Climate Stress Testing Methodologies

Current Practices, Challenges, and the Road Ahead

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Disclaimers

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Abbreviations and acronyms

AI	Artificial Intelligence
BAU	Business As Usual
BCBS	Basel Committee on Banking Supervision
BIS	Bank for International Settlements
CO_2	Carbon Dioxide
CPI	Consumer Price Index
CRE	Commercial Real Estate
CCR	Counterparty Credit Risk
DTI	Debt to Income
EBITDA	Earnings before Interest Tax Depreciation and Amortization
EBA	European Banking Authority
ECB	European Central Bank
ECL	Expected Credit Loss
ESA	European Supervisory Authorities
EPC	Energy Performance Certificate
ESG	Environmental, Social, and Governance
EU	European Union
FINMA	Swiss Financial Market Supervisory Authority
FX	Foreign Exchange
GDP	Gross Domestic Product
GHG	Green House Gases
GRI	Global Reporting Initiative
GVA	Gross Value Added
IAM	Integrated Assessment Model
ICAAP	Internal Capital Adequacy Assessment Process
IPCC	Intergovernmental Panel on Climate Change
ISDA	International Swaps and Derivatives Association
IT	Information Technology
KPI	Key Performance Indicator
KRI	Key Risk Indicator
LGD	Loss Given Default
LTV	Loan to Value
ML	Machine Learning
MRM	Model Risk Management
NGFS	Network for Greening the Financial System
PCAF	Partnership for Carbon Accounting Financials
PD	Probability of Default

P&L	Profit and Loss
PRA	Prudential Regulation Authority
RBI	Reserve Bank of India
RCP	Representative Concentration Pathways
RWA	Risk Weighted Assets
SARB	South African Reserve Bank
SAS	SAS Institute Inc
SSP	Shared Socio-Economic Pathway
TCFD	Task Force on Climate-Related Financial Disclosures
TNFD	Taskforce on Nature-Related Financial Disclosures
UER	Unemployment Rate
UNEP FI	UN Environment Programme Finance Initiative
VaR	Value at Risk

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This report is further informed by two supporting documents—*Survey Findings* and *Case Studies* and *Practical Examples*.

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About UNEP FI's Risk Centre

Since 2017, UNEP FI's Climate Risk and the Taskforce on Climate-Related Disclosures (TCFD) programme has taken a leadership role in developing good practices to identify, measure, disclose, and manage climate risk in the financial sector. Working with over 100 banks, insurers, and various investors, the programme has created numerous tools, frameworks, and guides to accelerate the implementation of good practices, focusing on implementing the recommendations of the TCFD and covering topics such as legal risks, climate stress testing, climate scenarios, climate tools, and other related areas. Furthermore, since 2022 UNEP FI has convened pilots on the Taskforce on Nature-related Financial Disclosures (TNFD), with the first set of pilots assembling 40 financial institutions from more than 20 countries.

In 2024, UNEP FI launched its Risk Centre. The Risk Centre provides a resource tailored especially for risk managers, integrating all its existing climate and nature risk-related work programmes, tools, and peer learning opportunities for assessing and managing climate and nature risks. The Risk Centre also aims to cover other sustainability risks, such as pollution and social risks, fostering a holistic approach to sustainability. The Risk Centre consists of a technical programme facilitated by working groups with the aim of producing decision-useful resources for the finance sector, such as cutting-edge tools, guidance, and methodologies.

Learn more about the UNEP FI Risk Centre here.

About SAS

SAS is a global leader in data and AI, empowering organizations to turn data into trusted decisions, faster. Our proven risk management solutions help financial institutions establish a risk-aware culture, optimize capital and liquidity and confidently address regulatory demands. With high-performance, on-demand analytics, SAS enables firms to balance short- and long-term strategies while navigating regulatory change and managing compliance. Used by 90 per cent of Fortune 100 companies, SAS helps solve the world's toughest challenges through the power of data and AI. Learn more at sas.com/riskmanagement.

About this report

This report focuses on methodological practices for climate stress testing and has been developed in collaboration between the UN Environment Programme Finance Initiative (UNEP FI) and SAS Institute Inc (SAS). **This report outlines common approaches and key considerations for climate stress testing**. It provides an update on the latest climate stress testing practices and potential use cases for climate stress testing outcomes, to enable risk professionals to stay abreast of the latest developments and strengthen their internal frameworks. Additionally, the report highlights areas for further enhancement in climate stress testing methodologies. Case study examples of climate stress testing conducted by banks are included to offer risk professionals practical insights and lessons learned.

As a result, this report is designed to support risk professionals in developing their climate stress testing methodologies by presenting peer practices, identifying areas for further prioritization, and providing findings that may assist in meeting supervisory expectations for managing climate risks.

This collaboration involved a workshop series covering various climate stress testing topics, including:

- Approaches for credit risk stress testing related to transition risk
- Approaches for credit risk stress testing related to physical risk
- Approaches for market risk stress testing related to climate risk
- Model risk management, and the integration of climate stress testing into business-as-usual (BAU) processes
- Integration of climate stress testing with decarbonization efforts, such as transition planning
- The role of technology, including appropriate IT systems and infrastructure, in supporting climate stress tests

In addition to the workshop series, participating banks completed a survey on climate stress testing practices. This report includes insights drawn from both the workshop series and the survey, which together define the scope of the report.

Supplementing this report, two supporting documents are provided. The *Case Studies and Practical Examples* document contains detailed case studies from banks and practical approaches to climate stress testing. The *Survey Findings* document presents results from the joint survey by UNEP FI and SAS.

This report aims to assist UNEP FI's Risk Centre in helping banks navigate emerging sustainability risk practices and strengthen their risk management capabilities. The findings will inform the Risk Centre's in-depth research programme and future work in sustainability risk management.

Key takeaways

Table 1: Summary of key findings from the report

Main findings	Survey findings	Case study and practical examples	Level of maturity	Future evolution and expected developments[1]
In addition to supervisory exercises, banks are increasingly conducting internal climate stress tests to support risk management.	57 per cent of respondents perform internal climate scenario analysis annually, beyond regulatory requirements. Only 9 per cent of respondents solely conduct regulatory exercises.	Not included	Established	Integration of other sustainability risks into risk assessment, including nature and social risks.
Choice of climate scenarios differs by time-horizon and risk type.	Internal scenarios are preferred for short-term time-horizons. NGFS and IPCC scenarios are used by most banks for long-term time-horizons.	Practical example drawn from a public annual report	Becoming established	Further development of short-term climate scenarios will draw on both internal, tailored scenarios and standardized scenarios such as those from the NGFS, applied according to the use case.
Increased use of BAU risk indicators by banks to measure the impact of climate risk.	More than 50 per cent of respondents use the following as output metrics: ▪ ECL ▪ P&L ▪ RWA/Capital Less than 20 per cent of respondents use a dynamic balance sheet approach.	Not included	Becoming established	Aligning the choice of balance sheet approach with the specific objectives of the exercise, using a dynamic balance sheet approach to accommodate adaptation and strategic repositioning.

1 Drawing from perspectives shared by senior experts from at PwC WPG GmbH, EY, Baringa, Oliver Wyman, Deloitte, and KPMG.

Main findings	Survey findings	Case study and practical examples	Level of maturity	Future evolution and expected developments[1]
Banks are adopting granular, bottom-up approaches to model transition risk-related credit risk as part of climate stress testing.	One-third of respondents assess climate risks for corporates at the counterparty-level and exposure-level. While less than 15 per cent of respondents use portfolio-level and industry-level analysis.	Practices Observed by the EBA Fit-for-55 Climate Scenario Analysis methodology TRISK methodology	Becoming established	Increased adoption of granular analyses encompassing both direct and indirect transmission channels, while broadening stress factors in scenario design to capture a wider range of potential impacts.
A more expansive and geographically granular approach to assessing physical risk-related credit risk has emerged in climate stress testing.	Commonly modelled physical hazards by respondents are: Flood risk (86 per cent) ▪ Water stress (48 per cent) ▪ Heat stress (43 per cent) ▪ Wildfires (38 per cent) More than 65 per cent of respondents use either geo-coordinates or zip-codes for analysis. 24 per cent of respondents model the compounding impacts of physical and transition risks.	Case studies by banks	Becoming established	Addressing methodological challenges and data limitations of assessing adverse physical events, with a focus on improving the qualitative understanding of potential risks.
Climate stress testing methodologies for market risk remains under-developed.	Almost 40 per cent of respondents use internally developed scenarios to assess climate risks across a short-term horizon.	Case study by a bank Fit-for-55 Climate Scenario Analysis methodology	Nascent	Refinement in approaches to translate macroeconomic variables into market shocks, while maintaining consistent transmission of impacts across asset classes.

Main findings	Survey findings	Case study and practical examples	Level of maturity	Future evolution and expected developments[1]
Banks are in the early stages of integrating climate models into MRM, with some emerging areas of alignment.	Almost 50 per cent of respondents build climate risk models as add-ons to already validated BAU risk models. One-third of respondents do not consider model risk embedded in their simulations.	Practical example drawn from a public annual report	Nascent	Systematic classification and tiering of climate models, as well as efforts to build internal modelling capabilities, where possible, to reduce vendor dependency to improve MRM.
Progress in embedding climate stress testing into BAU stress testing, risk management, and capital management varies across banks.	14 per cent of respondents have implemented climate risk factors into BAU credit loss impairment models. 38 per cent of respondents have embedded climate risk in their ICAAP models. 52 per cent of respondents use climate scenario analysis for transition and decarbonization planning.	Case study by a bank Practical example drawn from a public annual report	Nascent	Improved integration of climate risk into BAU practices, with climate stress testing results increasingly informing credit impairment, capital management, and capital allocation progressively.
Developments in technology[2] can support the implementation of solutions to improve and streamline climate stress testing.	All respondents (100 per cent) agree that technology can be improved to enhance analysis, maintain consistency, increase sensitivity, and automation processes	Case study by a bank	Becoming established	Developing internal solutions or leveraging vendor-provided tools to address challenges and realize automation benefits.

2 Including IT systems, software, and infrastructure.

Executive summary

Climate stress testing has emerged as a key tool for assessing financial institutions' resilience to climate-related risks. This report, jointly authored by the United Nations Environment Programme Finance Initiative (UNEP FI) and SAS Institute Inc (SAS), outlines **common approaches and key considerations for climate stress testing**.

Alongside participating in supervisory exercises, banks are increasingly conducting internal climate stress testing and scenario analysis to inform their risk management. A survey conducted jointly by UNEP FI and SAS with 21 global banks showed that climate stress testing is maturing with more than half of the respondents conducting internal climate scenario analysis exercises annually. A minority go further and do so on a quarterly basis. Similarly, more than three-quarters of the surveyed banks have developed in-house methodologies. Nearly half of these are built on, and linked to, existing business-as-usual (BAU) standard scenario analysis methodologies, while almost a third are based on stand-alone approaches.

Summary of climate stress testing practices

This report presents nine main findings on climate stress testing practices, summarized below.

1. Climate scenarios used as climate stress testing inputs

Key takeaway: Banks' choice of climate scenarios varies depending on the time-horizon and risk type.

Insights from the UNEP FI and SAS survey reveal that banks commonly assess climate risks over 3–10 and 20–30-year horizons, using the **Intergovernmental Panel on Climate Change (IPCC) SSP5-8.5, SSP2-4.5, and the Network Greening the Financial System (NGFS) Current Policies scenarios** for long-term physical risks; the **NGFS Delayed, Net-Zero, and Below 2 Degrees scenarios** for long-term transition risks; while most commonly relying on internally developed scenarios for short-term risks.

2. Use cases and modelled results

Key takeaway: Observed stress testing practices focus on metrics such as exposures, default risks, and profitability, typically based on static balance sheet assumptions.

Climate stress testing outcomes are primarily used to raise awareness and improve climate risk management practices. Based on the survey findings, the common output metrics include the following:

- **Exposure metrics** such as aggregated risk exposure and financed emissions, broken down by sectors, asset classes, energy performance, or top counterparties.
- **Key risk indicators** (KRI) such as Probability of Default (PD) and Loss Given Default (LGD).
- **Key performance indicators** (KPIs) such as loan loss provision, net income impact and profitability (P&L), and capital adequacy ratios.

The results of climate risk stress testing are significantly shaped by the assumptions made around portfolio composition, strategic business decisions and management response, and counterparty behaviour over time. **Most banks currently adopt a static balance sheet assumption**, where the composition of assets and liabilities is held constant throughout the scenario horizon. This approach is commonly used due to its practicality, transparency, and comparability, and is aligned with prevailing supervisory expectations applied across different jurisdictions. However, as the report outlines, a dynamic balance sheet approach, albeit more complicated, can provide a better reflection of real-world transition pathways, especially when a bank has articulated a clear decarbonization roadmap or a climate-aligned strategy.[3]

3. Approaches for modelling transition risk for credit risk stress testing

Key takeaway: Banks are increasingly adopting detailed, bottom-up approaches to model both direct and indirect impacts of transition risks on credit risk stress parameters.

As regulatory expectations and internal climate risk frameworks evolve, banks are increasingly expected to assess climate-related financial risks with greater granularity and precision. The level at which this analysis is performed varies depending on the scope of the exercise, the availability of data, and the level of institutional maturity. However, there is a clear industry shift away from high-level, top-down approaches toward more detailed, bottom-up assessments that reflect the actual risk drivers in banks' portfolios. Survey results show that **most institutions are performing their climate risk stress testing at granular levels—especially, counterparty level or exposure level.**

The report describes methodologies for assessing transition risks which rely on forward-looking carbon policy and climate-related technology variables, plus estimations of the shifts in rising costs, stranded assets, and market dynamics that can impact profitability

3 In regulatory stress testing, supervisors have relied on a static balance sheet approach, though more recent exercises increasingly incorporate dynamic assumptions.

and leverage. **Banks are engaging in modelling at various levels of granularity to assess the impact of transition risks on the probability of default (PD) risk parameter.** Banks are incorporating both indirect transmission channels—through macroeconomic indicators (such as gross domestic product [GDP], Consumer Price Index [CPI], and Unemployment Rate [UER]) and direct transmission channels involving climate-specific variables (such as carbon pricing and greenhouse gas [GHG] emissions).

4. Approaches for modelling physical risk for credit risk stress testing

Key takeaway: Banks are enhancing physical risk modelling by broadening hazard coverage, improving geographic granularity, and increasingly incorporating adaptive capacity and insurance considerations.

Banks are extending their models of physical risk by including additional hazards. Common physical risk hazards modelled are flood risk, water stress, and heat stress. Most survey respondents **perform physical risk assessment of corporates at the geographic coordinate level**. Geolocational data are more widely available for immovable property collateral, whereas data on the location of firms' economic activities through the value chain remain limited.

The majority of survey respondents model first-order climate risks, but only 29 per cent and 24 per cent of respondents model second- and third-order impacts, and adequately modelling these impacts remains a challenge. Some banks assess clients' adaptive capacity to physical risks by evaluating their climate adaptation strategies, while a few banks are also incorporating insurance considerations to a certain extent.

Only 24 per cent of respondents are currently assessing climate risks by compounding the impacts of physical and transition risks.

Case studies by banks demonstrating approaches for credit risk stress testing related to physical risk can be found in the document *Case Studies* and *Practical Examples*.

5. Approaches for market risk-related climate stress testing

Key takeaway: Current methodologies for climate-related market risk are relatively nascent and focus on translating scenario variables into market risk drivers.

Compared to credit risk, **methodologies for climate-related market risk stress testing remain relatively underdeveloped. Many banks currently conduct these exercises in response to regulatory requests or on an ad-hoc basis, rather than through fully embedded frameworks**. Current approaches often lack the granularity needed to reflect differentiated impacts across asset class, market structure, activity, and market liquidity. Most methodologies focus on translating macroeconomic or climate scenario variables into market risk drivers. A market risk approach builds on these inputs by modelling their transmission into financial markets, including price and yield curve impacts across different maturities, as well as shocks to volatility, market liquidity, and overall market structure.

A case study by a bank demonstrating their approach for climate risk-related market risk stress testing can be found in the document *Case Studies* and *Practical Examples*.

6. Integrating climate models into model risk management

Key takeaway: Still in its early stages, the integration of climate models into Model Risk Management frameworks shows convergence among banks on certain practices.

Many institutions are still in the early stages of integrating climate models into their Model Risk Management (MRM) frameworks. Current efforts are primarily focused on defining and classifying climate models—particularly those used in climate risk stress testing. One-third (33 per cent) of surveyed banks have not yet fully incorporated climate stress testing models into their MRM frameworks. Among banks that do apply MRM principles to their climate models, two common practices have emerged:

i. **Extending existing, validated business-as-usual (BAU) risk models with climate-related modules or overlays;**
ii. **Conducting internal validation of bespoke climate risk models**, often developed in-house or with limited reliance on vendor tools.

There is also a shift among some banks towards building internal modelling capabilities. This allows banks to reduce dependency on third-party models, better tailor methodologies to their portfolios, and enhance control over model assumptions and limitations, ultimately mitigating model risk in a rapidly evolving regulatory landscape.

7. Integrating climate stress testing into business-as-usual risk management and portfolio decarbonization efforts

Key takeaway: Banks increasingly view climate-related risks as drivers of broader financial risks and are working to integrate climate stress testing into existing stress testing frameworks.

As banks advance their climate risk assessment capabilities, climate-related risks are increasingly being recognized as key drivers of broader financial risks. A growing number of institutions are working to embed climate stress testing into their existing enterprise-wide stress testing frameworks, ensuring that climate risk is assessed not in isolation, but alongside other economic and financial shocks.

Some banks are **enhancing external scenarios by incorporating idiosyncratic shocks** specific to their portfolios or geographies (KPMG, 2025). Others are **developing internal scenarios that combine macroeconomic volatility with short-term climate tail risks**, enabling a more realistic view of potential risk transmission mechanisms.

Banks are increasingly looking to integrate climate risk into credit impairment and capital requirements, but only 14 per cent of respondents have already implemented climate risk factors into BAU credit loss impairment models. That said, 19 per cent of respondents are planning to implement climate risk factors within the next 12 months, with 24 per cent planning to follow suit within the next 36 months. Moreover, almost half (48 per cent) of the respondents from the survey stated that they reflect climate risk in their capital requirements.

A case study by a bank demonstrating its approach to integrating climate stress testing into its BAU risk management can be found in the document *Case Studies* and *Practical Examples*.

Key takeaway: Integration of climate stress testing with portfolio decarbonization efforts can improve efficiency and strengthen credibility.

Banks are conducting climate scenario analysis not only to meet regulatory stress testing requirements but also to **guide strategic planning activities such as identifying sustainable finance opportunities, engaging clients on transition pathways, and setting credible decarbonization targets**. Notably, stress testing typically relies on NGFS scenarios due to their macro-financial structure, whereas target setting and transition planning are more aligned with IEA scenarios, which offer greater sectoral and technological specificity. To enhance coherence across risk management, strategy, and regulatory compliance, banks should integrate these methodologies through harmonized data architectures, scenario alignment frameworks, and governance structures that promote cross-functional collaboration, for example the use of central case climate scenarios to inform business strategy. Such integration improves efficiency and strengthens the credibility of climate-related financial disclosures and ensures that climate considerations are embedded in capital allocation and long-term planning.

8. Supporting and enabling the role of technology

Key takeaway: To meet banks' expectations, current technology solutions must evolve to offer greater transparency, flexibility, and interpretation of results.

Current technology solutions, including IT systems, software, and infrastructure, for climate stress testing remain insufficient. Banks require solutions that provide: **more transparency when running analyses; improved flexibility and automation in (re)running sensitivity analyses; and a better understanding of the drivers behind the results**. Central stress testing platforms can be designed to accommodate a bank's needs and allow different teams involved to share data, scenarios, models, and results. In addition, such platforms can leverage and deploy a bank's common computational capabilities efficiently and effectively.

A case study by a bank demonstrating their approach for using the support of technology to conduct climate stress testing can be found in the document *Case Studies* and *Practical Examples*.

9. Next steps in climate stress testing methodologies and areas of development

Key takeaway: As climate stress testing matures, methodologies are expected to evolve in sophistication, relevance, and integration.

Drawing from perspectives shared by senior experts,[4] six themes emerge from trends shaping the next phase of climate risk stress testing:

i. Integration of climate risk into business practices, for example through risk provisions, lending, investment decisions, and capital planning.
ii. Inclusion of broader sustainability risks, such as nature and social risks, within risk assessments.
iii. Advancements in scenario design, including short-term climate scenarios and the use of artificial intelligence (AI).
iv. Refinement of modelling approaches, for instance in physical risk modelling, capturing transmission channels, and drawing on new data sources.
v. Strengthening of governance, including board accountability and embedding governance within control frameworks.
vi. Reporting of climate stress testing results through confidential supervisory submissions rather than public disclosures.

Wider adoption of climate-related regulations and practices that are interoperable can support rapid integration of climate-related considerations into risk management processes and frameworks of financial institutions. Harmonized measures could help level the playing field for the banking industry while enabling comparability of high-quality information to help enhance pricing, origination, and loss models. Consequently, these measures could incentivise prudent financial institutions and enable them to encourage their clients to transition to a net-zero economy.

4 At PwC WPG GmbH, EY, Baringa, Oliver Wyman, Deloitte, and KPMG

Chapter 1: Introduction

1.1 Adoption of climate stress testing by the banking sector

Climate stress testing has rapidly evolved into a critical tool for assessing financial institutions' resilience to climate-related risks. The methodologies have evolved over time, starting from top-down, exploratory approaches and maturing to include bottom-up and hybrid models, enabling a more detailed and institution-specific analysis. In addition, several key areas of climate stress testing have witnessed significant improvements. Scenario development has become much more sophisticated, for example, drawing from frameworks like those provided by the NGFS that now include a variety of transition and physical risk scenarios across different time-horizons which continue to evolve rapidly. Data availability has also strengthened, driven by better corporate climate disclosures and more comprehensive datasets. Furthermore, exercises have expanded their time-horizons, incorporating both short- and long-term horizons. Other examples of improvements include: progress in modelling physical risks, increased stakeholder engagement, and enhanced global collaboration on approaches and methodologies across jurisdictions.

These advancements have made **climate stress testing a useful tool** for assessing financial institutions' vulnerability to climate change. They help to identify financial risks arising from climate change and assess potential impacts on banks' business models. Climate stress tests have been particularly valuable in identifying gaps in climate risk assessment methodologies, such as data availability and quality. In addition, they help raise awareness on climate risks and mobilize climate action within and across institutions.

Climate scenario analysis has also now become **an integral component of financial regulation**, aiming to assess and enhance the resilience of financial institutions to potential systemic risks from climate change. Supervisory authorities globally have initiated various exercises to evaluate these risks, driving the development of methodologies and frameworks for climate stress testing and scenario analysis (FSB, 2025a; FSB, 2025b; FSB, 2025c; UNEP FI, 2024). Beyond meeting regulatory requirements, banks are **increasingly conducting internal climate scenario analysis** to inform their own risk management.

A survey conducted jointly by UNEP FI and SAS with 21 global banks[5] shows that 91 per cent of respondents conduct internal climate scenario analysis, in addition to meeting regulatory expectations and requirements.[6] Moreover, nearly half (48 per cent) of surveyed banks have developed their climate scenario analysis methodology in-house. Typically,

5 Details on the geographical distribution of survey respondents are available in the *Survey Findings* document.
6 Survey results are presented in Figure 1 of the *Survey Findings* document.

these are built on, and linked to, existing BAU standard scenario analysis methodologies. In contrast, 28 per cent use in-house methodologies that are stand-alone and not based on existing BAU methodologies. Around one in five (19 per cent) of the respondents stated that their climate scenario analysis methodology is provided by a third party and deployed and implemented in-house. A small fraction (5 per cent) outsource everything to third parties.[7]

Despite recent progress in improving climate stress testing methodologies, key challenges persist, including:

- Uncertainties in long-term climate projections and inherent model limitations.
- Forward-looking aspect of climate risks (as opposed to the backward-looking focus of some traditional risk models), coupled with scarcity or a lack of access to robust historical data on climate change.
- Integrating granular sectoral and exposures data—particularly for physical risks linked to asset locations and economic activities—remains difficult due to data gaps.
- Assessment of economic losses when quantifying the impact of physical risks, especially when modelling feedback looks and tipping points.

As a result, translating climate risks into financial impacts across credit, market, operational, liquidity, strategic, and capital risk dimensions remains challenging.

1.2 Scope of the report

Figure 1 illustrates the entire climate stress testing process, from defining objectives to modelling impacts and assessing financial risks. Firstly, the objectives of the stress testing exercise must be clearly defined. Once established, the climate stress testing process then involves designing scenarios that incorporate macroeconomic and financial shocks resulting from climate change over a specified time-horizon. A suite of models is then used to assess the impact across different risk types (such as credit and market risk) reflecting banks' balance sheets and income statements. These models rely on detailed exposure data and often incorporate historical data on profitability under various macroeconomic conditions. This process generates forward-looking projections of revenue, profitability (P&L), other balance sheet items, credit risk parameters, sectoral exposures, and capital adequacy. These insights can help inform risk management practices, investment decisions, transition planning (including setting decarbonization targets and supporting strategies), and client engagement.

7 Survey results are presented in Figure 2 of the *Survey Findings* document.

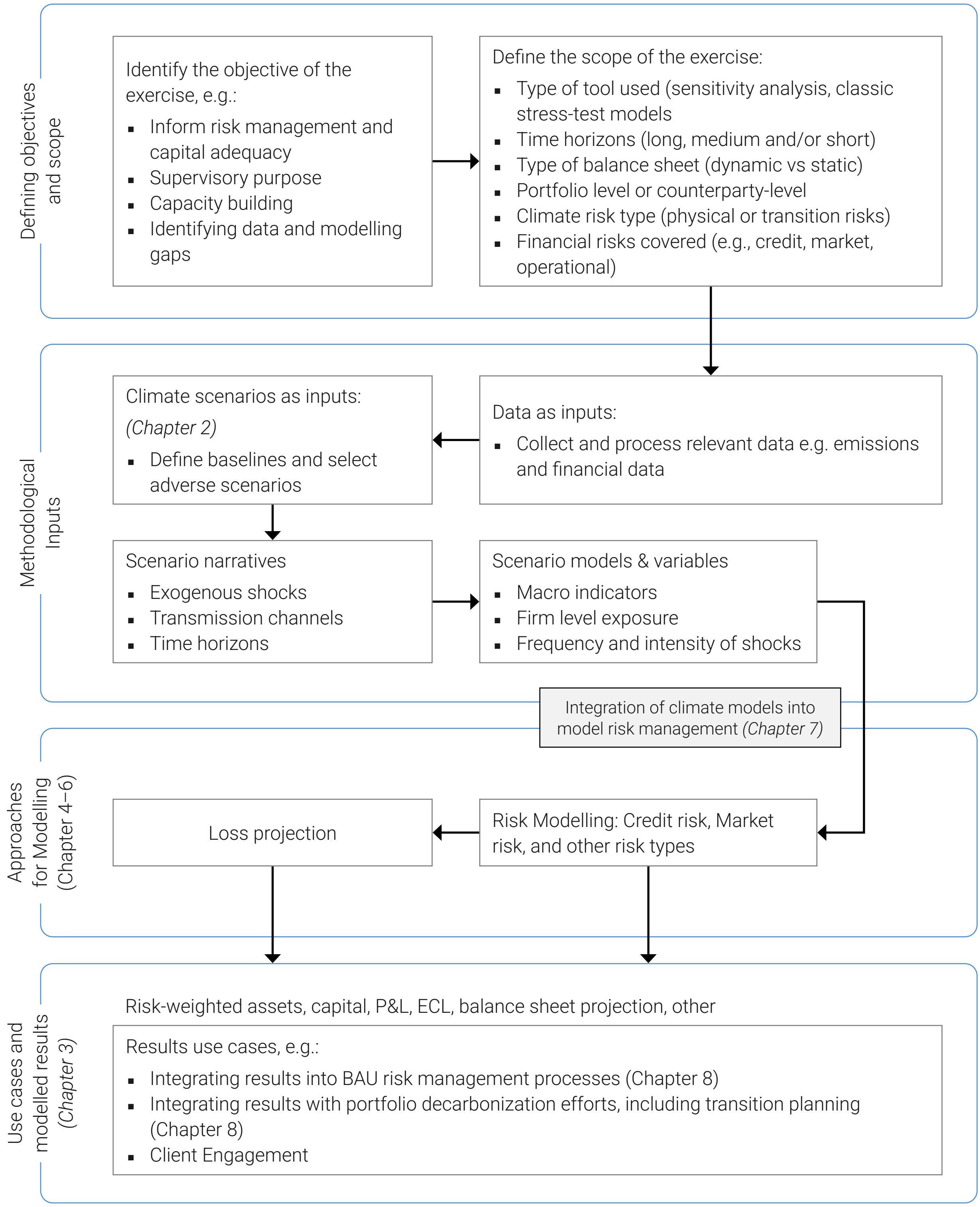

Figure 1: Overview of a process flow for climate stress testing (adapted from New York Federal Reserve, 2023 and EBA, 2025a)

This report outlines the latest practices and approaches banks use across the key components of climate stress testing, as illustrated in Figure 1. It also examines the role of technology[8] in supporting climate stress testing, while also providing insights into emerging trends and expected developments in climate stress testing.

8 Including IT systems, software, and infrastructure.

Chapter 2: Climate scenarios used as climate stress testing inputs

Section summary

- Banks are increasingly incorporating both long-term and short-term horizons into their climate stress testing, with the time-horizons of 3–10 years and 20–30 years as the most common time-horizons identified in the joint survey by UNEPFI and SAS.
- Based on the survey results, it is noted:
  - IPCC SSP5-8.5, IPCC SSP2-4.5, and NGFS Current Policies scenarios are common long-term physical risk scenarios used,
  - NGFS Delayed, Net-Zero, and Below 2 Degrees scenarios are common long-term transition risk scenarios used, and
  - Banks most commonly use internally developed short-term scenarios to assess short-term climate risks.
- Commonly used variables to perform climate stress tests include: carbon price; interest rates; investment size; energy prices; GHG emissions; oil, gas and energy demand; unemployment rates; GDP per industry; and unemployment.

Scenario analysis is a critical component of climate stress testing, enabling financial institutions to assess potential forward-looking impacts of various climate-related risks on their portfolios. This section presents commonly used climate scenarios, representative of standard approaches, though their suitability is dependent on the objectives of the exercise.

2.1 Commonly used scenarios for climate stress testing

As banks increasingly incorporate both short- and long-term horizons into their climate scenario analysis, the following outlines observed trends in time-horizons and scenario selection.

Short-term climate scenario analysis

Short-term analysis is conducted under conditions of "reasonable" uncertainty and aims to estimate financial impacts and evaluate capital and liquidity adequacy. It can also capture indirect effects and ensure consistency between counterparty risks and macroeconomic dynamics (EBA, 2025c). The UNEP FI and SAS joint survey shows that 62 per cent, 57 per cent and 24 per cent of respondents assess climate risks across 3–10 years, 1–3 years, and up to one year, respectively.[9]

From the banks surveyed, banks most commonly use **internally developed** short-term scenarios to assess short-term physical and transition risks. Increasingly banks are focusing on developing short-term scenarios that have low probability but high impact. **Existing long-term scenarios are often used as a starting point** for short-term scenario analysis of physical and transition risks, along with the short-term International Swaps and Derivatives Association (ISDA) trading book scenarios and short-term UNEP FI/NIESR scenarios.[10,11]

Long-term climate scenario analysis

In contrast, long-term analysis operates under "deep" uncertainty and uses a central scenario along with a range of distinct scenarios to assess alignment with climate goals—such as limiting warming to 1.5 degrees Celsius (°C)—and to test business model resilience (EBA, 2025c). The survey also reveals that 71 per cent, 48 per cent and 19 per cent of respondents assess climate risks across the time-horizons of 20–30 years, 10–20 years, and more than 30 years, respectively.[12]

As per the results of the UNEP FI and SAS joint survey, three long-term physical risk scenarios used for climate-stress testing stand out as the most common: **the IPCC SSP5-8.5 scenario, the IPCC SSP2-4.5 scenario, and the NGFS Current Policies scenario**. Meanwhile, the most common long-term transition risk scenarios used amongst those surveyed are **the NGFS Delayed, Net-Zero, and Below 2 Degrees scenarios**.[13]

An overview of the key attributes of the NGFS and IPCC scenarios, along with their benefits and limitations, is provided in the Appendix. This also includes details on the current limitations of climate scenarios and the ongoing efforts to address them.

An example on the climate scenarios and time horizons used by a bank to assess financial risk types can be found in the document *Case Studies* and *Practical Examples*.

2.2 Common variables used for climate scenario analysis

As illustrated in Figure 1, following the selection of scenario narratives, the combination of physical and transition risk variables with macroeconomic and financial variables used to quantify the impact of climate risks of a scenario comprises a core component of climate stress testing. Physical and transition risk variables are included in climate scenarios that are then translated to macroeconomic and financial market variables via direct and indirect transmission channels. Direct transmission channels include climate-

9 Survey results are presented in Figure 3 of the *Survey Findings* document.
10 Survey results are presented in Figure 4 of the *Survey Findings* document.
11 The survey was conducted prior to the release of the short-term climate scenarios by the NGFS (2025a).
12 Survey results are presented in Figure 3 of the *Survey Findings* document.
13 Survey results are presented in Figure 5 of the *Survey Findings* document.

related variables such as carbon prices, GHG emission intensity, and energy mix in existing or newly developed models. Meanwhile, indirect transmission channels reflect climate shocks to macroeconomic variables, such as differentiated sectoral impacts on GVA or sectoral shocks to property prices (EBA, 2025b). Table 2 provides an indicative list of scenario variables proposed.

Table 2: Scenario variables indicative list[14]

Macro-financial variables		**Climate variables**	
Macroeconomic	**Financial variables**	**Physical risk**	**Transition risk**
▪ GDP ▪ GVA growth ▪ Interest rates ▪ Unemployment rates ▪ Central bank rates/ policy interest rates ▪ Exchange rates ▪ Inflation/Consumer Price Index ▪ Corporate profits (aggregated and sector-level) ▪ Household income ▪ Labour productivity ▪ House market prices	▪ Counterparty financials ▪ Equity prices ▪ Bank rates ▪ Government bond-yields ▪ Corporate bond-yields	▪ Global & regional temperature pathways ▪ Frequency and severity of physical hazards ▪ Agricultural productivity ▪ Water consumption	▪ Carbon Price ▪ Electricity prices ▪ Energy prices for oil/ gas/coal ▪ Carbon footprint ▪ Emissions, sector GHG emissions (actual and projected) ▪ CO_2 & GHG emissions intensity (physical or economic intensity) ▪ Energy mix ▪ Energy consumption ▪ Electricity demand ▪ Oil & gas demand ▪ Energy Performance Certificate labels (EPC) and equivalent

Based on group discussions and feedback from the UNEP FI and SAS workshops, common scenario variables used for PD modelling of corporates include **GDP and carbon prices**. Other variables that are commonly used in PD modelling include **interest rates, investments, energy prices, GHG emissions, oil, gas and energy demand, UER, and GVA**.

14 Refer to: ECB report on good practices for climate stress testing, Section 4, Table 4; and Bank of England Discussion Paper—The 2021 biennial exploratory scenario on the financial risks from climate change, Section 4, Table 4. A

Chapter 3: Use cases and modelled results

Section summary

- Climate stress testing outcomes are primarily used to raise awareness and improve risk management practices, with growing potential to inform client engagement, mitigation strategies, and internal processes like risk appetite and target setting as methodologies evolve.
- Exposure metrics, KPIs, and KRIs chosen by banks to estimate the impacts of climate risk include ECL, RWA/Capital and P&L.
- Balance sheet simulations can follow either a static or dynamic balance sheet approach, depending on the treatment of assumptions such as portfolio composition, strategic business adjustments, and counterparty transition.
- While most banks currently use a static balance sheet approach in climate stress testing, which helps reduce the risk of underestimating climate-related risks, a dynamic balance sheet approach should be considered when significant portfolio changes are part of an approved strategy.

3.1 Overview of climate stress testing use cases

UNEP FI's 2024 report A Comprehensive Review of Global Supervisory Climate Stress Tests summarized current and future use cases of climate stress testing, as shown in Figure 2. Currently, the outcomes of climate stress testing are more commonly used to increase awareness of climate-related risks and opportunities and enhance market practices in managing these risks. The outcomes of climate stress testing can also play a role in driving engagement and discussions with clients. As methodologies develop, climate stress testing outputs could be better considered by banks for developing mitigation strategies and for supporting other internal approaches, such as informing risk appetite and supporting target setting.

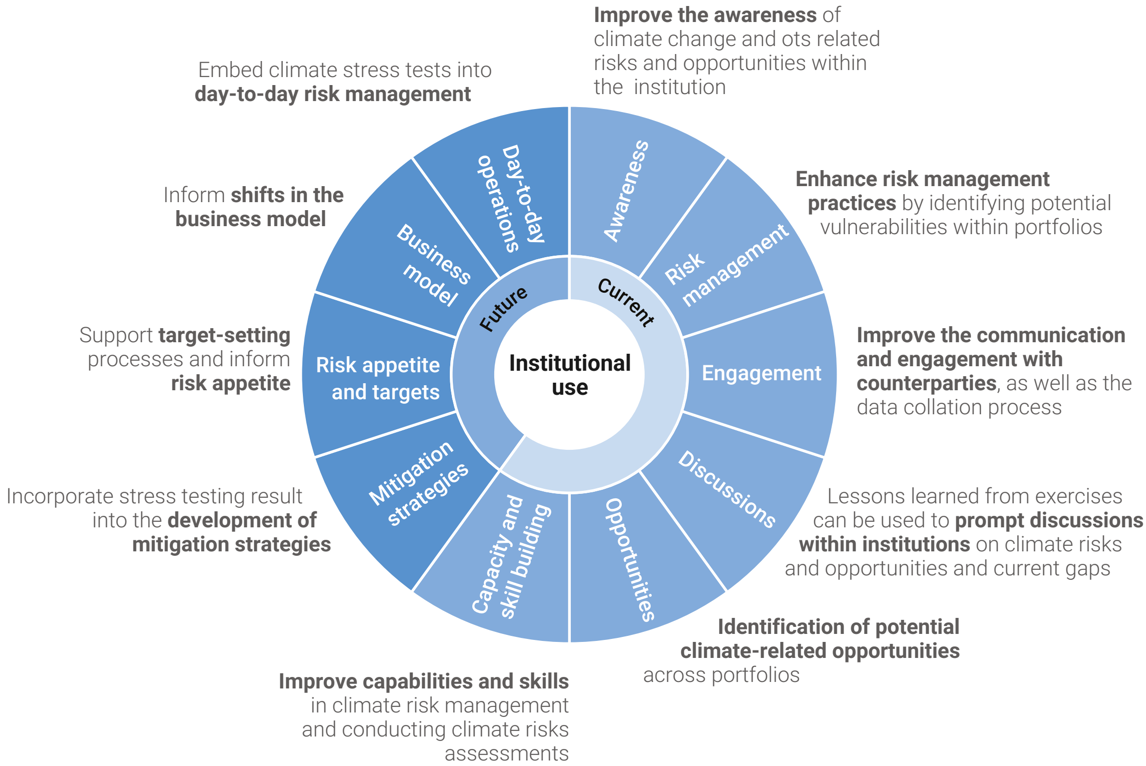

Figure 2: Use cases of climate stress testing (UNEP FI, 2024a)

3.2 Exposure metrics, key performance indicators, and key risk indicators used to estimate the impact of climate risk

Exposure metrics, KPIs and KRIs provide key financial metrics that quantify the impact of climate risks on a bank's financial performance, capital adequacy, and risk exposure. As per the results of the UNEP FI and SAS joint survey, the most common exposure metrics, KPIs and KRIs on which banks estimate the impact of climate risk are; **ECL (71 per cent of respondents), RWA/capital (52 per cent), and P&L (52 per cent)**.[15]

3.3 Income statement (P&L), balance sheet scope, and approaches

In climate stress testing, banks analyse both the income (P&L) statement and balance sheet to assess the financial impact of climate risks. The P&L statement captures short-term financial performance, including revenue and profitability, under different climate scenarios. Revenue sources may include interest income, trading income, and fees from financial services. Profitability metrics, such as net interest margin, operating profit, and

15 Survey results are presented in Figure 6 of the *Survey Findings* document

return on equity, meanwhile, help assess the financial impact of climate risks on a bank's performance.

Balance sheet simulations, on the other hand, offer a broader perspective on how climate risks impact a bank's assets and liabilities over time. These simulations can follow either a static or dynamic balance sheet approach, depending on how they treat key assumptions, such as portfolio composition, strategic business adjustments and counterparty transition. Detailed below are considerations for static and dynamic balance sheet approaches, including current practices observed.

Static balance sheet approach:[16] This approach simplifies projections by assessing risks under fixed assumptions, holding key elements—such as portfolio composition, business strategy, and counterparty behaviour—constant over the scenario horizon. For example, it can assume new lending, investment, or portfolio adjustments, and no changes to the business mix nor to risk appetite. While widely used, especially in long-term exercises, this approach is better suited for short-term analyses due to its inflexibility in reflecting changes. However, it can help avoid underestimating climate risks by limiting overly optimistic adjustments, while also making the process more transparent and easier to communicate (NGFS, 2021b; ECB, 2022).

Dynamic balance sheet approach:[17] This approach incorporates assumptions such as new lending and investment, portfolio reallocation, and changes in counterparty operations over time. This approach enables banks to adjust sector composition to assess sectoral decarbonization pathways and reallocate portfolios to mitigate physical risk exposure. This approach supports integration of a bank's climate commitments and expected strategic actions, such as reassessing relationships with clients based on their transition plans (HKMA, 2025). The results from a dynamic approach depend on a variety of factors, notably: how climate risk factors from scenarios are incorporated into a bank's models; how counterparties' transition plans are understood; and how the methodology dynamically allocates exposures to risk (ECB, 2022). As a result, this approach is better suited for assessing long-term climate risks, to better reflect an evolving risk landscape and real-world transition pathways. However, considering the uncertainties regarding transition pathways, policy developments, and market reactions, banks must be able to explain and substantiate their assumptions and planned responses, ensuring alignment with their publicly disclosed transition strategies (EBA, 2025e). The effectiveness of the approach depends on the dynamic assumptions applied, such as strategic actions that may be optimistic, and on the feasibility of portfolio reallocations, new activities, or risk reduction measures.

16 Assumes the balance sheet remains unchanged over time, thereby excluding adjustments in operations, strategic responses, or external factors.

17 Accounts for changes in a bank's operations, market conditions, and strategic responses to climate risks.

Objective: Test financial resilience	Objective: Determine business model resilience
▪ Measure financial impact ▪ Check capital and liquidity adequacy ▪ Short-term horizon ▪ Use of baseline and adverse but plausible scenarios	▪ Assess compatibility with global warming ▪ Check robustness of the business model ▪ Long-term horizon ▪ Use of a central scenario and a set of distinct scenarios
Approach: Static or dynamic balance sheet	**Approach: Dynamic balance sheet**

Figure 3: Examples illustrating how the choice of balance sheet approach varies depending on the objectives of the exercise (adapted from EBA, 2025c)

Nonetheless, **most banks still favor a static balance sheet assumption**, as shown in the UNEP FI and SAS survey results.[18] This reflects alignment with supervisory expectations, as a majority of supervisory exercises have relied on a static balance sheet assumption. Another reason for this is that a dynamic approach requires more data about relevant themes such as: firms' transition plans; GHG emissions by sector or region (so as to increase a stress test's granularity); physical assets owned by counterparties; and science-based emissions targets (UNEP FI, 2024c). As banks navigate ongoing data challenges, the increasing reliance on assumptions when using a dynamic balance sheet approach introduces greater uncertainty. While a dynamic approach provides strategic insights relevant to extended time-horizons, it is more resource-intensive and complex to implement than a static balance sheet approach (NGFS, 2021a). Therefore, **banks should carefully assess which approach best aligns with the specific objectives of their exercise**.

18 Survey results are presented in Figure 7 of the *Survey Findings* document.

Chapter 4: Approaches for modelling transition risk for credit risk stress testing

Section summary

- Methodologies rely on forward-looking carbon policy and climate-related technology variables and estimate shifts in counterparty EBITDA as a percentage based on a transition risk pathway.
- Direct impacts modelled include the price of carbon as an additional cost, increased expenditure due to the need for capital investments in low-carbon technology, and the potential of stranded assets.
- Indirect impacts modelled can include the price of energy passed downstream, increasing production costs across sectors and impacting firm profitability.
- To model the transition risk impact on the risk parameter PD, banks engage in modelling various levels of granularity, incorporating both indirect and direct transmission channels integrated into advanced satellite models.
- Applying PD overlay or shift on existing credit risk models is a common approach by banks for linking climate models with BAU credit models when assessing corporates.
- A number of financial modelling approaches can be undertaken to measure PD, of which the existing Merton model is among the most common but is constrained by limitations.

4.1 Context

In the shift to a low-carbon economy, banks face rising potential exposure to transition risks from policy changes, climate-related technology shifts, market preferences, and legal measures to mitigate climate change. These risks can increase costs for carbon-intensive borrowers, reduce their profitability and impact their ability to repay loans. Technological progress and changing consumer demands may also make certain business models obsolete, leading to stranded assets or lower revenues. This can undermine the credit quality of banks' loan portfolios and heighten financial risks, especially for banks heavily exposed to high-emitting sectors.

As a result, assessing transition risks is a crucial component of a bank's climate stress testing exercise. Polling results from the UNEP FI and SAS workshop indicate that two-thirds (66 per cent) of respondents consider their level of maturity to be 'intermediate'[19] or 'advanced',[20] while one in four (25 per cent) judge their maturity as 'beginner'.[21] A small minority (8 per cent) select to outsource the assessment of transition risks to a third party. Despite recent progress, climate stress testing methodologies for transition risks continue to face significant challenges. These include modelling limitations of existing financial models to capture forward-looking long-term transition risk impacts and a lack of granular emissions data available from borrowers. The section below outlines the common approaches to transition risk-related climate stress testing that are observed globally across the banking sector.

4.2 Overview of current approaches by banks

For transition risk, changes in policy and technological advancements are some of the key transition risk drivers that are factored into climate stress tests. As detailed in Chapter 2, the scenarios developed by the NGFS are the most commonly used scenarios when it comes to assessing transition risks as part of a bank's climate stress test. Banks can assess the different credit risk impacts of pathways with a combination of macroeconomic, technological and policy assumptions (UNEP FI, 2023). Carbon pricing is the **most common transition risk factor** selected by banks for climate stress testing, as scenarios often use it as a proxy for broader policy shifts, technological change, and rising carbon costs.

Most methodologies rely on forward-looking inputs, such as carbon policy and climate-related technology variables. These are modelled through transmission channels to translate transition risks into financial impacts. Assessing transition risks requires two types of datasets: (i) backwards-looking data, such as current GHG emissions; and (ii) forward-looking parameters. Projections can be based either on publicly reported company data or, where data are unavailable, on proxies and estimation techniques (UBS, 2023). These include extrapolating emissions from regional industry averages, activity data or public emission factors, and less commonly, using regression and machine learning (ML) models to estimate emissions (UNEP FI and GCD, 2025).

19 Intermediate level of maturity is defined as more mature methodology with increased quantitative coverage of broader sets of KPIs across wider asset classes. Performed on an ad-hoc basis, with limited usage of results for business decision-making.

20 Advanced level of maturity is defined as being capable of a detailed level of granular analysis, covering all relevant KPIs across all asset classes. It indicates the use of a methodology directly linked to the BAU stress testing process. Stress tests are performed frequently, and the results are used widely by businesses for decision-making (e.g. transition planning, loan underwriting). Quantitative approaches predominate.

21 Tactical/beginner approach performed covering the key KPIs across the key asset classes. Assessments are prompted by regulation. Expert qualitative adjustments are used most commonly and areapplied on a high level of granularity.

The level of granularity in climate risk stress testing varies by an institution's capabilities and the scope of the exercise, but a clear trend toward more granular, bottom-up analysis is emerging to better capture climate-related financial risks. Stress testing typically operates across three levels of granularity:

Asset or exposure-level: Evaluations of individual physical assets or collateral, particularly relevant for physical risk (e.g., flood-prone real estate). Technically demanding but increasingly feasible.

Counterparty-level: Assessments at the individual borrower level, especially for high-risk sectors like oil & gas or utilities. This enables precise risk measurement and informed client engagement.

Portfolio or sector-level: Analysis by industry, geography, or asset class. This is useful for identifying risk concentrations, though it may overlook firm-level variations.

According to the UNEP FI and SAS survey, **most institutions already apply stress testing at counterparty (38 per cent) or exposure level (33 per cent), with only 14 per cent using broader portfolio or industry-level analysis**. No respondents assess solely at the country level, even though a country classification could exhibit concentration and jurisdiction-specific dependencies.[22] This result reflects the growing need for granular insights to support strategic decisions, meet regulatory expectations, and strengthen resilience to climate risks.

Examples of quantifying transmission channels

Banks model both the direct and indirect impacts of transition risks. Direct impacts refer to risks that directly affect specific borrowers, counterparties, or asset classes, typically at the microeconomic level. In contrast, indirect impacts represent second-order effects that can arise through supply chain, market dynamics, and policy responses. Table 3 provides examples of the types of direct and indirect impacts, as well as macroeconomic impacts, modelled by banks for corporates. Outputs from transition risk scenarios are used to create risk factor pathways for sectors, capturing changes in direct emissions costs, indirect costs, capital expenditures, and revenues. For instance, efforts to reduce emissions may increase direct emissions costs, while indirect costs might be passed along the supply chain by upstream stakeholders. Additionally, capital expenditures could rise as firms invest in new low-carbon technologies. In a similar way, shifts in consumer preferences can lead to reduced demand and lower revenues for certain firms (BoC, 2021; BoC, 2023; UNEP FI, 2020). Quantification of these impacts requires financial and emissions data of firms at the micro-level (Climate Bonds Initiative, 2024).[23] At the counterparty level, the Bank of England's Climate Biennial Exploratory Scenario (CBES) exercise (2022) highlighted a good practice among banks of assessing corporate clients' vulnerability to rising carbon prices and policy changes, by considering both the capital investments needed for transition and the extent to which increased costs can be passed on to customers, while accounting for market dynamics and demand elasticity.

22 Survey results are presented in Figure 8 of the *Survey Findings* document.
23 Examples for quantifying transition risk impacts can be found in Climate Bonds Initiative, 2024.

Table 3: Examples of the direct, indirect and macroeconomic impact of transition risks modelled by banks for non-financial corporations

Direct impacts	▪ The price of carbon connected to scope emissions as an additional cost on capital expenditure, price elasticity of demand. ▪ Increased expenditure due to the need for capital investments in low-carbon technology, impacting firms' cash flow. ▪ Assets become stranded or impaired as they do not adapt to changed standards and consumer preferences (EBA, 2025c). ▪ Corporates held legally liable for failure to transition (EBA, 2025c). ▪ Increased maintenance and reconstruction costs as buildings need to comply with new standards, impacting firms' ability to repay mortgage loans (HKMA, 2025).
Indirect impacts	▪ Increased costs are passed on to consumers, and consumer demand decreases due to higher prices across the sector, causing a change in firm revenue. ▪ The price of energy passed downstream, increasing production costs across sectors and impacting firm profitability. ▪ Consumer preferences shift away from high-emission products, causing a change in firm revenue.
Macroeconomic impacts	▪ Impacts of carbon pricing and other government policies; for example, temporary inflation and changes in economic output due to the implementation of a carbon price (NGFS, 2024d). ▪ An economy-wide shift in labour markets as carbon-intensive sectors contract, resulting in higher unemployment, as well as shortages of skilled workers (EBA, 2025a). ▪ Impacts on the broader economy due to changes in energy mix, energy price, and energy use (NGFS, 2024; EBA, 2025c).

An **"Earnings at Risk"** approach is used by banks to estimate the shift in earnings before interest, taxes, depreciation and amortization (EBITDA) as a percentage based on a transition risk pathway, either at the counterparty level or the sector level. This is calculated by analysing unpriced carbon cost, which refers to the estimated future financial impact of internalizing a carbon price, expressed as a percentage of a company's EBITDA. For a particular company, factors considered are sector-level and locational information, as well as information related to time-horizons and the climate scenarios used. Deploying a combination of these factors can be modelled to predict shifts in EBITDA. Changes in EBITDA per customer can also be used to derive a sector-based score using climate-stress PD factors.

Approaches for integrating transition risk into PDs

Climate risk impact on PDs for firms can be calculated based on estimated changes in profitability, leverage, and the output gap.[24] Factors such as rising costs, asset devaluation, and shifts in market dynamics resulting from transition risks can impact these key drivers. The impact on profitability can be calculated based on a firm's revenue, total assets, and operating costs, including carbon and energy costs derived from climate scenarios. A firm's leverage ratio can be projected based on changes in total debt across the time-horizon and the investment required for developing green technologies to meet emission

24 The difference between an economy's actual output and its potential output, divided by its potential output (HKMA, 2022).

targets under different scenarios. Additional investments assumed may depend on the firm's revenue and on the replacement costs for assets (HKMA, 2022; Climate Bonds Initiative, 2024).

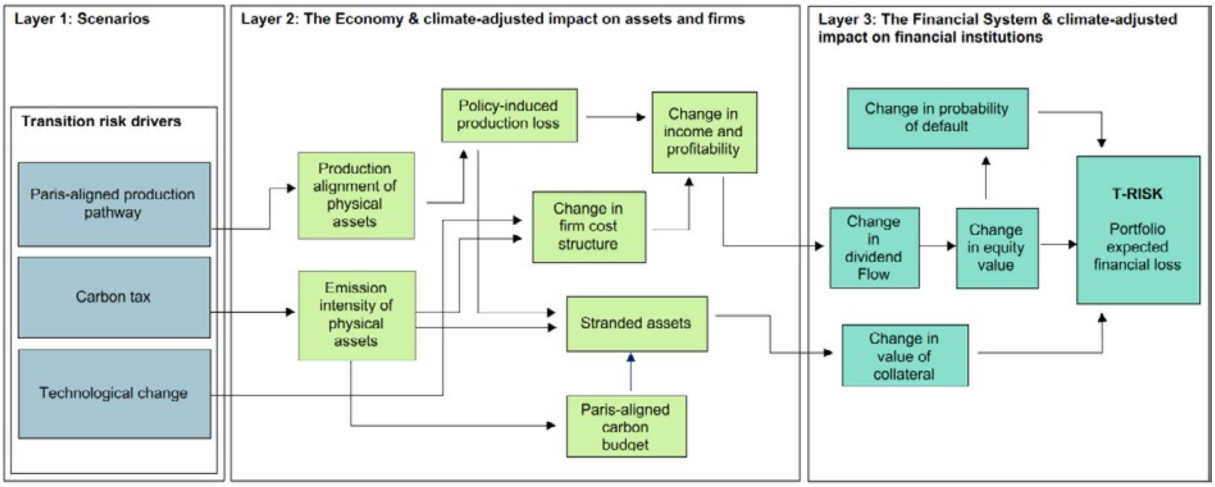

Figure 4: Conceptual overview of TRISK, illustrating key modelling components of a transition risk-related climate stress testing approach (Baer *et al*, 2022)

Insights from the UNEP FI and SAS workshops identified that banks are **engaging in modelling at various levels of granularity** to assess the impact of transition risks on the PD risk parameter. Banks are **incorporating both indirect transmission channels**—through macroeconomic indicators such as GDP, CPI, and UER—**and direct transmission channels** involving climate-specific variables like carbon pricing and GHG emissions. **These factors are integrated into advanced satellite models, which generate climate risk scores at both the sectoral and portfolio levels**. This approach is further complemented by granular analyses conducted at the counterparty or asset level. Many participating banks employ counterparty-level modelling to evaluate how shifts in financial metrics, such as EBITDA and changes in revenue, translate into credit rating adjustments and subsequent modifications in PD. One bank described an approach for estimating the transition risk impact on PD in a real estate portfolio by considering the renovation costs that reduce a customer's disposable income. This change leads not only to an adjustment in the credit rating for the specific customer but also to shifts in the bank's overall portfolio composition, as reflected in Energy Performance Certificate (EPC) rating distribution. Many participating banks noted that the depth and accuracy of such analyses remain partly constrained by data availability across different portfolio segments.

A couple of approaches can be undertaken to link climate models to credit BAU models:

i. Applying PD overlay or shift on existing credit risk models.
ii. Recalibrating existing credit risk models with added climate-related risk factors.

The first approach—applying a PD overlay—was the most common approach identified during the UNEP FI and SAS workshops. It can involve adjusting key financial metrics used in credit risk models to reflect the potential impact of climate risks on a firm's financials. For example, one method assumes that the impact of GVA shocks on the net income of corporates is proportional (EBA, 2025b).

However, incorporating climate transition risks into PD modelling remains challenging due to data gaps, the uncertainty of long-term horizons, the absence of historical data for model calibration, and the complexity of linking macro-level climate scenarios to borrower-level default probabilities.

An example of observed practices by the European Banking Authority on climate stress testing to integrate climate risks into PD can be found in the document *Case Studies* and *Practical Examples*. The integration of climate risk into credit risk models is explored further in Chapter 8.

Approaches to financial modelling

Table 4 details considerations for financial modelling approaches used by banks. A number of approaches can be undertaken to measure the probability of default, including:

- Linear regression modelling
- Generalized linear model (GLM)
- Merton model
- Vasicek one-factor model
- Markov Chain Transition Matrix model
- Monte Carlo Simulation
- Survival analysis
- Qualitative approach

Table 4: Observations in relation to financial modelling approaches used to assess transition risks

Merton Model	Linear Regression Modelling	Other Approaches
▪ The use of the existing Merton model is the most common approach identified among UNEP FI and SAS workshop participants. ▪ Connects the PD to the likelihood that a firm's asset value will fall below a threshold set by its liabilities. ▪ Can be adapted to assess transition risks by adjusting asset values to account for transition costs and introducing systemic risk factors related to the transition risk scenario (Reply Avantage, n.d.). ▪ As the model relies on volatility estimates drawn from historical data, it may not account for the unpredictable impacts of climate change, and incorporating overlays is difficult to model.	▪ Linear regression modelling is also a common approach used among UNEP FI and SAS workshop participants. ▪ Uses past data on defaults, leverage, and profit to estimate parameter values to determine causality between profits and leverage with the PD (Climate Bonds Initiative, 2024). ▪ For some banks, it offers a methodology that can be more easily understood and communicated across the institution. ▪ Linear regressions can fail to account for tail shocks (Blanc-Blocquel *et al.*, 2024).	▪ A smaller proportion of banks have also noted the use of Monte Carlo and qualitative approaches. ▪ Some banks also use a combination approach, such as combining linear regression or generalized linear models (GLMs) with the Merton model. ▪ The South African Reserve Bank (SARB) used a multifactor Vasicek model as part of its 2024 Climate Risk Stress Test, though noted challenges related to data scarcity and the reliance on assumptions (SARB, 2025).

Overall, there is no single "correct" approach identified that banks follow; this is also given due to the level of risk being quantified by measuring the gap between the baseline and the stress scenario.

Approaches for integrating transition risk into Loss Given Default

Climate risks can impact the drivers of LGD, including collateral value and recovery rates. For example, collateral values could decrease resulting from stranded assets due to regulatory and market demand changes. Climate risk could potentially impact reductions in recovery rates as lower collateral values can cause lower recoveries for lenders and business disruptions can impact a firm's ability to repay debts.

Approaches identified for modelling transition risk impact on LGDs include: assessing the indirect transmission channel impact using macroeconomic variables through satellite models at the sectoral level; analysing the direct transmission channel impact on collateral valuation impact; and estimating the impact via the correlation between LGD and PD. Meanwhile, approaches for linking climate models to credit BAU models include using stress testing results to inform LGD adjustments at portfolio or obligor/facility level, and adjusting existing LGD models to include climate risk factors (UNEP FI and GCD, 2025). A variety of modelling approaches can be undertaken for LGD modelling, such as the linear regression model, GLM, and the Frye-Jacobs model.

Incorporating transition risks into LGD modelling remains particularly challenging due to the difficulty of estimating future declines in collateral value from transition risk drivers, lack of historical data on such losses, and the complexity of linking forward-looking transition scenarios to asset recovery outcomes.

Summarized examples of transition risk-related methodologies, highlighting some of the key attributes of transition risk-related credit risk stress testing practices discussed above, can be found in the document *Case Studies* and *Practical Examples*. Further details on the integration of climate risk into credit impairments can be found in Chapter 8.

Chapter 5: Approaches for modelling physical risk for credit risk stress testing

Section summary

- Banks are extending their models of physical risk hazard transmission channels by including additional hazards.
- Banks either model a single physical hazard event for a given return period or average damages from multiple similar events to capture uncertainty and variability in physical risk estimates (US Federal Reserve, 2024b).
- UNEP FI and SAS joint survey shows that most banks perform physical risk assessment of corporates at the level of geographic co-ordinates.
- Some banks assess clients' adaptive capacity to physical risks by evaluating their climate adaptation strategies.
- An increasing number of banks are incorporating insurance considerations to a certain extent.
- Almost four-fifths (76 per cent) of banks are either combining the impact of transition and physical together or would like to do so.

5.1 Background

With rising global temperatures, the potential exposure to physical risks that banks face is growing. These risks, both acute and chronic, can impact banks through various transmission channels. For example, in the context of credit risk, acute physical risks such as extreme weather events can lead to asset damage or operational disruptions for borrowers. In turn, this can directly impair their ability to repay loans. Chronic risks, such as rising sea levels or prolonged droughts, can reduce property values or disrupt industries that are reliant on natural resources, thus undermining long-term credit quality. Furthermore, supply chain disruptions caused by climate events can reduce borrower profitability, thereby exacerbating default risks and impacting banks' loan portfolios (Deloitte, 2022).

As a result, assessing physical risks is a crucial component of a bank's climate stress testing exercise. However, methodologies for climate stress testing related to physical risks are less mature than those for transition risks. This can be attributed, but not limited, to the following factors:

- Physical risks are complex and dynamic, which make them harder to model (IMF, 2022).
- The need for highly granular and location-specific data (IMF, 2022).
- The interconnected characteristics of impacts of physical risks, which often cascade across different sectors and geographies (ECB, 2021b).
- The forward-looking aspect of physical risks and a lack of sufficient historical data further limits current modelling capabilities (UNSW Sydney, 2024).
- Barriers in translating the latest climate science into decision-useful information for financial services (Carbonplan, 2022; S&P Global, 2025).

UNEP FI and SAS workshop poll results showed that almost half (46 per cent) of attendees consider their maturity level for physical risk-related credit risk stress testing as 'intermediate'.[25] One fifth (20 per cent) of respondents described their maturity as 'advanced',[26] meanwhile, and around one quarter (26 per cent) put their level at 'beginner'.[27] A small minority (6 per cent) do not currently assess physical risk in their climate stress testing.

The section below outlines the common considerations and approaches to physical risk-related climate stress testing observed globally across the banking sector.

5.2 General approach to physical risk stress testing

Measuring physical climate risks involves three key components: **Hazard, Vulnerability and Exposure** (NGFS, 2023c; UNEP FI, 2023).

- **Hazards** represent the likelihood and severity of climate-related events, encompassing both acute events (e.g. extreme weather) and chronic changes (e.g. rising temperatures or sea levels). Identifying the types of hazards relevant to a specific context is the first step.

- **Vulnerability** reflects the susceptibility of assets or systems to damage from identified hazards. This includes both the sensitivity of these assets or systems to climate impacts, plus their adaptive capacity or their ability to respond, recover, and build resilience to these events. Actions to reduce or adapt to hazards are an essential component of addressing vulnerability.

- **Exposure** refers to the degree to which assets or systems are at risk of being impacted by climate events. It can also be described as "the nature and extent to which a system is exposed to significant climate variations". After identifying potential hazards, assessing the exposure of assets to these hazards is critical.

25 Described as a more mature methodology with increased quantitative coverage of a broader set of KPIs across wider asset classes, performed on an ad-hoc basis, with limited usage of results for business decision-making.

26 Performed with detailed level of granular analysis covering all relevant KPIs across all asset classes with methodology linked to the BAU stress testing process. Stress testing is performed frequently, with the results used widely by the business for decision-making. Quantitative approaches predominate.

27 Tactical/initial approach performed covering the key KPIs across the key asset classes, performing on regulatory request and relying mostly on expert qualitative adjustments applied on a high level of granularity.

The hazards considered in a scenario need to be properly linked to the location of their exposures and the specific vulnerabilities of counterparties (EBA, 2025a).

Hazard module

The first step in an approach to physical risk-related credit risk stress testing is to identify relevant hazards and their likelihood using climate models for specific geographical areas. This involves gathering data projections for a range of climate hazards based on established climate scenarios. Widely used sets of scenarios include the NGFS and the IPCC scenario pathways (see Chapter 2).

Hazard data required to select relevant hazards requires a combination of internal and external data. These data can originate from a range of sources, including climate scenarios, climate data from meteorological and climate research institutions, geospatial data, historical damage data, hazard information from regulators, insurance data, and third-party hazard models. Internal data collection can be used to characterize assets based on geolocation and asset type. Internal data can also be used to determine the historical financial impact of past hazard events. Banks commonly use external data, such as open-source datasets, to collect forward-looking data on physical hazards using climate models. For example, open data sources such as ThinkHazard and the World Bank Climate Change Knowledge Portal are commonly used to identify relevant potential hazards for a given geographical location. Third-party data vendors can also provide more granular data on physical hazards.

Analysing hazard data requires setting clear parameters and thresholds to determine which physical hazards are most relevant for specific locations. Banks can consider a range of factors, such as (BCG, 2024):

- Time-horizon for modelling hazards
- Selection of climate scenarios
- Magnitude of the hazard, including metrics like return periods and probabilities of occurrence, and the deviation from median impacts, such as extreme versus average events.

Once hazards are identified, **they can be ranked by priority based on their relevance to the assessment.** Parameters for ranking hazards can include data from disaster risk maps, the probability of occurrence, the severity of occurrence, and other indicators. Different approaches are used to estimate the frequency and intensity of physical hazards. These range from simplified methods that scale based on current conditions and empirical reasoning through to sophisticated model simulations such as Monte Carlo (HKMA, 2025). Probabilistic disaster risk assessment can be performed to estimate the likelihood and potential consequences of physical hazards, which are characterized in terms of Return Period (SS&C, 2024a). Thresholds can be collected and implemented to quantify the severity of risks at specific locations, providing a robust basis for evaluating the potential impacts of these location-specific hazards.

Table 5 summarizes common hazard indicators used for specific hazard types. Banks select these metrics for each hazard identified. They do so based on the relevance of the metric to the selected hazard, the regional relevance, and the level of market adoption of the metric as a proxy for a given hazard (BCG, 2024).

Table 5: Illustrative physical hazard indicators (UNEP FI, 2024d)

Hazard group	Illustrative hazard indicators	
Temperature	▪ Average annual temperature (in °C) ▪ Maximum of daily temperatures (in °C) ▪ Number of days per year exceeding 35°C/38°C per year ▪ Number of days with Wet-Bulb Globe Temperature exceeding 25°C per year ▪ Absolute heat wave: annual count of three-day periods with high temp >35°C and low temp >24°C	▪ Days per year with temperature <-10°C ▪ Absolute cold wave: annual count of three-day periods with average temp <-5°C
Wind	▪ Maximum one-minute sustained wind speed (in km/h) experienced at the 100-year return period ▪ Average annual wind speed (in km/h) ▪ Maximum/minimum wind speed (in km/h) for the year	
Flooding	▪ Mean flood depth and associated frequency (e.g. depth of water [in metres] at the 100-year return period) ▪ Annual accumulation of rainfall in the 99th percentile ▪ Consecutive number of extremely wet days with over 20mm of rainfall ▪ Maximum daily rainfall over five consecutive days	▪ Total annual precipitation ▪ Average largest one-day precipitation ▪ Average largest five-day precipitation ▪ Precipitation percentage change
Drought	▪ Months per year where the rolling three- or six-month average Standardized Precipitation Evapotranspiration Index is below -2 ▪ Maximum number of consecutive dry days (daily precipitation under 1mm)	▪ Maximum daily total water equivalent precipitation (in mm) experienced at the 100-year return period
Wildfire	▪ Annual number of wildfires ▪ Annual probability of wildfire ▪ Combination metric: Max number of consecutive dry days, number of hot days (max temperature >40°C)	
Sea level rise	▪ Annual depth of the water (in metres) in coastal areas due to high tides	

Some banks opt to model a single physical hazard event to measure aggregate damages expected for specified return periods. Other banks analyse multiple physical hazard events within a region, each producing damages within a narrow range of the defined return period and then average the damage estimates from these events to account for uncertainties in climate modelling and differences in the characteristics of various physical hazard events (US Federal Reserve, 2024b). Flood risk, water stress and heat stress are some of the more commonly modelled physical hazards based on the UNEP FI and SAS survey results with 21 banks.[28]

Assets exposure module

Further analysis is required to assess the exposure of specific business activities to the selected physical hazards. Two main components of exposure data are the vulnerability of buildings and infrastructure by location. Therefore, the assets in the scope of the exercise and their location need to be identified and aligned with climate hazard maps. The UNEP FI and SAS joint survey **reveals that most banks perform physical risk assessment of corporates at the level of geographic co-ordinates**.[29] Such geolocational data are more widely available for immovable property collateral, whereas data on the location of firms' economic activities through the value chain remain limited (EBA, 2025a).

For each asset type, examples of key characteristics that need to be assessed include (BNP Paribas, 2024):

Detailed property data, including location, value, age, building materials, height, floors, and design standards. Key property characteristics to consider include year built, occupancy codes, number of floors, and building materials are needed to assess exposure (HKMA, 2025; US Federal Reserve, 2024b). As part of HKMA's 2023–2024 Climate Risk Stress Test, banks conducted a detailed geographic assessment to identify high-risk areas. They used public data on storm surges, flooding, and damage reports from recent extreme weather events. Some banks carried out in-depth analyses using fine spatial grids and building characteristics to estimate potential damages, while others applied a uniform damage ratio across all properties within the same geographical unit (HKMA, 2025).

However, collecting such granular data on assets for entire portfolios remains a challenge. The pilot climate scenario analysis exercise by the US Federal Reserve is illustrative in this respect. Faced with data gaps relating to building characteristics, participants in the pilot had to rely on national or regional-level property characteristics from third-party vendors and on damage estimates from academic studies of events that occurred in the past (US Federal Reserve, 2024b).

Vulnerability module

For relevant physical hazards, vulnerability can be assessed at the sectoral or asset level. The vulnerability module uses damage functions to quantify economic impact through loss in asset value and productivity (HKMA, 2025). Translation of return periods into direct damages to geo-localized physical assets can be conducted through local

28 Survey results are presented in Figure 9 of the *Survey Findings* document.
29 Survey results are presented in Figure 10 of the *Survey Findings* document.

damage functions for the type of physical hazard (SS&C, 2024a). Damage functions convert hazard indicators into estimated percentages of physical asset damage or operational disruption. Economic impact can be linked to a client's financial statement, such as capital expenditure (Capex), operating expenditure (Opex), and revenue (BCG, 2024). The aggregation of physical risk impact from individual assets to the overall firm is done by analysing ownership structures and by calculating each asset's contribution to firm revenue (SS&C, 2024a).

Methodologies for physical risk-related credit risk stress testing include modelling both direct and indirect impacts of physical risks. Table 6 provides examples of the types of direct and indirect impacts modelled by banks for corporates and real estate.

- Direct impacts can include direct damage to properties and production operations, which can disrupt business activities.
- Indirect impacts are often referred to as second-order impacts and can include risks exposed from the value chain or spillover effects due to climate risk impacts on the economy.

Survey results from the joint survey by UNEP FI and SAS show that 90 per cent of the respondents model first-order climate risks. While 29 per cent and 24 per cent model second-order and third-order impacts, respectively, as part of their climate stress tests. However, adequately modelling second-order and third-order impacts remains a challenge for banks.[30]

Table 6: Common direct, indirect and macroeconomic impacts modelled by banks[31]

Corporates	
Direct impacts	▪ Increase in insurance cost/premium payments ▪ Physical damage and repair (and adaptation) costs for business assets ▪ Depreciation of tangible assets, such as machinery ▪ Disruption to production and business output
Indirect impacts	▪ Cost increases due to supply chain disruptions ▪ Decrease in productivity ▪ Credit cost increases from client revenue losses ▪ Decrease in household income resulting from climate-related disruptions, such as health effects and economic losses ▪ Shutdown of operations caused by unavailability of insurance or by regulation

30 Survey results are presented in Figure 11 of the *Survey Findings* document.
31 Adapted from banks disclosure reports, US Federal Reserve's Climate Scenarios Pilot, EBA's Proposal on ESG Scenario Analysis, and HKMA's 2023–2024 Climate Risk Stress Test.

Real estate	
Direct impacts	▪ Direct physical damage and repair costs ▪ Increase in insurance premiums ▪ Decline in property value
Indirect impacts	▪ Decline in house prices due to disruption in the local economy ▪ Inflationary effects due to an increase in demand for labour and materials for repairs and supply shortages ▪ Guarantor rating downgrades

Macroeconomic impacts
▪ Indicators of sectoral exposure to physical risks ▪ Sectoral supply chain vulnerabilities and cascading effects ▪ Price shifts from supply shocks leading to inflationary pressure ▪ Reduced labour productivity across the economy ▪ Migrations and displacements

Identified good practices by banks for assessing counterparty vulnerability include estimating counterparty losses from a wide range of acute and chronic physical risks, impacts on labour productivity and costs, operational disruptions, and broader market dynamics such as effects on competitors (BoE, 2022).

Approaches for integrating physical risks into PD

To measure the impact of a physical hazard on a bank's portfolio, changes in PD can be assessed by modelling business interruption losses. This can be modelled by incorporating macroeconomic adjustments, such as changes to GDP growth or income levels, or by examining counterparty-specific metrics, like adjusted revenue, costs, or profit margins. For example, a rise in temperature can cause a shift in GDP, which can be linked to PD rates. Different shifts in GDP under different climate scenarios can have impacts on shifts in PD.

A company's value chain, such as a diversified or concentrated supplier profile, can impact the vulnerability. Therefore, a key component of measuring vulnerability is analysing the company's value chain and then determining the hazard exposure and the company's sensitivity to this hazard (UNEP FI, 2024d). Disruptions to corporate value chains can be categorized into three primary types: direct disruption resulting from physical damage to assets; indirect disruption caused by supply chain delays; and indirect disruption arising from interruptions to transportation routes.

Approaches for integrating physical risks into LGD

Physical damage loss in climate stress testing can be modelled by adjusting the loan-to-value (LTV) ratio, reflecting the impact of property damage on collateral value to estimate the impact on PDs and LGD. A decline in property value reduces recovery potential for lenders and increases LTV ratios, heightening credit risk. Climate shocks can be modelled by decreasing property values to account for uninsured damages or by assuming that borrowers take on additional debt to cover repair costs, further increasing LTVs and debt-to-income (DTI) ratios. For commercial real estate (CRE), adjustments can include incorporating downtime for income-producing properties, reflecting reduced net operating income due to damage-related business interruptions (US Federal Reserve, 2024b).

LGD haircuts—representing the reduction in property value—can be estimated using damage functions specific to each asset type and risk category, typically focused on acute physical risks. These damage functions are informed by historical loss data, scientific models, or expert judgment. They are tailored to account for variations in vulnerability based on factors like building type, construction quality, or geographic exposure. Chapter 8 provides further details on the integration of climate risk into credit impairments.

Some banks are taking into **consideration the adaptive capacity of clients** when measuring potential vulnerabilities to physical risks by exploring how counterparties adapt to relevant climate risks. In addition, banks are seeking to identify adaption solutions that can be implemented by clients to minimize vulnerability to physical risk. For example, banks engage with key clients to "benchmark, test and refine" financial impact calculations and to determine adaption measures (BNP Paribas, 2024). Along with counterparty adaptation plans, banks also consider local and governmental adaptation measures, depending on the time-horizon in selection (EBA, 2025a).

The role of insurance data in assessing physical risks by banks

Insurance data can inform assessments of how physical risks are mitigated through insurance coverage. **Practices by banks for modelling insurance costs on mitigation impact include** (BNP Paribas, 2024; ECB, 2022; US Federal Reserve, 2024b):

- Factoring in insurance coverage, thus allowing banks to evaluate the extent to which insurance can offset the financial impact from physical risks, such as property damage.
- Undertaking a detailed approach by assuming that insurance, reinsurance, and—to a smaller extent—public authorities bear the main financial impact of physical risk because of the insurance coverage and the public protection schemes that they respectively offer.
- Identifying the insurance protection gap (the portion of risks not covered by insurance) that could evolve under different climate scenarios, and analysing the financial impact of uninsured assets and the impact of changing insurance affordability and availability.
- Not including public insurance directly in the projects but assuming price shock mitigation based on past acute risk events.
- Factoring private insurance coverage into their projections by accounting for the percentage of insured assets.
- Combining insurance coverage rates for a set of borrowers in a sector and applying an exposure-weighted average.

Case studies outlining approaches applied by banks to physical risk-related climate stress testing can be found in the document Case Studies and *Practical Examples*.

5.3 Compounding the impacts of physical and transition risks

Lock-in effects could potentially lead to simultaneously high physical and transition risks in the coming decades. Properly calibrated transition risk scenarios may, at least partially, capture the lagged consequences of physical climate risks by leveraging the endogenous linkages embedded within the modelling framework. The following provides an overview of banks' current practices for compounding physical and transition risks.

Four key insights into banks' consideration of compound climate risk:

- Survey results from the joint UNEP FI and SAS survey[32] with 21 banking respondents show that **24 per cent of respondents are assessing climate risks by compounding[33] the impacts of physical and transition risks**.
- Over half (52 per cent) of respondents do not currently compound the impacts of both risk types but would like to do so in the future.
- An approach to doing this is to provide a weighting mechanism to the physical and transition risks. This mechanism is determined through specific qualitative assessments at portfolio and sectoral level.
- Of the survey respondents stating that they are compounding the impacts of physical and transition risks, 80 per cent report using at least one scenario to assess both transition and physical risks as part of their climate scenario analysis.

Four key insights into banks' considerations of excluding compound climate risk:

- Survey results show that **around a quarter (24 per cent) of surveyed banks do not compound the impacts of transition and physical risks and have no plans for doing so**.
- Reasons for not compounding the impacts can be:
  - Difference in the origination of the shocks considered
  - Risk of double counting
  - Trade-offs between physical and transition risks
- It is more difficult to bring together the results if banks use different climate scenarios to assess physical risks and to assess transition risks.
- About 38 per cent of survey respondents who do not currently compound the impacts of physical and transition risks say that they use at least one scenario to assess both transition and physical risks.

Overall, counterparty credit risk (CCR) management is an area of significant supervisory importance. Therefore, banks should begin incorporating climate considerations into CCR, to ensure robust risk management and alignment with emerging supervisory expectations.

32 Survey results for this section are presented in Figure 12 of the *Survey Findings* document.
33 Combination of physical and transitions risks that interact and amplify one another, potentially leading to a more severe overall impact.

Chapter 6: Approaches for market risk-related climate stress-testing

Section summary

- Methodologies for climate-related market risk stress testing are generally less mature than credit risk methodologies, with many banks performing exercises based on regulatory requests or on an ad-hoc basis.
- Currently, banks are integrating macroeconomic projections from climate scenarios into a methodology to forecast market risk factors.
- Methodologies are still limited in respect to capturing granular data for asset class, market structure, activity, and market liquidity.
- Metrics that can be used to quantify the financial impact of climate risks are P&L, RWA, and Climate VaR.

6.1 Context

Climate change could potentially impact interest rates, credit spreads, foreign exchange rates, equity, and commodity prices, as well as volatility and correlations, market liquidity, market depth, and market structure, leading to economic losses for banks due to market shocks and subsequent changes in counterparty exposure. Methodologies for climate stress testing related to credit risk are much more advanced than assessing market risk. However, a growing number of institutions are now conducting assessments for the latter. Over half of supervisory exercises now include a component for assessing market risk (UNEP FI, 2024a). In comparison to credit risk, climate stress testing for market risk involves different governance models, time-horizons, and exercise frequencies. The focus for assessment also differs, centering on the trading book rather than the lending book. Polling results from the UNEP FI and SAS workshops reveal that most participants consider their climate stress testing methodology for market risk to be at either the beginner level[34] or intermediate level[35] of maturity, with some currently not assessing market risk as a part of their climate stress test.

Integrating climate change into market risk stress testing brings about its own challenges. These include a lack of data on climate change impacts on market risk factors, and a strong reliance on proxies. Both these factors can create uncertainty and modelling limitations for integrating climate risk drivers into market risk and for capturing complex interactions. Identifying and quantifying how climate risks affect market variables, such as foreign exchange (FX) rates or credit spreads, is still underdeveloped. Assessing market risks requires short-time-horizons, such as spanning a single year or even down to intraday, days, or weeks. Climate risks need to be incorporated into existing market risk metrics, such as Value-at-Risk (VaR), which were not initially designed to handle uncertain climate scenarios.

This chapter focuses on climate stress testing of the trading book, primarily covering market risk. In some sections, references to counterparty credit risk (CCR) may also appear in the context of the trading book.

6.2 Approaches for assessing climate-related market risk

This section outlines the common approaches to climate-related market risk stress testing observed globally across the banking sector.

Short-term climate scenario analysis

Overall, to assess short-term climate risks, the UNEP FI and SAS survey and a survey by the ISDA working group on climate scenario analysis for the trading book show that banks commonly use internally developed short-term scenarios and the long-term NGFS scenarios as a starting point (see Chapter 2), along with the ISDA scenario family (ISDA, 2025). Modifications of the scenarios include "accelerating the time-horizon" and adding additional variables to enhance sectoral and regional granularity (ISDA, 2023).

Practices for modelling climate-related market risks

Climate risk drivers—physical or transition—**can result in changes to capital market variables, such as commodity and equity prices, interest rates, FX rates, and credit spreads**. General market volatility and its impact on a company's earnings is another notable factor. Key differences between physical and transition risk impacts are detailed below (as defined by OSFI, 2025):

34 'Beginner' level maturity is described as tactical/initial approach performed covering the key KPIs across the key asset classes. It is performed on regulatory request, relying mostly on expert qualitative adjustments applied on high-level granularity.

35 'Intermediate' level maturity is described as more mature methodology with increased quantitative coverage of broader set of KPIs across wider asset classes. It is performed on ad-hoc basis, with limited usage of results for business decision-making.

- **Physical risk:** Damage resulting from physical risks and perceived increased risk can impact the market value of investments, resulting in Mark-to-Market (MTM) losses in investment and/or trading portfolios.
- **Transition risk:** Unexpected changes in the valuation of debt and equity securities issued by affected firms can cause losses in investment and/or trading linked to those securities due to transition-related impacts.

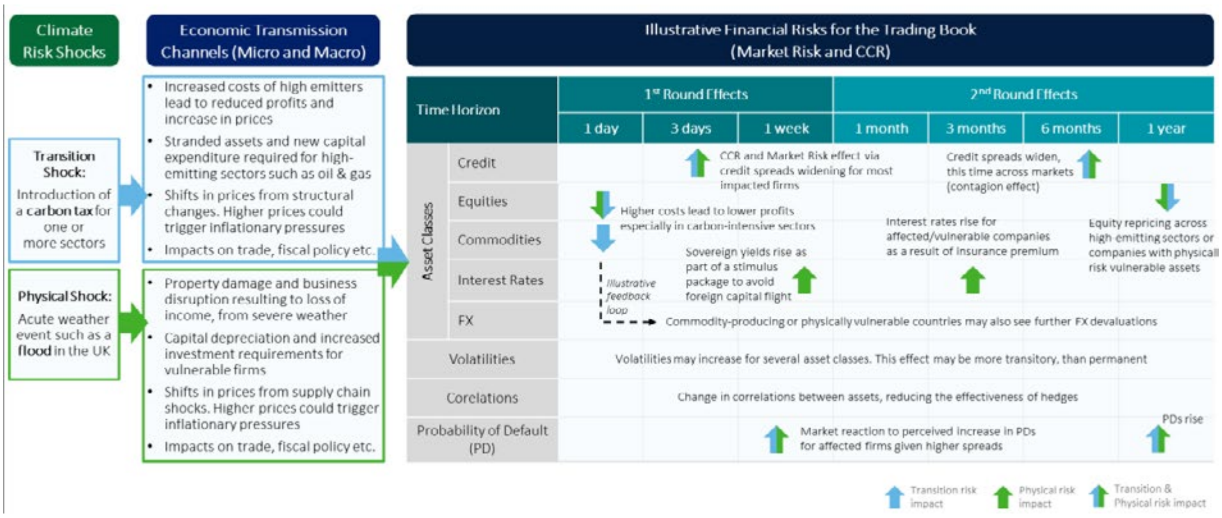

Figure 5: Climate risk transmission channels for the trading book, showing effects for both market risk and CCR (ISDA, 2023)

Table 7: Market risk specific examples of direct and indirect impact of both transition and physical risks modelled (ISDA, 2023)

Direct impacts	Indirect impacts
▪ Introduction of a carbon price can lead to an increase in costs, resulting in a decrease in profits for high-emitting firms, which consequently impacts equity. ▪ Stranded assets, such as fossil fuels becoming unviable due to regulatory shifts, impact the equity and credit spreads of affected firms. ▪ Direct damage to physical assets caused by extreme weather events can cause equity, commodity, and other asset classes' volatility. ▪ Sovereign bond yields rise in response to stimulus packages addressing climate shocks.	▪ An economic slowdown due to climate change in one region can impact trade flows, which can have an effect on FX rates, especially for physically vulnerable countries. ▪ Carbon prices and regulation can cause structural changes and shifts in prices, triggering inflationary pressures, which in turn impacts FX rates, interest rates, and commodity prices.

Currently, banks are integrating macroeconomic projections from climate scenarios into a methodology to forecast market risk factors for the trading book, such as measuring equity performance. This approach can include assumptions about the macroeconomic effects of carbon pricing, such as its impact on inflation and interest rates, which in turn affect profits, asset valuations, and overall GDP growth (ISDA, 2025). For example, banks participating in HKMA's 2023–2024 Climate Risk Stress Test assessed the impact of transition policies on investments in bonds and equities of issuing companies. The core assumption here is that changes in the companies' financial performance due to these transition policies can impact market perceptions and, therefore, influence the prices of bonds and shares. The extent of these price shifts was estimated through a combination of fundamental analysis, asset value theory, and correlation studies to relate the exposure of high emitting industries to relevant market indices (HKMA, 2025). Furthermore, capturing the potential impacts of climate change on market risks will require capabilities to model price and yield curve impacts across maturities, and shocks to volatility, market liquidity, and market structure.

A growing number of banks are drawing on both expert judgment and data-driven assessment to calibrate climate shocks for translating macroeconomic climate scenarios into market risk factors. Others rely solely on data-driven assessments in place of qualitative expert judgment (ISDA, 2025). To calibrate climate shocks, these quantitative data-driven approaches include the use of information on emissions, company-specific transition readiness, and historical extreme weather events (ISDA, 2023). The process of generating a shock may require a specific model for each asset class. The discounted dividend model to estimate climate impacted equity values is a common example of such a model.

Types of market risk metrics used to assess the financial impact of climate risks

Metrics, such as stressed P&L and RWA are being used to assess the financial impact of climate risks on the trading book (ISDA, 2023). Climate Value at Risk (Climate VaR) is also one of the most common metrics used for potential financial losses related to market risk (UNEP FI, 2023). Integrating climate considerations into traditional VaR models involves modelling how climate variables, such as carbon prices, impact asset valuations, particularly for high-emitting sectors. This requires combining historical data with forward-looking climate scenarios, including regulatory and technology pathways, and translating into financial impacts (UNEP FI, 2023). Climate expected shortfall (CES) is another metric that can be used to capture climate-related risk. CES measures the expected value that the observations exceed VaR (Lazar *et al*., 2025; LSE, 2022). One option when seeking to integrate climate risk into VaR and Expected Shortfall (ES) is to use Monte Carlo simulations conditioned on climate scenarios and to sample probability distributions of market risk factors (SS&C, 2024a). Further examples of risk metrics used to quantify climate risks include: Climate beta, which reflects sensitivity of stock prices to climate risks; CRISK, which captures market-based expected capital shortfall; and Carbon VaR, which estimates the VaR of securities resulting from future carbon prices (FSB, 2025a).

A case study outlining an approach applied by a bank to market risk-related climate stress testing can be found in the document *Case Studies* and *Practical Examples*.

Additional risk types to consider for climate stress testing

In addition to assessing market-related risks in the trading book, climate stress testing should also consider other related financial risks that may arise, including:

- **Liquidity risks:** Climate-related events can impact a bank's funding and deposit costs. For instance, depositors may withdraw funds simultaneously following an extreme physical risk event, potentially triggering a bank run, or banks could face sharp increases in funding costs driven by transition-related shifts.
- **Market liquidity shocks:** Extreme weather events can lead to large margin calls and market liquidity issues.
- **Compounding effects of market and counterparty risk:** Climate-driven market shocks could increase credit risk exposures by changing the risk profile and moneyness of derivatives positions, while a default combined with a liquidity squeeze may raise hedging costs or make it difficult to liquidate positions, resulting in additional losses.

In the context of climate change, risk assessment has largely focused on credit risk, while market risk has also gained emphasis. A comprehensive climate stress testing approach should, however, encompass additional financial and non-financial risks, including liquidity, operational resilience, business continuity, and strategic or business model risks. Banks could also consider scenarios related to legal risk from climate litigation. Importantly, climate stress tests should consider the compounding effects of climate incidents across multiple risk types.

Chapter 7: Integrating climate models into model risk management

Section summary

- Banks are increasingly prioritizing model risk management in the context of climate models.
- Many banks are in the early stages of establishing MRM for climate models, focusing on defining and classifying the climate models used in climate stress testing.
- One third of banks do not consider model risk in their climate stress testing simulations, based on the survey by UNEP FI and SAS.
- Two of the most common approaches by banks for addressing model risk in simulations are building climate risk models as add-ons to already validated BAU standard risk models and validating climate risk models internally.

7.1 Introduction to model risk

A model can comprise three aspects: an information input component, which is responsible for the assumptions and data; a processing aspect to transform inputs into estimates; and a reporting aspect to translate estimates into business information (PwC, 2022). However, models can be prone to errors, biases, and assumptions. The use of wrong data or sub-optimal modelling methodologies can lead to biases and uncertainty. Across the lifecycle of a model, model risk can arise through various components. These include incorrect identification of a model and implementation, lack of data and unreliable data, incorrect assumptions, modelling uncertainties, lack of accuracy of calibrations, incorrect understanding of model results, and an incomplete model inventory. In order to address these risks, and as required by several regulations globally, banks establish protocols and systems for Model Risk Management (MRM)[36] (PwC, 2022).

36 MRM refers to the framework and governance processes that oversee each stage of a model's lifecycle, including the design, development, validation, implementation, ongoing use, monitoring and modification of models. It aims to ensure that models are fit for purpose by minimizing risks related to errors, improper usage, or limitations in inputs, assumptions, outputs and applications. MRM focuses on identifying, assessing, monitoring and mitigating the risks associated with models used. (adapted from OSFI, 2023; GARP, 2018).

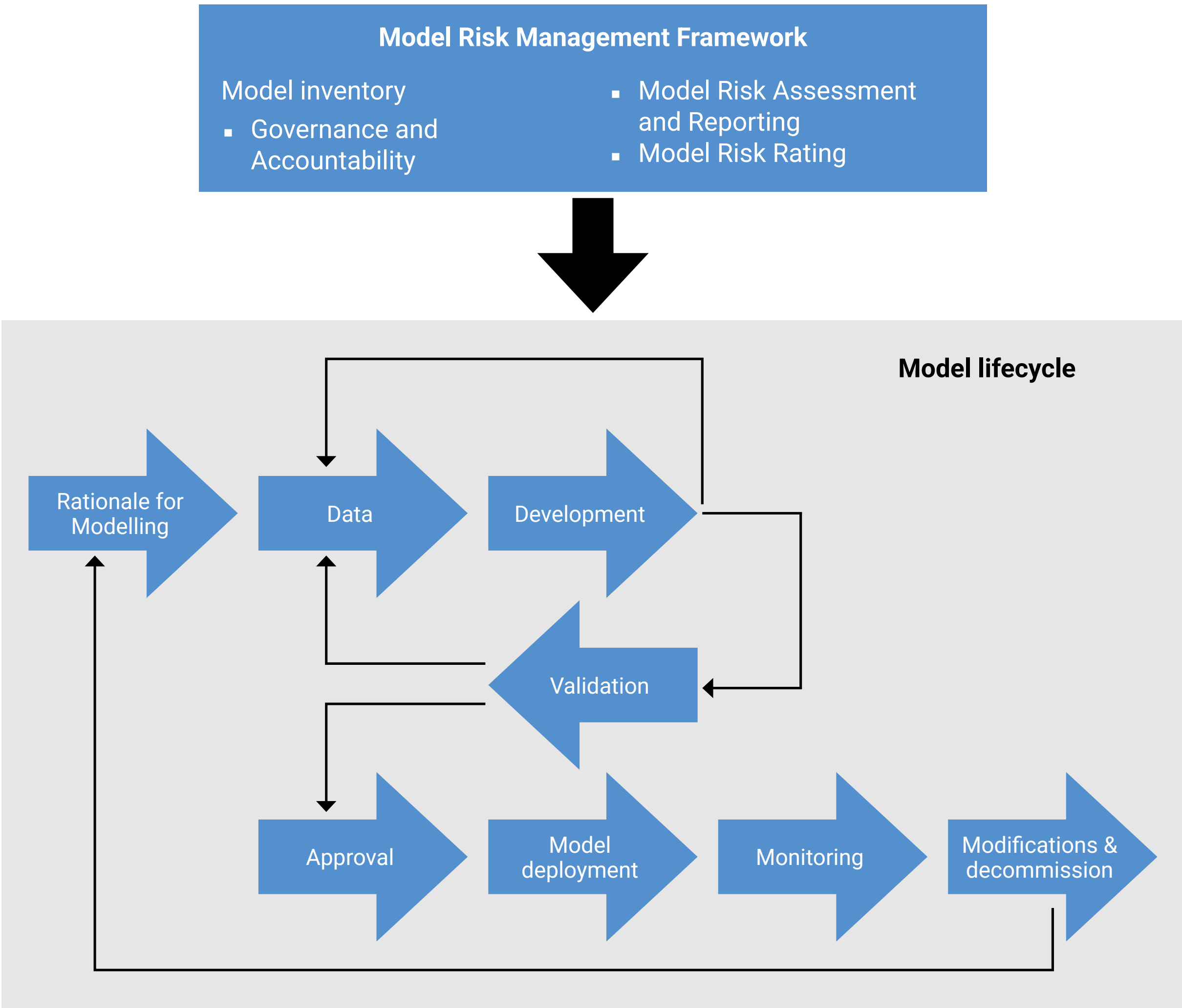

Figure 6: Components of MRM and interaction with the model lifecycle (OSFI, 2023)

Climate stress testing has introduced a new suite of models or repurposed current models for new use cases for banks, increasing their exposure to potential model risk. As a recent addition to banks' model inventories, **climate models bring an added layer of "risks and complexity"**. These new approaches include scenario expansion models, hazard models, integrated assessment models, and credit-impact-assessment models. To address these challenges, MRM teams must test and verify climate models. Alongside these challenges, many banks also rely on third-party vendor climate models, which introduce additional risks. These risks need to be managed through the development of climate-specific model validation practices, particularly in regard to potential issues arising from the lack of historical data. As a result, banks need to establish new documentation processes and enhance their MRM capabilities to incorporate climate models. A 2023 survey by McKinsey Risk Dynamics found that nearly a quarter (23 per cent) of US institutions and two-thirds (67 per cent) of European institutions have climate models under MRM oversight (McKinsey, 2023). Some banks also face supervisory pressure to assess the model risk associated with climate risk models. For example, as part of its 2023–2024 climate risk stress test, HKMA required participating institutions to assess model risks by estimating variations in results under different modelling methodologies and assumptions (HKMA, 2023).

This chapter covers important considerations for managing model risk in climate risk models used for climate stress testing and highlights current industry practices.

7.2 Managing model risk of climate risk models

As a starting point, it is important for banks to have an **established definition** of a climate model. This will help support identifying different models and ascertain the scope of the model inventory. A model inventory contains both the models in use as well as any information related to them. It includes characteristics such as uses and restrictions of the model, model owners, risk tiering, and model limitations. Inventory considerations for models generally include (PwC, 2022):

- **Model description:** Model inputs, including data, information about the model and its scope, model approval specifications, model limitations, and vendor purchase.
- **Responsibilities:** Model owners, users, developers, validators, and approvers.
- **Risk tiering:** Materiality of models, plus risk ranking based on categories such as model use, materiality, and complexity.
- **Life cycle:** Date of inception and production, model changes history, validation date, approval date, and timeframe of the model.
- **Documentation:** Validation report, development and implementation documents, approvals, and purpose statement, plus information on uses and non-uses, model development processes, and model vetting.
- **Findings:** References to outcomes and references to internal audits.

Additional considerations that banks need to consider when integrating climate models in the MRM processes, in line with existing requirements and standard practices, are (Mckinsey, 2023; BoE, 2018; EBA, 2025a):

- **Model definition and inventory**
  - Establishing a clear definition of the models used in the context of climate stress testing.
  - Maintaining a comprehensive model inventory, including models in use, under development, or retired.
  - Identifying model owners, users, dependencies, and outputs used as inputs for other models.

- **Governance and accountability**
  - The board of directors should define and document the integration of climate risk models into an MRM framework.
  - Senior management should execute and maintain the framework, assigning roles to model owners, users, and compliance functions.
  - Policies should be created to outline governance structures, responsibilities, and the scope of validation, review, and monitoring activities.

- **Model development and documentation**
  - Steps to ensure that models are conceptually sound, supported by research, and aligned with industry practices.

- Documentation about model purpose, assumptions, parameters, and limitations to enable independent replication.
- Emphasis on limitations and the comparison of results against alternative approaches or input sensitivity analyses.
- Method to assess whether scenario expansion and impact assessment approaches are aligned with the bank's opinion and risk appetite in light of a model's sensitivity to expert assumptions.
- Consideration of factors and their impacts that could not be integrated into the model by imposing additional risk factors based on expert judgement.

- **Validation, monitoring, and review**
  - Definition of new validation standards or enhancing current standards with MRM teams, working closely with model development teams for consistency in the development and validation processes.
  - Consideration and assessment of the interdependencies between models, providing a complete view of the model landscape to capture model risk.
  - Analysis of the new data sources used for climate modelling, including the appropriateness of the data.
  - New approaches to support the outcome analysis of models that have traditionally relied on back-testing to assess model soundness; consideration of alternative approaches, such as sensitivity testing[37] and benchmarking.[38]
  - Completion of model inventories with tiering and prioritization for model validation.
  - Regularly monitoring of performance and reviews of model design to confirm continued fitness for purpose and validity of assumptions.
  - Periodic revalidation of models, tracking known limitations and identifying new issues.
  - Adjustment of model parameters or usage when deficiencies or errors are detected, application of controls where necessary.

- **Handling model uncertainty**
  - Creation of a risk appetite framework to manage and monitor model uncertainty.
  - Documentation and justification of adjustments made to mitigate uncertainty and ensure models are aligned with business and economic perspectives.
  - Periodic assessment of parameter estimates and model performance under varying stress conditions.

- **External and vendor models**

37 Sensitivity analysis based on the provided scenarios with varied input factors. Induced variations in the model predictions allows users to: verify consistency in the model behaviour; understand how inputs contribute to model predictions; and assess the robustness of model outcomes to uncertain inputs of model assumptions. Sensitivity analysis can be performed on all components of a climate model (McKinsey, 2023); for example, performing sensitivity analyses to assess the impact of changes in model assumptions and parameters on the model outputs (HKMA, 2025).

38 Benchmarking enables MRM teams to evaluate and challenge a model's data, assumptions, and methodology. It involves comparing the model's performance, stability, and robustness against established standards, alternative models, or external benchmarks so as to ensure the model produces reliable and accurate outputs (McKinsey, 2023). An illustrative case in point is the practice of benchmarking modelling results against credible research studies (HKMA, 2025).

- Integration of MRM requirements into the vendor acquisition process and inclusion of new requirements for model vendors to address the challenge of lack of transparency on methodological choices and model specifications.[39]
- Verification of external resources adhering to the bank's MRM standards.
- Appointment of internal staff to oversee vendor models and address any identified issues.
- Validation of vendor models with adequate documentation of their methodologies and in compliance with supervisory expectations

7.3 Current status and practices for integrating climate models into MRM

The UNEP FI and SAS joint survey shows that a third (33 per cent) of banks have not fully incorporated climate risk stress testing models into their model risk management framework. Many banks are still in the early stages of setting up climate MRM. As such, they are still identifying which deliveries are models and which are scenarios for validation, raising the ultimate question banks need to answer: **What should be considered a model, a scenario, a statistical formula, or a small adjustment to a model?**

Insights from the UNEP FI and SAS workshops found that banks are currently trying to get an overview of the scenarios and models that are used to assess physical and transition risk. Following this, the priority will be to classify climate models with a grouping of models on criteria such as impact and severity level. Some banks are considering model tiering to focus on tier 1 climate models based on the impact of the model and the riskiness of the model.

Of the processes to address model risk in simulations, the survey results highlight two approaches as the most common among banks:[40]

Building climate risk models as add-ons on already validated BAU standard risk models (48 per cent of survey respondents)

Validating climate risk models internally (33 per cent of survey respondents)

Less common approaches used by banks to address model risk in simulations include:

- Performing sensitivity analysis on the impact of alternative modelling choices and assumptions on the results;

39 Certain climate model vendors will be newly introduced to MRM requirements. As such, they will need to be transparent and develop model documentation (McKinsey, 2023).

40 Survey results are presented in Figure 13 of the *Survey Findings* document.

- Performing sensitivity analysis on the impact of alternative scenario factor values on the results;
- Performing regular analysis attributing observed changes in the result to respective modelling components; and
- Validating climate risk models by a third party.

As part of MRM, it is important to assess and validate all model inputs, including climate data. Given limitations in data quality and coverage, robust data validation and governance are essential. All climate data should undergo thorough quality checks and verification. While this topic was outside the scope of the UNEP FI and SAS workshops, available literature highlights existing data gaps and the importance of climate data verification and validation.

Initial steps for integrating MRM for climate models include improving governance and creating a management framework with climate risk embedded. The integration of climate models into MRM requires greater robustness checks and a higher inclusion of internal audits. An example illustrating how a bank is developing in-house models to reduce dependence on vendor models and manage model risk better can be found in the document *Case Studies* and *Practical Examples*.

Overall, as mentioned above, integrating climate risk models into MRM is still in its early stages, with many banks either just beginning to explore this integration or not yet considering it. The slow progress is primarily due to the absence of well-established methodologies for mitigating model risk, as banks are still in the process of defining and categorizing climate models, before being able to rank these models based on risk. Additionally, the forward-looking attribute of these models presents challenges, with many banks lacking mature techniques for validating them effectively. Moreover, climate model validation requires specialized skills, highlighting the need for dedicated resources.

Chapter 9 further explores the role of technology[41] in addressing model risk.

41 Including IT systems, software, and infrastructure.

Chapter 8: Integrating climate stress testing into business-as-usual risk management and portfolio decarbonization efforts

Section summary

- Increasingly, banks view climate risk not as an isolated issue but as a key driver influencing asset valuation and broader financial risks.
- Banks are developing approaches for integrating climate stress testing into traditional stress testing, either by expanding the NGFS scenarios (KPMG, 2025) or developing internal scenarios.
- Banks are increasingly working to integrate climate risk drivers into PD and LGD models, with implementation expected by many within the next one to three years.
- Almost half of the respondents from the joint survey stated that they reflect climate risk in their capital requirements.
- Climate scenario analysis is most commonly being used for the identification and planning of sustainable finance opportunities, client engagement and transition, and decarbonization planning.

8.1 Integrating climate risk into business-as-usual processes

Climate risk is being integrated into risk management in two ways: as a standalone risk category, or as a cross-cutting driver affecting other financial risks like credit, market, and operational risk. Currently, many banks consider climate risk as a distinct category within enterprise risk management. However, there is a growing shift towards embedding climate considerations across all risk types, thus making it an inherent part of overall risk assessment rather than a separate risk type. As a result, climate risk management is no longer seen as an independent component but instead as a core component of enterprise risk management. This shift requires banks to invest in infrastructure, analytics, and governance for climate stress testing at the same level as other risk categories (SS&C, 2024b). As banks seek to embed climate considerations across all risk types, potential areas for incorporation into BAU processes include:

- **Standard governance processes:** Processes such as new products, large transaction approval policies, third-party vendors onboarding, and client onboarding, could be informed by insights from climate stress testing.
- **Risk identification:** Often regulatory-mandated, could formalize the inclusion of scenarios related to physical and transition climate risks.
- **Macroeconomic scenarios-based stress testing:** Many banks use these scenarios for BAU risk management, climate-related stress tests could be incorporated as additional scenarios to assess portfolio-level risk.[42]
- **Risk Appetite Setting:** Processes for defining risk limits could integrate climate stress testing by considering potential adverse outcomes from physical or transition risks.
- **Internal reporting:** Integration of climate risks into internal reporting can allow related exposures to be monitored and communicated across management and governance structures.

Overall, embedding climate risk into risk management frameworks can involve identifying and assessing how climate risks affect existing risk categories, and incorporating them into key processes such as risk appetite statements, internal capital adequacy assessment processes (ICAAP), and stress testing scenarios.

Integrating climate stress testing into traditional stress testing

Integrating climate risk into the internal stress testing framework requires aligning climate stress testing with existing macroeconomic stress tests. This involves formally incorporating climate-related risks into the broader stress-testing framework to ensure a comprehensive risk assessment. To enhance financial analysis, climate modelling techniques must be incorporated. In doing so, they can support multiple modelling approaches and a broad range of scenarios. Banks should consider multiple time-horizons, including short-term scenarios aligned with their planning cycles, as well as longer-term projections. The EBA's proposed guidelines on ESG scenario analysis recommend conducting a gap analysis of internal models to identify areas where climate-related variables can be integrated and modelling capabilities improved (EBA, 2025a). **Existing stress testing tools should be leveraged to integrate climate risks effectively.** The NGFS scenarios are not directly linked to macroeconomic stress tests. To bridge this gap, banks must simulate adverse shocks that capture both sustainability risks and macroeconomic risks. One approach is the integration of idiosyncratic shocks into the NGFS scenarios (KPMG, 2025). Some banks are developing internal scenarios that account for short-term tail risks and volatility by combining climate and macroeconomic stresses, such as extreme weather events, economic recessions and changes in market sentiment. A detailed example of how a bank is integrating climate into traditional stress testing can be found in the document *Case Studies* and *Practical Examples*. To effectively integrate climate-related risks into stress testing frameworks, banks must fully understand the scenarios they are running to avoid underestimating risk. A further challenge lies in granularity, as existing models often lack sufficient sectoral detail and resolution to capture climate risks accurately, and reliance on averages can underestimate potential risks.

42 The Joint Consultation Paper by the European Supervisory Authorities (ESAs) on draft guidelines for the stress testing of environmental, social, and governance (ESG) risks states that competent authorities should fully integrate ESG factors into stress testing frameworks (EBA, 2025e).

Uncertainty around climate stress testing—due to limitations in time-horizons, modelling approaches, and data quality—makes it difficult for banks to effectively integrate results into risk management frameworks. These uncertainties can lead to wide variations in estimated impacts, limiting their usefulness to inform risk management decisions (US Federal Reserve, 2024a). To address this, banks will need to invest in more granular data, improve modelling capabilities, build in-house climate expertise, and tailor scenario analysis to their business models solutions (US Federal Reserve, 2024a).

Integrating climate risk into credit impairment

The UNEP FI and SAS joint survey shows that **14 per cent of surveyed banks implemented climate risk factors into BAU credit loss impairment models**.[43] Approaches for incorporating climate risk factors in IFRS 9 estimates can include: umbrella overlays covering PD, LGD, and macro factors; in-model adjustments; post-model adjustments, such as evidence-based overlay; and expert judgment on post-model adjustment (UNEP FI and GCD, 2025).

Integrating climate risk into capital requirements

The UNEP FI and SAS joint survey results reveal that **almost half of the respondents reflect climate risk in their capital requirements**, including through ICAAP models, IRB models, or capital add-ons.[44] The banks that embed climate risks into ICAAP models do so by focusing on short-term horizons of typically three to five years. They assess the macroeconomic impact of climate-related scenarios using shock events, such as a regulatory transition shock or a physical risk shock (e.g. flood events) (EBA, 2025b).[45] Some banks are also considering chronic physical risks by modelling annual average losses in relation to the risks (EBA, 2025b). An example by a bank on integrating climate risk into ICAAP can be found in the document *Case Studies* and *Practical Examples*. A small minority of banks are embedding climate risk into capital add-ons, typically under Pillar 2 frameworks and subject to supervisory assessments such as the Supervisory Review and Evaluation Process (SREP) or equivalent processes across jurisdictions. Where possible, banks are leveraging traditional modelling approaches to enhance their analysis. In terms of embedding climate risk into IRB models, approaches remain in early stages with reliance on expert judgement on post-model adjustment. Other methods include in-model adjustment of PD, LGD and macro factors and evidence-based overlay covering PD, LGD and macro factors (post-model adjustment) (UNEP FI and GCD, 2025).

A case study by a bank on how climate stress testing is being used to integrate climate risk into broader risk management can be found in the document *Case Studies* and *Practical Examples*.

43 Survey results are presented in Figure 14 of the *Survey Findings* document.
44 Survey results are presented in Figure 15 of the *Survey Findings* document.
45 A more robust framework is required by regulators to ensure such approaches by banks effectively embed climate risks.

8.2 Integrating climate stress testing into portfolio decarbonization efforts

The survey by UNEP FI and SAS finds that, in addition to using climate scenario analysis for supervisory and internal climate stress tests, 38 per cent of respondents use climate scenario analysis for **client engagement**, while 52 per cent use it for **transition and decarbonization planning**. Other popular uses are for identifying and planning sustainable finance opportunities, steering portfolio allocation, and calculating and projecting financed emissions.[46]

Climate stress testing results can be used to inform banks' decarbonization strategies and net-zero goals. By assessing the impact of climate risks on their operations, portfolios, and clients, banks can support the development of strategies with net-zero commitments through scenario analysis. Quantification of climate risks through climate stress testing, such as climate-adjusted PD and LGD and climate VaR, can support transition planning by identifying exposure to carbon-intensive sectors. Furthermore, climate stress testing methodologies are increasingly taking into consideration the transition plans of clients as transition plans include addressing an institution's risks arising from climate change (GFANZ, 2022).

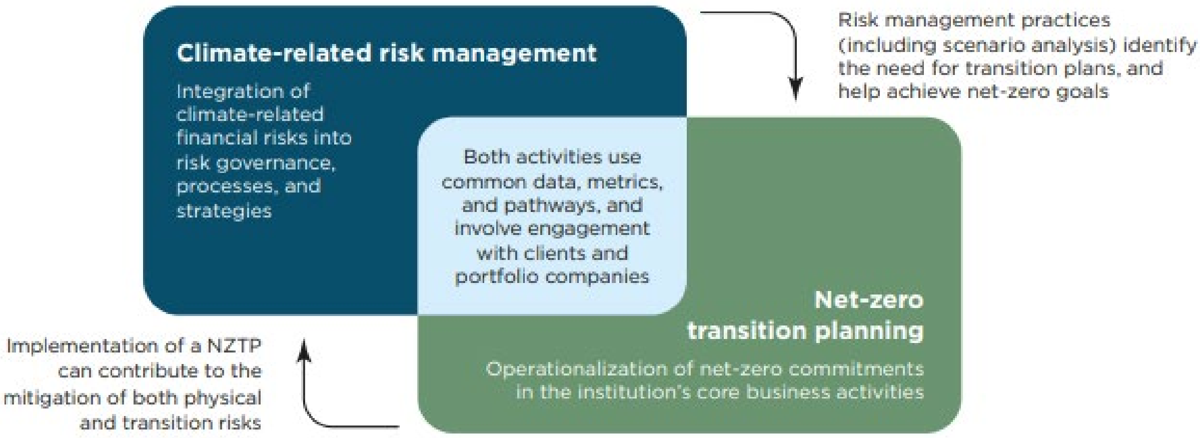

Figure 7: Relationship between risk and transition planning (GFANZ, 2022)

Since portfolio decarbonization efforts and climate stress testing often rely on common data foundations, overlapping scenario assumptions and shared metrics, they are inherently interconnected (Figure 7). Examples of overlaps are summarized below.

- **Common data:** Client/counterparty carbon emissions, financed emissions, sector emissions intensity, energy efficiency data, energy performance data, EPC classification, and use of proxies.
- **Climate scenarios analysis:** Assumptions of climate scenario analysis under different transition pathways and 'central case' climate scenarios (1.5°C and Net-Zero-aligned scenarios) over different time-horizons.

46 Survey results are presented in Figure 16 of the *Survey Findings* document.

- **Shared metrics and outputs:** Financial impact on CapEx, OpEx, and Revenue.

Effective integration of these methodologies within institutions requires close attention. To improve coherence across risk management, strategy, and regulatory compliance, banks should adopt harmonized data systems, aligned scenario frameworks, and governance structures that support cross-functional collaboration. An example on aligning climate risk with portfolio decarbonization can be found in the document *Case Studies* and *Practical Examples*.

Chapter 9: Supporting and enabling the role of technology[47]

Section summary

- Current technology support for performing climate stress testing remains insufficient.
- The key areas identified where banks will require increased support from technology are more transparency when running analyses, improved flexibility and automation in (re)running sensitivity analyses, and a better understanding of the drivers behind the results.
- Technological support (such as through a central stress testing platform) can help banks to share data, scenarios, models, and results across different teams, and to leverage and deploy common computational capabilities more efficiently and effectively across different forward-looking processes.

As noted by the Bank for International Settlements (BIS), "a bank's ability to assess its overall exposure to climate risks across all of its significant operations will be heavily dependent upon the quality of its IT systems and its ability to aggregate and manage large amounts of data" (BIS, 2021b). This statement holds particularly true for banks' forward-looking activities, such as climate scenario analysis, stress testing, and portfolio decarbonization simulations.

The traditional BAU stress testing process is one of the most complex processes at any bank, as is the underlying technology supporting it. This is often exacerbated by the kind of outdated, legacy risk systems that numerous banks have. A recent study by SAS & FT Longitude (2025) finds that three-quarters of the 300-plus banks pooled plan to improve in this area and increase their investment in risk management technology over the next year. This is driven by the need to automate risk management processes, improve simulation capabilities, rationalize hardware costs, and consolidate software providers. As banks work on improving their risk management capabilities, an opportunity for banks emerges to leverage these developments for the modernization of their forward-looking capabilities and their closer integration with climate stress testing activities.

Close integration with BAU processes and technology can generate numerous benefits and synergies for banks. A good example of an area for such integration is the calculations and simulations of RWA and financed emissions. These two processes share common counterparty-level data elements and apply similar asset-weighting calculation concepts

47 Referring to IT systems, software, and infrastructure.

that can be shared and leveraged (see case study example in the document *Case Studies* and *Practical Examples*).

Generally, implementing climate risk stress testing and portfolio decarbonization simulations on top of the existing stress testing processes poses additional and new challenges for financial institutions. Data limitations and volumes, longer timespan analyses, climate risk model specification and selection uncertainty, and the lack of standardized methodologies introduce significant obstacles. These obstacles put extra pressure on existing processes and infrastructure. Accordingly, institutions with legacy systems and/or a fragmented application landscape will face greater difficulty when responding to these challenges in an efficient manner.

When designing their climate stress testing and simulation modelling frameworks, banks must be aware of the challenges and limitations of their existing risk and stress testing environments. It is crucial that they carefully interpret the results generated over a 10-, 20-, or 30-year time-horizon, especially when relying on limited data and expert judgment models.

Lastly, as discussed in Chapter 8, climate scenario analysis is increasingly being used by a growing number of internal departments and stakeholders for various additional use cases, such as financed emission simulations, client engagement and opportunity identification, transition planning, and portfolio allocation steering.

Each of these additional application areas for climate scenario analysis brings in additional users, new data, and extra calculations, as well as new reporting specifications and process adjustments. Together, these create new demands for capabilities and availability of the underlying simulation infrastructure. To address these demands for technology resources and to meet the need to integrate climate stress testing with existing stress testing processes, banks are increasingly exploring how technology can support and centralize these various stress testing activities.

The centralized management and execution of these various forward-looking processes on an integrated stress testing platform allows banks to better address the challenges mentioned above. It also enables the various teams to share all data, scenarios, models and results. In these ways, banks can deploy their computational capabilities more efficiently across the various processes.

To implement such an integrated stress testing platform, banks can either rely on in-house developments or on software solutions already available from established providers, which they then only need to configure and adapt to their own requirements. In-house development allows for full customization but may require significant internal resources. Vendor solutions often include industry practices and dedicated support but may involve higher initial costs. Each option involves a different balance of internal effort, cost, and efficiency, depending on the bank's specific needs and strategy.

9.1 Addressing risks associated with model specification and selection

As discussed in Chapter 8, climate risk modelling and simulations expose banks to material model risk, which manifests extensively in climate risk stress testing.

Each alternative expert assumption, judgment, or methodology choice can significantly impact results, while the long timespan of the analysis magnifies the effect. The emerging key approach for banks to mitigate this model risk is to get a better understanding of how model assumptions, model specification, and the final model selection affect results. To gain these insights, banks need to rerun their simulations to assess the sensitivity of the results to changes in their methodologies and the underlying models. For example, HKMA requires banks to apply this model risk mitigation approach explicitly in its regulatory climate risk stress testing exercise (HKMA, 2023). Instead of submitting one set of results, HKMA requires banks to rerun their simulations multiple times with different methodology assumptions and configuration settings and submit all the alternative results together. Similarly, the EBA also considers it critical that banks understand the assumptions behind the scenarios and models they apply (EBA, 2025b).

Once the impact of modelling alternatives is explored, banks have to choose the models they want to apply for running their simulations. It could be a single champion model and methodology or a weighted blend of multiple models that averages the alternatives according to applied weights. This model selection process ultimately has a significant impact on the results.

The need for sensitivity analysis associated with model selection and attribution of the movements in the results to the modelling components introduces additional technological and analytical complexity. This includes the need to run and store results associated with alternative simulations, plus the demand for additional resources. If the sensitivity and attribution analysis process is not properly designed to take advantage of parallel execution, it could also result in longer execution time. **Therefore, it is not a surprise that only ten per cent of the surveyed banks currently perform such an analysis**. That said, there is an expectation that banks will gradually build additional capabilities, thereby allowing them to perform such analysis on a regular basis in the future.

The latest technology advances allow automation of such sensitivity and attribution analysis, helping banks to quickly understand and document the effect of using different models and model specifications.

Improving flexibility & modularity

Scenario analysis should be designed with adaptability and modularity in mind so as to allow for ongoing refinements as the environment and knowledge evolve (EBA, 2025b). To increase flexibility of their approaches, banks can now rely on more intuitive, visual, and modular plug-and-play interfaces. This replaces their over-reliance on dozens of pages of code, which can restrict access to only a few power users and limit a bank's overall flexibility. In a volatile regulatory and methodology environment, banks must be prepared to flexibly adjust their approaches. This could include for example: reshuffling their simulations and methodology approaches; moving certain models out and back in; and replacing scenarios, change assumptions, and mapping tables according to the latest industry good practices and rerun, while being able to assess and explain the impact of the change on the results.

9.2 Areas of technology support

More transparency when running analyses, improved flexibility and automation in (re) running sensitivity analyses, and a better understanding of the drivers behind the results are some of the key areas where the surveyed banks expect they will need increased support from technology.[48]

Improvements in these technological areas will ultimately help banks to answer many challenges that they face in performing climate stress testing efficiently and effectively.

Going beyond the regulatory needs, leveraging advanced analytics, scenario analysis, and simulation capabilities can support financial institutions in a number of key areas. In particular, it can help them to more quickly and easily assess the impact of alternative management actions and portfolio strategies on their KPIs and KRIs at the institution, portfolio, sector, and even individual customer level. All these inputs are important for making optimal decisions at the portfolio and customer level.

A key takeaway from the UNEP FI and SAS survey is that all of the surveyed banks find that their current technology support requires some form of technology improvements for it to be fully sufficient. This confirms the BIS acknowledgement at the beginning of this chapter; namely, that the maturity and quality of an institution's technology will define how much it can achieve in addressing climate risk. When designing their climate risks stress testing processes there is an opportunity for banks to leverage the momentum also to improve the integration of their various forward-looking simulation approaches and platforms. Executing climate risk stress testing and the various simulations in a more integrated manner on a modern stress testing platform can support banks in addressing the above by:

- Orchestrating and streamlining the various processes on a unified, central platform.
- Leveraging a dedicated engine designed for executing forward-looking risk analysis.
- Intuitively assessing and explaining differences between impacts of two different time periods, alternative scenarios, models, portfolios, and counterparties, plus exploring (interim) results at the desired granularity.
- Minimizing or avoiding manual processes and handovers and leveraging the low code risk capabilities.
- Reducing overall maintenance and resources effort.

Improvements in any of these areas can help banks to streamline not just their climate risk stress testing processes, but also generate integration benefits and synergies for their other forward-looking simulations applied in the different risk areas.

48 Survey results are presented in Figure 17 of the *Survey Findings* document.

9.3 Key enabling technology capabilities for (climate) risk stress testing

To support banks in the areas highlighted in Section 9.2, and the challenges discussed, the desired technology capabilities of a central stress testing platform can be grouped into the following areas:

- Process orchestration and governance
- Data management
- Scenario assumptions and portfolio growth
- Model execution and simulations
- Results exploration and analysis

Process orchestration and governance

Climate risk stress testing and any other stress testing processes are cross-functional exercises that require collaboration across multiple departments within a bank. The processes are often highly laborious and fragmented. Different teams often manage disparate risks and financial metrics across separate technology infrastructures and data sources. Stress testing components—including scenarios, assumptions, and results—are manually exchanged and communicated. This approach not only creates data silos but also leads to extensive reconciliation efforts due to the lack of integration with BAU production systems.

Figure 8 illustrates an example approach for orchestrating stress testing processes in an integrated fashion that provides a consolidated view of KRIs and KPIs.

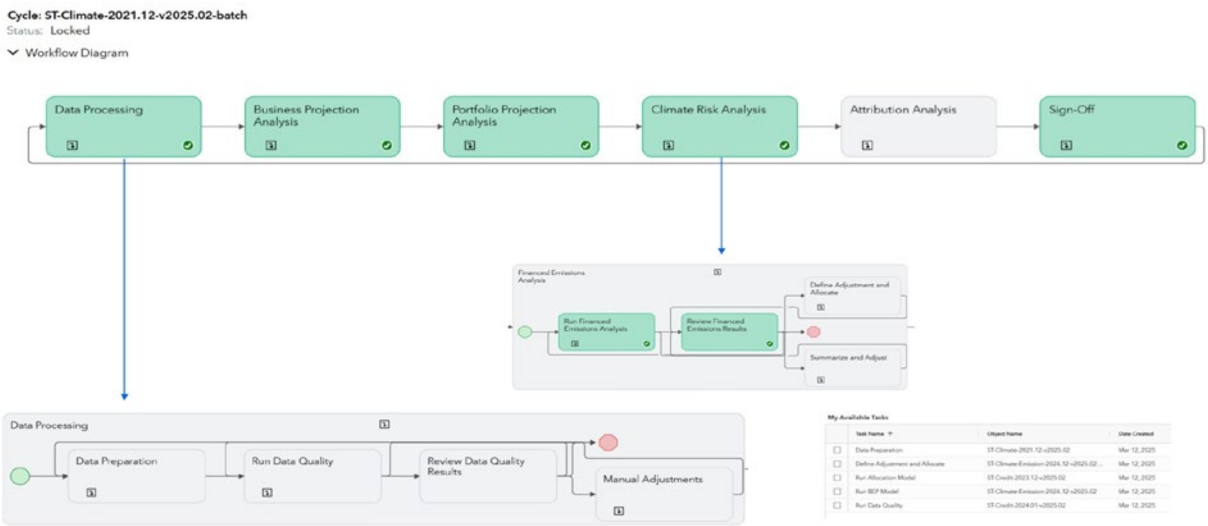

Figure 8: Example of an approach orchestrating climate stress testing process and governance (source: SAS)

Each step of the process corresponds to a certain set of activities performed by predefined people and/or systems. Individuals involved are assigned tasks based on their capabilities and responsibilities. Core stress testing system components—including data, scenarios, and business assumptions—are managed centrally. Meanwhile, the simulation across different risk types (financial or non-financial) and other climate-related metrics—for example finance emission—are orchestrated via the integration with the production systems in a modular fashion.

Such an approach can unburden the need for manual data exchange and provide a framework to iteratively simulate the impacts under different scenario pathways and management actions.

Data management

At the core of any successful climate risk stress testing exercise lies an effective data management framework. Advanced data management platforms enhance data transparency and availability via seamless integration with diverse data sources. These sources might range from legacy financial systems to specialized climate data, including those in geospatial format and those available in large volumes in open climate data repositories.

Scenario assumptions and portfolio growth

Modern stress testing platforms are built on a robust, object-based, modular architecture that facilitates the reuse of common components; namely, data, models, market scenarios, and business assumptions. Centralized repositories for climate scenarios and business strategy assumptions are critical to simulate the interplay between these elements effectively.

While regulatory-prescribed scenarios provide a necessary baseline, banks require the flexibility to adjust the evolution of different climate risk factors to account for uncertainty in the forecast narratives or apply sensitivity analysis on different climate risk factors.

Dynamic balance sheet assumption can help capture how the balance sheet structures may evolve over time in response to both climate-related shocks and longer-term transitions. It is important to recognize that balance sheets are fluid and are influenced by strategic business responses and climate scenario pathways.

Banks may proactively adjust their portfolios as they transition towards lower-carbon exposures, including reducing their lending to fossil fuel-dependent industries while increasing exposure to renewable energy projects. A robust stress testing platform enables banks to model these shifts, address the challenges of handling the increased volume of portfolio data and another set of alternatives, incorporating not only current exposures but also simulating changes in asset mix or new business investment over time.

Model execution and simulations

Efficient onboarding and continuous deployment of climate risk models are essential for keeping pace with the rapidly changing climate risk landscape.

Banks have access to a diverse array of technologies and implementation approaches for developing and implementing climate stress testing models. These range from in-house developments, including the use of open-source modelling environments such as R and Python, to specialized and largely preconfigured commercial stress testing software solutions. Through these commercial solutions, the development and configuration of models using both in-house and open-source languages is made possible. Each approach must be evaluated differently, considering factors such as internal effort, available expertise, expected internal and external costs, potential efficiency gains, and integration benefits within the existing business architecture. These considerations are unique to each bank.

An increasingly important aspect from the perspective of model risk management is the degree of model transparency and model governance concerning the models used in the bank's climate stress testing process. It is crucial to understand how the technology can demonstrably explain changes in results or describe the role of a particular model in the respective calculations.

Figure 9 (see below) illustrates an example of a modern pipeline-oriented approach to risk simulation that can help banks improve the transparency and governance of their climate stress testing models. Each component represents a modifiable part of the stress testing exercise, including models as well as data, scenarios, and business assumptions. The intuitive, visual interface can extend the access to stress testing models and simulations also to less technical users while still offering access to the coding environment in the background to the power users.

This can facilitate an in-depth understanding to various types of users of how different modelling choices impact outcomes, ensuring models are robust and reliable before being integrated into BAU decision-making.

Figure 9: Example of an approach orchestrating climate stress testing data and models into a visual pipeline (source: SAS)

Results exploration and analysis

The final step in the stress testing process involves interpreting and extracting actionable insights from the numerous possible simulated outcomes. It is imperative that risk managers and business owners can transpose complex outcomes into understandable metrics.

Interactive dashboards with automated attribution analytic features help assess the contributions of various risk factors and provide valuable insights into portfolio vulnerabilities and support proactive risk management decisions.

Overall, as confirmed by the survey results and statements from the regulators, the flexibility and efficiency of the supporting underlying technology plays a vital role in defining the maturity and effectiveness of bank's climate scenario analysis and stress testing processes. Furthermore, the extent to which the banks have managed to integrate these new processes with their existing forward-looking activities will define how much synergy and automation benefits can be achieved. The latest technological developments combined with a holistic integrated approach towards stress testing centralization can help banks in addressing a number of the identified challenges and bottlenecks, as illustrated by the examples and case study shared in this Chapter and in the supporting document *Case Studies* and *Practical Examples*.

Chapter 10: Next steps in climate stress testing methodologies and areas of development

Despite progress, climate stress testing results have been relatively benign, raising questions about the effectiveness of current methodologies as well as their general suitability for the purpose and the path forward. As highlighted in this report, challenges relating to scenario design, data gaps, and modelling continue to limit the usability of results across institutions. The following is a synthesis of key takeaways drawn from written inputs provided by leading industry experts,[49] as well as broader observations, on the evolution of climate stress testing and expected developments. These insights have been summarized in Table 8.

Table 8: Summary of key expected developments in relation to the next phase of climate stress testing

Themes	Key expected developments
Integration of climate risk into business and wider sustainability risks	▪ Assessment of nature and social risks, along with climate risks ▪ Better integration of climate risks into risk provisions, lending and investment opportunities, and capital plans ▪ Shift in climate risk identification from second-line risk teams to first-line business teams
Scenario design	▪ Development in short-term climate scenario analysis ▪ Capture of a wider set of stress factors ▪ Increased use of advanced technologies like AI and ML
Modelling approaches and risk parameters	▪ Improved understanding of transmission channels ▪ Enhancements in physical risk modelling ▪ Integration of risk mitigation measures into modelling approaches ▪ Refined method to translate macroeconomic variables into market shocks ▪ Availability of new data sources for modelling
Governance	▪ Adoption of more sophisticated governance standards ▪ Strengthened Board accountability ▪ Targeted training and upskilling of Board members ▪ Embedding governance within control frameworks
Reporting of climate stress testing results	▪ Reporting of climate stress testing results through confidential supervisory submissions ▪ Alignment of public disclosures with IFRS S2

49 At: Baringa, Deloitte, EY, KPMG, Oliver Wyman, and PwC Wirtschaftsprüfungsgesellschaft GmbH

Integration of climate risk into business and wider sustainability risks

As climate stress testing methodologies evolve, industry experts highlight the integration of broader sustainability risks[50] into risk assessment frameworks as a key area of future development. This includes the assessment of nature, social, and other sustainability risk factors as part of stress testing and scenario analysis. These assessments are still in the early stages, with one expert suggesting they may be as much as five years behind in development. Similarly, banks are increasingly expected to explore the interconnections between nature and decarbonization in their scenario analysis to better inform business strategy. An overview of tools focused on assessing sustainability risks, including climate, nature, pollution, and social risks, can be found in UNEP FI Risk Centre's open-access Sustainability Risk Tool Dashboard.

The broader integration is also reflected in growing supervisory expectations, as exemplified by the EBA's Guidelines on the management of ESG risks (2025d) and its Guidelines on ESG scenario analysis (2025a), as well as the Joint Guidelines by ESAs (2025e) on the integration of ESG risks into supervisory stress testing activities. Similarly, FINMA (2024) issued a circular outlining expectations for managing both climate- and nature-related financial risks.

Furthermore, industry experts note that climate risk is becoming better integrated into BAU practices in some jurisdictions, as banks incorporate climate risk factors into risk assessments and provisions, lending and investment opportunities' evaluation, and business and capital plans. Additionally, processes for climate risk identification are shifting from second-line risk teams to first-line business teams, signalling a deeper embedding of climate considerations within institutions.

Scenario design

Significant progress is underway in the design of climate scenarios used as part of climate stress testing, with industry experts highlighting a growing emphasis on the development and use of short-term climate scenarios as part of the next generation of scenario analysis. The recent release of the NGFS short-term climate scenarios (2025) is expected to accelerate developments in this area. However, institutions will need to continue developing tailored short-term scenarios for internal risk management, particularly with greater granularity for portfolios such as the trading book.

One expert noted that many large institutions are already adapting long-term scenarios into short-term scenarios by integrating macroeconomic and industry factors with short-term climate trends. Another expert emphasized the need for more actionable scenarios, suggesting that banks are increasingly focused on using realistic base-case climate scenarios and short-term bespoke scenarios to meet their needs. According to them, banks are turning to base-case climate scenarios (i.e. those considered most likely to occur) to

50 Non-climate risks can be assessed in the following ways: (i) as transmission channels for climate-related financial risks (e.g., household vulnerability, job losses amplifying credit risk, or nature loss reducing asset values); (ii) as output variables of climate scenarios, which influence their plausibility or desirability (e.g., inequality levels shaping political feasibility); and (iii) as parallel risk factors that banks are expected to manage under strategic or regulatory mandates, which interact with climate risk.

support climate risk identification, transition planning, estimation of financed emissions, and the integration of climate risk in their IFRS9 provisioning. In parallel, short-term bespoke scenarios are being developed to reflect specific strategies and business models, helping banks identify potential risks that could arise over a three- to five-year horizon.

Furthermore, experts anticipate scenario design to increasingly reflect a wider range of stress factors, including the interactions between climate drivers and macroeconomic shocks, as well as nature-related (e.g. pollination loss, water scarcity, and deforestation) and social risks (e.g. widening inequality amid climate adaptation and migration). Scenario sets will also need to be updated and tailored to reflect current climate and economic realities at the country or market level.

Looking ahead, next-generation climate scenario analysis is expected to utilize advanced technologies, such as AI and ML. According to the UNEP FI and SAS survey, one-third of survey respondents are considering the use of AI/ML in their simulations,[51] and this proportion is expected to grow as banks integrate AI into their workflows and as third-party vendors adopt AI-driven modelling approaches. AI-enabled platforms can support climate stress testing, scenario development, and model creation, while also helping to address data gaps. As these technologies evolve, they could be used to facilitate a dynamic balance sheet approach to climate stress testing, enable reverse stress testing, or support processing information more efficiently. Additionally, leveraging AI could accelerate the development of more granular models through downscaling, improving both data quality and modelling capabilities.

Modelling approaches and risk parameters

Several industry experts also foresee modelling approaches to evolve through various aspects. One important area of focus is the improved identification and incorporation of transmission channels, which can enhance the accuracy of assessing financial materiality. Building upon the work by supervisory authorities, such as the Basel Committee on Banking Supervision (BCBS) (2021b) and the Prudential Regulation Authority's (2025) consultation paper on enhancing banks' and insurers' approaches to managing climate-related risks, banks are placing increasing emphasis on understanding the transmission channels of climate and other environmental risk drivers, many of which are sector-specific and include idiosyncratic, macroeconomic, and second-round effects. The integration of transmission channels for nature-related risks will also be informed by emerging work from the NGFS and by available research such as the DNB–PBL study (2020) exploring how these risks are transmitted into financial risk. Moreover, banks are likely to take a practical approach, focusing on risk types and transmission channels in proportion to the materiality of those risks.

Another area of advancement is the assessment of adverse physical events, where banks are working to address both methodological challenges and data limitations. As part of improving physical risk analysis capabilities, instead of relying solely on costly third-party data, one expert observes that institutions are prioritizing a qualitative understanding of potential impacts, guided by the principle of being "approximately right rather than precisely wrong". Further enhancements are expected to include more localized, integrated

51 Survey results are presented in Figure 18 of the *Survey Findings* document.

approaches that combine physical climate risks with other environmental risks such as nature loss and pollution, more sophisticated modelling of second-order effects including supply chain contagion and extreme asset shocks, and the use of climate attribution science to refine physical risk modelling. In addition, systemic climate stress testing is likely to evolve further across both banking and insurance sectors to capture interdependence and highlight protection gaps.

Another component highlighted is the growing focus on modelling risk mitigation measures. This includes accounting for investments in physical adaptation and financial mechanisms, such as natural catastrophe insurance, which can potentially reduce overall risk exposure.

For the trading book, institutions are working to strengthen methodologies to better capture climate risk. This involves refining approaches to translate macroeconomic variables into market shocks, while ensuring consistent transmission of impacts across all asset classes.

New and emerging data sources are also expected to enhance modelling capabilities. These include improved sustainability reporting disclosures from corporate counterparties, satellite imagery, and land-based sensors for predicting weather patterns and climate-related disasters, as well as electricity sourcing monitoring and flow tracing. All of these measures can help banks better monitor their exposures.

Finally, one expert notes that evolving accounting standards are expected to increase pressure on banks to integrate climate risk overlays into provisioning calculations, particularly for long-term, stage-two exposures.

Governance

Supervisory authorities are raising governance standards for climate stress testing and scenario analysis, particularly as banks make greater use of bespoke scenarios and models. Further developments in relation to governance will likely include stronger Board accountability, encompassing oversight of climate stress testing, engagement on the outcomes, and targeted training and upskilling of Board members. Governance will also need to be embedded more deeply into banks' control frameworks, covering both the execution of stress testing exercises and the selection of climate scenarios. In addition, governance practices applied in model risk management and model validation will need to extend to climate stress testing, ensuring that climate scenarios and models are subject to the same rigour and oversight as other models.

Reporting of climate stress testing results

Banks are likely to limit the detailed outcomes of their climate stress testing to confidential supervisory submissions rather than public disclosures. These detailed outcomes may include impacts on PDs, ECL, trading exposures, and concentration risks. Public disclosures are expected to align with the International Sustainability Standards Board's Climate-related Disclosures Standard (IFRS S2) as the baseline.

As climate stress testing continues to advance across the areas outlined above, it will help address key challenges faced by banks in quantifying the financial impacts of climate risks. These challenges include the incorporation of their forward-looking attributes, uncertainties in long-term climate projections, and the need for more robust modelling of physical risks. Enhancements in these areas will improve the usability of climate stress testing results, enabling banks to apply insights more effectively. In particular, the results can be used to inform decision-making processes, including the development of mitigation strategies. They can also strengthen internal risk management practices, such as setting risk appetite and integrating climate risk factors into strategic planning and capital allocation.

Conclusion

Banks are increasingly conducting internal climate stress tests using scenario analysis tools in addition to meeting supervisory expectations. Although climate stress testing methodologies are progressing, they have not yet attained the level of sophistication of standard traditional stress testing approaches. This report presents common approaches and key considerations for climate stress testing, with eight key takeaways outlined below.

1. **Scenario selection is informed by the assessed time-horizon and risk type.**
   - Banks typically use IPCC and NGFS scenarios to assess long-term physical risks, NGFS scenarios for long-term transition risks, and internally developed scenarios for short-term assessments.
2. **Climate stress testing is becoming more aligned with traditional risk metrics.**
   - Banks are increasingly using BAU risk indicators, such as PD, LGD, P&L, and capital adequacy ratios, to estimate the impact of climate risks.
   - Most banks use a static balance sheet; however, this can limit the ability to reflect strategic repositioning.
3. **Assessment of transition risk-related credit risk as part of stress testing is becoming more established.**
   - Banks are using detailed, bottom-up models at the counterparty and exposure levels, as well as incorporating both direct and indirect transmission channels into advanced satellite models to produce climate risk scores for sectors and portfolios.
4. **More detailed and location-sensitive methodologies for modelling physical risk—driven credit risk are developing.**
   - Banks are expanding to include multiple hazards, often assessed using geo-locational data, although limitations persist around firm-level value chain data.
5. **Climate stress testing capabilities are more established for credit risk than for market risk.**
   - Many banks conduct exercises in response to regulatory requests or on an ad-hoc basis, focusing on translating macroeconomic and climate variables into market risk drivers without fully embedding them into risk frameworks.
6. **Integrating climate models into MRM is in the early stages.**
   - As part of establishing climate MRM frameworks, banks are in the process of identifying and classifying climate models and determining how to group them based on criteria of impact and severity.

7. **Integrating climate stress testing into BAU risk management frameworks and practices is nascent.**
   - Current efforts focus on incorporating climate-related factors into traditional stress testing frameworks, as well as integrating climate risk considerations into credit impairment assessments and capital requirement calculations.
8. **Technological advancements can contribute to the enhancement and optimization of climate stress testing.**
   - The maturity and effectiveness of a bank's climate scenario analysis and stress testing processes is driven largely by the flexibility and efficiency of the supporting underlying technology. The latest technological developments combined with a holistic integrated approach towards stress testing centralization can help banks in addressing identified challenges and achieve synergy and automation benefits.

Climate stress testing has advanced since its early days. However, its outputs—such as loss estimates and changes in credit risk parameters—remain modest, underscoring the limitations of current methods. Key ongoing challenges that limit its applicability include: uncertainties in long-term climate projections and inherent model limitations; forward-looking aspect of climate risks compared to the backward-looking focus of traditional risk models; data gaps that hinder integration of granular sectoral and exposures data; and difficulties in assessing economic losses when quantifying the impact of physical risks.

Based on industry perspectives, several key trends are expected to shape the next phase of methodological refinement. In line with these trends, banks are likely to:

- Broaden their risk assessments to encompass a wider range of sustainability risks.
- More fully embed climate risk into BAU practices, including shifting climate risk identification from second-line risk teams to first-line business teams.
- Strengthen short-term climate scenario analysis capabilities, supported by both tailored scenarios for internal risk management and the recently released NGFS short-term scenarios.
- Expand the set of stress factors within scenario design to capture a wider array of transmission channels and better reflect country- or market-level conditions.
- Enhance the assessment of adverse physical events, with increased emphasis on the qualitative understanding of physical risk impacts.
- Advance methodologies for modelling climate risks within the trading book.
- Leverage advanced technologies like AI and ML.
- Embed governance more deeply within banks' control frameworks and strengthen Board accountability.

The UK PRA's latest public consultation on banks' and insurers' management of climate-related risks reflects a broader trend of regulators across different jurisdictions issuing increasingly detailed guidance. The growing body of guidance enables wider adoption of interoperable climate-related regulations and practices, which can accelerate the integration of climate considerations into financial institutions' risk management processes. Harmonized measures support comparability of high-quality information. This, in turn, can encourage climate-conscious banks and support client transition to a net-zero economy.

Appendix

Overview of the NGFS scenarios

The NGFS scenarios were created to provide a common starting point for analysing the impact of climate risks on the financial system and the wider economy. The latest iteration of the NGFS long-term scenarios has created a set of seven scenarios, each fitting into one of the dimensions, as seen in Figure 10. The level of physical and transition risk described in each scenario is driven by the level of policy ambition, policy timing, technology levers and coordination levers.[52]

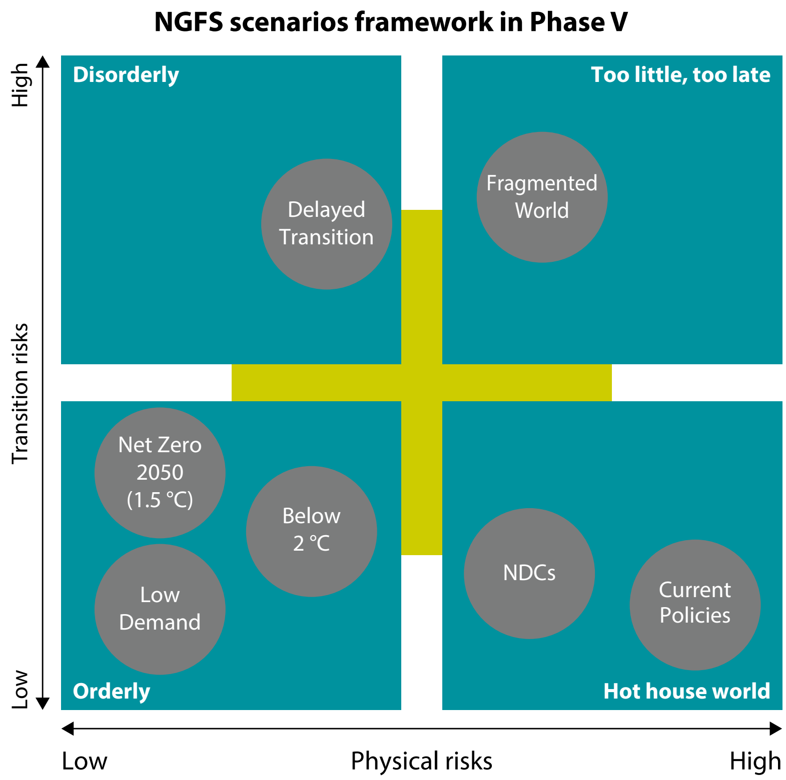

Figure 10: NGFS Phase V scenarios framework (NGFS, 2024a)

It is important to note that the NGFS scenarios have limitations, which may often result in institutions underestimating climate risks. This is a concern that has been highlighted by the UNEP FI and SAS survey, which finds that respondents perceive both physical and transition risk scenarios as moderately underestimating the severity of climate risks. The perceived benefits and limitations of the NGFS scenarios are detailed below.

52 For more information, see: ngfs.net/system/files/import/ngfs/medias/documents/ngfs_scenarios_main_presentation.pdf

Benefits	Limitations
Incorporates multiple models and assesses various scenarios across regions and industries to account for uncertainty in modelling climate-related macroeconomic and financial risks.	May inadequately assess the stressfulness of a mitigation pathway due to the cost optimization framework of Integrated Assessment Models (IAMs).
Can be used globally by central banks, financial regulators, and supervisors, fostering credibility and standardization in climate stress testing (NGFS, 2024).	Possibly underestimates financial risks as IAMs do not currently capture factors like non-linear tipping points (Frontiers in Climate, 2023).
Supports regulatory stress-testing requirements and climate-related financial disclosures (e.g. IFRS S2) (NGFS, 2024).	Fails to fully capture the interplay between physical and transition risks and their feedback loops.
Enhances relevance and reliability by aligning the scenarios' scientific basis with international climate goals.	Lacks sufficient regional granularity, limiting financial institutions' ability to assess and manage localised climate risks.
Provides internally consistent outcomes by integrating transition and physical risks with macro-financial trends (NGFS, 2024).	May not capture unique risks of individual financial institutions or specific regulatory priorities of jurisdictions.
Covers both acute and chronic physical risks, with ongoing enhancements in physical risk modelling (NGFS, 2024).	Lack specificity in sectoral coverage and contains insufficient detail for financial risk assessments (NGFS, 2024).
Models the decarbonization of the energy, industrial, transportation, agriculture, and real estate sectors.	Needs more refinement in respect to how physical risks are modelled (NGFS, 2024).
Offers an up-to-date perspective with the regular addition of the latest data (e.g. improved damage function accounting for temperature variability and precipitation) (NGFS, 2024).	
Uses the National Institute Global Econometric Model (NiGEM) for detailed macroeconomic projections (NGFS, 2024), including GDP, inflation, interest rates, employment, and trade flows.	

Overall, the NGFS scenarios serve multiple objectives, including risk identification, financial risk assessment, and portfolio alignment. They can also inform use cases such as business and operational strategy, climate-related financial disclosures, and product or service development. However, the NGFS cautions that while the scenarios provide a credible set of pathways, they have limitations and may not always be suitable for all user needs (NGFS, 2024).

Overview of the IPCC scenarios

The Intergovernmental Panel on Climate Change (IPCC) develops scenarios to assess potential future climate conditions based on socio-economic, technological, and environmental trajectories. These include: (i) Representative Concentration Pathways

(RCPs), which model greenhouse gas (GHG) concentration trajectories and their radiative forcing levels by 2100; and (ii) Shared Socio-economic Pathways (SSPs), which outline socio-economic developments that influence emissions and adaptive capacity. RCPs provide a framework for modelling potential climate outcomes based on different emission trajectories, with scenarios like RCP 2.6 aiming to limit warming below 2°C through significant emission reductions. SSPs complement RCPs by considering factors such as population growth, economic development, technological advancements, and policy orientation. It is important to note that the IPCC scenarios have many benefits and limitations.

Benefits	Limitations
Combine several disciplines, such as economics, social aspects and climate science.	Focus primarily on physical climate outcomes, lacking indicators that are useful for assessing financial risks.
Provide insights into the temporal effects of climate change, and highlights the different options that society has and how these play out under reasonably expected socioeconomic conditions (Frontiers in Climate, 2023).	Lack sufficient regional granularity, relying instead on global or continent-level projections that limit capacity to assess climate risks accurately.
Ensure robustness and alignment with global climate agreements, given the role of global climate scientists and modelers in their development	Limit the ability to make assumptions based on the present-day situation as updates are made on a relatively infrequent basis and these typically comprise underlying socioeconomic data rather than projections and real-time data (Oxford Economics, 2024).
Offer detailed projections of temperature rise, sea level rise, extreme weather events, droughts, floods, and hurricanes to assess long-term physical risks.	Focus on the cost-optimal mitigation pathways to the transition, in line with their original design to inform climate policy rather than provide a scenario analysis for the finance sector (Frontiers in Climate, 2023).
Cover a range of climate pathways, from low- to high-emission scenarios, thus helping banks assess exposure under different warming levels.	Could result in stranded assets and regional resilience disparities in light of their unsuitability for capturing rapid energy system changes (Oxford Economics, 2024).
Account for key socioeconomic factors such as population growth, urbanization, and land use, thereby enabling more realistic projections.	Do not model the economic consequences of climate tipping points or the complex interplay between physical and transition risks.

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UN environment programme

finance initiative

UNEP Finance Initiative (UNEP FI) brings together a large network of banks, insurers and investors that catalyses action across the financial system to deliver more sustainable global economies.

For more than 30 years the Initiative has been connecting the UN with financial institutions from around the world to shape the sustainable finance agenda establishing the world's foremost sustainability frameworks that help the finance industry address global environmental, social and governance challenges.

Convened by a Geneva, Switzerland-based secretariat, more than 500 banks and insurers with assets exceeding USD 100 trillion are individually implementing UNEP FI's Principles for Responsible Banking and Principles for Sustainable Insurance. Financial institutions work with UNEP FI on a voluntary basis to apply the sustainability frameworks within their industries using practical guidance and tools to position their businesses for the transition to a sustainable and inclusive economy.

Founded in 1992, UNEP FI was the first initiative to engage the finance sector on sustainability. Today, the Initiative cultivates leadership and advances sustainable market practice while supporting the implementation of global programmes at a regional level across Africa & the Middle East, Asia Pacific, Europe, Latin America & the Caribbean and North America.

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