assessed in the IPCC Special Report on Global Warming of 1.5°C (2018). Shock parameters are illustrative of potential impact in 2050.
- **Scenario C:** No transition towards carbon and GHG neutrality takes place. There is a continuation of current policy trends and failed improvements, resulting in a temperature increase in excess of 4°C (relative to pre-industrial levels) by 2100 assuming no transition and a continuation of current policy trends. Physical climate change is high under this scenario, with climate

impacts for these emissions reflecting the riskier (high) end of current estimates. Shock parameters are illustrative of potential impact in 2100.

This was the first time a major regulator has mandated a climate change stress test to be performed and the test was designed as a 'fact-finding' exercise to lay the foundations for future climate change scenario analysis. Given the relative lack of maturity in assessing the risks of climate change, the specifications were kept intentionally broad and the test provides a common starting point for Insurers of differing levels of complexity to further develop their analysis of the associated risks.

How general insurers interpret and apply the GIST climate change stress test?

To best evaluate the impact of the climate change scenarios as part of the GIST, Insurers are required to expand on traditional actuarial modelling processes and techniques to adapt to the defined timelines within the specification.

This requires leveraging historical data and providing a forward-looking assessment over an extended time horizon, whilst also evaluating the likelihood that extreme climate-related events will become more frequent and severe.

Actuarial outputs are consolidated with different analyses performed by teams across the business as part of insurance risk modelling, investments and credit assessment processes to provide a holistic view of the impacts of climate change.

To further support their internal processes for completing the GIST, Insurers also attend industry and regulatory roundtables to discuss how peers are adapting to the challenges of the stress tests and to discuss any queries that businesses may have regarding the GIST and preparing for the effects of climate change.

Challenges when carrying out the GIST climate change stress test

The primary challenges faced by insurers in assessing the financial risks posed by the three scenarios relate to the validity of the assumptions that are made as part of the test and the availability and accuracy of data that supports the calculations relating to these potential future events.

Participants of the GIST must calculate the evolving impact of climate change on their portfolios. However, due to the dynamic nature of the insurance industry, assumptions and predictions must be made as to how firms adapt to developments in economic, technological and business-specific trends. To support these calculations, a substantial volume of data is required which is not always readily available within currently existing models, given the relatively unknown and volatile nature of climate change.

As a result, assumptions and estimates must be made by teams across business functions to predict and enhance the modelling of these developments. Participants require a robust review and validation process for these assumptions to be established, to ensure that the predictions made are valid and in line with business, industry and regulatory expectations.

Outputs from the GIST climate change stress test
Following the conclusion of the GIST and the submission of general insurers' results to the PRA, the outputs of the test can be leveraged by Insurers to support analysis and business development in a number of areas, as well as enhancing firm-wide initiatives to support the global climate mitigation programme.

The GIST can help Insurers inform and amend their internal strategies and risk appetites to better manage and adapt to the impacts of climate change. In particular, key information relating to drivers and impacts can be used to enhance underwriting appetites and pricing mechanisms. This is comparable to the developments that have taken place in recent years relating to cyber risks, as recent, detailed information has helped to influence business attitudes towards this key risk area.

In addition, the GIST may allow Insurers to further develop existing modelling practices by extending the time horizon in focus beyond the conventional one-year period, as well as placing increased attention on the impact of long-tail business and allowing for the incorporation of further climate change factors.

3 Scenario identification and development

This section describes the key components for firms in developing climate scenarios and discusses options for combining and exploring interdependencies between these components using bespoke or off-the-shelf modelling approaches. As discussed in section 1, for firms that are just starting to consider how to use scenario analysis, a first step might be to start with asking a set of 'what if?' questions, such as examining the impact of the introduction of a carbon price, of say, $100.

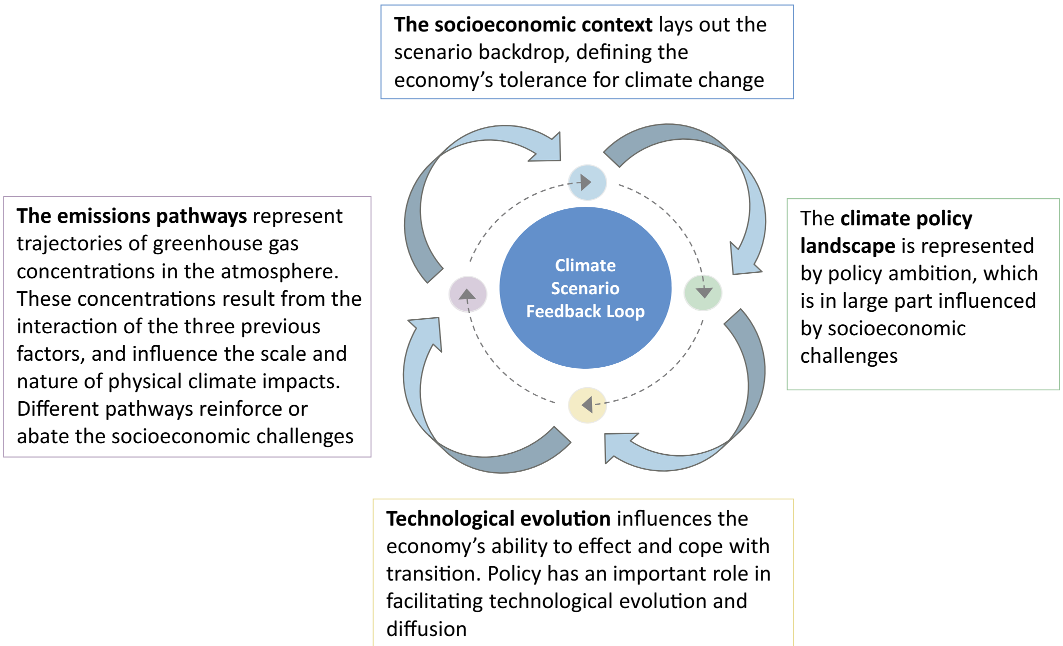
For firms that want to develop their own climate scenarios, there is a great deal of available research and literature that can help, with many of the key readings listed in section 6. Firms will then be better informed about which scenarios (or components of scenarios) will be most useful for their own financial analysis. Even if firms do not intend to develop their own scenarios, gaining an insight into the assumptions underlying different scenarios can be extremely helpful in guiding firms to the types of factors that they need to be considering in their day to day risk management.

A climate scenario can typically be described using a combination of the following components:

- Socioeconomic context
- Technological evolution
- Climate policy landscape
- Emissions pathways and associated changes in the physical atmosphere

Firms may choose to analyse only one of these components or may decide that analysis should cover several of these components. This will depend on the context of the business decision needed to be answered (see section 2) as well as the type and materiality of exposures. For example, an institution with mortgage exposures concentrated in only one specific geography may choose to focus on analysing emissions pathways and associated changes in the physical atmosphere. They may also want to consider the likelihood of policy changes requiring higher energy efficiency.

Figure 3: Feedback loops and interdependencies between the components of climate scenarios



The complexity of these exercises can rise rapidly as one considers the interdependence of these components e.g. the level of climate policy ambition and technological evolution will influence future emissions, which will in turn influence the socioeconomic context. These feedback loops should be considered in more sophisticated scenarios as illustrated by the above figure.

The next sections focus in turn on these four dimensions: socioeconomic context; technological evolution; climate policy landscape; and emissions pathways and associated changes in the physical atmosphere. This section then explores how to bring all four dimensions together when developing your own scenarios. Even if this seems too advanced at this stage, understanding these broad drivers of the scenarios can be helpful when thinking through the types of analyses that will be most suitable and helpful for your particular firm.

Socioeconomic context

Describing the socioeconomic backdrop can help to contextualise the setting in which a climate scenario occurs. For example, regardless of the level of policy ambition and technological evolution, a world in which consumption patterns become more sustainable could have a marked reduction in emissions, whereas a world in which fossil-fuelled development continues will either increase emissions or reinforce the pathway we are currently on.

The so-called 'Shared Socioeconomic Pathways' (SSPs) have been developed by internationally recognised teams of academics to support the analysis of the physical impacts of climate change. These SSPs may be a useful resource for firms in setting their socioeconomic narratives. SSPs are based on three important variables – GDP, population, and urbanization rate – foreseen for a wide range of countries/regions, up to the year 2100. The SSPs have been integrated with physical climate pathways in a range of Integrated Assessment Models (IAMs) to translate the socioeconomic conditions of the SSPs into estimates of future energy use characteristics and GHG emissions. Further description and examples of IAMs are detailed later in this section.

The box below sets out the five SSPs. SSP1 is the most benign outcome in which the socioeconomic challenges for adaptation and mitigation are low; SSP3 is the opposite case, where these challenges in both dimensions are high. As we will see later, these pathways are complementary to the 'representative concentration pathways' or RCPs, which describe different levels of greenhouse gases (see figure 4).

Definition of SSPs

- SSP1 – Sustainability: considers a coordinated and gradual shift towards a sustainable path
- SSP2 – Middle of the Road: a continuation of the current historical path with uneven development and income growth, and slow progress towards international sustainable development goals
- SSP3 – Fragmentation: assumes a resurgence of nationalism with countries focused on achieving internal energy and food security goals, and slow economic development
- SSP4 – Inequality: considers increased inequality where the gap widens between an internationally-connected society and a fragmented collection of lower-income societies. The former society diversifies its energy mix including low-carbon.
- SSP5 – Conventional (Fossil fuel) Development: global markets are increasingly integrated, and fossil fuel use increases driving rapid economic growth. There is faith in the ability to manage climate change, including by geo-engineering if necessary.

Source: Riahi et al., 2017, "The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview",

Technological evolution

Curbing emissions will require a shift to renewables, an increase in electrification, emissions abatement in industry and increased energy efficiency. Scenarios should define assumptions on the technologies that will drive a transition, the rate of progress of these technologies and their associated costs. Firms may need to explore technological progress not just in the energy system but also in different sectors such as aviation, transport and heavy industry.

Models that focus on Technology

The **Energy Technology Perspectives (ETP)** modelling efforts by the IEA highlight how policy objectives can be supported by scaling-up available low-carbon technologies across sectors, and further developing technologies that are in the pipeline. The analysis explores both a 2°C aligned scenario, and a "beyond" 2°C scenario which tests the limits of new technology deployment and keeps average global warming below 1.75°C. No assumptions are made about new ground-breaking technologies.

Bloomberg New Energy Finance (BNEF) releases their "New Energy Outlook" on an annual basis. This report is an economic forecast of the evolution of the electricity system to 2050, focusing on meeting demand using least-cost technology options. Inputs include renewable power cost curves, fuel prices and macroeconomic variables.[15]

The climate policy landscape

Describing a climate scenario implies making an assumption about future climate policy ambition. Climate policies will impact emissions either directly (e.g. through imposing taxes or quantity restrictions on emissions) or indirectly (e.g. through regulations on technology, materials and efficiency).

In developing a scenario, or assessing the plausibility of an existing scenario, it is important to consider climate policies across three dimensions:

- *Timing:* the economic consequences of emission reductions will be different depending on whether actions are taken sooner or later.
- *Scale:* refers to the speed and force with which climate policies are imposed, as well as their coverage; climate policy implementation could be smooth and gradual or could be accelerated, uncoordinated and abrupt.
- *Fragmentation:* addresses the degree of co-ordination across countries in tackling climate change. Firms with exposures in one or a limited number of countries may of course choose to start by considering one country at a time.

Scenarios with smooth, gradual, globally co-ordinated, and near-term implementation are generally considered as those with the most benign macro-financial consequences, while abrupt, accelerated, uncoordinated or deferred implementation scenarios are more likely to have disorderly economic consequences.

Firms may also wish to consider scenarios that describe alternative policy environments, including those characterised by an absence of climate policy or even a reversal.

15 *Source: IEA Energy Technology Perspectives: www.iea.org/etp/; BNEF New Energy Outlook: about.bnef.com/new-energy-outlook/*

Models that focus on climate policy

The **World Energy Outlook** model by the IEA which explores how future energy demand can be met under different levels of climate policy ambition. The three scenario narratives are below:

Current Policies Scenario (CPS): No change in policies from today leading to increasing strains on almost all aspects of energy security and a major additional rise in energy-related CO_2 emissions.

New Policies Scenario (NPS): broadens the scope to include policies and targets announced by governments. While the picture brightens, there is still no peak in global energy-related CO_2 emissions.

Sustainable Development Scenario (SDS): accelerated clean energy transitions put the world on track to meet goals related to climate change.

UNEP Principles for Responsible Investment (PRI) explores an alternative policy scenario focusing on the near-term “Inevitable Policy Response” (IPR) to climate change. UNEP PRI forecast a likely climate policy response in the near term (to 2025), based on the current macroeconomic environment and likely policy announcements. As the name suggests, the idea of this set of policy forecasts is to highlight that the policy response is ‘inevitable’ once the realities of climate change become apparent. The IPR forecasts policies by 2025 that will be ‘forceful, abrupt and disorderly’ (because of the delay). Some examples of the types of policies that will be introduced are: ban of vehicles with internal combustion engines by 2035; carbon pricing initially set at $40-60 per tCO_2, but rising to $100 per tCO_2 by 2050; heightened energy efficiency standards. Unlike scenarios which require a basic understanding of climate science, these forecasts provide a tool to help businesses think about what policy and technological developments are likely to occur, over a time horizon that is immediately relevant to businesses.

The impact on the real economy (by country, sector etc.) is modelled up to the year 2050. Financial institutions may consider this as an alternative or complementary scenario to those by the IEA, particularly given the focus on near-term responses.[16]

Emission pathways and associated changes in the physical atmosphere

The combination of and interactions between the socioeconomic context, climate policy ambition and technological pathways will result in a certain level of industrial activity and, therefore, GHG emissions. Increasing the concentration of GHG in the atmosphere will manifest in physical climate impacts, such as global average temperature rises and changes in precipitation patterns. Therefore, for the more sophisticated firms which want to develop their own climate scenarios, the following aspects should be considered:

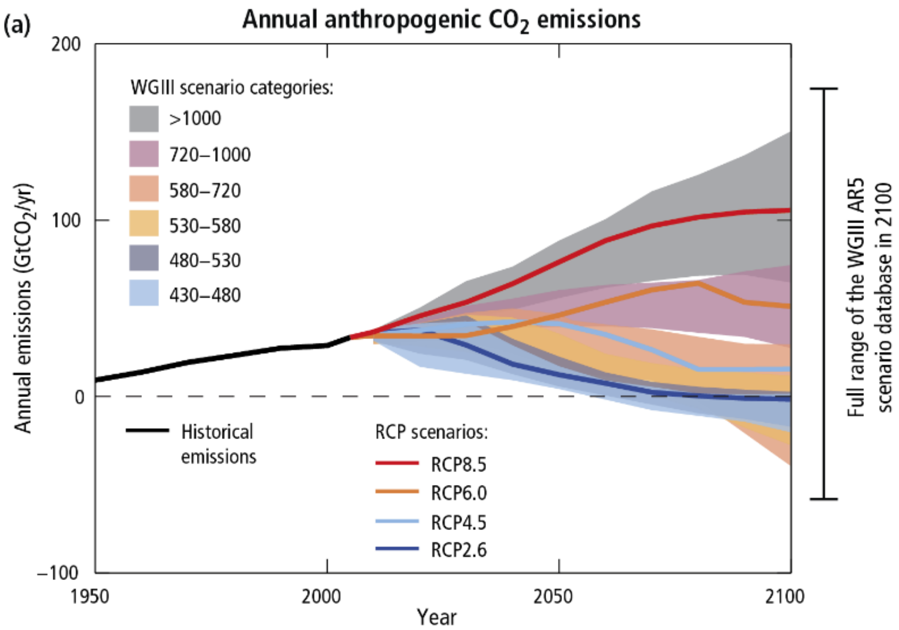
16 *Sources: IEA World Energy Model, www.iea.org/weo/weomodel/; UNEP PRI “Inevitable Policy Response”, www.unpri.org/inevitable-policy-response/what-is-the-inevitable-policy-response/4787.article*

- *GHG concentrations:* to understand the level and type of industrial activity that underpins the assumed emissions pathway.
- *Type of impact:* as physical impacts resulting from GHG concentrations can manifest in various ways, such as heat stress, water stress or flooding from sea-level rise.
- *Geographical distribution:* as the extent of physical impacts will differ significantly by country and region.

Models that focus on emissions pathways

The IPCC is the main public body tasked with developing the scientific knowledge and literature on the physical impacts of climate change. The IPCC maintains the Representative Concentration Pathways (RCPs) which model changes in atmospheric concentrations of greenhouse gases at different radiative levels.

Figure 4: Annual man-made carbon dioxide emissions for different global warming scenarios

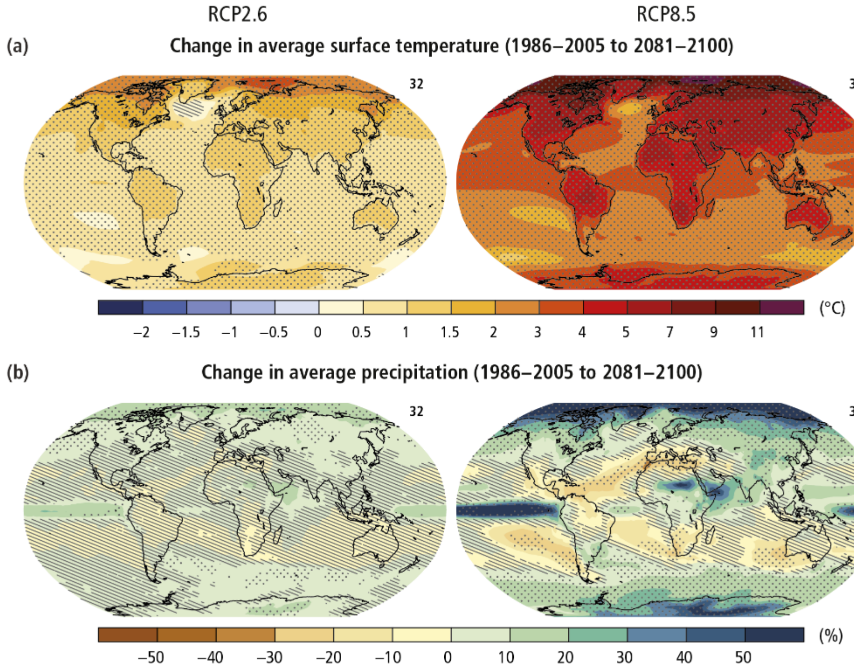


Source: IPCC (2014), "Climate Change 2014 Synthesis Report Summary for Policymakers", www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_SPM.pdf

The four RCPs are described below:

- RCP 2.6 is a stringent mitigation scenario which is representative of a scenario that aims to keep global warming likely below 2°C above pre-industrial temperatures.
- RCP 4.5 is an intermediate scenario which would likely result in 2.4°C global warming.
- RCP 6.0 is an intermediate scenario which would likely result in 2.8ºC global warming.
- RCP 8.5 is a scenario with very high greenhouse gas emissions that would likely result in 4.3ºC global warming.

Figure 5: Temperature and precipitation changes associated with different emissions pathways



Source: IPCC (2014), Climate Change 2014 Synthesis Report Summary for Policymakers, www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_SPM.pdf

The consensus around physical scenarios is that the impact of extreme weather events will be more frequent and severe the higher the rate of global warming. Numerous data providers translate the output of physical climate scenarios (such as the IPCC RCP scenarios) into formats that could be used as a starting point by financial or other institutions. This process often involves additional modelling work to increase the granularity (or resolution) of the results. Some data providers now have the ability to display the severity and frequency of physical events (e.g. sea level rise, heat stress, water stress) for specific geographical coordinates at five-yearly intervals over several decades. By overlaying exposures, firms can see which assets are more likely to be impacted by the physical effects of climate change. However, it is important to be aware of the strengths and limitations of different data providers and bear in mind the current uncertainty of such projections/modelling attempts (e.g. an estimate by one data provider might be orders of magnitudes higher based on what perils/scenarios/time horizons are considered). An overview of example datasets and tools available in the market as at June 2020 has been published alongside the Risk Management chapter. The list is not exhaustive, and no endorsement is indicated by inclusion in the list.

Developing climate scenarios

Firms may choose to combine the four components (socioeconomic pathways, policy ambition, technological evolution and emissions pathways) and explore their interdependencies either through (i) bespoke models or (ii) off-the-shelf models.

Developing bespoke modelling approaches requires firms to make a number of assumptions and use potentially complex modelling techniques. However, this option could be useful for developing rich insights into the macro-financial consequences of climate scenarios. Care should be taken to develop plausible scenarios using feasible combinations of the four core components e.g. a low emission pathway would not be compatible with low climate policy ambition and low technological evolution. Figure 6 shows combinations of SSP and RCP emission pathways that may be feasible. Linking back to the descriptions of SSPs in section 3, SSP1 is the 'Sustainability' pathway, based on a coordinated and gradual shift towards a sustainable path. This is not compatible with the RCP 8.5 pathway which has very high greenhouse gas emissions. Figure 6 illustrates the importance of ensuring internal coherence when defining the different attributes of a scenario.

Figure 6: Feasible combinations of SSP and RCP pathways

	SSP1	SSP2	SSP3	SSP4	SSP5
RCP 2.6 (1.5°C)	✓	✓		✓	
RCP 4.5 (2°C)	✓	✓	✓	✓	✓
RCP 6.0 (3°C)		✓	✓	✓	✓
RCP 8.5 (4°C)					✓

Off-the-shelf models include IAMs, which combine the four components described above and allow their interdependencies to be explored. Inputs typically include assumptions on policy, technology, and socioeconomic trends. Outputs typically include emissions pathways and changes in the energy system. While IAMs are a standard tool of analysis in climate change science, financial users need to be aware of the strengths and limitations of such models (e.g. modelling of tipping points). Issues include the sensitivity of results to assumptions and potential for insufficient granularity to enable firms to conduct impact assessment (see section 5 for further discussion). The box below provides a practical example of how one bank used IAMs to identify scenarios that were relevant to it. Figure 7 shows how energy is used in 2100 in each SSP and IAM. There are some differences in the energy mix (for example, the MESSAGE IAM in SSP3 looks to be an outlier), but generally, the energy mix is similar across IAMs for each SSP.

Integrated Assessment Models (IAMs)

Several standardised combinations of RCP and SSP scenarios are periodically run by the scientific and academic community using Integrated Assessment Models (IAMs). The outputs of these runs are used in several important analyses, such as the IPCC Assessment Reports, which are comprehensive policy and scientific reports on climate change. The inputs and outputs from each of these runs are freely available online in the SSP Public Database which is maintained by the International Institute for Applied Systems Analysis (IIASA).

Financial institutions can draw on the outputs of these standardised runs to help with their own internal scenario analysis. Note that not all combinations of RCP and SSP scenarios are run by each IAM. Therefore, depending on the nature of exposures, a financial institution may choose to focus on a specific IAM, since they all have slightly different attributes e.g.

- A financial institution with diversified, global exposures may choose to use an AIM which covers many sectors of the economy in limited detail.
- A financial institution with exposures concentrated in the energy sector may rely on MESSAGE which models the energy system in more detail.
- A financial institution with exposures in one country may consider GCAM which has individual country granularity for a number of key countries.
- A financial institution with exposure to gas and which wants to analyse the SSP2 scenario, for example, may opt for the "GCAM" IAM. Whereas a financial institution with exposure to coal may choose the IAM WITCH, where coal becomes underutilised in both the SSP1 and the SSP2 scenarios.

A non-exhaustive list of the most widely-known IAMs is provided below:

- **DICE:** Dynamic Integrated Model of Climate Change – Nordhaus (1992, 1994)
- **RICE:** Regional Integrated Model of Climate and Economy – Nordhaus and Yang (1996)
- **IMAGE** – Netherlands Environment Assessment Agency (PBL)
- **GCAM** – Pacific Northwest national Laboratory (PNNL)
- **AIM** – National Institute for Environmental Studies (NIES)
- **MESSAGE** – International Institute for Applied System Analysis (IIASA)
- **REMIND** – Potsdam Institute for Climate Research (PIK)
- **WITCH** – Fondazione Enrico Mattei and Centro Euro-Mediterraneo sui Cambiamenti Climatici
- **C^3IAM** – Centre for Energy and Environmental Policy Research, Beijing Institute of Technology

Source: SSP Public Database

This type of analysis is most likely appropriate for the more sophisticated of firms. However, it can be useful for all firms more generally to understand the underpinnings of the various scenarios and/or derive conclusions/ strategies from expert publications instead of running/trying to run IAMs themselves. There are guides available to provide further information, such as 'A Review of Criticisms of Integrated Assessment Models and Proposed Approaches to Address These, through the Lens of BECCS', by Gambhir, Butnar, Pei-Hi, Smith and Strachan (2019).

Also, there are video resources on YouTube, which can provide useful insights, such as this video produced by the Initiative on Climate Change and Governance (ICCG).

Case study: BNP Paribas - Scenario identification

In accordance with the TCFD's recommendation that firms should identify scenarios that are plausible, relevant, distinctive, challenging, and consistent, a firm may wish to enrich its own internal macroeconomic assumptions with existing, publicly available scenarios, designed by a recognised community of scientists. Among these scenarios are the five SSPs, the IEA 2DS, the IEA 450, the Deep Decarbonisation Pathways Project and the International Renewable Energy Agency.

First step: choosing the kind of scenario

The firm may decide to run analysis of scenarios that are consistent with a 2°C pathway (the upper-end of the 2015 UN climate conference in Paris (COP21) objective).

Second step: choosing the scenarios

The firm selects one scenario among the SSPs since:

- They are broadly documented;
- They are "popular" in the financial sector;
- They are widely used as benchmarks by governments at the COP Summits;
- They rely on simple, three data-sample inputs (GDP, population, and urbanization rate for a wide range of countries/regions, up to 2100).

When taken alone, i.e., in absence of any additional climate policy – like the Intended nationally determined contributions (INDC) – these baseline scenarios all lead in 2100 to global warming ranged between 3°C (SSP 1) and 5.1°C (SSP 5), which does not match with the kind of scenario chosen (2°C). But when mitigation measures/ climate policies are implemented, IAMs allow for the development of lower emission scenarios and the resulting less intense global warming.

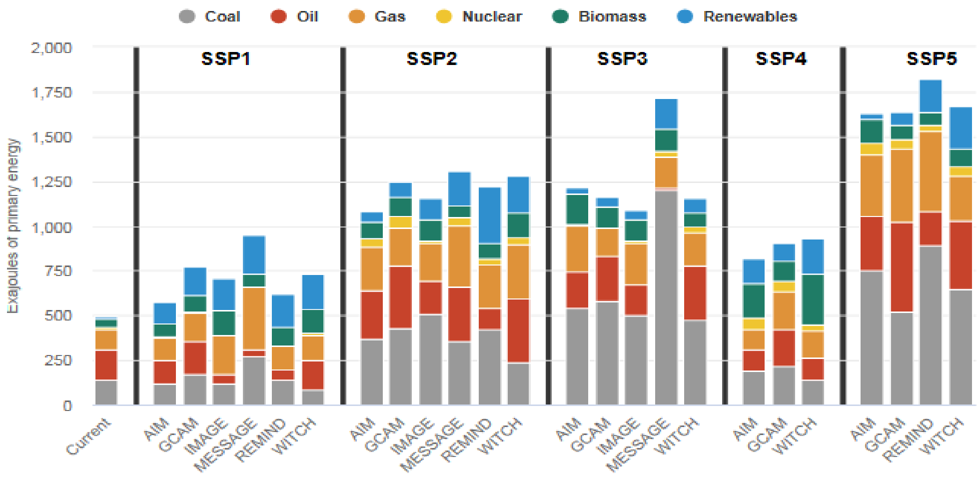
Six IAMs – called "AIM-CGE", "GCAM", "IMAGE", "MESSAGE-GLOBIOM", "REMIND-Magpie", and "WITCH-GLOBIOM" – were used to create energy use and emissions characteristics for the SSPs, and a total of 24 baseline scenarios were created by the different models simulating different SSPs, though not all models ran all SSPs. If Climate Action is taken, they show that under SSP1 and SSP2 there is a reasonable chance to cap global warming to 2°C by 2100, whereas under SSP3-5 the Paris agreement target is unlikely to be met. Of course, an institution wishing to analyse a 3.5°C scenario will add SSPs 3-4-5 to these SSPs 1 & 2.

Third step: choosing an IAM

According to the target it has chosen, the firm must select the most appropriate IAM as each IAM foresees an energy mix (for example, see figure 7):

- If the exposure to oil must be analysed, the firm may select, for the SSP1, the "MESSAGE" integrated assessment model, where the share of oil in the primary energy mix falls to the lowest compared with the current, prevailing situation;
- If the exposure to gas must be analysed in the SSP2 scenario, the bank may opt for the "GCAM" IAM,
- If the exposure to coal must be analysed, the firm can choose the IAM WITCH, where coal becomes underutilised in both the SSP1 and the SSP2 scenarios.

Figure 7: Primary energy in 2100- by model for SSP baseline scenarios (in absence of climate policies)



Source: www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change

Lower use of primary energy should lead to lower production, to lower prices, and to lower profitability, inputs that the firm should integrate in its own internal models.

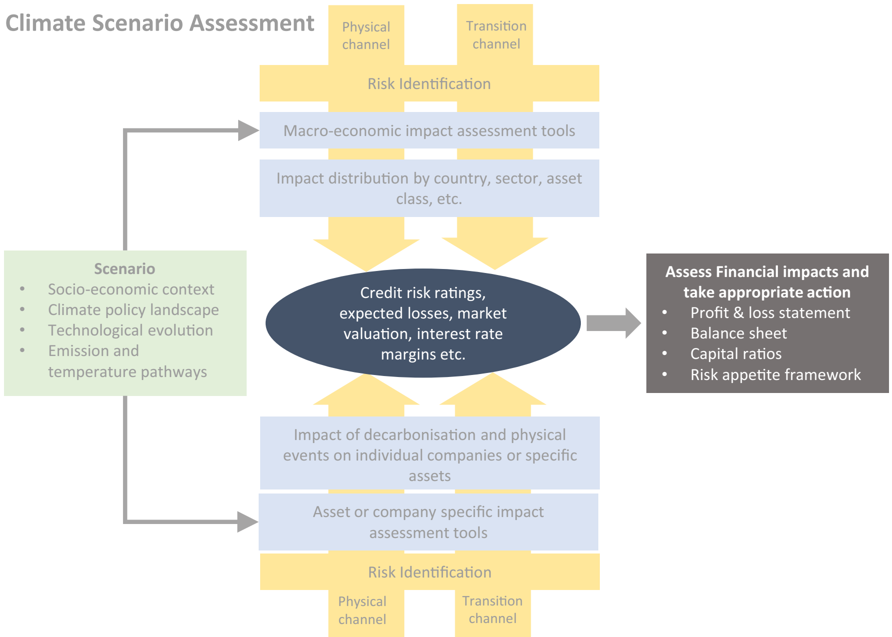
4 Scenario assessment

Firms, through their carbon exposures and physical assets, face transition[17] and physical[18] risks, which manifest themselves in existing risks types, such as market, credit, operational, underwriting and reserving and/or reputational[19] risks. Through scenario assessment a firm can model and quantify exposure to these risks. When assessing these exposures firms need to:

a. Define a risk measure to assess the impact of climate–related risks and opportunities on (e.g. credit ratings, enterprise value or market valuations) along with an appropriate time horizon over which changes will be assessed. Firms also need to consider what baseline to measure those changes against and what management actions should be taken into account.
b. Choose impact assessment tools to analyse the change in the chosen risk metrics for a given scenario e.g. consider whether tools that look at the impact distribution by country, sector, asset class, etc. are appropriate or whether tools that assess the impact of decarbonisation and physical events on individual companies or specific assets are required.
c. Assess financial impacts and translate these impacts into financial metrics used in decision-making e.g. profit & loss statement and capital ratios. Firms should also take appropriate action and conduct follow-up analysis if required.

The following figure illustrates the steps required to assess the financial impact of scenarios.

Figure 8: Approaches for impact assessment



17 Transitional risks can be quantified by virtue of the firm's exposure to financial and lending commitments to carbon producing entities as well as the potential macroeconomic impacts of the transition on factors such as GDP growth and commodity prices.
18 Physical risks can be quantified by virtue of the firm's exposure to assets and liabilities that are vulnerable to risks such as extreme weather events or chronic changes in climate patterns.
19 The impact from reputational and legal risks is largely a qualitative assessment in many cases detached from market or economic drivers.

Define risk measure

When assessing climate scenarios, firms need to measure the impact of climate-related financial risk drivers, either transition or physical or both, on their key financial metrics. This would mean quantifying through a variety of transmission channels (e.g. credit risk, market valuation, operational risk, etc). Ultimately, a firm will be looking to measure the aggregate impact of a climate scenario or shock into their income statements and balance sheet as well as other key financial metrics, such as risk-weighted-assets ratios or regulatory capital buffers.

Given the variety of transmission channels of climate-related financial risks, this quantification may require disaggregating the impact into separate components that feed into this process (e.g. the profit & loss statement at different levels or based on the internal configuration of a firm's portfolio). Furthermore, the approach for measuring the impact of climate-related financial risks on financial indicators will vary across the financial sector, as insurers and asset managers have different needs and use different internal performance models to quantity variations in their business and operating environment, e.g.:

- Insurers may choose to focus on measuring the impact of climate-related financial risks on claims and premiums that drive the profits and losses in their books.
- Banks may need to assess how climate-related financial risks are to be factored in their measure of risk-weighted asset ratios in order to inform their capital reallocation processes.
- Both banks, insurers and asset managers will also need to assess how climate-related financial risks can drive variations in their financial earnings and portfolio valuations.

In each case, the quantification of risk may involve reviewing the credit risk profile of customers, changes in counterparty ratings, repricing of collateral and underlying assets, etc. For example, a mortgage bank would be interested in assessing the potential impact of floods on its mortgage portfolio, quantifying physical damage with metrics that feed into the expected loss models. Likewise, a bank with an oil & gas portfolio would assess how potential carbon price movements may affect the credit risk profile of corporate borrowers and therefore the calculation of loan provisions. For smaller firms, it may be more sensible to start with one aspect of this analysis and build up expertise over time.

Time horizon

Firms need to consider suitable time horizons for the assessment of climate scenarios. This will in part depend on the business decision being analysed and the duration of firm's exposures. Climate change is typically characterised as having a long-time horizon and a multi-decadal approach is suitable for a more complete characterisation of the energy, economic and physical system. A long-time horizon also helps to understand the nature of transitions that could occur and the time taken for decarbonisation goals to be achieved.

Firms need to be aware however that while the transition away from fossil fuels will take a number of decades to achieve, the crystallisation of macro-financial risks from transition could occur considerably sooner and take multiple pathways in the short term. In contrast, impacts from physical risk, even though they are already starting to be felt, are likely to be similar in all emission scenarios in the near future. This is because the short-term temperature outcome is already locked in as it is dependent on past emissions. The most significant and extreme physical impacts are likely to arise only over several decades. Multiple emissions pathways are therefore needed to explore the full range of potential physical impacts in the long run.

Shorter-time horizons, therefore, may allow firms to construct alternative transition scenarios which carry the same physical scenario though, whereas longer-term horizons may allow firms to explore a richer combination of both multiple transition and physical outcomes.

Baseline

Firms may choose to assess the impact of climate-related financial risks in one of two ways:

1. As a one-off shock to their current portfolio. In this approach, the implicit underlying assumption is that the shocks being modelled are *not* already captured in current valuations or risk metrics (e.g. credit ratings and market valuations).
2. As the difference between a central projection and alternative pathways evolving over time. This approach involves developing a central or 'baseline' view about future emissions and temperature pathways, and then comparing it against one or more alternative scenarios. In this case, the central or 'baseline' projection could even be built by developing a specific macro-economic financial scenario, potentially using existing tools with no consideration of climate effects. One could then overlay this pathway with different emission and temperature pathways to create and assess the impact of alternative scenarios.

Firms may choose the first approach as it is simpler and it might be most suitable for assessing the impact of a specific stress on a firm's business activities, e.g. a physical event of particular severity and geographical location. Firms may also prefer this first approach as it condenses the multi-decadal dimension of climate-related financial risks into a single shock that is calibrated to capture the impact of transition and physical risks that arise over time. However, firms should be aware that this approach will not take into account management actions. Moreover, assuming no transition or physical risk in the baseline is not consistent with any of the published emissions and temperature pathways, although it is not clear what assumptions on these risks is priced into current market valuations.

The second approach enables more coherent assumptions to be made about future emissions and temperature pathways in the central projection. It also enables firms to more easily take into account management actions over time as the approach is not based on a one-off shock.

Off-the-shelf scenario analyses as discussed in the previous section may offer ready-to-use benchmark or reference scenarios that firms could use as a starting point to define a baseline. Firms may also be inclined to prolong current commitments in climate-related policies, such as nationally determined contributions (NDCs) and current carbon pricing schemes, as the basis for a transition baseline to test whether climate-related financial risk factors are adequately priced in a firm's book based on current assumptions. However, firms should bear in mind when choosing a baseline, the high level of uncertainty. For example, even if a specific carbon reduction pathway is selected as a baseline, climate science shows that in the long run it can lead to a variety of temperature outcomes and therefore multiple manifestations of physical events, with different degrees of severity and incidence.

Furthermore, the choice of baseline also needs to be taken into account when analysing and taking action based on the results of the scenario analysis exercise. If a baseline with limited reductions in emissions is chosen, then this will increase the size of transition risk relative to physical risk in the alternative scenarios. Whereas if a baseline with large reductions in emissions is chosen, then this will increase the size of physical risk relative to transition risk in the alternative scenarios.

In other words, choosing a baseline is not as straightforward as it might seem, and firms need to think through and be very clear in what assumptions they are making. Transparency of assumptions is critical in all aspects of scenario analysis – even for something that may seem fairly uncontroversial.

Management actions

Firms should consider management actions when defining the risk measure: for example, asset re-allocation to reduce exposure to carbon-intensive sectors; increasing the share of 'green' bonds. Given the long-time horizons, capturing these types of management action should result in more decision-useful scenario analysis output which allows different strategies to be tested.

That said, these actions also introduce further uncertainty into the analysis and may distort results if too much reliance is placed upon mitigating actions. Consequently, particularly for more subjective actions where there is uncertainty as to whether actions will be taken in a timely manner in practice, it may make sense to perform the analysis both with and without those actions in order to understand the impact on the results. Indeed, this type of analysis can help boards explore which types of actions are the most effective, which might prompt pro-active business model or portfolio changes.

Choose impact assessment tools

As firms come to understand the transmission mechanisms and risk drivers following the risk identification and scenario development stages, they will need to select appropriate impact assessment tools to analyse the change in the chosen risk metrics for a given scenario[20]. The use of these tools will depend on a firm's specific needs, i.e. whether it is a bank, fund manager or an insurer, what

20 These impact assessment tools are not part of the typical IAMs and the scenario modelling techniques discussed in the previous section, but still are necessary to measure the financial impact of transition and physical risk on financial firms.

risk type or risk measure they want to test, and which part of the business or balance sheet they want to stress. Also, the precise make up of a firm's portfolio and the asset classes included, either held in the book or as collateral for a security or loan, will also be important factors in selecting the appropriate tool.

Tools tend to fall into the following two broad categories, which differ by granularity:

- *Macro-economic impact assessment tools:* these provide an assessment of the macro-financial transmission and would be typically modelled with macro-economic parameters e.g. tools that look at impact distribution by country, sector, asset class, etc. to provide an aggregate impact measure.
- *Asset or company specific impact assessment tools:* these start with a granular assessment of the impact of decarbonisation and physical events on individual companies or specific assets e.g. real estate, fixed capital, etc. through the modelling of e.g. cash flows, net present value, carbon tax spending, damage costs, etc. It may include also a granular assessment of stranded or semi-stranded assets, in the form of either stranded capital or stranded valuation.

The most sophisticated firms might want to assess the full impact of transition and physical risks on their business, portfolios or individual exposures. In other words, they will want to allocate macro-economic impacts at a more granular level. The same scenario assumptions can be used for both categories of tools e.g. a core assumption about a pathway for a carbon tax can be used to narrow down and specify impacts on specific firms, or can be used to model the macroeconomic impact on demand and the distributional impact of the implications of tax revenue recycling.

As has been stressed throughout the chapter, smaller firms may not need to pursue both avenues in great depth. But it is very likely that climate scenario analysis will generally either explicitly or implicitly involve certain macroeconomic perspectives being translated into more granular assessments.

Case Study: PIMCO's proprietary climate-related financial risk tools

PIMCO's ESG specialists designed proprietary tools, looking within and across fixed income markets globally, to help credit analysts evaluate the potential impact of extreme weather events, the transition to a low-carbon economy, and other factors related to climate change. Ultimately, we look to map the likely winners and losers, notably based on scenario analysis, and the extent to which long-term climate-related financial risks are reflected in our credit views and bond prices, and, if they are not, what this could mean for issuers' credit quality considering bond characteristics (e.g. duration) over time.

At first, we identified relevant scenarios based on macro models, issuers' disclosures, and other sources such as academic research, consultants, think tanks and data providers. These informed PIMCO's proprietary methodology for assessing the financial impact of climate-related financial risks, e.g. impact on GDP and impact on issuer's ratings and bond prices as well as perspectives on different fixed income asset classes for a variety of climate-related financial risks.

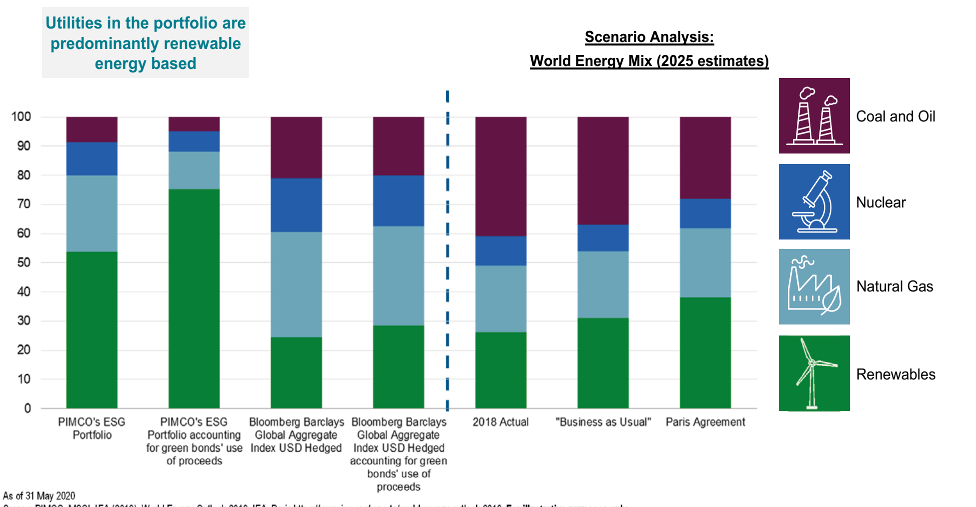
We outline below three examples and criteria used for scenarios identification.

Corporate Credit (Transition Risk Scenario)
The first approach we have taken may be referred to as 'output-based' as focuses on issuers' activities. It rests on technology pathways' alignment with the Paris Agreement, which informs several of our tools to evaluate climate-related financial risks, including PIMCO's Climate Macro Tracker (update on key macro data on climate change and the energy transition) and PIMCO's Portfolio Climate Risk Heat Map (high-level overview of exposure to climate-related financial risk among relevant sectors and assets).

A key source is the IEA, which produces reference scenarios based on global warming pathways and potential policy responses, resulting in different levels of energy demand and fuel mixes and illustrating macro trends in the energy, industry, transport, and buildings sectors.

For example, these data enable PIMCO to assess the average technology and energy mix of a portfolio compared with forward looking global energy scenarios modelled by the IEA, or to analyse disruption risks driven by the rise of electric vehicles that could displace oil demand.

Figure 9: PIMCO's sample ESG Portfolio energy mix compared with the current global energy mix and with different IEA scenarios for 2025



As of 31 May 2020
Source: PIMCO, MSCI, IEA (2019), World Energy Outlook 2019, IEA, Paris https://www.iea.org/reports/world-energy-outlook-2019. **For illustrative purposes only.**
For corporate bonds only; corporate metrics calculated based on corporate cash bonds. Unit is weighted average energy mix of a portfolio, based on issuers with an electricity generation business only (e.g. utilities, independent power producers), not including data on issuers' sourcing of electricity for their own energy needs. *Green Bond Adjusted* reflects energy mix for green bonds use of proceeds, representing a plausible range of actual energy mix financed by the bond. **"Business as Usual" refers to IEA current policies; Paris Agreement refers to IEA Sustainable Development Scenario (aligned with the UN Sustainable Development Goals and Below 2C trajectory based on the IEA definition).**
Refer to Appendix for additional investment strategy, portfolio structure and risk information

The second approach may be in part characterised as 'outcome-based' as it encompasses issuers' carbon emissions on top of their sector and subsector exposure. It consists of complementing the IEA with relevant sources and parameters to assess the impact of a particular scenario at the issuer level based on its carbon emissions and other relevant factors such as their geographical exposure or business profile that may determine the financial materiality of a particularly important variable when analysing transition risks: rising carbon pricing.

If the internationally agreed 1.5º–2°C limit for global warming is to be met, high carbon intensity sectors will be at increasing risk from tougher climate policies and higher carbon prices, and within these sectors it is possible to differentiate issuers, in part based on their carbon emission pathways.

Aside from IAMs and the IEA, the High-level Commission on Carbon prices for instance suggests a specific range to use for the carbon pricing deemed compatible with the Paris Agreement-aligned scenario (US$50–100/t$CO_2$ by 2030) and the Carbon Disclosure Project (CDP) is one example of a research provider that may be leveraged to translate this scenario into an impact on companies' financials for specific industries. These data then feed into PIMCO's Issuer Climate Risk Score (e.g. company specific analysis for corporate credit).

Sovereign and Municipalities (Physical Risk Scenarios)
A third approach built on the context of PIMCO's assessment of physical risks for Sovereign and Municipality bonds looked at the IPCC Representative Concentration Pathways, especially those that suggest a global failure to curb GHG emissions and meet the Paris Agreement (e.g. RCP 8.5 and SSP5). These scenarios were for instance used in the literature to assess the GDP sensitivity of the US economy to different climate scenarios and indicated that credit risks for the country and certain regions could potentially be greater under such assumptions.

Conclusions: Recommendations for Scenario Identification
One overarching consideration when screening scenarios is to be able to consistently translate climate-related data available at scale (e.g. portfolio-level) into granular metrics that are actionable in the context of PIMCO's credit analysts' assessments and investment decisions (our use case).

A second general principle is the need to adapt and complement sources on scenarios to reflect the range of possible outcomes in practice (e.g. sudden versus gradual change, or impact of changes across the value chain and asset classes) and issuer-specific drivers (e.g. including qualitative data regarding their adaptive capacity or resilience).

A third is that scenarios that model extreme shocks, e.g. 1.5º–2°C for Transition risks (e.g. IEA's 'Sustainable Development Scenario' and IPCC RCP 4.5) and 4-6°C for Physical risks (e.g. IEA 'Current Policies Scenario' and RCP 8.5), facilitates the identification of patterns and outliers.

A fourth is that this is an iterative process in that, for example, conclusions at the issuer level are to the extent feasible informed by issuer's disclosures and in turn also help to assess the gaps in their reporting on climate -related risk scenarios and their strategy (e.g. based on the TCFD recommendations), which PIMCO seeks to address when engaging with them as bondholder (including in the context of the Climate Action 100+ initiative).

Macro-economic impact assessment tools

Firms regularly use these tools to assess the resiliency of their business model to macroeconomic stresses in the financial system over the capital planning horizon (~3-5 years). These models can be used to quantify the impact on market and credit risk exposures of both instantaneous and prolonged macroeconomic stresses in the financial system. Input variables can typically include GDP, unemployment, interest rates, currency rates and commodity prices, as well as assumptions on asset devaluations (equity prices, and credit spreads). In the assessment of climate scenarios, further input variables representing key risk drivers may be required, e.g. agricultural productivity, carbon intensity, energy demand, carbon pricing, electric vehicle penetration, etc. Outputs of these approaches can typically include the P&L impact from an instantaneous market shock, as well as changes in reserve levels to account for increased losses on lending activities.

To assess transition risk across large portfolios as the low-carbon transition inevitably results in changes to macroeconomic variables. Firms could analyse the fiscal and distributional consequences of a carbon tax regime or the trade implications of border carbon adjustments. These tools have low granularity – that is, they are not especially detailed. Therefore, a tool may apply a single shock across whole sectors or countries and is unlikely to account for specific company or geographical idiosyncrasies. This could be partially overcome using overlays to account for such idiosyncrasies, e.g. assuming more severe credit rating downgrades or defaulting specific counterparties that are particularly sensitive to a low-carbon transition.

To assess physical risk, a simple approach would involve grouping physical asset exposures by country, and applying shocks at that level of granularity, without disaggregating to more specific geographies or regions, and without differentiating between individual physical risk factors, e.g. hurricanes, flooding. Initially, the scope may cover only assets owned by the firm but evolve over time to include assets owned by clients, e.g. transmission lines owned by a power company banking client, or residential homes owned by mortgage clients. Input shocks could be derived using existing indicators which assesses the capacity of each country to adapt to the physical impacts of climate change. Other approaches for deriving the magnitude of shocks could be a country-level heat-map which could be further refined for the largest concentrations using bottom-up approaches.

Asset or company specific impact assessment tools

These models require more involved analysis and are resource-intensive, meaning they are typically applicable for smaller portfolios. These models are characterised by high granularity which considers company- and/or geography-specific idiosyncrasies. These tools are likely to vary more significantly from firm-to-firm, e.g. banks may use credit rating models, asset managers may use asset allocation models and insurance companies will have models to project natural disasters.

To assess transition risk, firms could use tools that focus on the granular impact of decarbonisation on specific assets, sectors and corporates with direct or indirect carbon exposures. These tools assess the breadth of asset types exposed to transition risk, define the potential impacts and incorporate these in the asset financial model. These include a wide range of quantitative tools, qualitative techniques and financial models which provide a quantum of change in e.g. asset valuation and credit risk ratings as a result of transition risks rising or being crystallised as well as includes the use of databases of ESG ratings, sectors scorecards structured around climate-related financial risk, as well as data platforms for the screening and monitoring of portfolios vulnerable to a rapid switch of the economy to non-carbon energy sources.

To assess physical risk, firms could use a wide variety of tools that help them to identify and quantify physical exposure to climate change in their portfolios. Such models help estimate direct costs of damage and changes in asset valuations, credit risk ratings, or heat-map scores with granularity at the corporate or asset level. These include geographical data systems to locate assets at risk, e.g. mortgage portfolios backed by real estate assets vulnerable to floods or rising sea levels, as well as valuation models that link the locational data to internal risk models. It should be noted that currently, "such tools" mostly allow for an assessment of today's physical risks and are also mostly limited to the key natural hazards (cyclones, flooding, etc.). Estimating financial losses for secondary perils (e.g. wildfires, torrential rainfall), which are important in the context of climate change, are generally less sophisticated. Models currently also tend not to allow for a holistic forward-looking view (e.g. 20+years) that would not only include changes in peak perils but also secondary perils and potential amplification effects due to human activities (e.g. urbanization, land-use, etc).

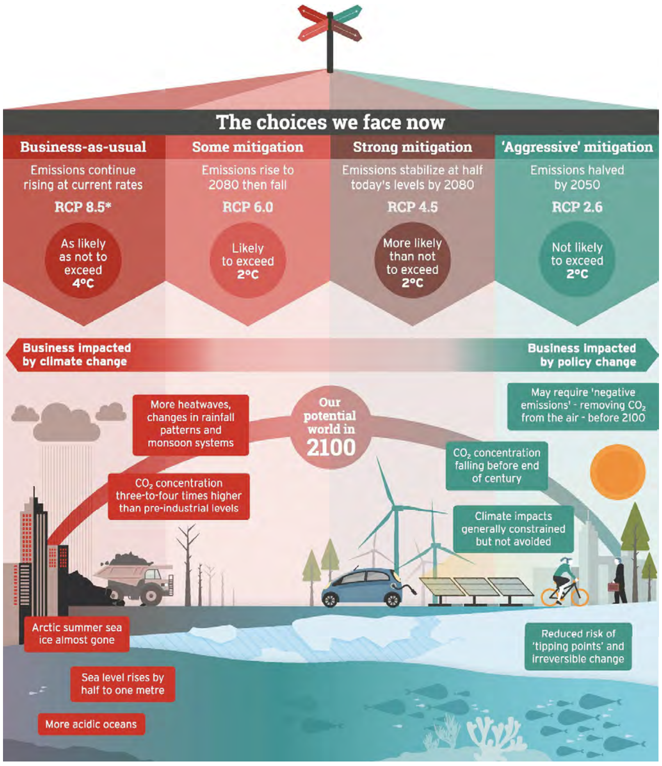
Case Study: Aviva's Climate Value-at-Risk

The United Nations Environment Programme Finance Initiative (UNEP FI) Investor pilot project recently published a Changing Course report. In the report they presented a Climate Value-at-Risk (Climate VaR) measure developed in conjunction with Carbon Delta, an environmental FinTech. This Climate VaR measure provides a holistic forward-looking view of the impact of climate-related transition and physical risks and opportunities on investors' equity and corporate bond portfolios over the next 15 years. Along with nineteen other institutional investors from eleven countries, Aviva participated in the UNEP FI Investor pilot and has extended the Climate VaR approach with Elseware, a risk management and quantification expert consultancy, to enable it to be applied to its whole balance sheet. To support this initiative, we set-up an internal inter-disciplinary team with representation from across the business to manage the project day-to-day and an expert panel was set-up to review and challenge the main assumptions made in the selection, development and modelling of the scenarios. The panel included internal experts as well as three external experts

(Simon Dietz, Nick Robins, Swenja Surminski) from the Grantham Research Institute on Climate Change and the Environment at the London School of Economics.

The VaR measure allows four potential future scenarios with respect to climate change developed by the IPCC to be analysed. Each scenario describes a potential trajectory for future levels of greenhouse gases and other air pollutants and can be mapped to potential temperature rises and levels of mitigation required: 1.5°C (aggressive mitigation), 2°C (strong mitigation), 3°C (some mitigation) and 4°C (business as usual).

Figure 10: The choice we face now.



Source: TCFD.

It is important to note that the four scenarios all assume a gradual path, in which temperatures rise slowly but climate policy is ramped up at varying speeds with a fairly high degree of global coordination. They do not consider the transition risk in a more chaotic policy environment, where there is lack of global coordination and policy action is taken too late and too suddenly.

This may result in an understatement of climate-related financial risks. The initial result of Aviva's Climate VaR analysis compares a plausible range of outcomes (5th to 95th Percentile) from the different scenarios considered. As can be seen from this analysis, exposure is greatest in relation to the Business-as-Usual 4°C scenario where physical risk dominates, negatively impacting long-term investment returns on equities, corporate bonds, real estate, real estate loans and sovereign exposures.

Figure 11: Initial Climate VaR output by scenario for Aviva's shareholder

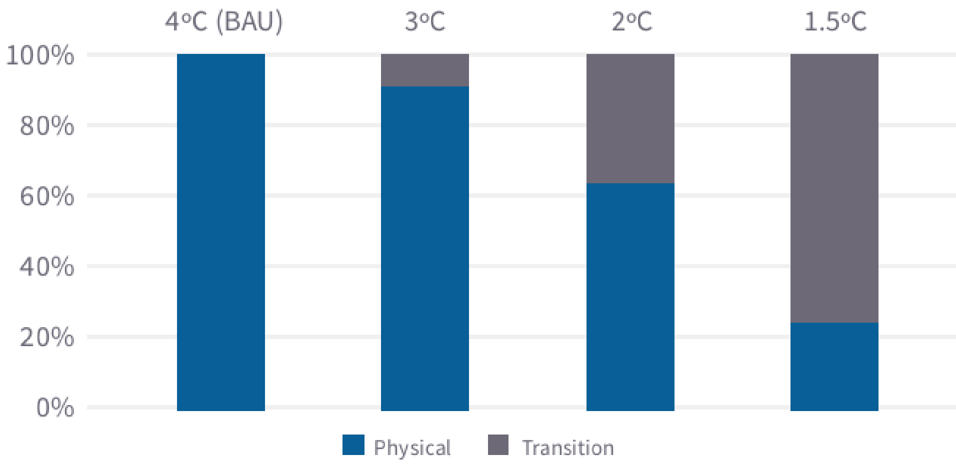
funds as at 31/12/2018.

The grey bars represent the range of outputs between the 5th Percentile and the central estimate for each scenario and the orange bars the range between the central estimate and the 95th Percentile.

Source: Aviva.

The aggressive mitigation 1.5°C scenario is the only scenario with potential upside. Physical risk impacts are much more limited but there is still downside risk on long-term investment returns from carbon intensive sectors (e.g. utilities) as a result of transition policy actions. This is offset partially by revenues on new technologies from some sectors (e.g. motor vehicles). When aggregated together to determine an overall impact of climate-related financial risks and opportunities across all scenarios, the plausible range is dominated by the results of the 3°C and 4°C scenarios, reflecting that neither existing or planned policy actions are sufficiently ambitious to meet the Paris Agreement goal. The 1.5°C scenario is dominated by transition risk, even after taking into account mitigating technology opportunities. In the 2°C scenario, transition and physical risks are more evenly balanced, whereas in the 3°C and 4°C scenarios physical risk dominates (see figure 12).

Figure 12: Physical versus transition risks by scenario for Aviva's shareholder funds as at 31/12/2018.



Source: Aviva.

In all scenarios the impact on insurance liabilities is more limited than on investment returns. However, there is potential for some impact on life and pensions business as a result of changes in mortality rates in different scenarios either from physical effects such as more extreme hot and cold days or transition effects related to changes in pollution levels. The impact on general insurance liabilities is relatively limited because of the short-term nature of the business and the ability to re-price annually and mitigation provided by our reinsurance programme. However, the physical effects of climate change will result in more risks and perils becoming either uninsurable or unaffordable over the longer term.

Examples of impact assessment tools, databases, methodologies

To help firms choose the most appropriate impact assessment tool to assess their exposures and quantify impacts according to their specific needs, a non-exhaustive inventory of the available impact assessment tools, databases and methodologies are provided (see list of example datasets and tools published alongside the Risk Management chapter). Each tool has been classified based on physical or transition risks and opportunities, transition channels relate to lower emission pathways – e.g. new climate policies and technology; physical channels relate to acute (e.g. increases in acute weather events) and chronic effects (e.g. increases in average temperatures and sea level rises), and whether it is a macro-economic or asset/company specific impact assessment tools. The scope and scenarios used have also been highlighted.

Assess financial impacts and identify required actions or follow-up analysis

Firms should assess financial impacts and translate these impacts into financial metrics to be used to inform decision-making e.g. Profit & loss statement and Capital ratios. This translation should be comparable with the way these metrics are already incorporated in decision-making, whilst taking into account potential differences in the time horizon and baseline used.

Depending on the insights from the analysis, firms may decide to take actions or undertake follow-up analysis. For example, if the results of the scenario analysis showed the board that there was an unacceptably high concentration of transition risk in a particular portfolio, it may suggest a move to diversify, or perhaps to conduct a deeper dive in order to challenge some of the assumptions and test the adaptive capacity of the firms in the portfolio.

As illustrated in the Figure 1, these insights should feed back in an iterative way to the overall end-to-end process of scenario analysis. Insights gained from the financial impact analysis should feed back into the refinement and identification of new risks; they should also provide insights into potential exposures; and they should inform the on-going development of existing scenarios and support the identification of potential new scenarios to be analysed.

Case Study: JP Morgan Climate Transition Scenario Analysis

This case study describes some of the main stages in our thought process for exploring the impact of an abrupt low-carbon transition on credit ratings in carbon-intensive sectors.

1. Identify potential exposures to climate-related financial risks

The objective of our exploratory analysis is to assess the impact of an abrupt low-carbon transition on the credit ratings of key exposure concentrations. A natural starting point is exposures in carbon-intensive sectors, although different segmentations of the portfolio could also be relevant.

2. Develop suitable climate-related scenarios

Carbon-intensive sectors are potentially exposed to a low-carbon transition since fossil fuel demand will need to reduce in order to meet low-carbon emissions trajectories and additional costs may be imposed on carbon-intensive activities through a presumed carbon price. At least two drivers can accelerate reductions in fossil fuel demand; changes in climate policy and technological evolution. This case study focuses on the impact of a change in climate policy, although an abrupt and unexpected change in either of these drivers could result in a financial stress.

It is useful to consider a range of different warming trajectories given uncertainty over the future pathway. One possible narrative is to assume that policy results in a price on carbon at a level consistent with the warming trajectory. Some of this additional carbon cost may be passed onto consumers, which would therefore impact both expenditures (from the carbon price) and revenues (from lower fossil fuel demand). Note that scenario narratives should be tailored to target the objectives and exposures of each firm undertaking the analysis. Another possibility for the scenario narrative would be, for example, bans on certain carbon-intensive fuels/technologies which impact fossil fuel output.

The level of the carbon price and change in demand for each sector can be estimated in multiple ways, for example by considering demand elasticities for individual products, or by extracting demand estimates from IAMs or the IEA World Energy Outlook model. The approach taken should reflect the availability of resources and the required sophistication of the analysis.

To isolate the impact of the change in climate policy, all other scenario variables can be held constant (e.g. socio-economic backdrop, technological evolution) and the scenarios can be applied using a closed book assumption. These are simplifying assumptions that should be clearly documented and refined over time in line with firm's own specific objectives.

3. Assess the financial impact of scenarios

To estimate the impact on credit ratings, we can estimate "scenario-adjusted" financials for exposures in the carbon-intensive sectors. These scenario-adjusted financials would reflect the impact of higher costs and reduced revenues. It should be noted that this gives a point-in-time or historical perspective only, and it is also important to consider each company's ability to cope with a low-carbon transition going forward. The scenario-adjusted financials can be inputted to internal models to calculate scenario-adjusted ratings and scenario-adjusted losses.

5 Challenges and barriers

There are many challenges and barriers to overcome in performing scenario analysis in particular the breadth and magnitude of the effects of climate change, the extended time horizons, uncertainty and lack of recent historic precedents.

The following figure summarises these key challenges and barriers.

Challenges and barriers	
Breadth and magnitude of transition and physical risks	Climate change will affect all agents in the economy (households, businesses, governments), across all sectors and geographies. It is hard to know where to start and which effects to prioritise in analysis. The risks will likely be correlated and, potentially aggravated by tipping points, in a non-linear fashion. This means the impacts could be much larger, and more widespread and diverse than those of other structural changes.
Extended and uncertain time horizons and feedback loops	The time horizons over which climate-related financial risks may be realised are uncertain, and their full impact may crystallise beyond most current business planning horizons. Conversely, social tipping points are rarely modelled but may mean some transition elements affect certain sectors abruptly, using past data may not be a good predictor of future risks and currently there is often little economic incentive to take the short-term actions needed, and some major economic barriers.
Weakness of many climate economic models	Many economic models of climate impacts perform poorly in higher warming scenarios, with simplistic damage functions that fail to reflect the compounding impacts of a cocktail of physical risks and social implications that are consistent with the science.
Data gaps and comparability of disclosures	Firms may need to use additional metrics requiring new data and new modelling methods to capture climate impacts on the economy and their business. Such variables might include hazard factors for physical events or greenhouse gas emissions from specific economic activities. Firms are likely to find that their existing risk models will also need to be adapted to capture climate factors.
Cognitive bias	Cognitive bias must be recognised and accounted for when developing and using any type of scenario. For example, people unconsciously assess probability of a future event or outcome on the basis of how easily they can remember past examples or how easily they can imagine possible events.

Breadth and magnitude of transition and physical risks

The financial risks from physical and transition risk factors are relevant to multiple lines of business, sectors and geographies. The full impact on the financial system may therefore be larger than for other types of risks, and is potentially non-linear, correlated and irreversible. The breadth and magnitude of climate-related financial risks means that scenarios need to link macro-economic and asset or company specific assessments and translate these into usable granular outputs. This can add layers of complexity in the scenario and create a lot of uncertainty. This could become a major barrier to their use in practice, if a proportionate approach is not adopted.

Therefore, it is crucial to specify the purpose of the scenario, and to focus its design on the most relevant components. It may be preferable to start with a simplified outline scenario, using existing research, data and models, and iterate, adding additional elements where material. The large amount and wide variety of off-the-shelf research, data and models available is itself a challenge, so a clear focus on purpose will help to determine the approach and sources to utilise and the nature and granularity of output needed. For example, if the timeframe being considered is short, some of the longer-term trends may be negligible or could be represented simply.

Many firms will have limited resources to devote to grappling with the complexities of scenario modelling. It is important that the “perfect does not become the enemy of the good”. A helpful analogy here is given by the challenges life insurers have faced in modelling longevity, which involves long timeframes and complex assumptions about behaviour, lifestyles, policy, healthcare etc. These models have developed and taken more elements into account over time as understanding and research has evolved. Carbon-price can, for example, be a good place to start as an anchor for a range of mitigation policies (e.g. a core assumption about a pathway for a carbon price can be used to narrow down and specify impacts on specific sectors or businesses).

Extended and uncertain time horizons and feedback loops

The time horizons over which climate-related financial risks may be realised are uncertain, and their full impact may crystallise beyond most current business planning horizons. Using past data may not be a good predictor of future risks and currently there is often little economic incentive to take the short-term actions needed, and some major economic barriers. However, the magnitude of future impacts will, at least in part, be determined by the actions taken today (tragedy of the horizon).

While using a shorter timeframe (up to a few years) may seem more relevant for decision-making now, the most significant impacts from physical risks will arise over decades. Conversely, transition risks can occur much sooner, if momentum builds towards a policy change and public opinion shifts (as happened for example with diesel emissions or plastic bag use). Selecting an appropriate time horizon for a scenario looking at either transition or physical risk or both effects together will therefore require trade-offs to be made.

There are high levels of uncertainty and a variety of feedback loops and path dependencies between:

- the development and deployment of technologies;
- the decision-making by companies, financial institutions, governments and regulators;
- implementation and enforcement of public policies;
- actual and future environmental impacts including climate change, and
- the economic and financial impacts on economies, companies and financial institutions.

There is currently a major gap between the Paris Agreement targets and global action, at a government, corporate and individual level. This is linked to the great economic paradoxes of long-term threats to humanity posed by climate change combined with rising fossil fuel demand, low cost of emissions and high cost of abatement (e.g. new infrastructure or carbon capture and storage (CCS)). Therefore, it is important that key assumptions and their difficulties are transparent and understood by the users and decision-makers. For example:

- Transition pathways to meet the Paris Agreement targets often assume extensive CCS. However, major institutions have proposed that CCS is yet to be proven economically so is unlikely to be scaled up by several orders of magnitude and will remain a niche solution.
- Efficiency savings play a large role in some scenarios but in well-documented 'rebound' effects, efficiencies usually drive demand up not down.

Even the best scenarios can turn out to be inaccurate. For instance, analysis of energy technology scenarios developed during the 1980s found that "successful long-range forecasts of key variables such as energy consumption, is generally poor."[21] The IEA have also consistently underestimated the growth of renewable energy[22]. The outputs of these scenarios can also have consequences: "When the IEA and the US Energy Information Administration say that modern renewable energy will produce less than 1% of the world's electricity many decades into the future, that deters serious politicians, investors or business people from backing them" (Michael Liebriech, founder of Bloomberg New Energy Finance, 2017).

In order to work with and "decompose uncertainties". Diverse groups of internal and external analysts could be asked to list different ways in which key financial indicators of interest might have a high, medium or low value due to climate-related factors by the future timeframes of interest. A second step could be to then consider the consequences of these changes occurring in a variety of simple

21 Morgan, Granger and David Keith, 2008. "Improving the way we think about projecting future energy use and emissions of carbon dioxide" Climatic Change 90(3) https://scholar.harvard.edu/files/davidkeith/files/92.morgan.improvingscenarios.e.pdf

22 Carbon Brief, October 2017 www.carbonbrief.org/iea-renewable-electricity-set-to-grow-40-globally-by-2022

time sequences. Creating probability distributions for these outcomes either needs to be done very carefully or this step may not always be needed[23].

When developing scenarios, it also important to explain whether it represents a central or tail case, and if it is more of a central case, to indicate where the tail risks may lie. As while the long-term physical impacts of climate change are foreseeable, there are widespread perception gaps about the macro-economic effects, the likely pathways and outcomes, the scale of action needed and the strength of policies that would entail.

Weakness of many climate economic models

Many economic models of climate impacts are poor in higher warming scenarios (i.e warming of 3-6°C). Physical and social scientists recognise the impacts of such scenarios as increasingly catastrophic, impacting human society in many destructive ways. History tells us that societies tend to struggle to cope with such onslaughts in rational and constructive ways. However, economic models tend to have mild or simplistic damage functions that fail to respond in a way that is consistent with the scientific analyses and expectations.

For example, the cumulative impact of a cocktail of physical stresses and disasters may impose exponential costs to restore assets, infrastructure and production, and prompt change of activity different from that which infrastructure was designed for, reducing economic efficiency or stranding assets. It can impair business cases for investment, reducing aggregate demand. More severe or frequent regional food and water crises will also be disruptive. In more extreme cases, these can provoke greater international friction, migration, refugee crises and/or conflict, with further consequent feedback effects in a destructive loop. Most economic models will still project net economic growth under 5°C warming or more. This needs to be reconciled with projected physical and social impacts of such warming that imply the loss of the majority of global output.

Data gaps and comparability of disclosures

Another issue is data. Some questions are difficult to resolve based on currently available data, particularly for matters that are specific to a firm or property and not in the public domain, e.g.:

- flood exposure for property depends on resilience measures adopted
- knock-on impacts will depend on supply chain flexibility and alternative sources of materials or products
- the extent to which the impact of climate-related financial risks and opportunities are captured in current asset valuations
- uncertainty regarding the relative likelihood of different climate scenarios occurring

23 See ideas developed by Granger and Keith, 2008, p. 209-211.

Financial firms may need to use additional metrics requiring new data and new modelling methods to capture climate impacts on the economy and their business. Such variables might include hazard factors for physical events or green-house gas emissions from specific economic activities. Firms are likely to find that their existing risk models will also need to be adapted to capture climate factors. There is also likely to be a feedback loop from downstream model development to scenarios: as firms develop methods to assess impact, this may lead to new requirements for scenario metrics which in turn requires developments in scenario methodology. Firms also should be aware that IAMs are not specifically tailored for their needs and consequently adjustments may be required to enable the outputs to be incorporated into existing modelling frameworks.

A further issue is that, while progress is being made, there is still low comparability of climate-related disclosures from companies regarding their climate change risks and opportunities[24]. Corporate disclosures are an important building block for firms' own analysis and disclosures. While it may not be possible to fully address these challenges and barriers, there may be steps that can be taken to improve the consistency and comparability of scenario outputs, while avoiding narrow and homogenous analysis that is not decision useful for analysts and decision-makers at firms.

In the short term, the use of reference scenarios and good disclosure about scenario selection and design will be the key mitigants. Key regulatory authorities, institutional investors, banks and stock exchanges are increasingly signalling that mandatory disclosure requirements are approaching or have already been implemented. Over the last few years, such signals have helped to broaden the number of companies that are making climate-related financial disclosures as well as increasing the level of granularity of disclosures. Stronger signals/encouragement from regulators, investors and other firms can expand and improve corporate disclosures further.

Cognitive bias

Many academic research reports have found a variety of cognitive biases affect decision making. Cognitive biases must be recognised and accounted for when developing and using any type of scenario. For instance, it is well documented that people unconsciously assess probability of a future event or outcome on the basis of how easily they can remember past examples or how easily they can imagine possible events. This is known as the 'availability heuristic': what is out of sight is effectively out of mind. A linked additional challenge is that substantial evidence shows that "the more detail that one adds to the story line of a scenario, the more probable it will appear to most people, and the greater the difficulty they are likely to have in imagining other ways in which variables of interest might arrive at the same values." Scenario analysis within organisations can also serve to "reinforce biases and narrow the span of an organisation's

24 TCFD 2019 Status report www.fsb-tcfd.org/publications/tcfd-2019-status-report/

attention" which could result in the conscious or unconscious individual /group/ organisation suppression of analysis or scenarios where there could be negative or undesirable consequence[25].

It may be possible to agree some standardisation of key variables used in scenario analysis. However, to avoid some cognitive biases, it is important to use scenario analysis to assess a wide range of potential future outcomes, particularly outcomes that might seem unlikely today.

25 Granger and Keith, 2008

Annex 1 Resources

- CRO Forum report "The heat is on – Insurability and resilience in a Changing Climate"
- NGFS first comprehensive report
- TCFD hub - over 200 articles on scenario analysis.
- UNEP FI Investor Pilot report "Changing Course"
- UNEP FI Banking Pilot reports

How to prepare scenario analysis

- 2-Degree Investing Initiative report "Transition Risk Toolbox: Scenario, Data and Models"
- Acclimatise briefing note "Using scenarios in corporate disclosure of climate risk"
- Center for Climate and Energy Solutions report "Using scenarios to assess and report climate-related financial risk"
- Ceres report "A Framework for 2 degrees Scenario Analysis: A Guide for Oil and Gas Companies and Investors Navigating the Energy Transition"
- CDP technical note on Scenario Analysis
- Climate Disclosure Standards Board guide "How can companies considering TCFD recommended scenario analysis provide disclosures that help investors"
- CDSB webinar "Scenario Analysis Case Studies"
- Kosow & Gaßner academic paper "Methods of Future and Scenario Analysis"
- McKinsey article "From scenario planning to stress testing"
- North American CRO Council report "Scenario Analysis Principles and Practices in the Insurance Industry"
- Paltsev, 2016. "Energy Scenarios: The value and limits of scenario analysis" MIT Center for Energy and Environmental Policy Research
- PwC guide "Getting Started with Scenario Analysis"

How to use scenario analysis information

- Cicero article "Climate Scenarios demystified: A climate scenario guide for investors"
- Energy Transition Risk Project report "Investor primer to transition risk analysis"

Other documentation

- CarbonBrief article "How 'Shared Socioeconomic Pathways' explore future climate change"
- Carbon Pricing Leadership Coalition "Report of the High-level Commission on Carbon Prices"
- Hsiang et al. 2017. "Estimating economic damage from climate change in the United States" Science.

- Integrated Assessment Modelling Consortium AIM-CGE model documentation
- Institutional Investors Group on Climate Change report "Navigating Climate Scenario Analysis"
- Intergovernmental Panel on Climate Change AR5 Synthesis Report
- International Energy Agency "World Energy Outlook 2018" report
- International Institute for Applied Systems Analysis "Shared Socioeconomic Pathways Database"
- International Institute for Applied Systems Analysis Message-Globiom model
- Joint Global Change Research Institute "Global Change Assessment Model"
- PBL Netherlands Environmental Assessment Agency Image 3.0 model documentation
- PIMCO ESG Investing Report 2018
- PIMCO report "Managing Climate Risk in Investment Portfolios"
- Potsdam Institute for Climate Impact Research Remind model
- Riahi et al., 2017. "The Shared Socioeconomic Pathways and their energy, land use and greenhouse gas emissions implications" Global Environmental Change.
- Weyant, 2017. "Some Contributions of Integrated Assessment Models on Global Climate Change" Review of Environmental Economics and Policy.
- WITCH model

Annex 2
List of reference climate scenarios

Provider	Name	Key characteristic	Emission peak year	Year for net-zero emissions	Reference
Energy transition scenarios					
IEA	Beyond 2 Degrees Scenario	Limits warming to 1.75°C by 2100. Starts in 2014.	2017	2060	2 Degrees of Separation, PACTA, TPI, TCFD technical supplement
IEA	Energy Technology Perspectives 2 Degrees scenario	ETA 2°C scenario. From 2014-2100	2020	2060 for power	TPI
IEA	Sustainable Development Scenario	Combines climate and social targets for limiting global warming to 2°C. Starts in 2016 until 2040.	2020 for energy and industry	Not modelled (beyond 2040)	PACTA
IEA	New Policy Scenario	Pathway if all new policy, set out in countries' NDCs, are effectively implement. From 2016-2040	2029 (China peak energy only)	Not modelled (beyond 2040)	2DS, PACTA, TPI, TCFD technical supplement
IEA	Current Policy Scenario (CPS)	Business-as-usual without new climate policies. From 2016-2040	No peak	No net zero	PACTA, TCFD technical supplement
IRENA	RE Map	Doubles renewable energy share of world's energy mix by 2030. From 2010-2030			PACTA, TCFD technical supplement
Greenpeace	Advanced Energy [R] evolution	Pathway for a fully decarbonised energy system by 2050			PACTA, TCFD technical supplement

Provider	Name	Key characteristic	Emission peak year	Year for net-zero emissions	Reference
Institute for Sustainable Development	Deep Decarbonization Pathway Project (DDPP)	Country level pathways for reducing emissions consistent with 2°C. From 2010-2050			TCFD technical supplement
Bloomberg	BNEF reference scenario	Power sector pathway scenario			PACTA, TCFD technical supplement
Physical climate scenarios					
IPCC	Representative Concentration Pathway (RCP) 8.5	High emission scenario, 4-5°C, consistent with no policy changes to reduce emissions	No peak	No net zero	TCFD technical supplement
IPCC	RPC 6	High-to-immediate climate emissions scenario, 2~3.7°C.	2080	No net zero	TCFD technical supplement
IPCC	RCP 4.5	Immediate climate emission scenario. Global emissions peaking in 2040 and falling rapidly thereafter until 2080	2040	No net zero	TCFD technical supplement
IPCC	RCP 2.6	Limits warming to the Paris Agreement's target of 2°C by 2100	2020	2070	TCFD technical supplement

Source: PRI Table of climate reference scenarios (available at: https://www.unpri.org/climate-change/directory-of-climate-scenario-tools/3606.article)

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