CLIMATE FINANCIAL RISK FORUM

CLIMATE FINANCIAL RISK FORUM GUIDE 2024

RESILIENCE WORKING GROUP: SHORT-TERM SCENARIOS CHAPTER

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Contents

This chapter represents the output from the cross-industry Resilience Working Group of the Prudential Regulation Authority and Financial Conduct Authority's Climate Financial Risk Forum ("**CFRF**"). The document aims to guide financial services companies to create, leverage and embed short-term climate scenarios for the purposes of their business strategies and risk management.

Acknowledgements

This chapter has been written by the Short-term Scenario Analysis (STS) sub-group of the Climate Financial Risk Forum (CFRF) Resilience Working Group.

It is largely written by practitioners, and is intended to support practitioners working in banks, insurers and asset managers, who support STS analysis in a number of use cases, e.g. strategy, business planning, risk appetites, stress testing, capital adequacy, pricing, reinsurance and disclosure across different functions. It aims to enable firms to better understand their exposure and reflect outcomes from STS analysis in decision making.

The views in this chapter reflect the individual participants and not necessarily the views of their employers.

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Foreword

The changes in climate induced by anthropogenic greenhouse-gas emissions are a long-term phenomenon. They do however increasingly manifest themselves in the short term.

Global temperature records continue to be reached, with the summer of 2023 the Northern Hemisphere's hottest in recorded history[i]. Five natural thresholds already risk being crossed, according to the Global Tipping Points report[ii], and three more may be reached in the 2030s if the world heats 1.5°C above pre-industrial temperatures.

The impacts from extreme weather events on the economy are increasing, with higher disruptions and climate-related losses around the world and are difficult to forecast. The effort to adapt or mitigate this physical risk will also play out in the long-term, given the investment cycles at play. Most emissions plans and targets refer to dates ranging from 2030 to 2050.

The 14th edition Emissions Gap Report[iii] published by the United Nations 2023 highlights that we are not on track to meet the 1.5°C target set out by the Paris Agreement, in the context of energy security concerns. There is a high level of uncertainty around the speed and scale of the transition. For financial institutions, this short-term uncertainty on both physical and transition aspects represents risks to be managed.

This chapter showcases how short-term scenarios can be used to assess the impact of such climate-related economic risks. It offers a framework enabling practitioners (banks, insurers, and asset managers) to better understand their exposures and reflect outcomes of short-term scenarios in their strategy and business models.

This work has been a collaborative effort between banks, insurers, and asset managers, as well as consultancies and academics that have been convened by the Bank of England and the Financial Conduct Authority. We are deeply grateful to all who provided feedback, conducted reviews, or contributed to the production of this chapter.

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1 Purpose

This chapter recognises the overall importance of robust climate scenario analysis, both short- and long-term, to support decision-making. In particular, this analysis intentionally focuses on Short-Term Scenarios ("**STS**"), which are defined as scenarios of six years or fewer (based on our survey of STS members which suggests this is the duration typically used in financial services).

Firms are facing increasing demand to understand the impact of climate change across their business models and activities. This is particularly important amidst uncertainties stemming from fossil energy consumption on the one hand, and the increasing occurrence and impact of weather events on the other.

Current business use cases require a more complete view of short-term climate-related risk than is proposed by scenarios and models presently used by the industry. These use cases include analysis of transition to net zero, tracking progress against interim targets and ambitions (typically by 2030), and the analysis of the financial resilience of business plans or portfolios.

The purpose of this chapter is to propose a framework for practitioners (banks, insurers and asset managers) to consider in evolving climate-related risk modelling for short-term use cases. This framework is an evolution of previous frameworks proposed by the CFRF in its scenario analysis chapters developed in the 2020[iv] and 2021[v] sessions. It also builds on content from the 2022-2023 chapters for banks[vi], insurers[vii], asset managers[viii], and other financial firms[ix].

The chapter examines some of the challenges in short-term climate scenario analysis, e.g., extreme weather events, interdependencies between climate risks and macro-financial developments, and assessing the likelihood of events.

This chapter includes case studies to illustrate current best practices, thought leaders' work and the results of two surveys. Given the evolving nature of short-term scenario design and modelling, quantitative case studies remain limited. The surveys confirm that most members and data providers are in the process of developing climate STS, but their progress varies widely. Litigation risk and nature-related financial risks are not in scope of this chapter.

2 Executive summary

This chapter proposes a framework that can be adapted and deployed by financial services firms to conduct STS analysis for a variety of use cases.

The framework outlines key questions and considerations for firms and industry practitioners interested in conducting climate STS analysis. It examines the various stages of STS analysis, from defining the purpose of the analysis and setting out appropriate narratives and variables, to modelling indicative financial impacts and likelihood, before discussing the importance of review and challenge of the results and taking appropriate management actions.

Figure 1: Our Climate STS Analysis Framework

- **Defining the use case and associated time horizon**

The first step in the framework is to consider how the STS analysis could be used to support decision-making and to determine the time horizon for the analysis. Different use cases will require different resilience considerations, which will impact the intensities of risk to be explored. This work should take into consideration the business activity and the firm's climate strategy as well as the wider market environment. We define short-term time horizons as six years or less.

- **Defining STS narratives**

This section considers how a risk event is expected to manifest during the time horizon (e.g., the frequency and severity of the event) and what are the socio- and macro-economic contexts (e.g., how will technology or policy ambition evolve to tackle climate change). Several frameworks have been developed to support firms with defining STS narratives (e.g., the Network for Greening the Financial System (NGFS)[x] and the Banque de France STS narratives[xi]). While there are advantages of uniform and pre-determined STS, there are also benefits of using bespoke scenarios tailored to a firm's specific needs and vulnerabilities.

- **Selecting variables through risk and transmission channel assessment**

This section looks at steps three and four of the framework. When assessing climate STS impacts, firms should consider what physical and transition risks could occur during the specified time horizon, consistent with the chosen narrative, either simultaneously or separately. Certain locations, sectors and even individual companies, entities or individuals may be affected to a different extent by the parameters being used within the scenario.

Firms can quantify the impact of the risk events through a variety of first order (e.g., the consequences of implementing policy changes) and second order (e.g., impacts on a firm's capital requirement) transmission channels. For each of these transmission channels, there will be a set of associated variables to model. Depending on the purpose and data availability, a firm can choose whether to use a bottom-up or top-down approach to defining variables and modelling.

- **Calculating financial impacts for STS analysis**

There are a range of modelling approaches currently used, with different advantages and limitations. Climate models have been used principally for long-term scenario modelling. There are developments underway to improve short-term modelling, both in terms of the breadth of the transmission channels and variables being modelled, as well as the understanding of their limitations. However, these improvements may not enter the mainstream for several years. In the meantime, it is more likely that firms will adapt either existing climate long-term models or other short-term models (e.g., those used for capital management) to incorporate climate-related risk. Firms can choose a baseline scenario that acts as a benchmark to compare results against.

- **Assigning likelihoods**

Assessing the likelihoods of climate STS is a recent area of focus, and there is no consensus in the financial industry about its relevance. In this section, we address the question of the importance of likelihoods for STS, describe key use cases in their assessment and explore some of the approaches, both qualitative and quantitative, currently being developed by industry practitioners and academia.

- **Review and challenge of STS analysis**

It is important to review and challenge[xii] the results of climate STS analysis before being used to inform decision-making. Given the lack of historical precedent, some uncertainty will likely remain. Limitations will also need to be considered. Well-tested climate scenario analysis can build trust in the results and help to facilitate a net zero transition, whereas poor scenario analysis can give rise to greenwashing risk[xiii].

- **Management actions**

Decisions may be taken based on multiple sets of inputs, in addition to the STS analysis, and will depend on the stakeholders and the business use case. Therefore, firms should consider how to integrate the results of the STS analysis effectively and proportionately into the overall strategic decision-making, including their business planning and investment decisions.

3 Defining the use case and associated time horizon

The purpose for measuring the impact of climate risk and the time horizon will vary across the financial sector, reflecting the differences in business models banks, insurers, and asset managers. E.g.:

- Insurers may choose to focus on measuring the impact of climate change on the claims and premium volumes that drive the profits and losses in their books.
- Banks may need to assess how climate change is to be factored in their measure of risk-weighted asset ratios to inform their capital reallocation processes.
- Asset managers may seek to adjust their sectoral asset allocations for a given portfolio considering climate-related risk, to stabilise their projected return profile.
- Banks, insurers, and asset managers can also assess how climate-related risk drives variations in their short-term financial earnings, asset and liability valuations, and solvency and liquidity positions.

3.1 What is the purpose of the STS analysis?

Defining the purpose of an STS analysis exercise is equivalent to scoping the use case(s) the analysis should inform, clearly setting out its requirements to ensure the scenario design and its modelling delivers on those requirements.

A summary of typical use cases across the financial sector that would benefit from STS analysis is shown in **Error! Reference source not found.** below. These are an evolution of the use cases presented in previous CFRF guides, e.g., Session 3's CFRF 2022 guides: Scenario Analysis - physical risk underwriting guide[xiv], and Scenario Analysis Working Group – Banking guide[xv]. The purpose of the use case will determine the severity of risk explored, with greater resilience considerations leading to more severe risks .

*Figure 2: Illustrative examples of use cases for climate STS analysis**

Typical climate scenario analysis use cases in the financial services sector, with varying resilience considerations			
Strategy	Projected funded emissions	Identifying uninsurable risks	**Risk identification**
Business Plan	Sectoral analysis to inform asset allocation and exclusion policies	Reinsurance purchase	Management Actions
ISSB/TCFD	Support discussion with asset manager on their decisions/metrics	Pricing	**ORSA/ICAAP/ILAAP**
Transition plan	Internal credit ratings	Management of underwriting footprint	Operational or liquidity risk
Performance against net-zero objectives and interim targets	Assessing portfolio CVaR or temperature alignment	**Reinsurance/Catastrophe Bond/Other risk transfer**	**Risk Appetite monitoring**
Macroeconomic forecasts	Asset picking/stock selection	Input into Life underwriting assumptions	**Capital adequacy (SII)**
Credit decision processing	**Insights to internal credit ratings for applicable asset classes**	Underwriting decision processing	Expected Credit Loss (ECL)
Results highlighted were common responses of use cases supported by climate STS modelling in the STS Maturity Survey. The importance of each use case depends on the priorities of each company and will vary by type of institution.			

* Own Risk Solvency Assessment (ORSA); Internal Capital Adequacy Assessment Process (ICAAP); Internal Liquidity Adequacy Assessment Process (ILAAP); Solvency II (SII); Taskforce Climate Financial Disclosure (TCFD); International Sustainability Standards Board (ISSB)

Below we present two case studies which illustrate short-term use cases. The first one is Aviva's illustrative examples of climate STS analysis[xvi] and the second one is a scoping of a short-term use case - business planning for a composite insurer.

Case study 1: Aviva's illustrative examples of climate STS analysis

Aviva's 2023 Climate report summarises how STS analysis has helped to inform several use cases (e.g., Solvency II internal model, GI pricing and reinsurance).

Figure 3: An extract from Aviva's 2023 Climate report

"We use scenarios to understand how climate-related risks might impact Aviva's strategy, financial and operational resilience, and franchise/reputation and, therefore, the management actions we might need to take as a result. This is primarily a qualitative assessment informed by quantitative indicators.

We map emerging risks and trends on our emerging risk spectrum according to the nature and size of their impact to assess their materiality. The outcomes are reported to our Board and Senior Management, which informs the prioritisation for management action and reporting (see Risk Spectrum figure). This is an ongoing exercise and position of the emerging risks and associated scenarios will evolve in line with science and best practice."

Our process for monitoring and managing climate-related risks

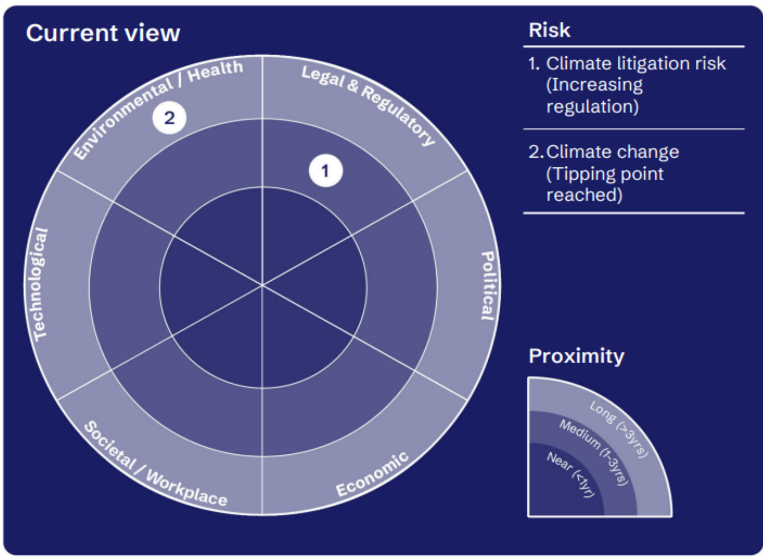
We use a variety of metrics to monitor and manage alignment with global or national targets on climate change mitigation and the potential financial impact on our business, including operational carbon emissions, financed emissions, monitoring of sovereign holdings, investment in sustainable assets, weather-related losses, temperature alignment, and Climate Value-at-Risk (Climate VaR). We continue to enhance our understanding of litigation risk to reduce the risk of harm arising from greenwashing risk.

We use scenario analysis as an input to our risk assessment processes to test the resilience of our business strategy and adapt our business to ensure its longevity as an asset manager, asset owner, insurer, and pension provider. For example:

- We reflect the potential short-term impact of climate change, where appropriate, in our internal model Solvency Capital Requirement, over a 1-year time horizon.
- We are adapting to a world of increasing physical risk. We have built the possibility of short-term extreme weather events into our general insurance pricing, reinsurance programme design and monitor actual weather-related losses versus expected weather losses by business. Well-exercised and effective plans are in place to respond to major weather events and weather-related claims supported by exposure mapping and flood modelling tools.
- We use long term scenario analysis as one of the inputs into the climate-related risk assessment process. For example, Climate VaR is used to support our risk management, quarterly internal reporting process and annual production of external disclosures as well as our ORSA allowing us to understand the extent to which climate change will impact our business based on different IPCC scenarios. Climate VaR is also used to review the resilience of our strategy.

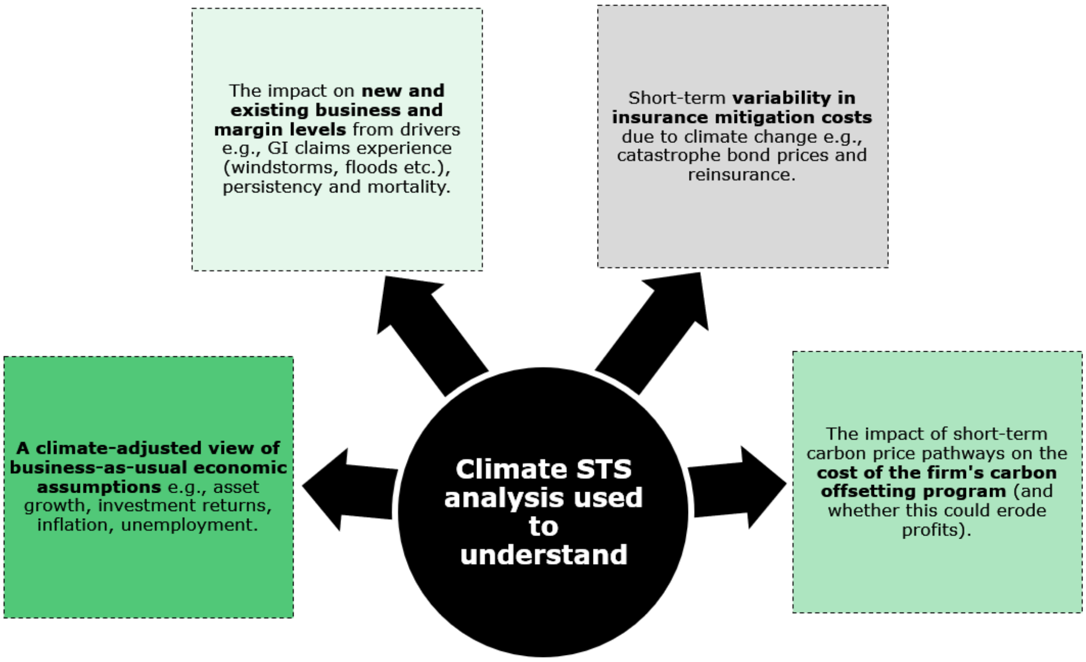
For example: from an asset perspective, the Climate VaR is used to identify how we can change our capital allocation to reduce our exposure to both transition and physical risks. From a liability perspective, we have modelled the transition risks of our underwritten Personal Lines and Commercial Lines books. This bespoke analysis informs our future underwriting and pricing strategies.

Figure 2: Risk Spectrum



More information can be found on Aviva's 2023 Climate Report, pages 30-31.

Case study 2: Scoping of a short-term use case - business planning for a composite insurer.



3.2 What is the associated time horizon?

Determining the right time horizon for their STS analysis may be driven by the selection of use cases and the duration of a firm's exposures, e.g., business planning decisions may entail time horizons of three to five years.

The decision of which time horizon to use is non-trivial and could have a significant impact on the results of modelling analysis, given that transition and physical risks will materialise significantly differently between shorter-term and longer-term horizons. E.g., adverse weather events could occur over the next one to two years, whereas the impact of bank defaults due to, e.g., transition or physical risks could emerge over a longer five-year period.

Firms may choose to apply multiple short-time horizons (e.g., a one-year analysis could be used for a trading book and a five-year analysis could be used for business planning or stress and scenario testing for both banks and insurers) to both fulfil multiple use cases and perform high-level sensitivity analysis on time horizons. The choice of time horizon will impact the narrative chosen because it is expected to take different lengths of time for different climate-related risks to occur.

4 Defining STS narratives

To date, most climate scenario narratives have focused on long-term systemic relationships and trade-offs between the environment, energy systems and the global economy. However, STS narratives are required to enable firms to explore how risks may manifest over the near-term and to explore the interactions between risk drivers, transmission channels, and tail risks in short-term horizons.

Compared to long-term scenarios, there is an absence of trade-off between transition and physical risks. There is a time lag between climate policy interventions and changes in global average temperatures, such that the near-term physical risks exposure is already effectively 'locked-in'. This results in more possible combinations of events in short-term narratives, e.g., worst-case physical risk can be combined with worst-case transition risk in a single scenario.

Climate shocks might generate second-order macro-financial impacts in the short-term due to the interactions of these shocks with macro-economic stresses. This may lead to a compounding of risks that substantially increases the economic severity of certain climate shocks and impact government policy. Customer as well as investor expectations and behaviour, may lead to a rapid re-pricing of risk (i.e., a climate Minsky moment) and the market may overshoot its fundamental value.

4.1 What are the risk events and socio-economic contexts?

Climate-related risk is multifaceted and will manifest in a variety of direct and indirect ways. When defining STS narratives for a given use case, it is important to consider which are key potential risk events and the wider socio and macro-economic contexts that will be affected by climate change.

A. Risk events and socio-economic contexts

Firms should consider the overall story that the STS is trying to articulate and how this might manifest in the future, with a focus on how to qualitatively describe such a scenario. Key elements to be considered are:

- **Macro-economic contexts:** macro-economic factors are in general better understood and easier to model, although there remains significant uncertainty for more extreme events e.g., supply-side disruption, trade-wars, commodity price spikes, cyclical demand-driven economic downturns and financial crises.
- **Socio-economic contexts:** these often have greater uncertainty e.g., migration crises, armed conflict, social movements and boycotts, pandemics, changes in political landscape.
- **Physical risk:** e.g., increasing the frequency and/or the severity of extreme heatwaves, droughts, flooding, storms or other acute or chronic weather events or patterns. A scenario can be selected to present a relatively benign sequence of weather events, or to include the occurrence of more catastrophic and severe tail events or series of events, especially where losses are amplified[xvii] due to compounding impacts[xviii]. This latter point is particularly important considering that long-term scenarios used to date are widely regarded as not necessarily capturing features such as tail risks, tipping points and non-linearities.[xix]
- **Climate policy landscape:** plausible but severe policy changes could be introduced in the next three to five years, e.g., globally recognised carbon taxes and carbon border adjustment mechanisms, banning of certain non-transition-aligned activities, introduction of subsidies for sustainable activities,

government investment in green energy or development of green technologies, introduction of polices on waste, other pollutants, or nature restoration. There are numerous elections due to take place 2024, including in the US and UK, which means a range of policy outcomes are possible depending on the political views on climate change of the those elected.

- **Technology evolution:** plausible technology breakthroughs that may occur, e.g., breakthroughs in green energy, or improvements in existing technology e.g., green hydrogen, battery technologies, carbon capture and geoengineering.
- **Public and investor sentiment and behaviour:** e.g., rapid changes in consumer and investor preferences in relation to high carbon assets or expectations shocks where the current valuation of assets changes significantly and suddenly due to the additional pricing in of further future physical risk.

B. Existing STS narratives

Several frameworks have already been developed to support firms with defining STS narratives. 'Off-the-shelf' publicly available climate STS narratives hold several benefits, including ease of access and ability to compare with peer institutions, e.g., through external disclosures.

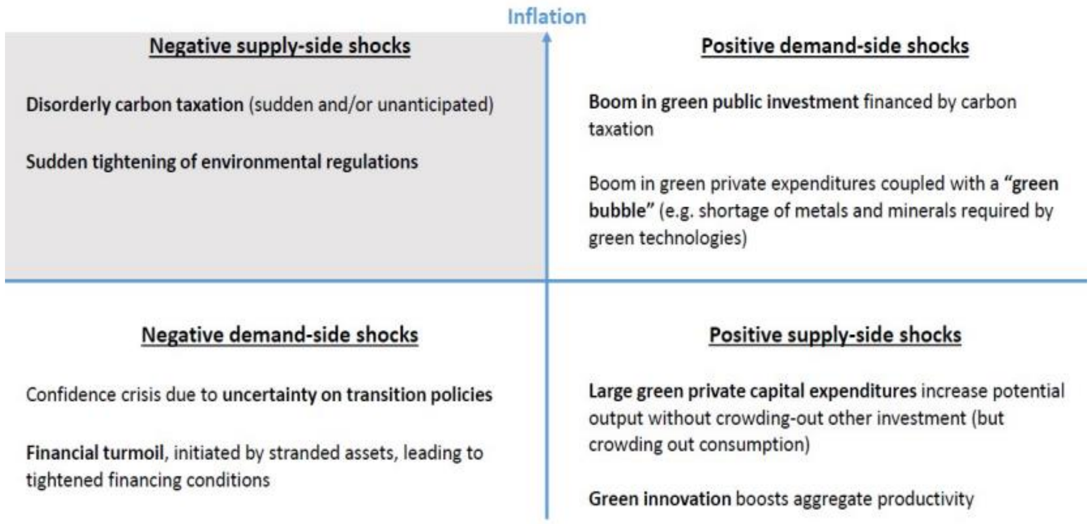
The following summarises the Banque de France STS[xx] and NGFS STS narratives[xxi]:

Case study 3: The "Banque de France's paper on: Using Short-Term Scenarios to Assess the Macroeconomic Impacts of Climate Transition"

The Banque de France (BdF) developed a typology of potential transition shocks which can be drawn on to inform potential scenario narratives. The provided classification allows users to identify key macro-economic variables (e.g., inflation) via choosing a "family of transition shocks".

The methodology classifies underlying transition shocks into positive and negative supply, as well as demand, shocks, thus creating four categories. The BdF provides eight STS narratives – two in each category (see figure 3 below).

Figure 4: Climate transition: A wide diversity of shocks, which can coexist.



Case study 4: NGFS STS climate scenarios

To support practitioners with defining scenario narratives, the NGFS have written a Conceptual note on short-term climate scenarios which defines several STS narratives for the industry to consider.

Figure 5:NGFS STS scenarios

The following summarises the UNEP FI & NIESR scenarios[xxii]

Case study 5: UNEP FI & NIESR scenarios

United Nations Environment Programme Finance Initiative (UNEP FI) and National Institute of Economic and Social Research (NIESR) have developed a tool that allows users to explore short-term shocks related to macroeconomic events, transition risks, and physical risks, either in combination or independently, across a five-year time-horizon for various jurisdictions and regions. Users can select a combination of three short-term shocks and associated stress levels to generate their own potential shock scenarios for internal use.

Figure 6: UNEP FI & NIESR scenarios shocks

Transition shocks: *Driven by rapid policy implementation, technological advancements, and market shifts.*

- **Stringent carbon price**
- **Green spending**
- **Stranded assets**

Physical shocks: *Acute and chronic physical hazards and its accompanying consequences.*

- **Climate migration**
- **Chronic physical impacts**
- **Acute physical impacts**

Macroeconomic shocks: *Large-scale, unexpected impact on the economy.*

- **Geopolitical tension**
- **Greenflation**
- **Inflation**

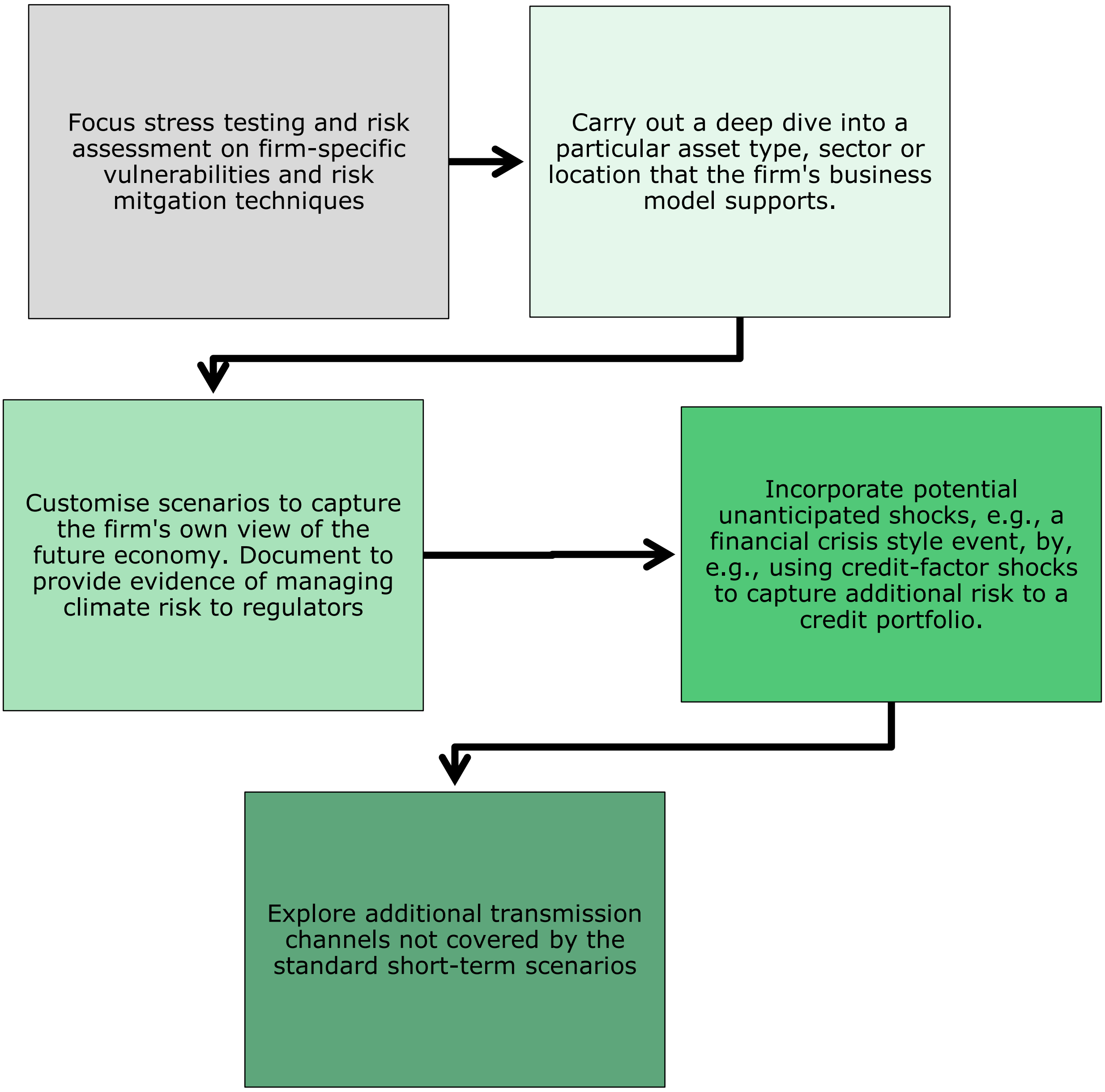
For all shocks in all regions, the impacts of the shocks on the following variables can be displayed: Gross Domestic Product (GDP), Domestic demand, Imports (goods and services), Exports (goods and services), Effective exchange rate, Real effect exchange rate, Inflation rate, Long term real interest rate, Policy rate, Equity prices, and Real personal disposable income.

C. Bespoke climate STS narratives

While there are advantages of using pre-defined STS, there are situations where these scenarios cannot adequately address firms' specific circumstances. Thus, firms could consider exploring bespoke scenarios that are tailored to their specific use cases and needs.

Bespoke climate STS narratives can be described as tailor-made or customised plausible views of the future developed for use by specific firms. They can help to reflect a given firm's unique business model, product mix, geographical reach, corporate strategy, and client base. Using bespoke climate scenarios can help firms to manage the climate-related risks specific to their business model and risk profile, strengthening their resilience. It also helps them to meet ever-evolving climate-related regulations and disclosure requirements. E.g., a firm can construct a bespoke scenario using the framework in this paper as per Figure 7.

Figure 7: Developing a bespoke scenario for Climate STS analysis



The following summarises **Barclays' 2023 Climate STS analysis** [xxiii]

Case study 6: Barclays' 2023 Climate Internal Stress Test

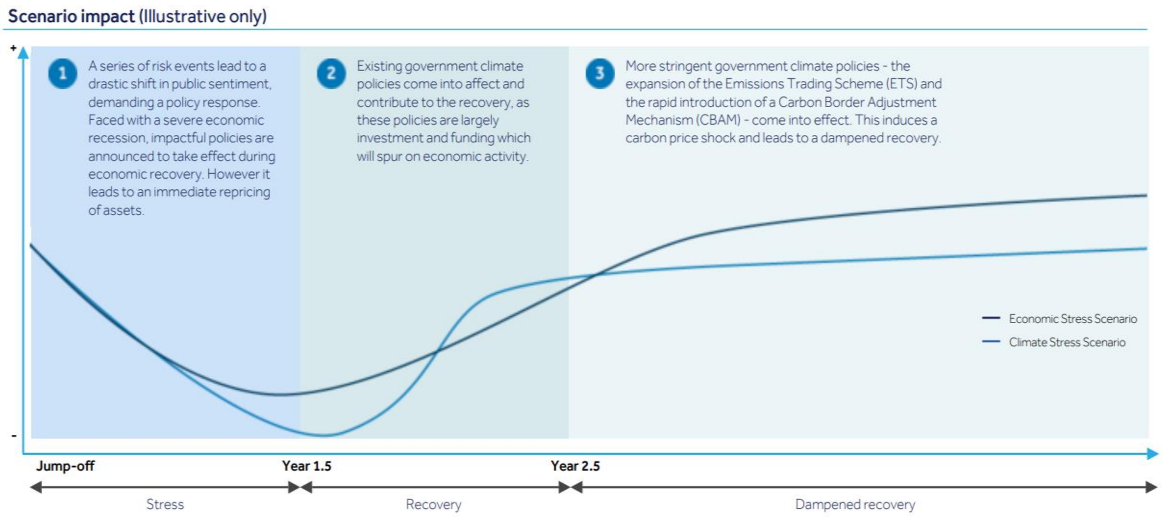
In 2023, Barclays undertook a climate stress test to assess the firm's financial resiliency to climate risks over and above the financial impact of existing macroeconomic internal stress tests – and the extent to which Barclays would remain within risk appetite.

The STS was internally designed with consideration of Barclays' specific portfolio vulnerabilities. External scenarios e.g., those provided by the NGFS, while offering granular and detailed scenario information for financial institutions, tend to focus on longer trends and display limited volatility, with assumptions that may be less relevant to Barclays' specific businesses. As such, the scenario was designed with a greater focus on short-term tail risks and volatility.

The scenario narrative spanned a five-year horizon, aligned with the Bank's Medium-Term Planning and Internal Stress Testing scenarios. Specific variables were expanded using a combination of models and subject matter expert judgement by Barclays' Scenario Expansion Team.

The scenario saw initial policy announcements that trigger immediate asset repricing, while more stringent policy requirements unfold over a longer time horizon – dampening recovery in the outer years as depicted in the below chart through stages 1, 2, and 3. Against this backdrop, the scenario also includes consideration of physical risk, notably hazards of which Barclays' clients are most susceptible to e.g., flood and drought.

Figure 8: An illustration of short-term scenario impact from Barclay's 2023 annual report



More information can be found on Barclays' 2023 Annual Report, pages 131-135.

5 Selecting variables through risk and transmission channel assessment

Once a scenario narrative has been defined, the next step is to identify the areas of highest risk, as well as the physical and transition risk transmission channels, and the financial and economic variables. The variables can be defined on an absolute basis (from pre-existing variables) or relative to a specific baseline scenario. Key challenges and considerations in STS variables generation should also be identified.

5.1 Which locations, sectors and counterparties are at risk?

Every firm will have a unique exposure to climate-related risk, depending on the combination of the locations, sectors, and individual counterparties that they are investing in and/or underwriting. Equally, each individual counterparty will be uniquely exposed to climate-related risk, although counterparties within the same sector and region may be affected similarly.

Additionally, some sectors will be more exposed to physical risk, while others will be more exposed to transition risk, noting that almost all sectors will be exposed to both. There is also a growing body of work to understand the exposure of various sectors to liability or litigation risk; this is covered in significant detail in the CFRF Session 3 paper on climate litigation risk[xxiv].

Firms should carry out a materiality assessment when devising their scenarios. This can consider which locations and sectors in their portfolio are likely to be materially affected by a range of physical risk events, or whether transition risks will materialise differently across different jurisdictions. We note that this process may be iterative, as the modelling stage of the analysis will confirm which sectors and regions are most at risk within a firm's portfolio.

Understanding the materiality of exposure for different sectors and locations is a useful step to identifying the form of modelling required later in the STS analysis process. E.g., high-level sectoral analysis may indicate whether sector-specific or sector-agnostic modelling is more appropriate, which in turn will point to a selection of an appropriate model and appropriate choice of variables.

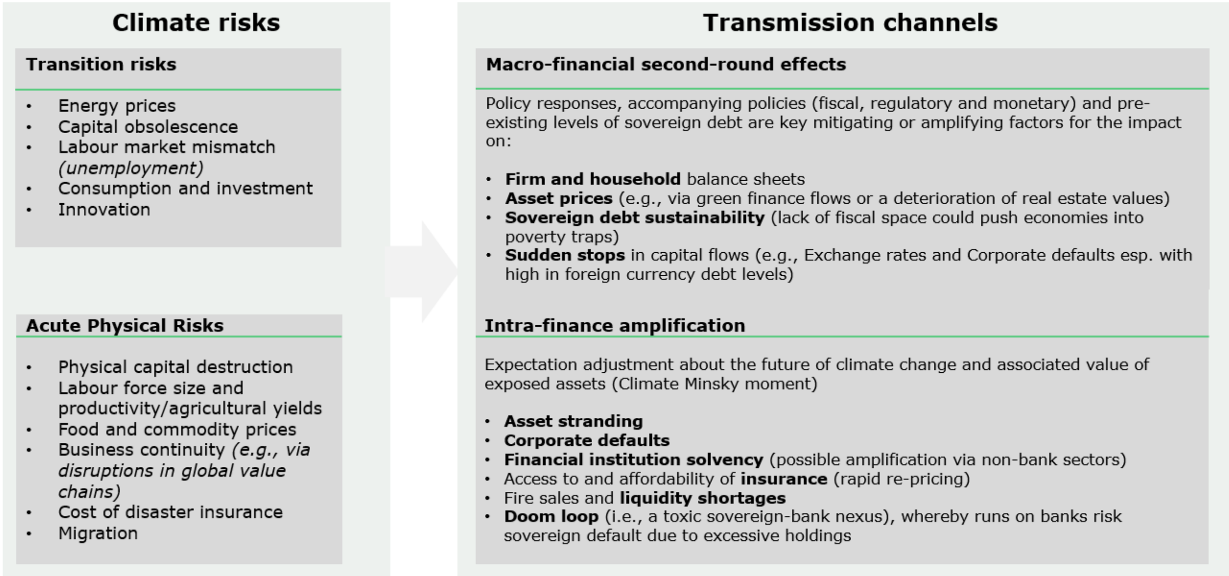
5.2 What are the first and second order risk transmission channels?

The transmission channels may often be similar to those identified under longer-term climate scenarios. E.g., channels include the introduction of more stringent climate policy for which a carbon price functions as a proxy of policy intensity. However, STS narratives can allow for transmission channels with a greater intensity of interaction between physical and transition risks in the short-term. This is driven by the fact that both physical tail risks and transition tail risks may occur simultaneously in the STS, leading to complex and extreme feedback loops between both forms of climate-related risk.

This interaction in short-term horizons can take place through macro-financial channels e.g., initial climate stresses or shocks (e.g., an energy price hike, a natural catastrophe, or a policy reversal), and second-order effects on key macro-economic variables (e.g., equity indexes, asset prices, sovereign debt credit spreads, exchange rates, and credit growth). Identifying the channels of shocks that impact key macro-financial variables is not straightforward. A natural catastrophe event combined with a green transition push is likely to cause cross-sectoral shifts in production and consumption trends with knock-on effects on input-output prices across sectors.

A useful example is the NGFS conceptual paper[xxv] on STS narratives which elaborates on the transmission channels and amplification of the stress. This considers three types of amplification mechanisms and feedback loops: (i) climate-economy direct impacts, (ii) macro-financial second-round effects, and (iii) intra-finance amplification.

Figure 9: First and second order physical and transition risk transmission channels based on the NGFS STS conceptual paper



The EU climate risk assessment[xxvi] categorises climate risk into five "clusters": ecosystems, food, health, infrastructure and economy and finance. These can be considered in a similar way to transmission channels described in this section.

These transmission channels can then re-inform the risk assessment that identifies the sectors and counterparties which are likely to be most impacted. Identifying relevant sectors and counterparty types enables an assessment of whether the potential risks will need to be modelled on a sector-specific or sector-agnostic basis. It will also enable the universe of potential variables to be narrowed to a more concise list of variables.

Furthermore, the transmission channels and initial risk assessment can then be used to identify which types of models are likely to be required for variable generation, which in turn can inform the variables which may be available. A key consideration when selecting variables will be whether the identified transmission channels will be better captured through top-down or bottom-up modelling approach. Depending on the purpose and data availability, a firm can choose whether to use a bottom-up or top-down approach to defining variables and modelling. Some firms may choose to merge both approaches for robustness.

- A **bottom-up approach** requires granular data and translates the impact of granular and asset-level climate-related risk variables (e.g., the probability of default, or transition plan credibility) onto counterparty financial statements.
- A **top-down approach** requires less detailed data and sector-level models are used to establish a relationship between macroeconomic variables (e.g.,

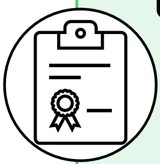
carbon prices, or unemployment rates, or gross value added as a sector-wide proxy for sectoral growth) and credit-risk.

5.3 Which variables impact assets and liabilities?

Many variables that firms are familiar with for long-term scenario analysis remain important in STS. However, there should be more focus on variables relating to near-term shocks, especially those in the macro-economy, e.g., inflation and consumption, and divergence from expectations of smooth pathway trajectories.

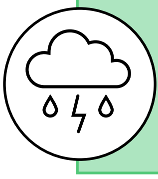
The interconnection between transition and physical risk variables may not follow the gradual feedback loop as in long-term scenarios. STS analysis that incorporates severe acute physical events, triggering a transition policy shock, may require assumptions of fast-moving policy reaction functions, societal response, and behaviour patterns which are not the typical outcome of long-term climate scenario modelling and for which there is scant observable history of past economic and financial stress either.

A. Examples of variables:



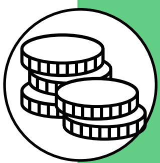
Transition risk variables

Transition risk variables include subsidies for green initiatives, explicit carbon taxes and energy price shocks. These can be quantified using global factorse.g., Brent oil prices, or more country-specific factors e.g., electricity prices. Innovation shocks could be parametrised through the unit cost of capital for green energy technologies or carbon sequestration mechanisms.



Physical risk variables

Physical risk variables describe abnormally severe weather, e.g., tropical cyclones, hurricanes, heatwaves or wildfires. These may be parameterised by windspeed, millimetres of rainfall and wet-bulb temperature increases. Further variables describing shocks to agricultural production or yields which drive changes in specific commodity indexes and food prices may be included in Climate STS.

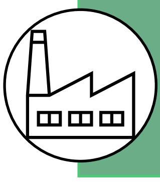


Macro-economic & macro-financial impact variables

Macro-financial variables capture the impacts on the financial markets and the boarder economy of transition and physical risks as they crystalise.

Variables (e.g., GDP, consumption or investment) can reflect abrupt shifts in economic patterns resulting from a climate policy shock or an extreme weather event, as well as second-order impacts (e.g., migratory crises and commodity price shocks).

Financial market variables e.g., bond and equity prices, can illustrate impacts of stranded assets due to abrupt policy shocks or sharp price corrections resulting from a green bubble burst.



Sectoral & micro-financial impact variables

Sectoral and micro-financial impact variables illustrate the short-term impacts of climate shocks on the firms' business model or a sector's performance. Examples include projections of EV sales in the car industry, energy efficiency standards for buildings or the Gross Value-Added (GVA) of the sector. GVA variables can help to disaggregate macro stresses into specific sector impacts and identify sectors most vulnerable to near-term climate risk, e.g., high-emission sectors.

B. Severity of the variables

Practitioners can consider how severe risk channels could be over the next three to five years and incorporate this into STS narratives via assumptions.

For acute physical risk, assumptions on incidence and damage can be used to perform short-term 'climate-conditioning'[xxvii] of standard catastrophe models in use by the industry. E.g., considering the severity of an extreme weather event based on damage or incidence for a 1-in-100-year event.

For transition risk, severity can be established based on, e.g., the peak level or steepness of the assumed carbon price trajectory or other variables reflecting transition risk intensity. The macro-financial severity can be benchmarked using conventional metrics e.g., the depth of the GDP fall, the decline of an equity price index or the shock to an asset price or to credit spreads in a particular sector.

Severity of scenario variables can be particularly challenging to estimate. Because the frequency and severity distributions of risk events will change less in STS compared to the long-term, tail outcomes can be explored to incorporate severe physical hazards or material deviations from recent trends in transition risk variables.

The following summarises **HSBC's 2023 Climate STS analysis**[xxviii]**:**

Case study 7: HSBC's 2023 Climate Scenario Analysis Exercises

In 2023 HSBC explored five scenarios with different levels of physical and transition risks over a variety of time periods, assuming varying levels of governmental climate policy changes, macroeconomic factors, and technological developments. Three distinct timeframes were considered: short term up to 2025; medium term from 2026 to 2035; and long term from 2036 to 2050.

The scenarios were created using external publicly available climate scenarios as a reference, including those produced NGFS, IPCC and IEA. HSBC adapted them by incorporating the unique climate risks and vulnerabilities to which the bank and its customers across different business sectors and regions are exposed. The short-term scenario was:

- A Near Term scenario, which assumes both a disorderly transition push towards net zero and a sharp increase in extreme climate events over a five-year period until 2027.

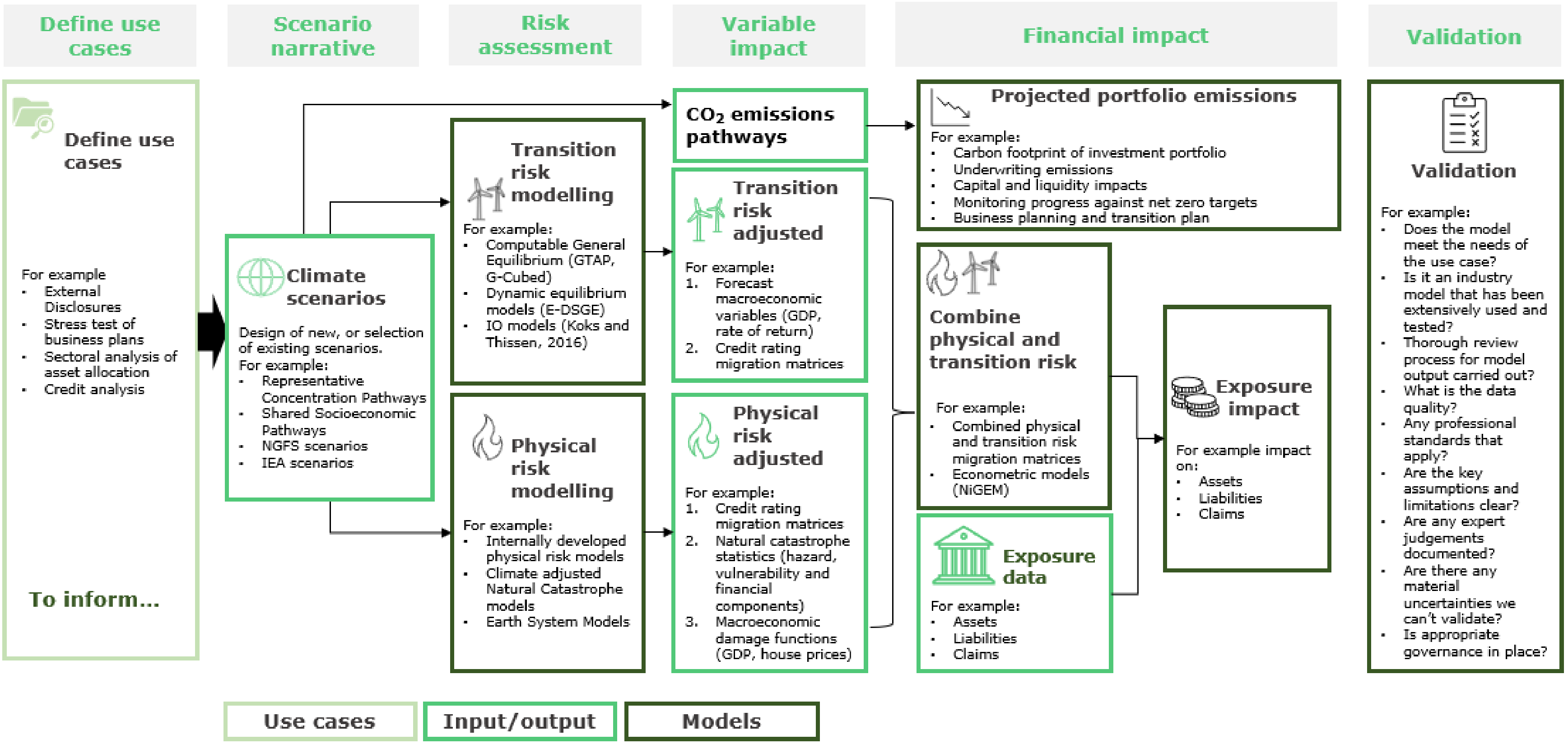
Rise in global temperatures by 2100 (vs pre-industrial levels)	Focus horizon	Assumed variation in global climate policies	Assumed pace of technology change and adoption	Assumed socioeconomic impact	Assumed carbon price ($/tCO2)	Assumed change in energy consumption (% change after 2022)	Assumed change in CO_2 emissions (% change after 2022)	Climate risk	
								Physical	Transition
1.4°c	Short to medium term	High	Based on existing technology	Very high	193	*-14%*	*-34%*	▲ Higher	▲ Higher

More information can be found on HSBC's 2023 Annual Report, pages 225-230.

6 Calculating financial impacts for STS analysis

After the STS narrative and corresponding variables have been defined, the next step is to evaluate the financial impacts and metrics required to support decision-making. *Figure 10* below depicts a modelling framework and provides illustrative examples of existing models. The depth of each step in this end-to-end approach will be based on the use case, required model granularity and level of expert judgement required. Many of the existing models have traditionally focused on longer time horizons, however, these can be adapted for STS modelling. The purpose of the use case will determine the severity of risk explored, with greater resilience considerations leading to more severe risks.

Figure 10: High-level framework for an end-to-end modelling approach for STS combining top-down sectoral models for transition risk and bottom-up models for physical risk.



6.1 What are the key limitations of existing modelling approaches?

Climate risk models are continually improving, in terms of the breadth of the transmission channels and variables being modelled. At the same time, there is growing understanding of their limitations (see Annex CAnnex C: STS Climate models). Whilst similar model frameworks are used in both short-term and long-term modelling, data and modelling sub-processes (e.g., approaches to interpolation in short-term) should be tailored to a STS perspective. Additional limitations may arise from attempting to model the impact of STS through models designed for long-term scenarios. Therefore, firms should be aware of the limitations of climate risk models before deciding when and how to deploy them and be clear about the limitations and assumptions when communicating the results for internal or external purposes. We highlight some of the key limitations of climate models in use by firms below.

Physical risk tends to be understated	•**Physical risk impact tends to be understated** as certain acute physical risks are not modelled and it is difficult to model climate outcomes from assessing 'known' and *'unknown' unknowns* of physical risk. This may result in underestimation of the impact of a business-as-usual scenario. Some warn that it could lead to a *misinterpretation that a green transition scenario is more adverse*. This limitation should be transparently communicated in any disclosure.
Unidentified risk transmission channels	•**Unidentified risk transmission channels** could lead to the underestimation of the impact of climate change. The *CBES findings survey* (published by the CFRF in March 2023) shows that *83% of CBES participants* who responded agree that risk transmission channels and drivers (which have either been identified but not yet modelled, or are not known) lead to an underestimation of risk.
Interactions between physical and transition risks	•The interation **between physical and transition risks**, and the *aggregation of these* to achieve a consolidated view of climate-related risk, are not always captured. Aggregation approaches, e.g., using rating migration matrices, have limitations which firms should seek to understand. It should be noted that the non-linear complexity of these interactions can apply to *non-climate-related risk drivers, e.g., geopolitical risks*.
Lack of **standardised and accessible data**	•**Physical location** of many assets, or the composition of firms' supply chains and infrastructure are often unknown attributes. •**Sufficient granularity** of data is not always available. •There is a **lack of standardisation** in the approach to collect data. Multiple ways to define proxies and to build exposure data assets can lead to further potential variation in results and to underestimation of climate-related losses.
Level of granularity	•**Models may not have the required spatial resolution** to model risk at the level of granularity required. •improved ability for models to handle large amounts of data at a more granular level will be needed to increase the reliability of STS analysis results.

Refences: *'unknown' unknowns* [xxix], *misinterpretation that a green transition scenario is more adverse* [xxx], *CBES findings survey* [xxxi], *CBES participants* [xxxii], *aggregation of these*[xxxiii], *non-climate-related risk drivers, e.g., geopolitical risks* [xxxiv]

6.2 Are new models needed to model STS?

To date, climate risk models (as shown in Figure 10) have been used principally for long-term scenario climate modelling. In the interim, it may be most practical to apply adjustments to these existing models to address their limitations for short-term modelling (see section 8.2).

Firms may be able to adapt their current short-term modelling capabilities (e.g., for ORSA/ICAAP/ILAAP purposes) within the business to incorporate climate-related risk. However, there is an opportunity for new models to be developed that better capture the nature of short-term risks. We consider two case studies below of new models that thought leaders are developing, which could be adopted by firms in the future.

The following summarises **Generating scenarios algorithmically**[xxxv] [xxxvi]

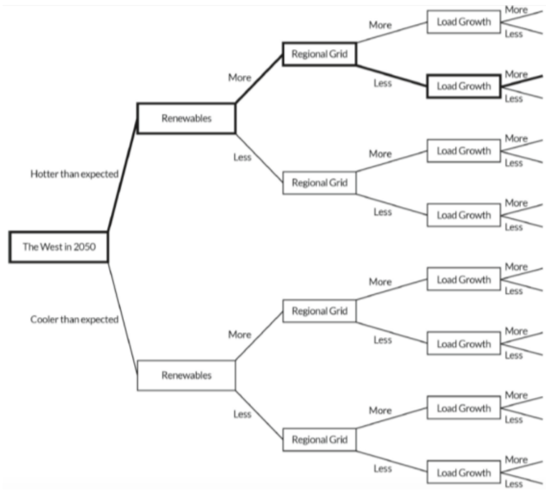
Case study 8: Stochastic modelling from RiskThinking.AI

Current climate models and stress testing use only a small set of deterministic scenarios, which may not fully account for tail risks (see section 6.1). This method generates a stochastic distribution of STS, including low probability and high impact scenarios (e.g., 2023 summer heatwave in Europe that was followed by extreme rainfall).

Forward-looking projections are sourced from all leading climate models to generate novel scenarios of the future. These include scenarios that combine optimistic and pessimistic projections, e.g., more extreme precipitation and more drought. Or, when including transition risk, hotter temperatures, and higher carbon prices. They may also include unintuitively optimistic scenarios of the future, whereby the overall impact of climate change is less severe.

Figure 11: A single scenario from Generating scenarios algorithmically

Scenario: By 2050 California's average temperature will have risen more than expected. The growth of renewable energy generation is more than was predicted and the regional grid has not materialized as much as was expected. Load growth by contrast is more than was expected.



The approach generates a scenario tree with the extreme values and the corresponding likelihoods as inputs. The tree generates a distribution of scenarios, along with their likelihoods and associated impact.

The following summarises **Credit risk modelling**[xxxvii] [xxxviii] **and the ECB**[xxxix xl]

Case study 9: Credit risk modelling and the ECB

Rising volatility from future climate shocks is expected to interact with the short-term systematic cycles of credit risk, potentially accentuating credit shocks. In turn, this would have capital effects. However, further work is needed to incorporate credit risk in climate scenario modelling.

To assess the volatility and deviations from average long-term trends, and the subsequent capital effects, STS climate models will need to incorporate factors representing past systematic credit shocks expected to occur in the time horizon of STS. Current approaches to modelling future credit risk focus on changes to smoother, long-term economic trends.

The ECB proposes that physical and transition risk for wholesale credit risks could be calculated by adapting existing wholesale probability of default models. There is no data to measure empirical links between climate and credit risk. Instead, firm costs and profitability would be adjusted in response to climate impacts, which would give an adjusted credit risk impact.

6.3 How do we model the baseline scenario?

To understand the significance of the impact of climate-related risk, firms can choose a baseline scenario that acts as a benchmark to compare results against. There are various ways of selecting a baseline, including the following options currently in use by some firms.

A. Best estimate of the projected manifestations of climate risk

Here, the firm chooses a scenario they view as most likely. Other climate scenarios reflect departures from our best estimate of future climate change manifestations, and hence the impact of unexpected climate-related events. This is useful when future projections already exist. E.g., countries make projections of food supply based on expected agriculture yields due to climatic conditions. We can change the expected agricultural yields to reflect different levels of climate-related risk compared to existing projections and quantify the impact of this change on food supply.

B. Absence of future climate-related risk

Using a hypothetical scenario with no future additional climate-related risk (often referred to as a 'counterfactual' scenario) relative to some baseline year allows us to quantify climate change risk relative to today's conditions. This can remove some uncertainty about estimating the most likely impact of climate change (although uncertainty remains in the starting conditions) and can therefore be easier to understand in risk analysis. However, this is unlikely to reflect the real world since consensus is now that some level of physical and/or transition risk will inevitably occur in the short-term, meaning that uses would need a 'current policies' scenario for comparison to avoid risk of misinterpretation.

C. Consensus about the risk of climate change priced into assets

Market prices of assets are assumed to consider some future level of climate change risk i.e., a market consensus. Using this market consensus as a baseline can clarify the likely impact of unpriced climate change on asset values. As for all risk modelling using market pricing, a range of assumptions may be applied to underpin what the market consensus may be for a given sector.

D. Carbon budget implying a certain degree of warming

For this option, we assume a certain carbon budget. Other climate scenarios then imply different degrees of warming and transition activity due to a departure from this carbon budget. This has the advantage in that it relates to the temperature and carbon targets used in international policy. However, although some countries have domestic carbon budgets, there is no consensus on how to allocate carbon budgets[xli] to different countries. This means that an allocation may need to be assumed, e.g., using Nationally Determined Contribution (NDC) pledges as an approximation where available. This approach is commonly taken in calculations of the Implied Temperature Rise ("ITR") for investment portfolios.

Ultimately, the options outlined above indicate that there is no single correct baseline to use; the most suitable method depends on the use case and the view of the firm that is conducting this analysis. This leads to a wide range of climate scenario analysis results from different firms depending on the assumptions used (although this is a feature shared by modelling of other risk types). For use cases where consistency is important, e.g., mandatory regulatory disclosures, an alternative would be to develop and use an external standard for the baseline used in modelling, noting that this does not currently exist.

6.4 What are the required outputs and level of granularity?

The use case (or modelling purpose), along with the firm's specific risk exposures and business model, will drive the required granularity and scope of the output. Furthermore, the output should account for different types of climate-related risk and the various approaches to measuring STS impacts.

A. Illustrative examples:

Stress testing exercises seek to inform an entity's resilience to extreme events. Such exercises aim to calculate the impact of climate change on a range of variables e.g.:

- macroeconomic variables (e.g., GDP, unemployment, inflation, real estate prices, exchange rates, interest rates, equity prices)
- transition risk parameters (e.g., carbon price, energy price)
- physical hazard metrics (e.g., precipitation or near-surface wind speed) or location

The adjusted variables are then used to calculate the financial impacts on the entity's assets, liabilities, and claims. These are calculated before the impact of climate change is incorporated into the entity's capital buffers.

Regulatory stress testing

Here the analysis may focus less on stress-driven metrics and instead consider variables informing key trends in specific economic sectors or projected counterparty performance under the near-term assumptions of the short-term scenario.

This would require the modelling of variables e.g.:

1. The gross added value of the sector under scope
2. Key production and consumption variables
3. Economic and market variables (e.g., GDP, inflation, stock prices)
4. Specific sector variables (e.g., for the automotive sector, this would include electric vehicles sales or efficiency metrics of new electric batteries.
5. Greenhouse gas emissions

Strategic planning and portfolio optimisation

7 Assessing climate scenario likelihood

The STS maturity survey suggests that, to date, there is no industry consensus on whether assessing scenario likelihoods is beneficial and should be required. Assessing climate scenarios likelihood remains an understudied area, albeit one where academics and an increasing number of practitioners are starting to focus on and where proposals around suitable approaches are starting to emerge.

7.1 Why are likelihoods important for STS?

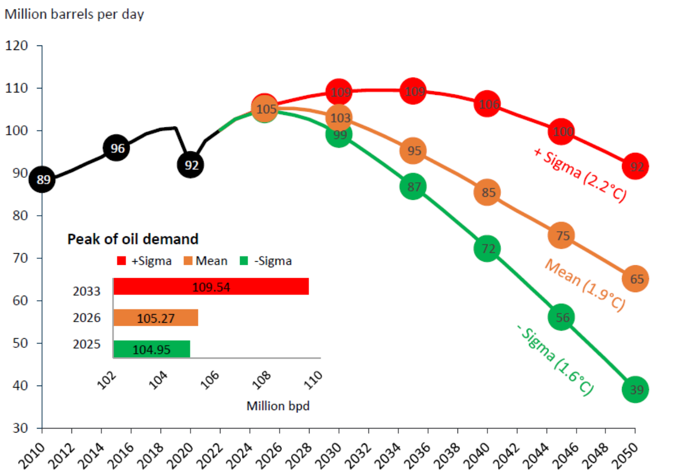
To date, firms have generally refrained from calling climate scenario analysis outputs a "forecast", as they are still getting comfortable with the limitations and uncertainties associated with their modelling. However, firms are now looking to expand their STS use cases to understand the resilience of their business, including its strategy and risk appetite. Therefore, they may want to understand how concerned they should be with specific scenario features, e.g., tail events, and how much consideration should be given to established extreme climate scenarios compared to 'rare' combinations of severe but plausible events, e.g., a physical tipping point event leading to widespread transition risk-generating reactions, or market panic; a sudden surge in climate activism and a shift in consumer sentiment. However, one key reason why assigning likelihoods to STS is so challenging, particularly for transition risk, is the existence of a wide range of views on energy supply and demand, even in the near future.

Rystad Energy's Oil Scenario Report[xlii] **and RMI's Energy Transition Narrative**[xliii] highlight some likely scenarios that could impact the energy sector.

Case study 10: Rystad Energy's Oil Demand Scenarios

Rystad Energy's scenarios are all driven by historical trends, technological developments, macro forces and governmental actions in the short term. Oil demand is forecast across three scenarios: Mean, + Sigma and –Sigma.

Figure 12: Oil demand- three varied climate trajectory scenarios



- *Rystad Energy view the Mean scenario as the most likely.*
- *The +Sigma and -Sigma scenarios assume a reasonable upside and downside probability range from the Mean scenario respectively, with oil demand predicted to peak in 2033 and 2025.*

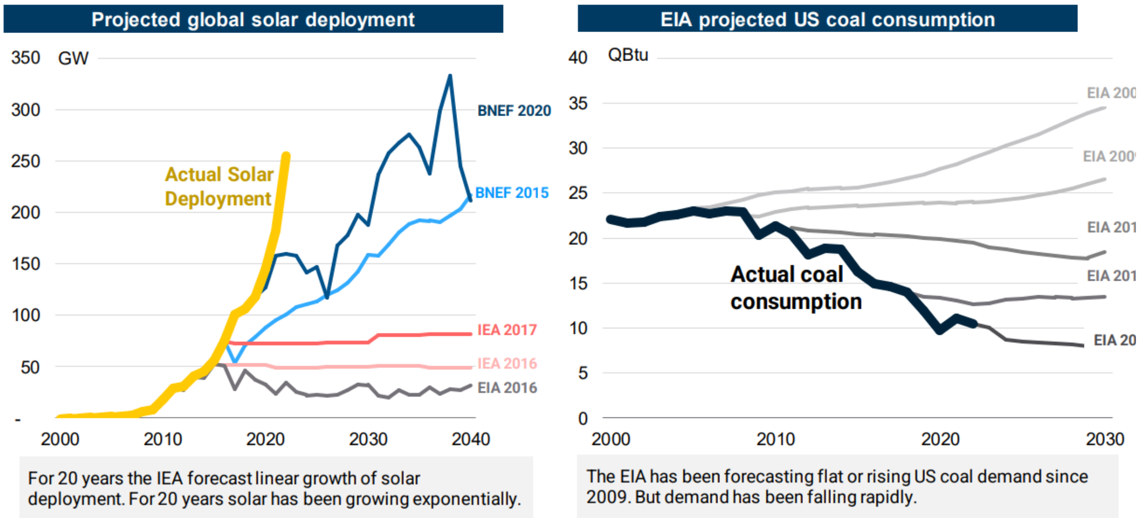
The variation in short-term forecast is mainly driven by assumptions in the Passenger Vehicle sector as it contributes to 28% of oil demand and electrification of vehicles is unfolding rapidly. In the Mean scenario, they reduce communicated EV auto manufacturers sales targets to meet a realistic exponential growth, given battery production capacity and regional adoption constraints, while in the Sigma scenario they assume all the communicated targets are met. In the +Sigma scenario, the required infrastructure adopts more slowly, therefore the EV adoption.

Case study 11: RMI's Energy Transition Narrative

Rocky Mountain Institute (RMI) predicts that if we continue on the existing learning and growth rates, solar and EVs will rise to dominate sector sales by 2030 and the entire fossil fuel system will be very different by 2030 when change will be priced into markets.

RMI also observe that energy modellers have failed to reach agreement on the baseline view of energy transition pace and scale, even for the short-term scenario. In the past, many energy modellers have continuously underestimated the exponential growth in renewable sales and rapid decline curves for renewable costs.

Figure 13: Most energy modellers have missed the transition



Some of the key reasons for this underestimation include:

- Linear thinking: assumes linear technology change rather than S-shaped curves
- Turning point: underestimates the timing and impact of peak oil demand on the investors decision
- Static world: assumes static technologies, policies, business models and societal perceptions

These common errors in forecasting energy transitions call for more forward-looking assumptions to be tested in the climate scenario.

7.2 Use cases for STS likelihood assessment

There are a wide range of use cases for STS likelihood assessment across banks, insurers, and asset managers e.g., business planning, disclosures, and trading book product pricing exploration. We explore key use cases below:

- It would be important to express scenario likelihood to set the financial risk appetite for climate risk
- Risk appetite is typically determined based on internal stress test results and is subsequently translated into limits that control day-to-day risk taking across the firm.
- Likelihood assumptions are inherently implied in the risk appetite process - i.e. the more likely a risk is to materialise, the more it has to be captured in risk limits. E.g., in setting market risk appetite, the VaR computes the amount and probability of potential loss (confidence level) over a defined time horizon. Similarly, the likelihood of the transition or physical risk scenario should be taken into consideration for setting climate risk appetite.

Risk appetite

- Disclosure standards, e.g., IFRS9, may require a rationale for the identification and selection of explored climate scenarios based on criteria of plausibility and likelihood.
- This may include an assessment based on plausibility of the stress within a probability distribution framework, either qualitatively or quantitatively.
- The baseline scenario would be assessed as more likely or carrying a higher probability of occurrence. In contrast, scenarios identified as tail risk outcomes, with materially severe impacts, would be attached to lower probabilities or likelihoods.
- Identifying the likelihood of the baseline scenario then facilitates comparisons to "severe but plausible" scenarios, e.g., those which typically are designed for stress testing purposes to explore resilience to material and non-negligible risk & vulnerabilities in the climate of exposures of a firm.

Disclosure standards and the baselining

- As firms use STS to inform their business planning exercises, views on scenario likelihood can inform decision making by providing e.g., 'pessimistic' and 'optimistic' views relative to a central house climate scenario.
- Furthermore, STS likelihood assessments could improve their understanding of how likely it would be for any given STS to occur within a firm's typical strategic planning horizon and hence inform the relevance and materiality of climate management actions.

Business planning

- As firms assess progress towards meeting interim net zero targets, questions e.g., "how likely is it we will stay below 1.5°C?" become increasingly pertinent and highlight the interest by some firms in being able to assess the relative likelihoods of scenarios.

Target setting

7.3 Approaches to assigning a likelihood to a climate scenario

Assessing STS likelihoods is driven by the key variables and assumptions underpinning each scenario, e.g., carbon pricing, technological change, and the occurrence of acute or chronic physical risk events. Current approaches to assigning likelihoods are emerging. Practitioners could either apply expert judgement, in a qualitative manner, or seek a more analytical approach. The choice of approach will be dependent on a firm's ability to source sufficient expertise, data and the use case in question. While scientific understanding and modelling capabilities continue to improve, radical uncertainty will likely always characterise climate related risks to some extent. This should be taken into account in likelihood assessments. Below we outline examples of how firms could approach assigning likelihoods.

A. Qualitative expert judgements

To date, this is considered the most common approach adopted by firms. A team, typically formed of management and climate experts, will review and challenge the existing STS (e.g., the NGFS conceptual note) and/or climate-risk models. They can then decide the rank orders of the likelihood of these scenarios given the use case of the STS analysis (e.g., evaluate the resiliency of a firm's strategy). Qualitative phrasing, e.g., 'challenging' or 'speculative'[xliv] could also be included to bound the likelihoods of scenarios. Such an exercise should involve a broad range of inputs from specialists in climate, geopolitics, and socioeconomics, to consider consequential impacts of adverse weather events on top of the current world political events.

B. Probabilistic likelihood

A next step is to look to assign probabilities to scenarios. This requires significant expert judgement and there will be considerable uncertainty in the probability derived due to limitations discussed earlier in this report. Over a short-time horizon, practitioners should consider the likelihood of key assumptions that could drive the largest variability.

This assessment does not need to be in the form of a full probability distribution for the scenario, which is incredibly challenging, but can instead focus on simpler quantitative methods.

Podcast:

This podcast, in collaboration with GARP, will provides further discussion on the various approaches to assigning likelihoods.

Below we introduce two case studies from 'thought leaders' who are focusing on this area within their research.

Case study 12: An empirically grounded model-based probabilistic forecast of energy transitions from Professor Doyne Farmer

Firms play a key role in real economy transition. The speed at which a firm is financing the transition to net zero is a key use case due to the impact on the firm's financial statements. Hence, some firms are now looking for tools e.g., "what-if" analysis to assess the climate impact under multiple scenarios. One challenge is to design and "predict" the possible transition scenarios of different climate policies as inputs to these analyses.

It is found that the deployment of new technologies, e.g., for hydroelectric power or nuclear, follows similar S-curves (with exponential increase first then flattening out), when forecasting using time-series models. This can be used to perform out-of-sample back-testing to calibrate the modelled S-curve for the green technology concerned, e.g., decide at what probability (i.e., confidence interval) a S-curve starts to flatten out, supplying X% of market share.

Case study 13: An algorithmic framework for measuring the financial risk of climate change from RiskThinking.AI

As discussed in Case study 8, some model developers are specialising in this area by using an algorithmic framework that can generate multi-factor scenarios based on expert judgment. An ensemble of the future is created from a scenario tree structure, with each path representing a unique combination of all the risk factors with associated compounded likelihood. Firms may choose to adopt this capability from third party providers, but we note they are unlikely to be able to develop this approach in-house.

7.4 Why are some firms against assigning likelihoods to climate scenarios?

For those firms who don't see the need to assign a likelihood to a STS, the main argument is that there is significant uncertainty around scenario drivers (e.g., short-term climate policy or tipping points) and there is no basis to formulate probabilities. Further uncertainty is introduced given the set of possible future outcomes is also unknown.[xlv]

This is partly why existing climate scenarios, e.g., the NGFS scenarios, are not associated with any likelihood[xlvi], so as to not convey a false sense of foreseeability. In addition, assigning probabilities could lead to decisions based on a 'weighted average' baseline. Decision makers need to take a rounded view of the full range of scenarios, looking for decisions that are robust in a range of states of the world, and developing a preparedness and resilience towards the unexpected.

8 Review and challenge of STS analysis

To be reliable and useful for decision-making, practioners should review and challenge the results of climate STS analysis, to the fullest extent possible, before using them to make decisions. However, given the lack of historical precedent, some uncertainty will likely remain. Understanding the impact of these limitations will help practioners to decide whether they are material enough to need to make any adjustments.

8.1 How do we review and challenge the outputs of STS modelling?

At present, there is no regulation or guidance provided by a professional body specifically for climate scenario and model validation, although this may become more regulated over time. In the absence of regulation, we suggest a principles-based framework that is broadly in line with general risk management and professional guidance applied in the UK financial services industry (e.g., Solvency II[xlvii], Basel[xlviii], the PRA's SS1/23[xlix] or the FRC's Technical Actuarial Standards)[l].

A. Challenge the scenario

Challenge should be provided around narratives and variables underpinning the selected STS. Where proportionate, an independent reviewer should interrogate the approach used to choose the STS (see Section 3) and confirm that the assumptions are appropriate for the chosen purpose and use case. This ought to include ensuring that uncertainty within the STS has been understood and communicated.

B. Thorough review process

All models used as part of STS require a thorough review process, however the approach to this may differ depending on whether the model is internal or from a third-party. If an extensively tested industry model has been used, then obtaining documentation from the model vendors, combined with verifying the suitability of the model and testing any adjustments made to the model output could be sufficient. Otherwise, a higher level of review will be needed. This may include sense-checking assumptions, testing the model when subject to extreme inputs and back-testing (where practical). Data quality should be assessed with gaps or assumptions made commented on as part of validation to convey the potential impact on results. Poor data will lead to poor modelling results and firms should look to address any gaps in the data.

C. Check modelling output meets requirements

The review process should include a conclusion as to whether the results met the need(s) of the business use case(s) established at the start of the scenario development as part of the use case scoping process. This may result in suggested actions or improvements that will then be fed back into the model development cycle (see section 7.2). Actions and improvements are more likely to be required for off-the-shelf severe scenarios, where tail-risk and feedback loops are not fully captured at present.

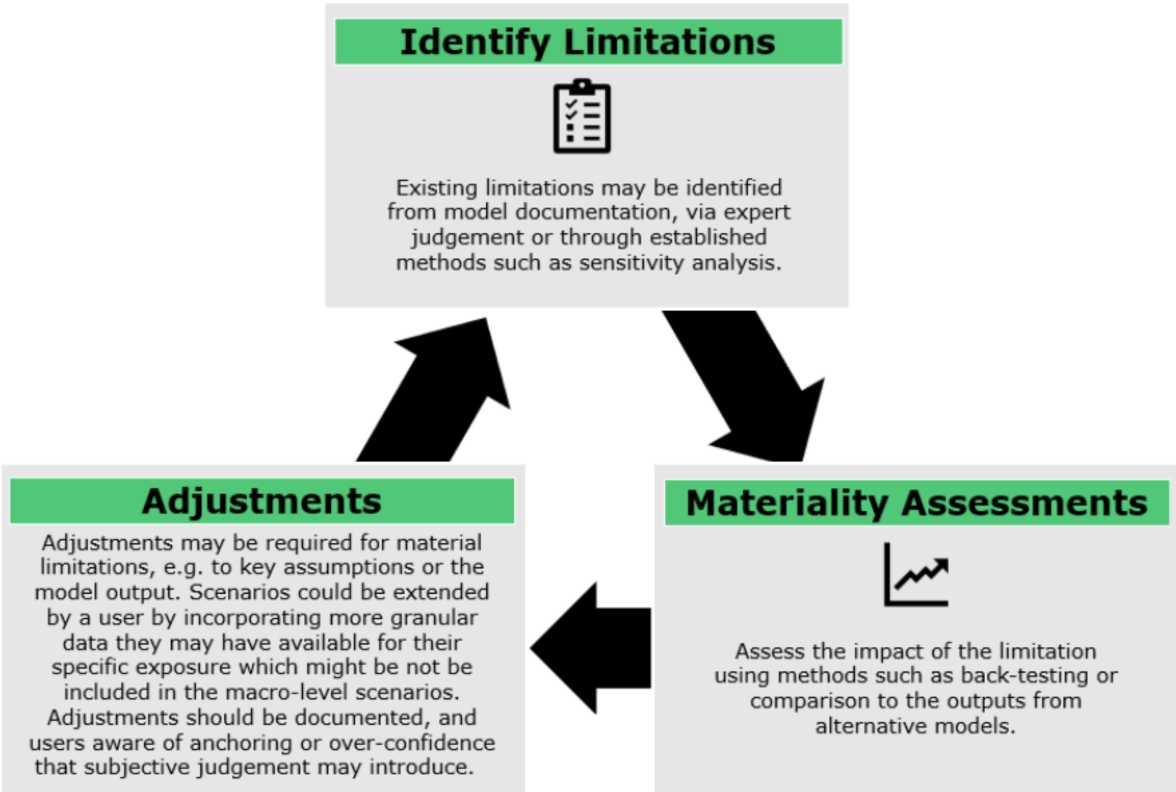
D. Good model governance

Firms can apply their usual governance guidelines to STS modelling. This should include a clear internal review process, with senior management oversight (making sure individuals involved have sufficient technical knowledge). A robust model maintenance process should be used for both internal and third-party models. There should be clear documentation for all models, which is understandable and could be audited by a third party. This reduces the risk of inappropriate use of the output and of greenwashing claims. Documentation should include key assumptions, key expert judgements, demonstrating challenge of the scenario, model limitations and any material uncertainties that are difficult to validate (e.g., the impact of 'unknown' physical risk), along with their potential impact on results.

8.2 How can STS limitations be addressed?

The validation process may identify several limitations that users should consider addressing. While new models and approaches are being developed, we suggest an iterative approach to help model users to adjust models and to address limitations.[li]

Figure 14: Addressing model limitations



The following Case Study explores how adjustments can be made [lii liii]

Case study 14: SwissRe approaches to adjust for physical risk

The financial impacts of physical risk are acknowledged to often be underestimated due to the non-linear nature of the risk and underlying transmission channels that aren't fully captured. In 2019, the Bank of England explored how climate-conditioned catastrophe models can be adjusted to try to address this:

1. **Partially/fully rebuild the model**, typically by adjusting the frequency and/or severity of events. The approach is "most scientifically robust but requires considerable research effort and time" so may only be possible for the original model developers.

2. **Adjust model outputs** using a one-off approximate adjustment factor based on available data. This method is more efficient, but it requires expert judgement to assess a reasonable adjustment.

SwissRe used the second approach in 2021 to model the impact of physical risk on economic outcomes. SwissRe used proxies to attempt to capture missing transmission channels and multiplicative factors to increase the severity of physical risk (x5 for moderate and x10 for severe outcomes).

9 Management actions

The final stage of the STS analysis framework is to take decisions informed by the output of the analysis and feed them into the strategic conversations that boards will increasingly need. To inform decision-making, the outputs of climate STS analysis should be translated into management information.

Given the relative immaturity of climate STS and the associated likelihood, deciding on an 'appropriate' course of action is difficult. The actions will also depend on the role of the stakeholder and the use case. However, management actions will broadly fall under one of three options – revising exposures to reduce climate-related risks or increase opportunity under the STS, holding a different level of capital to cover climate-related risks or engaging with high-emitting or high-risk companies or lobbying governments to implement effective science-based actions. This is shown via two examples below:

Objective: To assess whether current capital held is sufficient to cover the impact of climate change

Key stakeholder: Risk function

Output of use case: A regulatory stress testing exercise highlighted that there is a larger than expected exposure to short-term climate risk.

Management action: The risk function agrees to increase the capital held to make sure that the capital levels are sufficient to cover the impact of climate change and meet regulatory requirements.

Regulatory stress testing

Objective: To align the investment portfolio with a net zero emissions pathway.

Key stakeholder: Investment function

Output of use case: The modelling of climate emissions of the investment portfolio indicates the short-term emissions of certain counterparties are expected to be significantly higher than other parts of the portfolio.

Management action: The investment function decides to dis-invest from those counterparties to others with a climate risk profile with lower emissions.

Strategic planning and portfolio optimisation

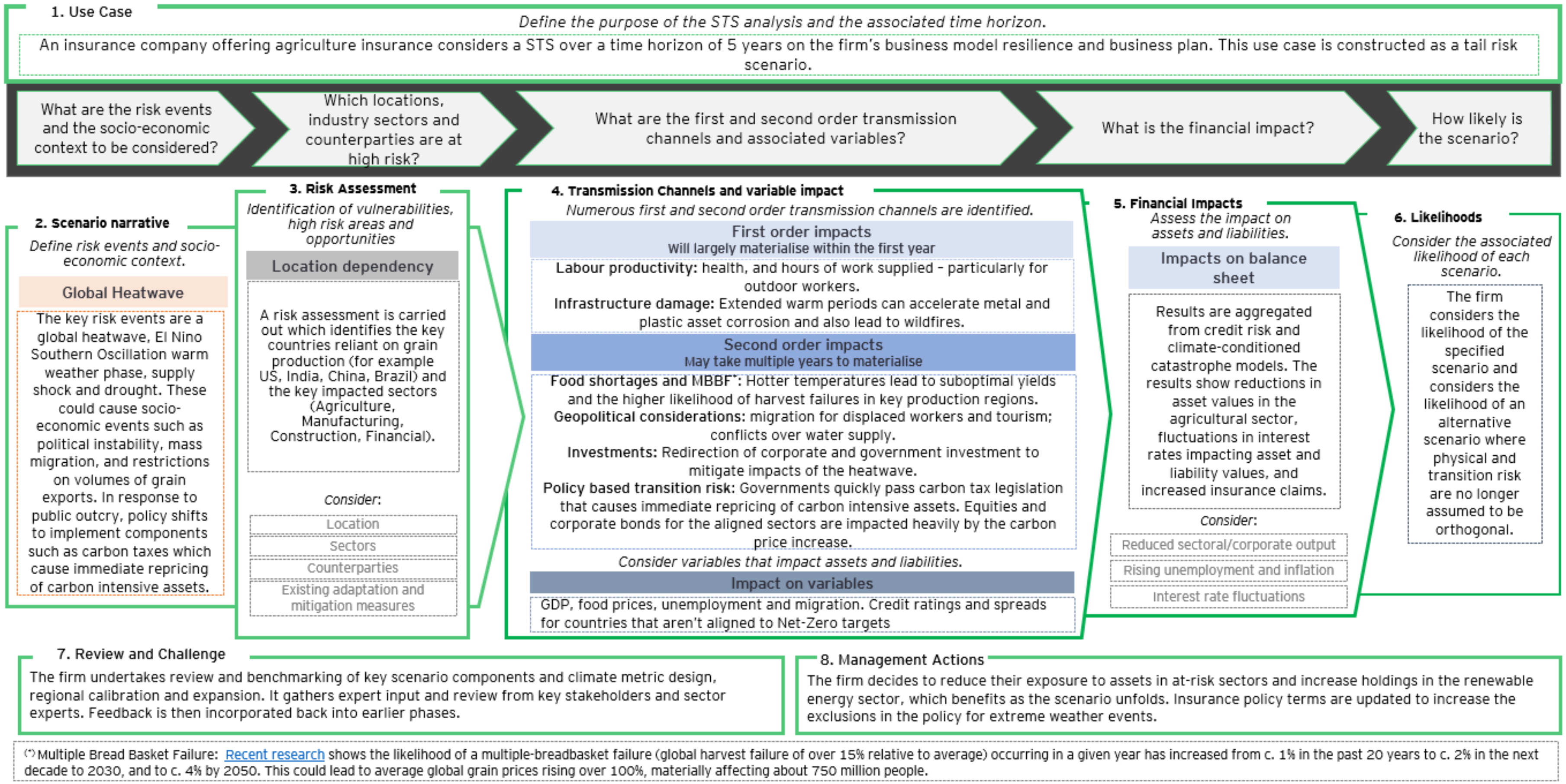
We recognise that management actions are taken with information from multiple sources, rather than being solely driven from one piece of analysis. In many cases, outputs from STS analysis are just one set of inputs into a broader set of strategic conversations. It is important that the impact due to climate change is highlighted separately from other factors, so that the size of climate-related risks is unambiguous.

Firms can then consider how to effectively integrate the results of their STS analysis into their overall strategic decision-making, including their business planning, with which boards will increasingly need to engage. This involves the use of a forward-looking approach considering narratives and heuristics, as well as models and data.

10 Case Study

This section illustrates the application of the STS framework set out in this guide through a hypothetical case study exploring the impact of major global heatwave shocks alongside other extreme weather events in various countries around the world over a five-year period. This also causes some governments to introduce policy measures, resulting in further global macro-economic shocks.

Figure 15: Case Study, adapted from Kornhuber et al. 2020[liv]



11 Conclusion

Given the increasing regulatory drivers and public scrutiny, it is critical for the financial services sector to act to mitigate climate risk in all its forms, while also balancing this with putting mechanisms in place that influence corporate decision-making. No action is not an option.

This framework is intended to provide an insightful reframing of the emerging but rapidly evolving climate modelling space. It may be deployed by financial services firms to embed STS in decision-making, either by choosing from standard scenarios families or constructing bespoke scenarios. This will help firms to understand their potential climate-related exposures, identify opportunities in the near-term and make more risk-informed business decisions.

Conducting STS analysis is not a trivial exercise. This is exacerbated by the evolving nature of STS design and modelling. Thus, expert judgement will be required to construct the narratives and select the relevant variables to be considered. In particular, significant data and modelling limitations exist, which means that it is important to review and challenge assumptions and caveats of the modelling before taking the results into consideration for decision-making.

Evolution of STS will be driven by several developments. Technological advancements and data and modelling capabilities are rapidly evolving every day, while wider understanding of the impacts of climate change are continuing to grow. Climate models are becoming increasingly sophisticated, particularly modules pertaining to the short-term. Short-term use cases are being increasingly adopted and fully integrated by firms. These developments will likely improve the capacity and reliability of performing such analysis over the coming years.

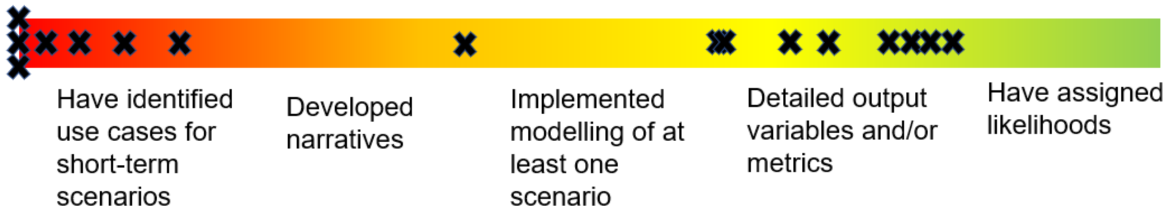
Initiatives of collaboration between industry, academia, regulators and consultants should continue to help address the challenges of STS analysis.

Annex A. STS Maturity Survey Results

In September 2023, the CFRF STS Sub-group conducted a survey to evaluate members' progress in developing climate STS narratives. This survey covered the use of climate scenario modelling in general, along with the use of STS narratives, modelling, variables, and likelihoods. 17 member firms responded to the survey, 41% were banks, 30% insurers and 29% asset managers.

The survey highlighted that while some respondents are in the very early stages of developing STS, others have progressed to the point of considering how they may assign likelihoods. For respondents that are currently immature with regards to STS, almost all of them plan to develop narratives and modelling capabilities within the next year, emphasising that this is an area of high priority development area. Climate scenario modelling is commonly used by respondents for external disclosures, scenario and stress testing and risk reporting, with an increasing focus on STS analysis for business planning purposes.

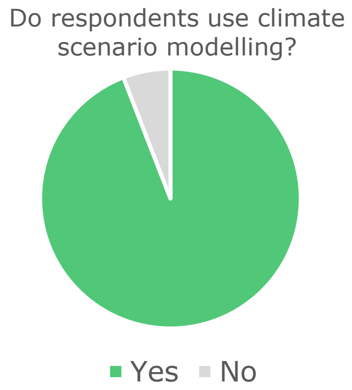
Figure 16: A heat-scale showing the maturity of climate STS development

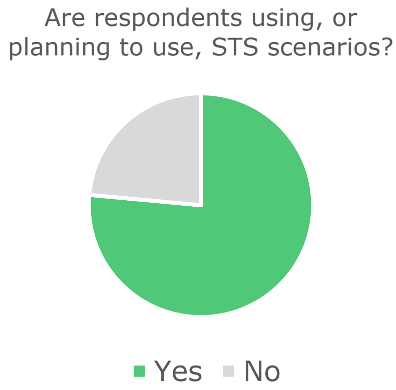


A.1 Use of climate scenario analysis and time horizon

Almost all respondents use climate scenario modelling and the majority of these then use, or are planning to use, STS analysis. Almost half of respondents are considering a single STS, with the rest considering three or more scenarios.

Figure 17: Extent to which respondents use scenario modelling

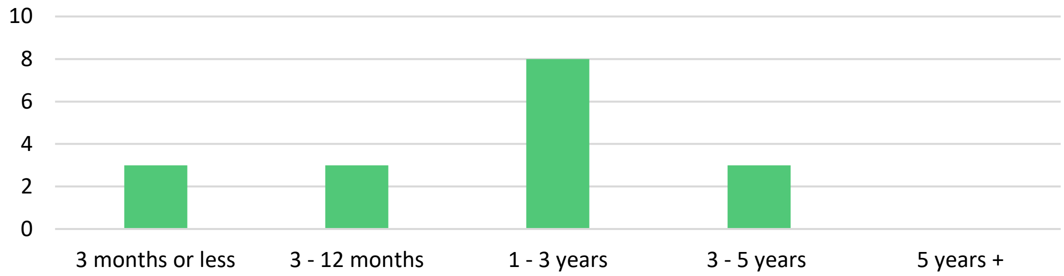




All respondents consider “short-term” to be a maximum of five years, however the exact duration used is dependent on the type of institution:

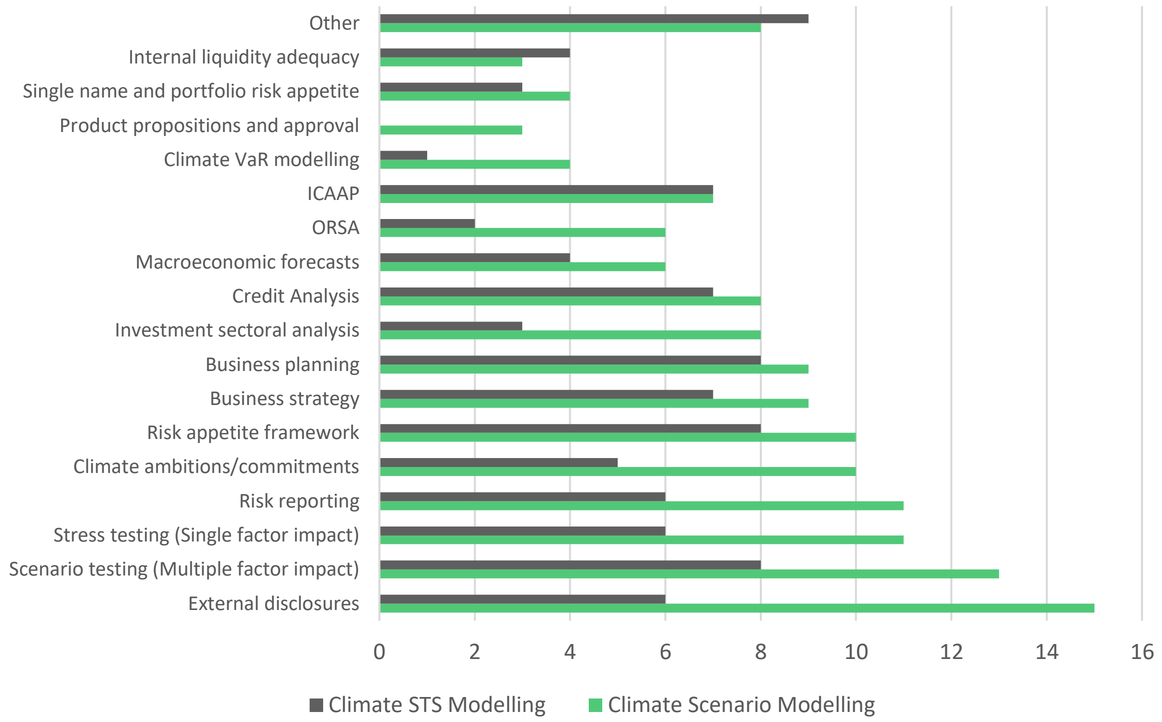
- Insurers and asset managers almost all responded one to three years.
- Banks were split on their answer, with the expectation that this is due to the purpose of their use cases. E.g., the application for capital models being less than a year, and the application for business planning tending to be three to five years.

Figure 18: How to define the time horizon of STS



Almost all respondents use climate scenario modelling for external disclosures, with a significant number of respondents using it for scenario testing and stress testing. The "other" category includes (pricing, uninsurable physical risk assessment, asset allocation, non-life product underwriting, exposure management and credit authorities and approval).

Figure 19: Use cases which are supported by climate scenario modelling



The use cases for STS analysis are more focused on internal purposes e.g., business planning, risk appetite framework and scenario testing. Nearly three quarters of respondents consider specific use cases when using STS. For respondents that have developed climate STS, a range of approaches have been adopted for reference scenarios. Some are based on NGFS scenarios with adjustments applied, whereas others have developed more bespoke scenarios, e.g., on a case specific basis, or a macroeconomic stress scenario.

A.2 Narratives

We have set out a list of some typical narratives used by respondents below. Most respondents adjust long-term narratives to STS, but a few have developed STS narratives from scratch to try to address potential gaps in existing long-term narratives e.g., geopolitics, tipping points, feedback loops and disruptive technology.

Figure 20: Typical STS narrative themes

Adjusting long-term narratives to the STS	Building STS narratives from scratch
Change in frequency and severity of physical risk events	Tipping point of Atlantic Meridional Overturning Circulation slowdown leading to fire sale of fossil fuel industry and increased climate activism
Varying adoption of carbon removal technology, influenced by carbon prices. Retrofitting of buildings to achieve improved Energy Performance Certificates	University of Exeter scenarios[lv]
Increased national commitments to be 'Paris' aligned	

A.3 Modelling

All respondents either already model climate STS or are planning to develop modelling capabilities within the next two years.

A.4 Variables

Respondents are using a range of variables in climate STS analysis. Most variables were focused on financial or transition risk, with only a few considering physical risk variables (although one participant considered quantification of several physical risks).

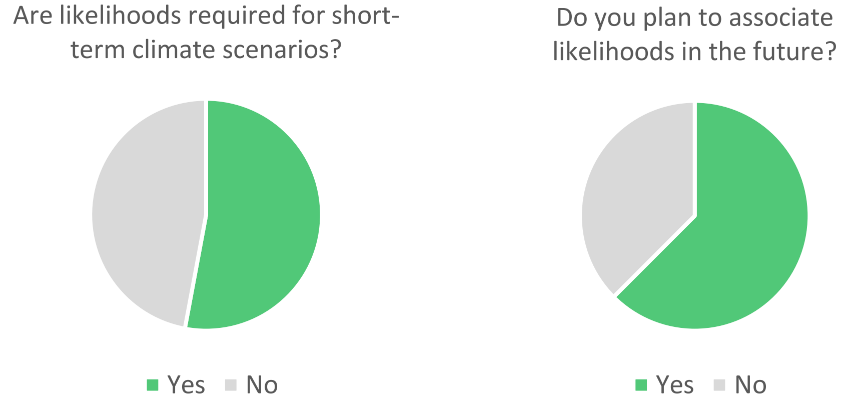
Figure 21: Variables considered for modelling in climate STS analysis (Variables in bold were used by multiple respondents)

Transition based	Physical based
Gross Domestic Product	**Temperature increases**
Carbon price	**Flood events**
Unemployment	Sea level rise
Base rate	Wildfire events
Minimum Energy Efficient Standard	
House price index	
Sectoral Gross Value Added	
Equity prices	
Carbon emissions	

A.5 Application of likelihoods to STS analysis

Respondents were split on whether they believe likelihoods should be assigned to climate STS. No respondents currently associate likelihoods with STS. Respondents that are intending to associate likelihoods in the future have not yet established an approach for this. It was acknowledged by several respondents that a level of expert judgement will be required in these decisions.

Figure 22: Approach to likelihoods in climate STS analysis

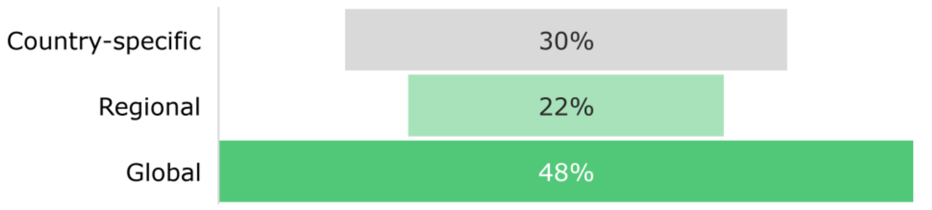


Annex B. Data Providers Survey Results

In October 2023, the STS Sub-group conducted a survey to evaluate data providers' current and planned development of climate STS. 18 climate data providers responded with the survey covering the: geographical coverage of data, intended market, data sets and climate pathways used and the use of modelling and variables. The definition of short-term used for this survey was five years.

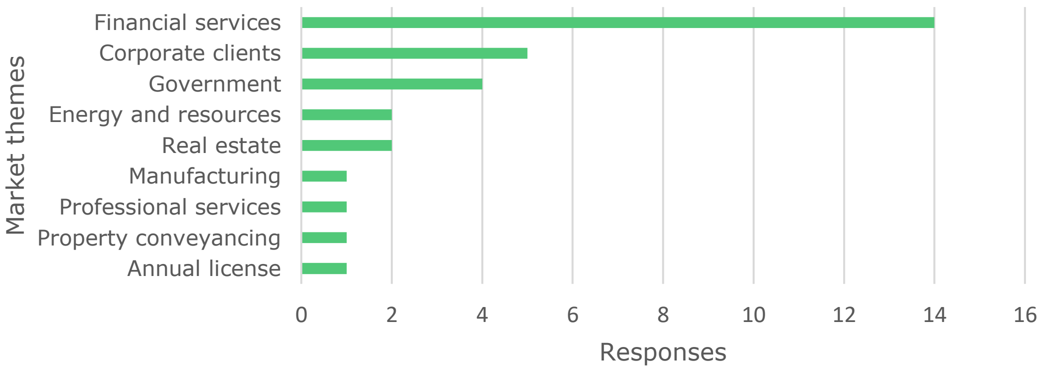
Most respondents to the survey either have, or are developing, short-term climate modelling capabilities. 78% of these models are, or are anticipated to be, commercially available. For data providers that have not explored the development of climate STS modelling capabilities, a variety of responses was given. These included a focus on long-term scenarios, a lack of resources and poor data quality for physical climate-related risk. Almost half of the data respondents' models are global models. Regional and country-specific models had a relatively even split for the remaining models available.

Figure 23: Regions covered by respondents' climate models



All data providers referred to part of the financial services sector as forming part of their intended market. Regulatory disclosures to date have focused on this sector which is likely to be a driver for this.

Figure 24: Intended market for survey respondent's models



Most respondents use publicly available data sources for their models, and there is a fairly even split between internally sourced and externally licenced data.

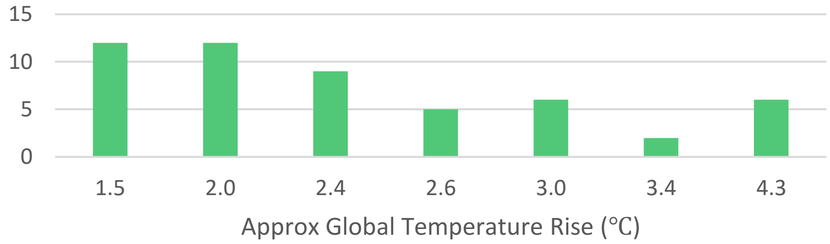
Figure 25: Data sources underpinning models

Publicly available data sources include the Coupled Model Intercomparison Project (CMIP), the Fifth Generation of European Centre for Medium-range Weather Forecasts Reanalysis (ERA5), UK Climate projections 2018 (UKCP18), Global Trade Analysis Project (GTAP), International Best Track Archive for Climate Stewardship (IBTrACS), Integrated Surface Database (ISD) and EU Global Energy and Climate Output (GECO).

B.1 Scenario Narratives

Almost all respondents mentioned Representative Concentration Pathways (RCPs) or Shared Socioeconomic Pathways (SSPs) in response to what scenario narratives underpin their model. These pathways are used by the NGFS, IPCC and IEA narratives. Other narratives included those that aligned to a business-as-usual scenario or net zero scenarios. Respondents' narratives are grouped based on the global temperature rise associated with that scenario in 2100.

Figure 26: Global temperature rises associated with respondents' models



Most respondents use narratives that cover a range of implied temperature rises, however there is a focus of scenarios that align to 1.5℃ and 2℃. This may be driven by the regulatory focus for firms to align targets to Net Zero or the Paris Agreement. Respondents have also explored different types of transition, e.g., orderly and dis-orderly narratives as part of their scenarios.

B.2 Modelling

Just over 70% of respondents model both transition and physical risk, although it appears more common to measure only physical risk, than only transition risk.

Transition risk variables were diverse but tended to focus on macroeconomic variables rather than purely financial variables. Almost all respondents that cover physical risk provide a form of flood, windstorm, and wildfires, and more niche examples include bioclimatic indicators and extratropical cyclones.

Figure 27: Types of transition risk and physical risk variables considered

Transition risk variables	Physical risk variables
Macroeconomic variables (e.g., GDP, inflation, interest rates, corporate spread)	Flooding (riverine, coastal, and pluvial)
Financial (incl. revenue loss, commodity price volatility)	Wind (windstorm, tropical and extra tropical cyclone, and tornado)
Technology (incl. retrofitting costs and energy efficiency)	Temperature extremities (extreme snow, heatwaves, and cold-waves)
Carbon price/taxes	Drought
Asset prices	Coastal erosion and inundation
Reputation (incl. credibility of net zero actions)	Freeze, thaw, and hail
Greenhouse gas emissions	Subsidence
Policy (e.g., bans on highly-polluting technologies, energy efficiency regulation)	

Annex C. STS Climate models

Figure 28: Types of STS climate modelling

Model	Purpose	Modelling Stage	Limitation overview	Examples
Transition Risk				
Integrated Assessment Models (IAMs) e.g., Computable General Equilibrium models (CGEs) and Dynamic Stochastic Equilibrium models (DSGEs)	**IAMs**[lvi] produce narrative-based transmission pathways for integrated variables, e.g., policy ambition, land use and projected emissions. **CGEs**[lvii] and **DSGEs**[lviii] are both numerical macroeconomic models. CGEs analyse the impacts of changes in policy upon the economy upon the view that the economy consists of multiple different sectors with individual supply and demand functions. DSGEs[lix] are a subset of CGEs that are also designed to analyse the economic impacts of climate-related shocks, as well as changes in policy.	Risk assessment	• Reliant on numerous defined parameters and assumptions.[lx] • Assumptions of a linear relationship may make such models unsuitable for modeling complex non-linear dynamics. • Potential oversimplifications made, e.g., omission of important feedbacks and integrations between variables. • Some rely upon an assumption that the economy is in a state of equilibrium (which is reached over longer time scales[lxi]) which limits applicability to STS analysis. • Only represent the end state of the system upon adjustment rather than progressive change over time. • May require unrealistic assumptions e.g., all markets are perfectly competitive[lxii] and all agents in the economy have perfect information and foresight. • Sectoral and regional coverage can be limited.	**IAMs**: REMIND-MAgPIE, MESSAGEix-GLOBIOM, GCAM **CGEs**: GTAP[lxiii], G-Cubed **DSGEs**: EMuSe model described in Hinterlang, Martin, Röhe, Stähler, and Strobel, 2023, CatDSGE
Semi-structural economic models	Combination of elements of both structural and reduced-form models, which are used to simulate macroeconomic variables for a given scenario, often used in the context of analysing counterfactual policies.[lxiv]	Risk assessment	• Highly data intensive to produce useful outputs. • Model complexity can entail challenging communication of results. • Some models, e.g., NiGEM, lack sectoral granularity.	NiGEM
I-O (Input-Output) models	I-O frameworks represent sectoral interdependencies through the interaction of the flow of goods and services between different sectors of the economy.	Risk assessment	• Accuracy of leakage measures. • Assumes an absence of supply constraints is unable to capture feedback loops.[lxv] • Oversimplification, especially on the production side of the economy.	Koks and Thissen, 2016
Physical Risk				
Circulation Models e.g., General Circulation Models (GCMs), Regional Climate Models (RCMs) and Earth System Models (ESMs)	**GCMs**[lxvi]**:** Large-scale climate models that analyse the physical processes pertaining to climate dynamics (e.g., atmospheric and ocean dynamics). Typical resolutions range from 250km to 600km. **RCMs**[lxvii]**:** Regional-scale climate models, based on the same principals as GCMs, but are able to provide higher-resolution outputs. **ESMs**[lxviii]**:** Integrated atmospheric, ocean, land and cryosphere models. These models expand on CGMs to capture interactions between different components of	Risk assessment	• Computationally expensive[lxix] due to requirement to model a large location, model at a high resolution and/or due to the integration of several models. • Not well-suited to modelling the complex, non-linear dynamics of the Earth system. • GCMs and RCMs are not well suited to modelling impacts of feedback loops. • Not suited to modelling impacts of abrupt climate change or STS shocks, so less applicable for STS analysis. • Often calibrated using historical data which can lead to overfitting and poor predictions.	**GCMs**: CCSM, HadGEM **RCMs**: WRF, RegCM **ESMs**: MAGICC, MIROC

	the Earth system, including the carbon cycle and biogeochemical processes.			
Natural catastrophe models (NatCat)	NatCat models[lxx] consist of four key components: event, hazard, vulnerability and financial modules. Models can be run stochastically in order to enable companies to output a distribution of results. Financial modules[lxxi] of NatCat models translate the physical damages of climatic events into monetary losses. Additional features, e.g., limits and deductibles, can then be applied depending on the nature of the firm.	Risk assessment and financial impact	• High dependence on quality of input data and assumptions restricts the temporal and spatial coverage. • Rarity of catastrophe events[lxxii] limits effectiveness of model validation. • Limited capacity to perform independent modelling of transition risk. • Limited ability to capture the complex interactions between economic conditions and climate-related variables. • Computationally expensive.	SEAGLASS, Moody's RMS, EQECAT, AIR Worldwide, JBA.
Transition Risk and Physical Risk or Carbon Emissions				
Large-scale econometric models	Models designed to simulate the behaviour of the economy[lxxiii] under different scenarios of economic and technological developments. They capture the interactions between financial and climate variables; they also provide insights into how different policies and scenarios might affect the climate[lxxiv]. They are built using dynamic equations to represent supply and demand with coefficients based on regressions.	Financial impact: Exposure impact	• Reliant on assumptions about the relationships between key financial and climate variables. • Computationally expensive due to their data-intensive nature. • Vulnerable to oversimplifications due to their inability to capture all complex interactions between financial and climate variables the economy and environment which can lead to inaccurate predictions.[lxxv]	NiGEM
Projected emissions models	Models that can project emissions trajectories based on different scenario pathways, e.g., Representative Concentration Pathways (RCPs). Projections[lxxvi] rely on assumptions e.g., future economic growth, fossil fuel prices and electricity generation costs.	Financial impact: Projected portfolio emissions	• Strong dependency on assumptions about future unknowns (e.g., evolutions in scalable technology, population growth, changes in policy). • Difficulty in efficiently validating[lxxvii] projections of the future. • Dependence on accurate and up-to-date data. • Requires an accurate baselining of current emissions.	CMIP6[lxxviii]
Credit risk models	The integration of physical and transition risk into existing credit risk models[lxxix]. They are used to forecast future trends and to identify the potential climate-related credit risk posed at company or sectoral level in light of both physical and transition risk.	Financial impact: Exposure impact	• No data exists to explicitly measure empirical links between climate and credit risk. • Expected gaps in climate risk currently captured in credit risk models.[lxxx]	Climate-adjusted PD.
Physical and transition risk aggregation models	Models used to overlay physical and transition risk impacts onto credit risk, asset valuations and other key outputs.	Financial Impact: Combine physical and transition risk	• Difficulty in back testing and validation. • Ensuring that the same assumptions have been applied to the base model as well as the climate risk aggregation is non-trivial.	Combination of REMIND-MAgPIE, MAGICC and Kalkuhl & Wenz (2020)

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