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The 2023 Climate Risk Landscape

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- PwC
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Abbreviations

APS	Announced Policies Scenario
AR5	Fifth Assessment Report
AR6	Sixth Assessment Report
BIS	Bank of International Settlements
CAPEX	Capital Expenditure
CCS	Carbon Capture and Storage
CO_2	Carbon Dioxide
CDR	Carbon Dioxide Removal
CDSB	Climate Disclosure Standards Board
CISL	Cambridge Institute for Sustainability Leadership
CLIMAFIN	Climate Finance Alpha
CMIP-6-project	Coupled Model Intercomparison Project
COP	Conference of the Parties
CVaR	Climate Value at Risk
DD	Distance to default
EBITDA	Earnings Before Interest, Tax, and Depreciation
ECB	European Central Bank
ESG	Environmental, Social, and Governance
EU	European Union
ETH Zürich	Swiss Federal Institute of Technology in Zürich
EV	Electric Vehicle
FAO	The Food and Agriculture Organization of the United Nations
FI	Financial Institution
FSB	Financial Stability Board
FPS	Forecast Policy Scenario
GDP	Gross Domestic Product
GFANZ	Glasgow Financial Alliance for Net Zero
GHG	Greenhouse Gas
Gt	Gigatonnes
IAMs	Integrated Assessment Models
IEA	International Energy Agency
IFRS	International Financial Reporting Standards
IMF	International Monetary Fund
IMP	Illustrative Mitigation Pathways
IPCC	Intergovernmental Panel on Climate Change

IPR	Inevitable Policy Response
IRENA	International Renewable Energy Agency
ISSB	International Sustainability Standards Board
LGD	Loss Given Default
NDCs	Nationally Determined Contributions
NFRD	Non-Financial Reporting Directive
NGFS	Network for Greening the Financial System
NGO	Non-Governmental Organisation
NLP	Natural Language Processing
NZAOA	Net-Zero Asset Owner Alliance
NZBA	Net-Zero Banking Alliance
NZE	IEA Net Zero by 2050 Scenario
OECM	One Earth Climate Model
OPEX	Operating Expenditures
PACTA	Paris Agreement Capital Transition Assessment
PAT	Portfolio Alignment Team
PD	Probability of Default
PRA	Prudential Regulation Authority
PRI	Principles for Responsible Investment
QFTs	Quarterly Forecast Trackers
RCPs	Representative Concentration Pathways
RMI	Rocky Mountain Institute
RPS	Required Policy Scenario
SASB	Sustainability Accounting Standards Board
SDGs	Sustainable Development Goals
SFDR	Sustainable Finance Disclosure Regulation
SSPs	Shared Socioeconomic Pathways
STEPS	Stated Policies Scenario
TCFD	Task Force for Climate-related Financial Disclosures
TCS	The Climate Service
UNEP FI	United Nations Environment Programme Finance Initiative
UNFCCC	United Nations Framework Convention on Climate Change
VRF	Value Reporting Foundation
WBCSD	World Business Council for Sustainable Development
WEF	World Economic Forum
WEO	World Energy Outlook
WMO	World Meteorological Organization
WRI	World Resources Institute
XDC	X-Degree Compatibility

Executive summary

The past few years have demonstrated a remarkable level of volatility. Efforts to establish a "new normal" after the COVID-19 pandemic were interrupted by the Russian invasion of Ukraine, and a wave of food and energy crisis. Central bankers have continued to raise interest rates to tame inflation, ending the "lower for longer" regime that has persisted since the Global Financial Crisis. Amid these changes, societies must contend with the worsening effects of human-caused climate change and the critical economic transition to a net-zero emissions future. The impacts of climate change and the necessary transition will impact almost every human and natural system. Successful companies and communities will be ones that are resilient in the face of these challenges.

Developing climate resilience and contributing to a sustainable future requires action today. Organisations that recognize this are seeking to better understand their climate risks and opportunities and the strategies they should pursue. Climate risk tools can assist in the decision-making process and by validating climate strategies and uncovering new insights about climate risk. The pace of development and deployment of climate risk tools within the financial sector has been breath-taking.

UNEP FI's 2023 Climate Risk Landscape report aims to assist financial actors in better understanding this diverse and dynamic landscape of climate risk tools. The report explores the major market trends in both physical risk and transition risk tools and provides detailed analysis on dozens of individual tools. Some of the key findings found within the report are as follows:

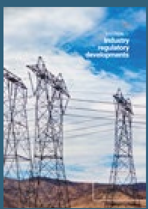
Greater integration of different climate risks within tools—tool providers have recognised the need for financial institutions to understand the full range of climate risks faced by a counterparty of portfolio. This has led to the expansion of integrated physical and transition risk tools as well as additional coverage of specific hazards within physical and transition risk assessments. This work is still ongoing and many risk interaction effects and tipping points are not typically captured.

Focus on net-zero commitments within tools—as countries and companies around the world set ambitious targets for reducing greenhouse gas emissions, climate risk tools are being developed to help them set targets, assess their alignment, and implement their net-zero strategy. That has included the incorporation of a greater range of net-zero scenarios within tools as well as greater granularity for sectoral decarbonisation pathways.

Rising regulatory demands are accelerating tool use and functionality—mandates for climate-related financial disclosures have come into effect in jurisdictions across the world. Regulatory climate scenario exercises and climate stress tests are becoming more common as well. This regulatory pressure has both expanded the demand for climate risk tools and also resulted in a growing suite of purpose-built tools, designed to address climate disclosures and scenario exercises.

New data and new insights are top priorities for financial institutions—many institutions involved in UNEP FI's working group on climate risk tools expressed a desire for tools to continue to progress on addressing data gaps and offering decision-useful information. As climate tools become more central to financial analysis, institutions appear excited to explore leading-edge data and decisioning techniques such as those offered by geospatial data and machine learning algorithms.

These trends and many others are explored in greater depth throughout the report. The report is structured into the sections noted below.



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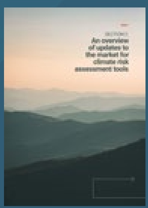
Industry Regulatory Developments

Section 2:
An overview of updates to the market for climate risk assessment tools



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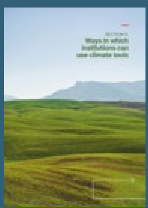

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Introduction

As the importance of integrating climate change-related risks into economic projections is being realised, many financial institutions (FIs) have been looking for effective ways to understand and quantify the financial risks from climate change in order to form an appropriate response. These risks are divided into two categories: physical and transition risks. Physical risks refer to risks resulting from environmental events such as floods, wildfires, and landslides, among many others. In contrast, transition risks are associated with policies, technologies, laws and similar actions designed to shift the economy toward lower fossil-fuel consumption (FSOC, 2021). FIs also should take further steps to consider a third category of risks—namely, those related to legal liability (i.e. litigation). Litigation risks can include people and businesses seeking compensation for losses associated with physical or transition risks, or legal challenges that require a certain course of action (PRA 2021). Although physical and transition risks exist in their own categories, climate-related litigation can exacerbate these risks (NGFS, 2021). These different climate-related risks are screened and assessed using risk assessment tools that utilise existing data and projecting methodologies provided by different vendors. Due to the expanding market for climate risk assessment tools, FIs can choose from a variety of vendors and their respective climate risk tools. In that context, there is a growing commitment to the Paris Agreement to keep global warming below 2°C so as to achieve a net-zero state by 2050 (United Nations, 2015). In response to this challenge, climate risk tools play a crucial role in identifying and measuring hotspots of greenhouse gas (GHG) emissions in portfolios. In this way, they contribute to managing net carbon emissions and bringing them to net zero by 2050.

Since the Financial Stability Board (FSB)'s TCFD recommendations in 2017, UNEP FI has conducted a series of piloting exercises. It has also developed publications to include physical and transition risk assessment tools. FIs have deployed these to understand the potential impact of climate change in their respective fields. The start of the piloting series, known as Phase I of the TCFD Banking Program, collaborated with Oliver Wyman and Acclimatise to develop an approach for evaluating corporate lending portfolio exposure to transition and physical risks under different climate scenarios (UNEP FI, 2018). In 2019, UNEP FI designed Phase II of the UNEP FI TCFD Banking Program to help FIs expand their toolkit for climate risk assessment and disclosure, exploring climate scenarios, data and methodologies, and reporting and governance issues (UNEP FI, 2020).

Following the finalisation of Phase II, UNEP FI has continued to contribute to the climate risk assessment universe through in-depth research and publications. The UNEP FI's 'The Climate Risk Landscape' report, hereby referred to as the *2021 Landscape Report*, aims to inform financial institution members about the similarities and distinctions among current climate risk assessment tools. It elaborates on the types of climate-related risk evaluated by these tools, their analysis level, and their focus sectors. FIs can choose from the vast number of climate risk tools and can work with a vendor that caters to their investment and environmental goals. An overview of current trends and challenges in the climate risk tools market coupled with an understanding of the methodology and assumptions of these tools, helps FIs make an informed start in their search for specific vendors. Following the first landscape report, the case studies presented in UNEP FI's 2022 The Climate Risk Landscape: Tool Supplement, hereby referred to as the *Tool Supplement*, incorporate the perspectives of FIs working with different tool providers. This programme allowed participating FIs to gain insights into how different vendors accomplish climate risk assessments. In return, vendors received recommendations on improving their methodologies and user access.

Stemming from the physical and transition risk outlines summarised in the *2021 Landscape Report* and *Tool Supplement* publications, this report first covers the developments from the two most recent annual Conference of the Parties (COP) meetings and relevant regulatory updates that followed in the past year. It moves on to discuss the advancements in different climate risk assessment tools, their methodologies and scenario usage, general trends and challenges observed in the market, use cases, and a roadmap to help FIs choose and utilise commercially available tools in this market. This paper aims to provide insights into the differences between vendors regarding how their climate risk tools process input data and how FIs can interpret the given output assessments into their sustainability goals. The information included in this paper can guide organisations searching for specific climate solutions that align with their global and institutional climate-related commitments. The continuation of this research programme also seeks to provide transparency on the providers' offerings so that organisations can foster a collaboration that is beneficial to them.

Important to note for this report and beyond is that the world is currently experiencing a climate crisis, with rising global temperatures and increasingly extreme weather events such as heatwaves, droughts, and floods. To mention a few examples, 2022 brought devastating floods in Pakistan, scorching heatwaves in Europe, and tragic wildfires in Australia and California. The evidence of this crisis is undeniable, and immediate action is needed to address the causes of climate change and mitigate its effects on communities and ecosystems. The climate crisis is not a future event—it is happening now.

SECTION 1:

Industry and regulatory developments

Looking back, COP26 launched a wave of private-sector commitments to battle climate change. These gathered momentum in 2022 and have continued up to the writing of this report. At COP26 in 2021, a coalition of over 450 FIs controlling over US$130 trillion in assets came together to form the Global Financial Alliance for Net Zero (GFANZ). Collectively this group committed to pursue an economy-wide transition to net-zero emissions. GFANZ is the world's largest partnership of FIs, comprising of seven net-zero alliances. It supports the members of these alliances with tools and frameworks in order to assist them in realising their net-zero commitments. GFANZ's efforts centre on a small number of specific focus areas. One of these is the provision of guidance to FIs regarding the adoption and implementation of effective transition plans. It defines such plans as "a set of goals, actions, and accountability mechanisms to align an organisation's business activities with a pathway to net zero. This should be consistent with achieving net zero by 2050 at the latest" (GFANZ, 2022).

Throughout 2022, GFANZ has published numerous supplemental guidance documents to assist FIs in their transition planning. In particular, this information is assisting firms to develop credible net-zero transition plans. Other outputs include assistance in determining the impacts of a net-zero world on the real economy and in developing metrics for the alignment of FIs' portfolios with net zero. In addition, the documentation contributes to a fuller understanding of the phaseout of financing and operations of high-emitting assets. This alliance has enabled net-zero commitments to become mainstream in the financial sector, with over 550 financial firms as signatories. Another encouraging fact is that members of the alliances under GFANZ—specifically, participants in the Net-Zero Banking Alliance (NZBA)—have committed to using science-based targets of 1.5°C scenarios. In GFANZ's words, these targets form the "backbone of transition plans and the bedrock of a 1.5-aligned economy" (GFANZ, 2022).

As net zero goes mainstream within the financial sector, climate finance is being increasingly recognised for its critical role in supporting the actions needed to combat climate change. To fill financing gaps under the Paris Agreement for both mitigation and adaptation, developed countries need to provide at least US$100 billion a year in climate capital. For their part, developing countries are facing adaptation costs of up to US$340 billion per year by 2030, increasing to US$565 billion per year by 2050. This is in addition to mitigation costs of up to US$850 billion per year by 2030 (IFAD, 2022). The global gap is large and continues to widen. The pressing need to scale up commitments around climate finance has become one of the reasons why climate risk assessment tools related to opportunity and transition readiness are crucial for FIs.

Alongside financial commitments, the need exists for agreement on investment criteria and proper risk management aligned with a low-carbon economy. New regulations have rapidly evolved in recent years. Notably, the European Union Taxonomy Regulation (EU Taxonomy) came into force in July 2020. This set six environmental objectives; climate change mitigation, climate change adaptation, the sustainable use and protection of water and marine resources, the transition to a circular economy, pollution prevention and control, and the protection and restoration of biodiversity and ecosystems. The EU taxonomy provided a classification system and set out the world's first 'green list' of sustainable business activities (PwC, 2021). This regulation also placed new taxonomy-linked disclosure obligations on companies and financial market participants by amending disclosure requirements in the EU's Non-Financial Reporting Directive (NFRD) and the Sustainable Finance Disclosure Regulation (SFDR) (ESG Enterprise, 2021). These actions have enhanced transparency on businesses' social and environmental impact, while also elevating pressure on financial organisations to obtain a complete overview of their climate-related exposures. These rules came into effect in 2022.

At COP26, the International Financial Reporting Standards (IFRS) Foundation announced the creation of the International Sustainability Standards Board (ISSB). The board aims to provide a global baseline for sustainable disclosures that outline the climate-related risks and opportunities that are most relevant to investors and the capital markets (IFRS, 2022). The ISSB standards will attempt to converge global standards and build upon existing voluntary standards such as the TCFD, the Value Reporting Foundation (VRF)'s Integrated Reporting (IR) Framework, the Sustainability Accounting Standards Board (SASB) standards, the Climate Disclosure Standards Board (CDSB) Framework, and the World Economic Forum (WEF)'s Stakeholder Capitalism Metrics. Though the ISSB's proposed measures are not currently mandated, the G7 Finance Ministers and Central Bank Governors have recently reaffirmed their commitment to move towards mandatory climate-related financial disclosures. Thus, they have welcomed ISSB to work on definite global baselines to mobilise sustainable finance (IFRS, 2022). As mandates for public disclosures of climate-related risks unfold in various jurisdictions, so will the need for FIs to conduct rigorous evaluations of how their assets contribute to climate change as well as their exposure to its impacts.

Central bank climate stress testing has expanded as a risk management practice in the financial sector. The European Central Bank (ECB) and Bank of England both carried out such tests in 2022, for instance, with the US Federal Reserve (Fed) planning to follow suit with a climate scenario exercise in 2023. In the case of the ECB, European banks were assessed for the robustness of their current stress testing frameworks. Attention was also given to their capacity to produce climate risk factors and stress test projections, along with transition risks and acute physical risk events. A core part of stress testing exercises carried out by central banks is climate scenario analysis. This provides insights into the risks and opportunities that may impact a firm, its clients, and its market in a changing world. To date, central banks and financial regulators from 31 nations have employed climate scenario analysis as a means of assessing the impact of climate risks on the financial system and the overall economy, according to the Scenarios in Action report published by the Network for Greening the Financial System (NGFS) (NGFS, 2021). Scenario analysis has increased the need for institutions to improve their quantitative capabilities with respect to the carrying out of climate assessments. This is because such assessments are seen as critical not just for stress testing but also for official disclosures and for internal strategy. Consequently, the market expects growing demands from FIs for assessment tools that provide more accurate and quantitative data.

SECTION 2:

An overview of updates to the market for climate risk assessment tools

A summary of the most recent developments in the climate risk tool landscape.

1. Growing integration of different climate risks within tools
2. Updated scenarios and a growing focus on net-zero commitments
3. Improved data availability and transparency regarding tool methodologies
4. Development of user-friendly and purpose-built tools to meet disclosure needs

2.1 Growing integration of different climate risks within tools

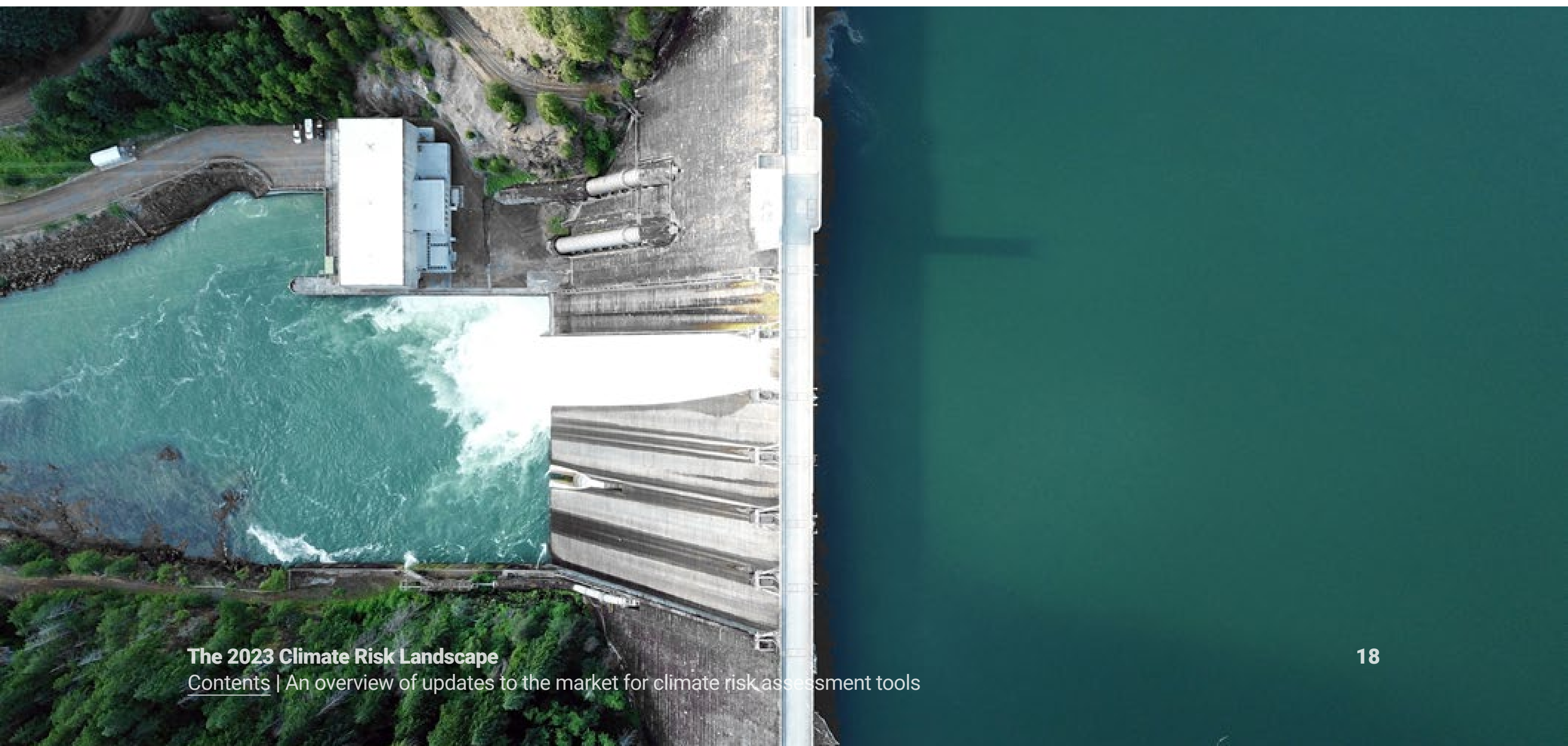
Since the 2021 Landscape Report and the Tool Supplement, numerous developments and trends have emerged in the tool market. Firstly, tool providers faced rising demand to offer integrated solutions. Past landscape reports by UNEP FI into risk assessment tools revealed that most tools covered either physical or transition risk. However, feedback during our recent piloting exercise demonstrated a growing desire among banks to see physical and transition risks covered in the same platform as an integrated solution. Recently, the tool provider industry has witnessed considerable consolidation and mergers. This has resulted in a concentration of providers among both established firms and newly merged providers. This trend has also spread to the business consulting and accounting sectors. This process of consolidation allows vendors to better meet banks' needs and to improve their capabilities. Joining their expertise around modelling, scenarios, and data, for instance, enables providers to offer a more enhanced approach to assessing climate risk.

Increase in partnerships and acquisitions

The *Tool Supplement* highlighted the partnership between Oliver Wyman and S&P Global to create Climate Credit Analytics. The tool presently focuses on transition risks, but the providers indicate plans to expand coverage to physical risks in the near future. Additionally, S&P Global acquired The Climate Service (TCS) and its integrated risk Climanomics platform in January 2022. The risk tool market landscape also features some new partnerships. In June 2021, for instance, US-based investment management firm BlackRock acquired Baringa's Climate Change Scenario Model and announced a long-term partnership focused on innovation and ongoing co-development of transition risk models. BlackRock has also established a partnership with Rhodium Group on the physical risk side. This has seen it acquire additional models. Other recent acquisitions include Moody's Analytics' purchase of RMS, Four Twenty Seven, and Vigeo Eiris, and McKinsey's move to buy Planetrics and Vivid Economics. WTW acquired the physical risk consultancy Acclimatise and Climate Policy Initiative Energy Finance in 2021 and the Butterwire research platform in 2022. In July 2022, Intercontinental Exchange (ICE) announced the acquisition of Urgentem. ICE has incorporated its existing physical climate risk solutions with Urgentem's emissions database and transition risk analytics in order to provide a full suite of sustainable finance services (Basar, 2022). Further, Quantis joined the Boston Consulting Group to accelerate sustainable transformation. Most recently, in November 2022, McKinsey Sustainability and Moody's Analytics announced their intention to join forces. This collaboration will bring together complementary strengths of both companies: on the one hand, Moody's brings its deep physical climate risk and credit risk modelling capabilities; on the other, McKinsey Sustainability offers its extensive expertise in modelling transition and physical risk, as well as in advising FIs on integrating climate risk into business processes and reducing financed emissions (McKinsey, 2022). Individual tools have also evolved their risk methodologies to take on a more integrated approach. PwC's Climate Excellence tool was previously listed as only assessing transition risks, but, as of mid-2021, it also offers coverage of acute and chronic physical risks.

Improved coverage of climate risks

Climate risks include both physical and transition risks that come from disruptive events. Physical hazards such as heat waves, floods, and wildfires, are events or conditions that have the potential to cause harm to people or the environment. At the same time, transition risks focus on the financial, economic, and social risks related to large carbon emission reductions and decarbonisation. The world is witnessing an increase in migration as individuals seek to relocate in hopes of escaping poverty, disease, and malnutrition resulting from changing ecosystems. More services offering comprehensive physical hazards and transition risks are now entering the market. Munich Re, for example, has a Location Risk Intelligence tool that now includes a natural hazard edition covering 18 physical hazards. Meanwhile, XDI complements its asset specific analysis with additional measures of contextual risk, including 'first mile risk', 'regional economic risk', and proxies for 'sector-based supply chain risk. Another example of improvement is in the coverage of Scope 3 emissions. Providers such as ICE, ISS ESG, and S&P/TCS are now offering more granularity in this regard. As a consequence of the market integration seen in recent years, more second-order effects of climate impacts are now also getting addressed. The overall effect is to shed more light on the consequences of climate change. Interestingly, the causative factors now being identified and mapped by providers are shown to be broader than previously might have been expected.



2.2 Updated scenarios and a growing focus on net-zero commitments in many tools

The mainstreaming of net zero

The rapid activity witnessed in the private sector reflects the urgency to push for an immediate and all-encompassing transition towards decarbonisation. The international scientific community agrees that the global average temperature must be kept below 1.5°C above pre-industrial levels in order to avoid the worst possible climate outcomes and the crossing of tipping points. In recent years, a global consensus on the need to limit warming to 1.5°C and reach net-zero CO_2 emissions by 2050 has taken place. This has been heavily influenced by the Intergovernmental Panel on Climate Change (IPCC)'s Special Report on Global Warming of 1.5°C report, which showed that the harmful effects of 2°C of warming were much more significant than those of 1.5°C. Increasingly, governments are either proposing firm net-zero goals or considering doing so. At present, over 91% of global GDP (representing 83% of global GHG emissions) is captured by government net-zero targets (Net Zero Tracker, 2022). Private-sector actors have also made commitments to decarbonise and are devoting resources to setting specific targets and beginning their journeys to net zero.

This growing focus on net zero has required tool providers to ensure that they include 1.5°C pathways in their offerings. Firms that have made net-zero commitments are looking to set their targets using clear pathways to 1.5°C with the assistance of alignment tools. Supervisors have shown increasing interest in 1.5°C scenarios as the goal of net zero emerges as a firm aspiration and a mainstream governmental policy. As a result, new 1.5°C transition pathways developed by organisations like the NGFS and International Energy Agency (IEA) are now integrated into many tools. Providers like Moody's Analytics, ICE, CLIMAFIN, Oliver Wyman/S&P Global, BlackRock's Aladdin Climate, and Ortec Finance already offer Net Zero 2050 scenarios on their tools. The MSCI organisation added the NGFS scenarios in early 2022 and supplementary IPCC scenarios for the physical risk assessment towards the end of the same year. In the near future, ISS ESG is also expected to incorporate the NGFS scenarios into its climate risk evaluation tools. Similarly, WTW's methodology includes orderly transition to 1.5°C among nine scenarios. For its part, Planetrics provides an assessment underneath orderly transition scenarios, including net-zero 2050 and below 2°C. In addition, it incorporates disorderly scenarios for Divergent Net Zero and Delayed Transition, with a policy ambition of 1.4–1.6°C as well as the Inevitable Policy Response's (IPR) Forecast Policy Scenario (FPS) and 1.5°C Required Policy Scenario (RPS). Such moves are evident among organisations outside this year's working group. The Cambridge Institute for Sustainable Leadership (CISL) provides a case in point. In its publication Targeting Net Zero, CISL has included the ClimateWise physical risk framework within its overarching Net-Zero Framework for FIs. A net-zero framework explains the details of a financial institution's strategic response to net zero through business models.

Updated scenarios

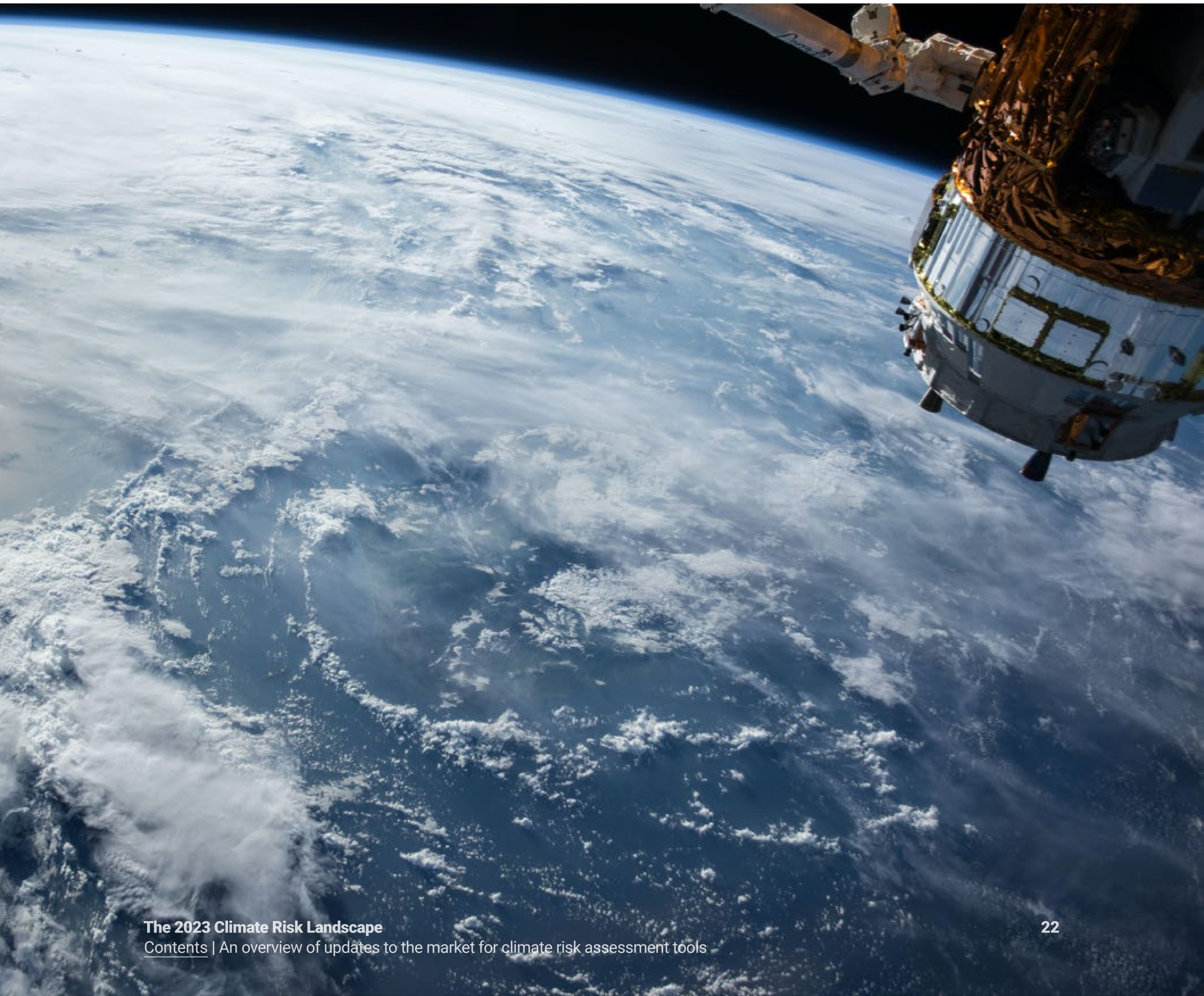
In addition to the growing focus on 1.5°C, scenarios have been updated more broadly, providing greater detail into sector behaviour under various decarbonisation scenarios. The IPCC provided an updated set of scenarios for tool providers to draw on. These scenarios reflect newer assumptions about elements such as renewables, government policies, and the latest carbon budget in the Working Group III (WGIII) contribution to the Sixth Assessment Report (AR6) report (IPCC, 2022). The final synthesis report is expected to be published in 2023 (IPCC, 2022). The IEA has updated its Net-zero Emissions by 2050 Scenario (NZE), offering a comprehensive account of how policymakers and others could respond coherently to the challenges of climate change, energy affordability, and energy security (IEA, 2022). This follows the IEA's 2021 *Net Zero by 2050* roadmap for the global energy sector to achieve net zero. In this publication, the IEA explored the implications of the NZE for the economy, the energy industry, citizens, and governments.

In September 2022, the NGFS published its third set of climate scenarios, which incorporated countries' commitments to reach net-zero emissions, increased sectoral granularity, and improved representation of physical risk (Mazars, 2022). The Principles for Responsible Investment's (PRI) Inevitable Policy Response (IPR) scenarios reflect likely policy developments based on a granular assessment of government commitments and policies currently under consideration (PRI, 2023). At the same time, industry experts are exploring the decarbonisation pathways for individual sectors. The publication of an academic article in the journal, *Nature Climate Change*, about reducing carbon in the US residential sector is one illustrative example of a wider trend. Tool providers are now integrating the latest transition scenario and assumption updates into their tools to reflect the speed at which society is acting and the economy is shifting. Moody's Analytics now has the capability to include additional macroeconomic variables to NGFS, for instance, showing the relationship between the predefined NGFS assumptions and the overall economy. BlackRock, MSCI, ICE, Planetrics, Oliver Wyman/S&P Global, and PwC are examples of some providers that are using the latest NGFS scenarios, and we anticipate that more will do so in the future.

Table 1: Updates to the most commonly used major models: IPCC, IEA, and NGFS, as of December 2022

Model	General Updates	Scenario Specific Updates
IPCC	Working Group III contribution to AR6: ▪ Alignment to 1.5°C scenarios is still possible but will require rapid and deep decarbonisation in all sectors. Renewables or fossil fuels with carbon capture and storage (CCS) will help achieve the necessary emissions reductions. ▪ Carbon dioxide removal (CDR) technology will balance residual GHG emissions. ▪ An expansion of policies and laws addressing mitigation have avoided excess emissions, but progress is uneven. ▪ Paris-Aligned financial flows are lagging. ▪ The GHG emissions drivers of the Shared Socioeconomic Pathway (SSP) scenarios are global population growth of 8.5–9.7 billion people by 2050 and GDP increases of 2.7–4.1% per year from 2015–2050.	▪ **Illustrative Mitigation Pathways (IMP)**: Show mitigation strategies to achieve rapid decarbonisation, focusing on renewables, achieving negative GHG emissions, low energy demand, shifting development pathways, and gradual strengthening of near-term mitigation actions. These IMPs are associated with below 2°C and 1.5°C scenarios, and some are classified alongside SSP1–1.9. ▪ **SSP2–4.5**: Global consumption-based carbon dioxide (CO_2) and CH_4 emissions in urban areas are expected to increase from 29 to 34 Gt in 2050. ▪ **SSP3–7.0**: Global consumption-based CO_2 and CH_4 emissions in urban areas increase up to 40 Gt. This pathway assumes slow technological change, high population growth, and high fragmentation, which could mean that warming pathways of 2°C or less may not prove feasible (medium confidence). ▪ **SSP5–8.5**: This pathway would assume a reversal of current technology and/or mitigation policy trends (medium confidence).
IEA	2022 World Energy Outlook (WEO): ▪ Provides key insights into how responses to the current global energy crisis sparked by Russia's invasion of Ukraine ties into its future scenario assumptions. ▪ Government policy responses are putting a clean energy economy and a fossil-fuel peak into view in their updated model assumptions. ▪ Stated pledges will help in the climate fight but there is still a gap between current ambitions and a 1.5°C future. ▪ 1.5°C achievement will ultimately come down to the speed and total investment in an economy built on clean and affordable energy, enabled by effective policymaking and incentives.	▪ **STEPS—Stated Policies Scenario**: Energy-related CO_2 emissions plateau and fall around 2050, leading to a rise of 2.5°C in global average temperature by 2100. Global energy demand growth of around 1% per year by 2030 is met almost entirely by renewables. It projects a global peak demand for fossil fuels such as coal in the coming years, natural gas flattening by 2030, and oil in the mid-2030s. ▪ **NZE2050—Net-zero Emissions by 2050**: CO_2 emissions fall to 23 Gigatonnes (Gt) by 2030 and to zero by 2050. There is a 50% increase of global energy demand by 2050, mostly coming from emerging economies. Getting to net zero requires a tripling of spending on clean energy and infrastructure by 2030. Achieving the NZE pathway is narrow but achievable with the necessary policy and technology advances. ▪ **APS—Announced Pledges Scenario**: Fossil-fuel demand is put into decline by 2030. GHG emissions peak in the mid-2020s and fall to 12 Gt in 2050, which is associated with a temperature increase of 1.7°C by 2100. Increases in global clean energy manufacturing are a driving factor for rapid deployment of clean technology.

NGFS	**Updated NGFS Scenarios for central banks and supervisors**: ▪ Includes country-level commitments to net zero at COP26 until March 2022. ▪ Incorporates the most updated trends in solar, wind, and other key mitigation technologies. ▪ GDP and population data assumption updates from the IMF World Economic Outlook 2021. ▪ Short and long-term effects from the war in Ukraine are excluded. ▪ Contains a more detailed representation of physical risk, including acute risks. ▪ Transition risks are represented with increased granularity in the transportation and industrial sectors.	▪ **Current Policies Scenario**: GDP losses up to 2100 are the highest in physical risk scenarios (up to 20% relative to prior trend). Limited transition risk is reflected by low impact to macroeconomic variables such as unemployment and inflation. ▪ **Disorderly Scenarios**: GDP losses from transition risks are highest, due to a combination of transition speed and investment uncertainty. Policy uncertainties could lead to higher investment premiums in the short term (i.e. two years); these level off thereafter. ▪ **Net-zero 2050**: Moderately negative GDP losses, with a balance of costs from carbon prices and overall energy costs, with recycling of carbon revenues into policy investments and employment taxes.



Additional time horizons

Short-term horizons

Along with updating the number and range of scenarios offered, tool providers are extending their time horizons. Tool providers started to include short-term time horizons on their platforms as analysts need to consider the effects of current climate shocks on their assets, such as the 2020 Australian wildfires and recent catastrophic flooding in California in Pakistan, as well as the drastic temperature rises across Europe in Summer 2022 (the hottest on record). The low-carbon transition also needs to happen quickly and in an orderly fashion in the short term. Further, the short-term transition targets are essential features of transition plans. Hence, it is crucial for investors to understand how—based on long-term scenarios with short-term interim steps—the targets of corporates align with the speed and scale of interim measures required to achieve them. Entelligent's transition risk (T-risk) scoring measures the short-term (two-year) price movements of corporate equities and fixed income of client portfolios. The scoring system is updated on a quarterly basis. On the physical risk side, Munich Re has a feature to track the financial impacts of climate events such as hurricanes in real-time. This live analysis is available through its location risk intelligence feature.

These tools can also help identify potential climate-related risks. That said, they cannot always capture the very short time horizon of some specific extreme weather events and other hard-to-predict hazards. In addition, providers also started to project transition risks in the medium and long term to align for an orderly transition. The Climate Credit Analytics tool offered by Oliver Wyman/S&P Global provides an extreme short-term scenario featuring a three-year carbon tax. Planetrics provides in-year impacts and can support on-custom, short-term scenario development.

In sum, it is important to note that no climate model can predict certain incidents with 100% accuracy or highlight specific weather events with the same accuracy as real-time weather forecasts. What climate models offer is a probability range. They can also project changes in the frequency and intensity of extreme weather events. In this way, they help in the identification of areas at increased risk of hazards. Other tools can also be used to predict specific weather events. An example is numerical weather prediction, which may have higher resolution and which can provide more accurate forecasts in the near term.

Long-term horizons

It is essential to measure both physical and transition risks in the long term because of the dynamics of climate change and decision-making. The current policies regarding carbon pricing, abatement technology developments, and net-zero commitments pave the way towards a future that is path-dependent on present developments. Therefore, tool providers need to offer long-term time horizons so that banks can see what their future assets could look like based on policy and financial decisions taken today. MSCI, CLIMAFIN, BlackRock's Aladdin Climate, JBA, Munich Re, XDI, Moody's Analytics, South Pole, ISS ESG, The Climate Service/ S&P Global, ICE, and Ortec Finance all provide time horizons extending until 2100, while McKinsey's Planetrics can conduct long-term analysis outside of its platform.

2.3 Improved data availability and transparency regarding tool methodologies

Faced with more pressure from FIs, regulators, non-governmental organisations (NGOs), and corporates from the real economy, the tool providers are improving and refining their methodologies and approaches. WTW, for instance, has applied an innovative approach to expand coverage, combining natural language processing (NLP) with financial data-based machine learning to analyse public, private, and fixed-income products.

Method transparency

There are certain challenges and limitations that these tools might never be able to overcome because of the uncertainty of climate change or because of the limitations of modelling and data. Despite these constraints, providers can enhance representations of uncertainty through qualitative methods or through the implementation of shock scenarios. Furthermore, the execution of multiple scenario analyses and sensitivity analyses within individual scenarios (i.e. Monte Carlo simulations) can provide a comprehensive understanding of the sensitivity of results to assumptions and parameters, shedding light on known unknowns. Additionally, it is crucial for providers to communicate openly and honestly about the limitations of their analysis and the potential presence of unknown unknowns.

Climate change does not necessarily follow a linear trajectory. Furthermore, its shocks do not follow a normal distribution, with tail-end catastrophes and tipping points as real possibilities (Battiston et al., 2017). Climate analytics company CLIMAFIN has been upfront and transparent about general climate uncertainty in the Integrated Assessment Modelling (IAM) and emphasised the additional uncertainties of model choice and policymaker unpredictability. They also pointed out that the metrics banks used to make decisions or to report financial disclosures are entirely dependent on the chosen scenarios and a model's underlying economic assumptions, such as the utility curve, the expected rate of future production, and the estimated social cost of carbon. Additionally, Planetrics provides multiple sensitivity analyses to test uncertainty. It also offers transparent documentation to ensure the validity of its model. Even if the modellers of the tools could accurately predict the costs and benefits of a particular pathway, the realisation of that pathway still needs to be ascertained because of assumptions about the rationality and aggressiveness of policymakers. When tool providers are open about how their models and methodologies work, banks can better understand the risk their portfolios face and therefore produce more responsible and effective reports. Most FIs surveyed flagged transparency as one of the most important factors when choosing or collaborating with a vendor.

What do you find most important when choosing/collaborating with a vendor?

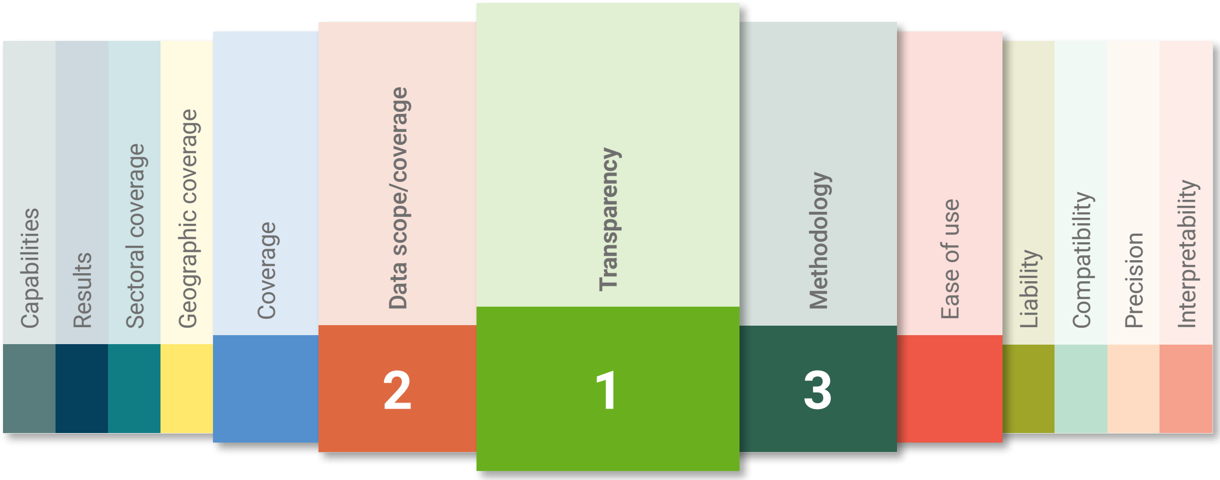


Figure 1: Survey results of important factors when choosing a vendor (UNEP FI, 2022).

Given the immense uncertainty around climate change and economic modelling, there is even more pressure for tool providers to be transparent about their coverage, methodologies and chosen metrics of different sectors and emissions. Methodology and approaches can be communicated by materials from vendors. One example is MSCI ESG Manager that offers downloadable factsheets to explain their functions and fundamental approaches. ISS ESG, S&P Global's TCS, and Oliver Wyman/S&P Global provide their users with comprehensive methodology documents, allowing banks to work through the modelling assumptions they make and interpret the output with greater understanding and confidence. Users who access BlackRock's Aladdin Climate via the integrated platform have access to comprehensive education materials covering both methodology and metrics via tear sheets, whitepapers, and 'deep dive' videos. Moody's Climate Solutions provides its clients access to over one thousand pages of methodology and validation documentation on climate risk data and analytics.

By enhancing transparency among the climate analytical solutions, the credibility of the solutions is likely to increase. At the same time, tool provides face the challenge in today's increasingly competitive environment of protecting their intellectual property. One potential way to address these conflicting demands is to use a third-party for validation. This can boost the trust in the tool without the risk of commercially sensitive information being compromised. To improve transparency, companies could also choose to disclose information in standardised reports, such as those submitted in line with TCFD recommendations (MSCI, 2022).

Data availability

Another notable trend is the gradual improvement in the clarity with which Scope 3 emissions are estimated. For instance, many providers now account for all three emission Scopes in their methodologies; examples here include MSCI ESG Research, ICE, ISS ESG, Oliver Wyman/S&P Global and Planetrics. In part, this extra clarity is the result of requests from FIs for greater transparency on the topic. One tool provider to respond is Carbone 4, which announced in November 2021 that it would introduce a simplified, bottom-up approach to calculate Scope 3 emissions through sectoral statistical ratios. The market trend of transparency thus facilitates exchanges between peer tool providers and, even more importantly, it supports the cultivation of domain knowledge for FIs.

The accumulated knowledge is further enhanced by increased data availability and open-source approaches provided by international organisations, research institutions, and private-sector vendors. For example, the IEA has established a Policies and Measures Database in order to bring together information about past, existing, and planned government policies and measures relating to climate change. These government actions might be geared towards reducing GHG emissions, improving energy efficiency, supporting the development and deployment of renewables and other clean energy technologies, or other climate-related goals. IEA also provides free datasets regarding sub-sectors in the energy industry. The NGFS, meanwhile, provides data and technical resources corresponding to its scenarios. Likewise, the International Monetary Fund (IMF) supplies downloadable metadata on its climate change dashboards for all indicators, from financial risk to government policy and economic activity. As for the World Bank, it provides global data on historical and future climate, vulnerabilities, and impacts through its Climate Change Knowledge Portal.

The 2° Investing Initiative has delivered a series of software and web-based, open-source climate analytic solutions, including PACTA SaaS, PACTA for Banks, PACTA for Investors, and PACTA for Authorities. These tools have been co-developed by a dozen researchers since 2012, with input from research partners and FIs. Users can access them free of charge (2DII, 2022). PACTA is now under RMI's stewardship. Another example of data transparency is the Climate Risk Toolbox created by the Food and Agriculture Organization of the United Nations (FAO). The web-based toolbox aims to support the FAO's overall aim of accelerating agricultural transformation and sustainable rural development. It does so by providing users with the means to conduct climate risk screenings based on advanced climate-related geospatial data (FAO, 2022).

2.4 Development of user-friendly and purpose-built tools to meet disclosure needs

There are several ways that tools express their output metrics. The *2021 Landscape Report* categorised them as quantitative, semi-quantitative, financial, non-financial, and representative of temperature alignment. Building off the last report, most providers use either quantitative or financial metrics to represent their risk assessments. Examples include assets linked to climate risks, GHG emissions quantities, probability of default (PD) or loss, expected loss given default (LGD), and value-at-risk. It has been observed that banks consider metrics such as PD and LGD to be pertinent for decision-making processes, as these are essential to conduct supervisory pilot scenario analyses and stress tests. These metrics are often required for such exercises and are deemed to be core estimates by supervisory authorities. According to Climate Credit Analytics' methodology, it is easier to understand metrics if they are expressed as changes to financial statements rather than stand-alone "climate scores". However, this does not mean these qualitative climate scores should not be included as output metrics. For example, there is merit in providing temperature alignment or climate narrative metrics in addition to quantitative or financial values. Since last year's landscape report, PwC and Ortec Finance's ClimateMAPS have introduced dashboard features that explain the climate transition risk that a portfolio has accumulated in written words. ClimateMAPS includes policy and transition metrics, as well as slow-onset and extreme weather per hazard narratives and heat maps. Additionally, there are qualitative narratives for risks that are currently difficult to quantify, such as tipping points. Planetrics has updated its PlanetView platform to include information boxes that provide context and definitions for outputs to aid interpretation. During UNEP FI's 2021–2022 exercise, FIs piloted climate risk tools, assessing both physical, and transition risk, and provided feedback on the form of the outputs generated. They believed it would be especially helpful to include qualitative features to support the interpretation of results. One such feature could be a written explanation of the sum of expected financial loss due to climate change per hazard and per asset. PwC has recently introduced a heatmap feature, aimed at facilitating the visualisation of metrics' impacts on a global map of a bank's assets (PwC, 2020). Additionally, MSCI ESG Research provides access to a platform known as Climate Lab Company that enables banks to delve into individual issuers and examine their Asset Locations and Hazard Maps.

Exceptions exist. The Frankfurt-based tool provider, 'right. based on science', for example, does not use a combination of qualitative, quantitative, and financial metrics. Instead, it expresses all metrics in degrees Celsius, believing that this measure helps close the gap between abstract climate change impact and financial actors' perception of how they can contribute to reaching net zero.

Usability, interactivity, and improved visualisation through geospatial mapping can be a way for tool providers to produce more digestible output alongside quantitative data. Mapping a portfolio of assets is particularly useful when determining physical risks and individual hazards on individual investments. An example is Munich Re and XDI, who use this feature to map physical locations to their exact coordinates. Within Munich Re's offering, a firm can overlay climate hazards (e.g. flood risk) across multiple temperature scenarios up to 2100 on a specific asset. Intuitive colour scaling is included in each category. Visualisation in a user-friendly manner can assist with interpreting results beyond the exportable scores and financial impacts seen in an Excel spreadsheet.

The financial industry has been advocating for the adoption of metrics related to transition and physical risk assessments to facilitate the provision of meaningful disclosures. In recent times, several providers have developed tools that align with disclosure requirements, including BlackRock's Aladdin Climate. This tool presents its findings in the form of a platform-based interface and data sets that can be further analysed or tailored to incorporate additional data or alternative economic assumptions. This versatility enables banks to engage with the data at a deeper level and refine their understanding of the transition risk that they may face. Other tool vendors create disclosure reports for their users. MSCI, McKinsey's Planetrics, Oliver Wyman/S&P Global, and ISS ESG have automated exportable features that can easily facilitate comparisons. For PwC, the export function is available for the transition real estate. ICE, a relatively new tool provider and one more heavily focused on climate stress testing, generates TCFD compliance reports for its users. Although downloadable reports and summary metrics may not have the same detail as the asset-by-asset assessments that underpin them, they can be valuable for decision makers to understand a firm's overall climate risks.

While these different combinations of metric types and automated report features are important to banks, there still seems to be an interpretation gap. According to a survey conducted in 2022 by UNEP FI's Tools Demo working group, two of the biggest challenges that FIs face when using a tool are the interpretation of outputs and the understanding of the methodologies used in the tools. These firms are looking for more than the existing features to help them understand the risk in their portfolios, and providers must evolve their offerings to meet these demands. In addition, as a reiteration of a point made in Section 3.3, there is a continuous need for tool providers to be transparent about the metrics and reports they deliver and how they estimate them. Methodological documents may need to be considered as an additional part of tool outputs to facilitate strong risk interpretations.

What are the biggest challenges you are facing within that process besides data availability and modeling certainty?

Figure 2: Survey results of challenges FIs are facing with vendors outputs (UNEP FI, 2022).

SECTION 3:
Overview of transition risk approaches

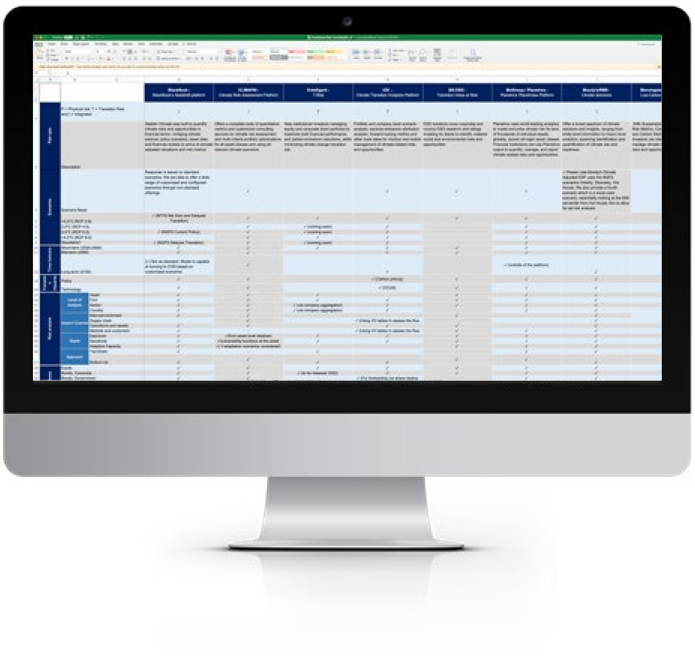
3.1 Introduction to transition risk assessments

Transition risk assessments can require access to detailed inferences about the development and deployment of future technology, a considerable amount of emissions data, a wide range of climate and macroeconomic models, and an understanding of forward-looking climate and economic assumptions. Almost all methodologies use climate hazards and forward-looking carbon policy and technology variables as inputs to measure the risk to clients on their operations and value chains, with results often expressed in financial metrics. This section provides an overview of current transition risk methodologies that commercial service providers have developed.

This report compares various methodologies in the transition risk assessment space. However, for those looking to explore more detailed comparisons of methodological features, we suggest referring to the rigorous assessment of selected transition risk methodologies conducted by the Swiss Federal Institute of Technology (Bingler, Colesanti Senni and Monnin, 2020). Other additional resources include a recent article from the IEA (IEA, 2021) and a technical documentation from the NGFS (NGFS, 2021), as well as an academic paper by Bingler *et al*. that focuses on how risk assessment methodologies could be enhanced (Bingler, Colesanti Senni, 2020).

In the link below, readers can find an excel summary of several service providers and their transition risk assessment tools and analytics. The information incorporated in this overview has been obtained from publicly available sources, survey responses, or contributions from most climate assessment service providers, following the assessment framework developed by the *2021 Landscape Report*. The set of service providers listed and reviewed in this section is certainly not exhaustive, but we have attempted to include the principal commercially available methodologies.

Click here to access the transition risk assessment tools and analytics service providers



3.2 Climate Transition Scenarios

Transition scenarios form the basis of tool providers' core assumptions when evaluating financial risks from climate change, and they are built around a global temperature target or emissions pathway. Despite the growing universe of scenarios, there are four common storylines or pathways that most models follow: (i) ambitious Paris Agreement-aligned action; (ii) delayed Paris Agreement-aligned action; (iii) current policy commitments; and (iv) business as usual (WBCSD, 2022). For example, the six NGFS scenarios can be translated to these four categories. Orderly net-zero 2050, Below 2°C, and Divergent Net Zero correspond with ambitious Paris Agreement-aligned action, as they all include immediate action with below 2°C warming targets, considering both an orderly and disorderly transition. The Delayed Transition scenario is Paris Agreement-aligned in ambition as it has a 1.6°C target, yet policies and technology changes are slower, hence it is comparable to delayed Paris Agreement-aligned action. Current Policies are represented under the Nationally Determined Contributions (NDCs) scenario, and business as usual correlates with the Current Policies scenario.

Many transition scenarios make use of complex Integrated Assessment Models (IAMs), which answer "what if" questions and provide "insights, not numbers" into different mitigation options. As the NGFS points out in its key messages, the scenarios are not forecasts. The purpose of its scenarios is to explore future risks and prepare for their potential shocks to the financial system, including plausible (though not always probable or desired) futures (NGFS, 2022). Understanding IAM assumptions is crucial to interpreting the complexity and interactions of each pathway (UNEP FI, 2021). The primary assumptions of these models include gross domestic product (GDP), population growth rates, and global carbon pricing; secondary assumptions may comprise shadow carbon pricing that includes the social cost of carbon, shifts in consumer behaviour, improvements in energy efficiency, increased productivity, technical progress such as CCS, and renewable energy development and deployment (NGFS, 2022).

Numerous institutions have developed transition scenario models in recent years. However, many tool providers use a sub-set of models from the IPCC, IEA, the NGFS, IPR, the International Renewable Energy Agency (IRENA), and the One Earth Climate Model (OECM). A summary table of these scenarios can be found in Appendix A, including outlines of their representative pathways, their associated temperature increases, and the basis of their development. In partnership with Vivid Economics, the World Business Council for Sustainable Development (WBCSD) has also developed a catalogue of well-known transition models and bespoke approaches accessible through an interactive online tool. For the scope of this updated report, we summarise three key models for transition risk analysis: the IPCC, IEA, and the NGFS.

International Panel on Climate Change (IPCC)

The IPCC's Sixth Assessment Cycle has incorporated enhanced climate models from the Coupled Model Intercomparison Project (CMIP-6-project), allowing the IPCC to take outputs from multiple IAMs and average the results to reduce uncertainty (WBCSD, 2022). The WGIII's contribution in 2022 can be categorised by four headline conclusions that form the basis of the assumptions determining transition risk across the IPCC scenarios:

GHG emissions have risen globally, yet the unit costs and policies enabling low-emissions technology have dramatically accelerated deployment since AR5's release in 2014	A transition to global net zero by 2050 will require an all-encompassing system transformation to be accomplished with a portfolio approach spanning mitigation technologies, energy efficiency, retrofitting, CDR, and demand-side measures	Linking mitigation and adaptation is crucial for sustainable development	A strengthened global response in the form of better designed governance, regulation, and economic instruments will remove barriers to mitigation in the near term

International Energy Agency (IEA)

The IEA's annual World Energy Outlook (WEO) provides cutting edge research into global trends in energy demand and supply and their implications for energy security, environmental protection, and economic development. It creates detailed projections through its Global Energy and Climate (GEC) Model, which gathers over 20 years of modelling capabilities and is designed to replicate the entire energy system (IEA 2022). The assumptions underlying the transition risk scenarios from this year's WEO can be summarised as follows:

Global energy demand will increase significantly in all scenarios, with a majority coming from emerging and developing markets.	Investments in clean energy are still well below the requirements for net zero by 2050.	Despite underinvestment, enabling policies can rapidly increase renewable technology investments that can put a peak-fossil fuel timeline into view.	No new investments in unabated coal power plants and mines are to be made after 2030 to reach net zero by 2050, and global demand for coal falls in all scenarios, though more quickly in advanced economies.

Network for Greening the Financial System (NGFS)

The NGFS's scenarios are a starting point for analysing climate risks in the economy with special consideration for the financial system. The scenarios aim to prepare the financial sector for future shocks and risks associated with climate change. The model assumptions across scenarios have been updated in its third iteration in 2022, with three key conclusions directly influencing transition risk below (NGFS, 2022):

A higher carbon price is needed to achieve a net-zero transition by 2050, as seen by inclusion of a shadow carbon price. The shadow price accounts for policy intensity and changes in technology and consumer preferences.	The scenarios assume low to medium availability of CDR technologies but vary across differing cost assumptions, countries, and availability of CDR options.	The net-zero transition will require massive investments in green electricity and storage. Coal will also be wound down to nearly zero in 2050, and renewables and biomass will deliver about two-thirds of global energy needs.

Updates from other institutions

OECM 2.0 was commissioned by the United Nations Net-Zero Asset Owner Alliance (NZAOA) in August 2022 with the goal of developing science-based sectoral decarbonisation pathways and targets for 12 major industries. OECM 2.0 improves upon OECM 1.0 by merging three independent models into one connected MATLAB-based energy assessment model covering the entire global energy system. It also enhances the model by incorporating energy demand and supply scenarios for each sector using individualised GDP projections, market forecasts, and material flows while covering Scope 1, 2, and 3 emissions. In the future, OECM will be a part of a growing scientific effort to develop a transition pathway that achieves a 100% renewable energy future, also known as 100RE modelling. The main conclusions from recent studies are that 100% renewable is feasible worldwide at low cost (Scott, 2022).

The IPR recently developed Quarterly Forecast Trackers (QFTs) in November 2022 to assess policy, technology, and land use developments. Along with this, QFTs measure the speed of policy ambition against their 2021 IPR scenarios of IPR 1.8°C Forecast Policy Scenario (FPS), and the 1.5°C Required Policy Scenario (RPS). QFTs also provide in-depth detail of accelerations in energy, land-related, and technology developments via policy gap, heatmap, and 10-point scale analysis (PRI, 2022). In January 2023, IPR announced the first integrated nature and climate IPR Forecast Policy Scenario + Nature (FPS + Nature). This meets the need for a forward-looking view of how policy trends relate to protected areas, land restoration, nature markets, climate drivers, as well as how technology and social trends impact land use and energy-related value drivers. FPS + Nature is seen as a 'beta version' for future nature-related scenarios (IPR, 2023).

IRENA provides transition modelling of the energy system with a focus on renewables. Through its 2022 World Energy Transitions Outlook, it also models the scaling-up of electrification and energy efficiency measures that are enabled by renewables, hydrogen, and sustainable biomass, along with last-mile use of CCS—all of which it identifies as key drivers to maintain a 1.5°C pathway. The Outlook presents an analysis of the actions required by 2030 to achieve the 1.5°C pathway in 2050, as recommended by the IPCC. In line with other findings already mentioned, progress towards these goals will require well-targeted investments into renewables with a portfolio mix of technologies. These investments must be enabled by policy packages to incentivise fossil-fuel phasedown and encourage society-wide behaviour change (IRENA, 2022).

3.3 Transition risks

Transition risks are related to the adjustment process toward a low-carbon economy. The drivers of these risks are generally global, even though the specific nature of these drivers will vary in different national economic contexts. The list below covers the different risks, including the description of possible developments to measure the climate-related changes that could generate, increase, or reduce transition risks. These transition risks, once realised, could result in stranded assets, loss of markets, reduced returns on investment, and financial penalties. However, if properly anticipated and effectively managed, these challenges can also present opportunities for improvement and may result in superior performance compared to peers who are less prepared.

Table 2: Transition risks and indicators

Transition risks	Risk drivers
Policy and Legal	▪ Increased pricing of GHG emissions, carbon footprint Scope 1–3 ▪ Enhanced emissions-reporting obligations ▪ Mandates on and regulation of existing products and services ▪ Exposure to litigation
Technology	▪ Substitution of existing products and services with lower-emission options (within lifetime = stranding assets; after lifetime = replacement investment) ▪ Unsuccessful investment in new technologies ▪ Stranding new investments ▪ Upfront costs to transition to lower-emission technologies ▪ Higher operating costs from high-emission technologies
Markets	▪ Changing customer behaviour ▪ Shift in consumer preferences ▪ Uncertainty in market signals ▪ Increased cost of raw materials ▪ Shift in financial and balance-sheet asset values ▪ Failure to capture new market opportunities and technologies via clean technology research and development and clean technology export activities
Reputation	▪ Stigmatisation of sector ▪ Increased stakeholder concern or negative stakeholder feedback ▪ Brown Share Assessment

3.4 Risk assessment methodologies

Compared to the 2021 Landscape Report, little has been updated within the methodology's areas. However, the essential topics are summarised in the upcoming section. Methodologies for the forward-looking analysis of transition risks must incorporate a range of variables and estimates that affect the economic impact at the macroeconomic or sectoral level, which then translate to the firm level. Finally, they must enable the long-term financial impact on an FI to be estimated. Generally, there are two different data sets: (i) backward-looking status quo data such as GHG emissions; and (ii) forward-looking parameters. The combination of these data points, especially the forward-looking piece, can be used in different metrics and use cases.

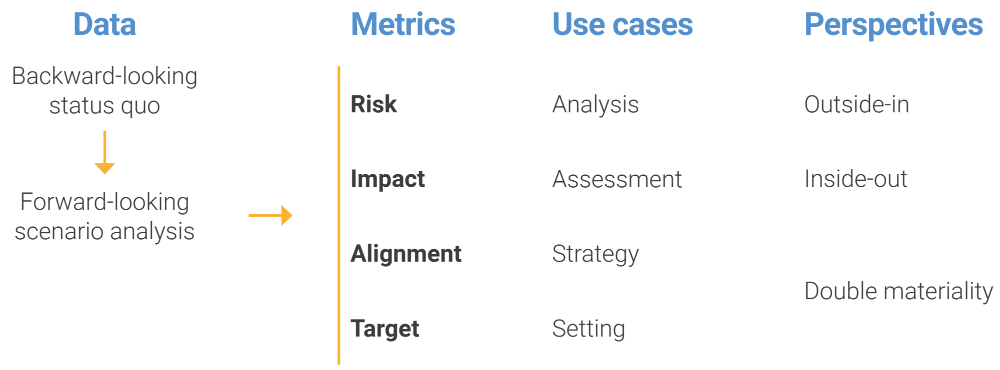


Figure 3: Transition metrics landscape (Julia Bingler, for UNEP FI, 2023)

All categories relate to the viewpoint of chosen perspective: i.e., outside-in, inside-out, or double materiality considerations. None of them are mutually exclusive, as an FI can use an alignment strategy to make a gap analysis that allows it to assess the risks. Figure 4 below gives an overview of how the data sets and metrics can be used through a bottom-up structure to generate financial impact results.

Most of the tools specialised in transition risk assessment use a general analysis structure to generate a climate-adjusted financial risk indicator as one of the common outputs. The flow starts with selecting a temperature limit that the organisation wants to consider under a specific scenario analysis approach. In the next step, there are the socio-economic assumptions that the analyst needs to identify to translate temperature limits into society development parameters, such as technology development assumptions. The user feeds those assumptions into a climate model that the IEA and similar expert institutions provide. These three input factors comprise a specific transition scenario—namely: (i) the temperature limits, (ii) the socio-economic assumptions, and (iii) the climate transition model.

An illustrative transition scenario example is the IEA's Beyond 2-degree Scenario (B2DS). This scenario sets a rapid decarbonisation pathway in line with international policy goals. For the first time, the B2DS looks at how far clean energy technologies could go if pushed to their practical limits, in line with countries' more ambitious alignment goals with the Paris Agreement. Another generated output could be a normative IEA scenario that shows a pathway for the global energy sector to achieve net-zero CO_2 emissions by 2050, with advanced economies reaching net-zero emissions in advance of others. This scenario also meets key energy-related objectives of the United Nations Sustainable Development Goals (SDGs), particularly those relating to the achievement of universal energy access by 2030 and significant improvements in air quality. Another output example is the REMIND-MAgPIE model output from the NGFS. This optimisation model integrates macroeconomic agriculture, land use, energy, water, and climate systems (see Appendix C).

Top-down vs. bottom-up structure

These model outputs are then put into an economic model with either top-down or bottom-up designs, or a combination of both. Top-down design directly models economic impacts at the macroeconomic or sector level, where the end user would receive the change in GDP or demand in specific product categories. Bottom-up design, in contrast, builds the economic impacts up from the firm level. This follows a technology model where the result is expressed as the technology investment that is required to reach a specific temperature limit.

Bottom-up methodologies provide more granular assessment with arguably more accurate near-term results. The reason for this is that bottom-up approaches consider the effects of climate change in the recent past, typically based on recall and specific aspects of human-environment systems. This can include information about specific human practices and their impacts, as well as the feedback loops and complex interactions that have occurred between human activities and the environment. This approach provides more detailed information at the firm level and throughout the supply chain. Such approaches include BlackRock's Aladdin Climate, Carbone 4's Climate Impact, ICE's Element6, XDI's Cross Dependency Initiative, WTW's Climate Transition Value at Risk, PwC's Climate Excellence Tool, Oliver Wyman/S&P Global's Climate Credit Analytics, Planetrics, Verisk's Transition Risk Tool, and Moody's Investors Service's (MIS) Carbon Transition Assessment and Carbon & Energy Transition metrics.

Top-down approaches measure emissions against the global carbon budget. The argument in favour of this approach is that country-level emissions data are often more reliable and consistent than firm-level emissions data. Country estimates are likely to be more thoroughly verified than emissions from any individual firm. Additionally, top-down approaches more readily capture the networked effects of interacting climate risk drivers, including policy, technology, and physical risk. Ortec Finance's ClimateMAPS and Entelligent's SmartClimate Technologies are examples of top-down approaches.

Other providers, such as MSCI, employ a hybrid methodology that integrates both top-down and bottom-up approaches to assess the risks posed by future policies aimed at addressing climate change. ISS ESG has hybrid approach capabilities, but it largely relies on a top-down approach derived from regional and country-level assumptions about the carbon price. These prices translate to higher emissions costs in the form of increased company-level operating expenditures (OPEX).

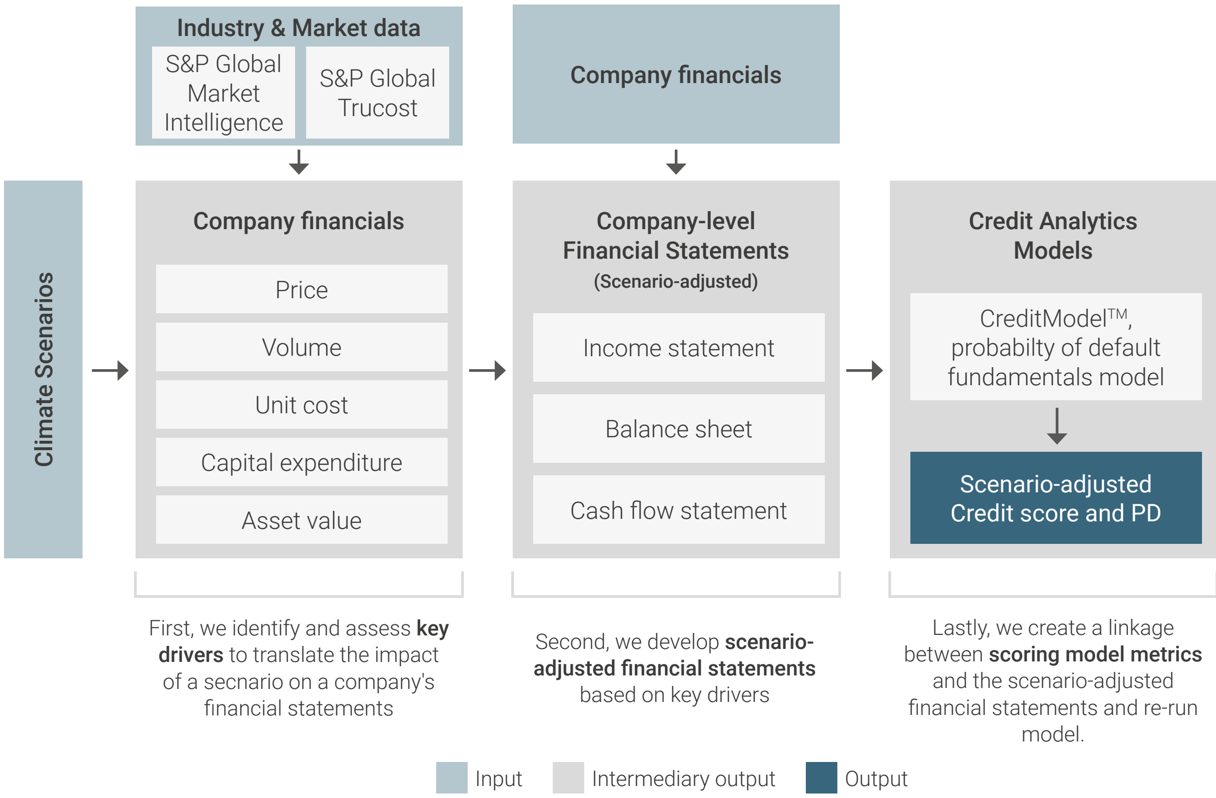


Figure 4: Bottom-up module sample (Oliver Wyman/S&P Global, 2020).

In the next phase, model outputs expressed as the change in GDP or technology investments are combined with firm-level economic climate risk indicators; e.g. emissions-intensive revenues or low-emissions capital expenditure (CAPEX). There are two options for analysis: a microeconomic model or a firm-level analysis of the model output. Among other deliverables, both options will lead to an output that describes a firm's risk profile in terms of revenues and costs changes.

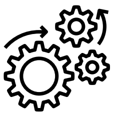
The analysis structure could stop there. However, as most FIs are interested in integrating those results into their internal processes to influence their credit risk processes, they must incorporate the model outputs into their financial modelling. Depending on their level of analysis, FIs may calculate the climate value-at-risk (cVaR) or the climate-adjusted probability of default (PD). Generally, climate risks can be transferred through different micro or macro transmission channels to financial risks. As an example, transition risks will affect businesses' profitability and households' wealth, which will create financial risks for lenders and investors. With that, those risks can lead to a shock in the broader economy through investment challenges and effects on productivity. They can also pose a massive threat when the transition leads to stranded assets.

Further, there are the effects of acute and chronic physical risks to consider. Acute impacts result from extreme weather events that can lead to business disruptions and damage to properties. These events can increase underwriting risks for insurers, leading to lower insurance coverage in some regions and impairing asset values. The second area of physical risks are chronic impacts, particularly from increased temperatures, sea levels rise, and precipitation that may affect labour, capital, land, and natural capital in specific areas. These changes will require significant investment and adaptation from companies, households, and governments. An important consideration is the possible climate-economy feedback cycle, which means that climate risks can have economic impacts and that, likewise, economic impacts can create climate impacts.

Using climate scenarios and associated socioeconomic pathways to determine financial risk at the sector and firm level depends on the approach the methodology takes. The methodology must enable the assessment of a range of variables and assumptions that affect the economic impact at the macroeconomic or sectoral level. Then, it must facilitate the translation of those impacts at the firm-level and subsequently generate an estimation of the financial impact to the FI in question. This report bases its methodological assessment on the framework developed in the Changing Course report, which looks at each methodology's scope and breadth of assessment. The scope of an assessment is across four principal impact channels:

Macro-environment: Economic trends at the macro-level tend to be the starting point for top-down analyses. Policy and technology changes at the country and sector level could impact macroeconomic indicators, such as economic growth, the balance of trade, and exchange rates (particularly in the case of disorderly transitions or price shocks).

Supply chain: Policy or technology shifts could see impacts on the upstream or downstream supply chain of counterparties; for example, through changing costs of electricity generation or increased demand for certain products such as electric vehicles.

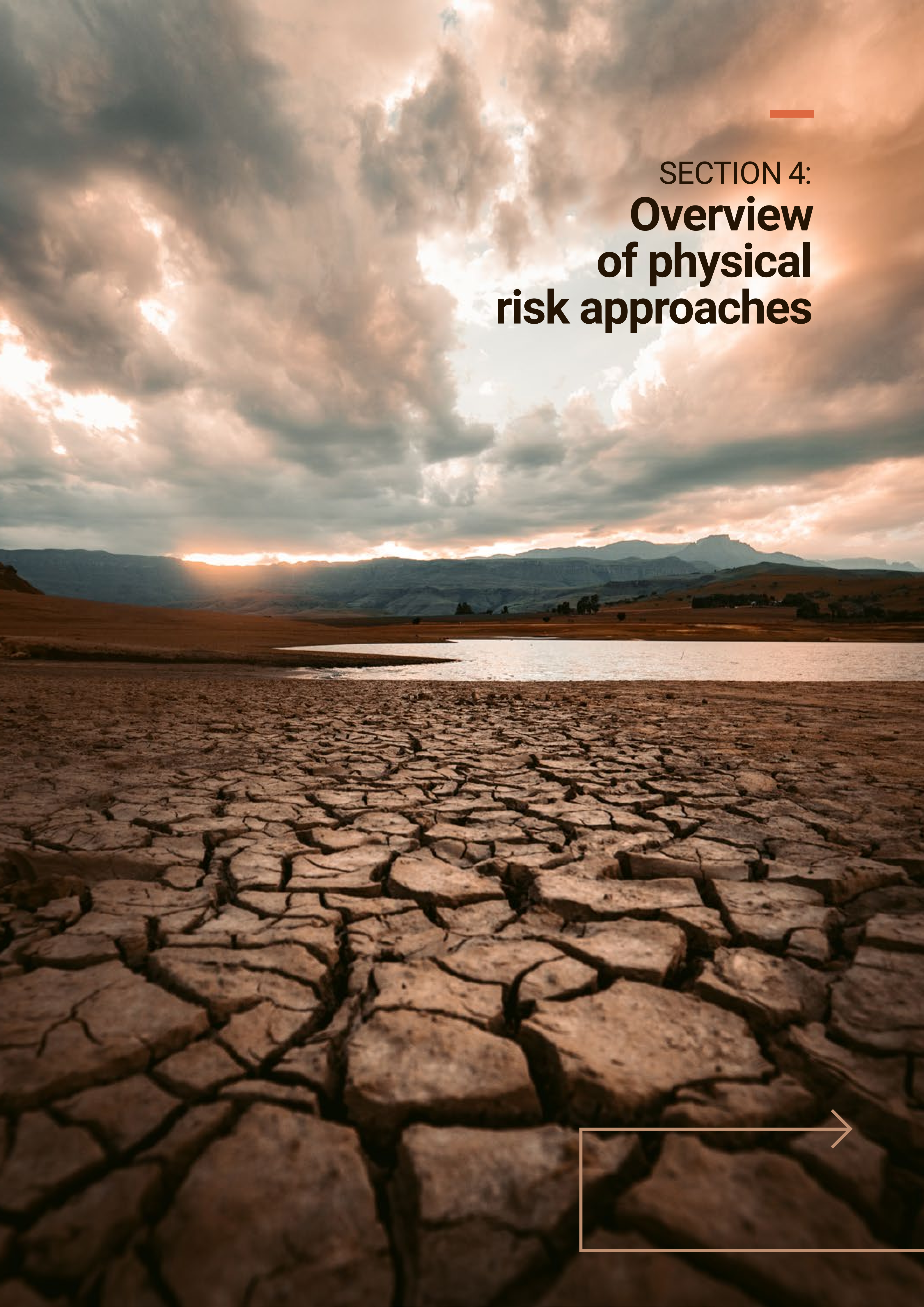


Operations and assets: This impact channel directly affects the operations of counterparties; i.e. Scope 1 emissions.

Market: For emissions-intensive industries, most transition impact will be through the Scope 3 emissions of consumers; so, for coal mining or oil & gas production, policy or technology changes will lead to changes in market demand.

SECTION 4:

Overview of physical risk approaches

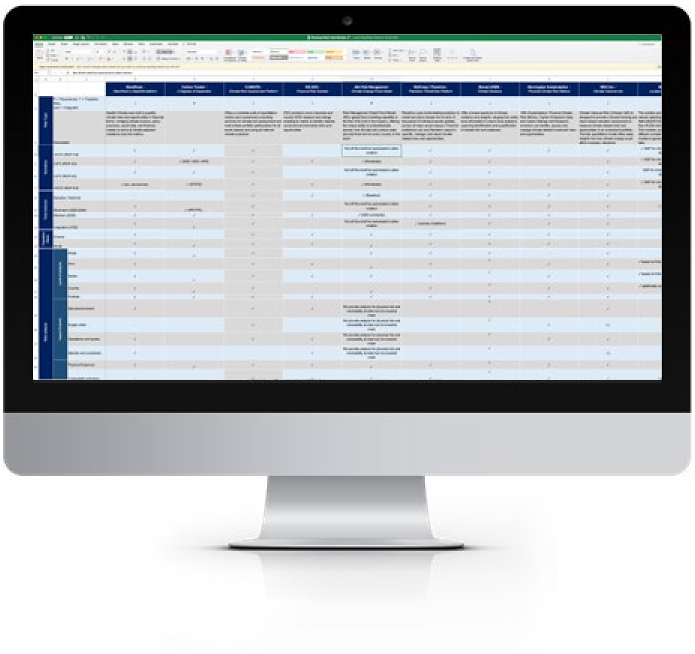


4.1 Introduction to physical risk assessments

This section provides an overview of the latest physical risk methodologies and builds on the structure of the original *2021 Landscape Report*. The aim of the updated version of the work in this report is primarily to accomplish completeness and to list new vendors with their offerings and coverage. Many FIs will continue to assess their transition and physical risk exposure. In response to this industry need, vendors can be expected to provide more robust and detailed integrated risk assessment solutions.

As with the transition risk overview in Chapter 3, the hyperlink below takes readers to an excel overview of multiple physical risk tools. The set of service providers listed and reviewed in this section is undoubtedly incomplete. However, we have attempted to include the principal commercially available methodologies. We also let participants choose which providers they want to have the detailed analysis of this year. For a detailed overview of the survey methodology and a set of case studies by banks using a selection of methods, please refer to the Charting a New Climate report. Beneath are a few additions to the commentary provided in the previous *2021 Landscape Report*.

Click here to access the physical risk assessment tools and analytics service providers



4.2 Physical risk scenarios

The IPCC, a United Nations body that reports on the state of climate research and is convened by UNEP and the World Meteorological Organization (WMO), established the Representative Concentration Pathway (RCP) scenarios for atmospheric GHG concentrations. These effectively measure the amount of warming that could occur by the end of this century. The RCPs are labelled after a possible range of radiative forcing values in the year 2100 (values commonly used include: 2.6, 4.5, 6.0, and 8.5 Watts per square metre) (IPCC AR5, 2014). Radiative forcing (RF) is a measure of the extra energy in the climate system, where the RF of a gas is defined as the difference between incoming solar radiation and outgoing infrared radiation caused by the increased concentration of that gas. Scientists use these values to estimate potential temperature rises and subtract the energy flowing out from the energy flowing in. If the number is positive ("positive forcing"), there is a warming. If the number is negative ("negative forcing"), then there is cooling. Although RCP scenarios also apply to the transition side, they are more commonly used for physical risk assessment since different RCPs are converted into relevant potential temperatures. Figure 5 below elaborates on the four pathways developed by IPCC, which describe different climate futures that span a broad range of forcing in 2100.

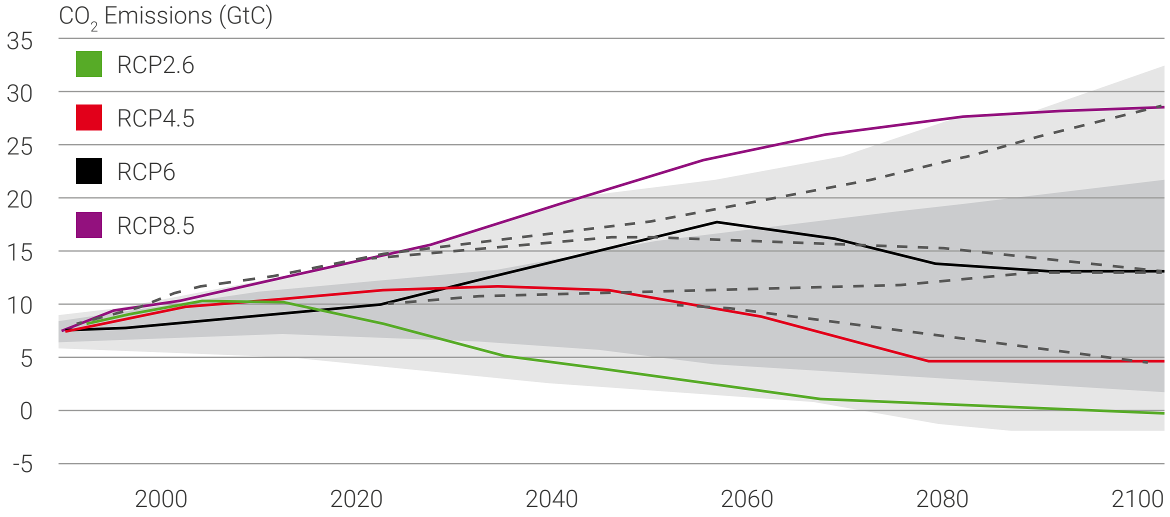


Figure 5: Emissions of carbon dioxide across the RCPs (van Vuuren *et. al.*, 2011).

RCP 2.6	A strong mitigation scenario leading to a warming typically aligned to <2°C of warming by 2100 relative to the pre-industrial period (1850–1900)
RCP 4.5	A moderate mitigation scenario leading to a warming at the end of the 21st century of more than 2°C relative to the pre-industrial period (1850–1900)
RCP 6.0	A low mitigation scenario leading to a warming at the end of the 21st century of probably less than 3°C relative to the pre-industrial period (1850–1900)
RCP 8.5	A no mitigation scenario leading to a warming at the end of the 21st century of probably more than 4°C relative to the pre-industrial period (1850–1900)

These RCP scenarios did not include socioeconomic "narratives" alongside the parameters. This explains why, since AR5, the original pathways have been considered together with Shared Socioeconomic Pathways (SSPs). Those models analysed how socioeconomic factors, such as population, economic growth, education, urbanisation, and the rate of technological development, may change over the next century. They also defined how societal choices can lead to changes in RFs. RCPs and SSPs are judged to be complementary. Combining them together allows for a standardised comparison of societal changes and the resulting level of global warming (Taylor, 2018). The RCPs set pathways for GHG concentrations that represent the amount of warming that could occur by the end of this century. In comparison, the SSPs set the stage on which reductions in emissions will (or will not) be achieved. They are used in six IAMs to derive emissions scenarios without (baseline scenarios) and with climate policies (mitigation scenarios). Each SSP can theoretically be coherent with several RCPs as long as it is plausible within the underlined narrative (Carbon Brief, 2018).

The latest version of SSP scenarios was developed in 2021 by the IPCC AR6. These scenarios are expressed in the format of SSPx-y, where 'SSPx' refers to the socioeconomic trends underlying the scenario, and 'y' refers to the approximate level of radiative forcing (in Watts per square metre) resulting from the scenario in the year 2100 (Reuters, 2021). Detailed descriptions are listed below. The IPCC AR6 has provided the explicit mapping between SSPs, and temperature rises in near, mid, and long terms, as presented in Appendix D. Figure 6 also outlines these five SSPs narratives and illustrates that global warming is near-linearly proportional to the CO_2 emitted.

SSP1–1.9	The IPCC's most aggressive scenario that describes a world where global CO_2 emissions are cut to net zero around 2050, with warming hitting 1.5°C but then dipping back down and stabilising around 1.4°C by the end of this century
SSP1–2.6	This scenario imagines the same socioeconomic shifts towards sustainability as SSP1–1.9, but temperatures stabilise around 1.8°C higher by 2100
SSP2–4.5	This pathway assumes that CO_2 emissions hover around current levels before starting to fall mid-century, but they do not reach net zero by 2100. Temperatures rise 2.7°C by the end of this century
SSP3–7.0	On this path, emissions and temperatures rise steadily and CO_2 emissions roughly double from current levels by 2100. By 2100, average temperatures have risen by 3.6°C
SSP5–8.5	Current CO_2 emissions levels roughly double by 2050. The global economy growth is fueled by exploiting fossil fuels and energy-intensive lifestyles. By 2100, the average global temperature is a scorching 4.4°C higher

Every tonne of CO_2 emissions adds to global warming

Global surface temperature increase since 1850–1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)

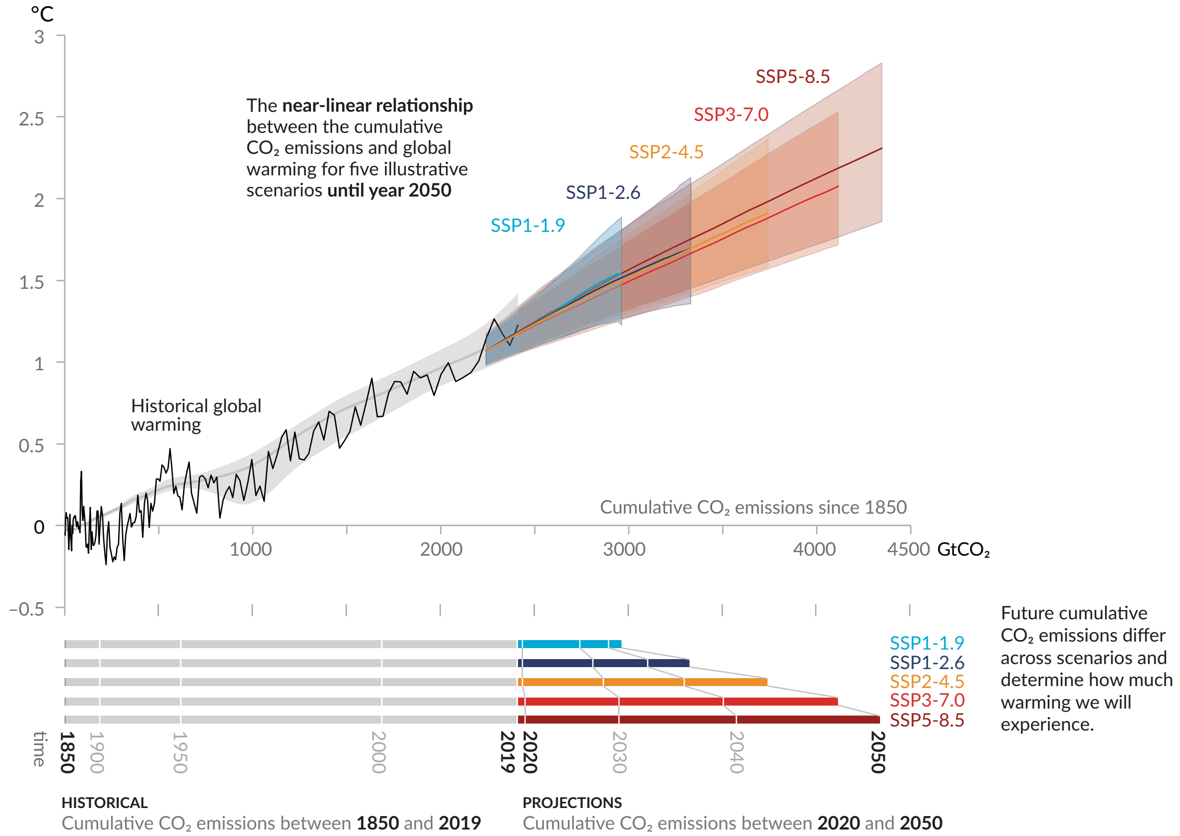


Figure 6: Every tonne of CO_2 emissions adds to global warming (IPCC, 2021).

As mentioned in Chapter 4.2, since 2016, the CMIP-6-project has combined SSP and RCP frameworks, and has defined eight future scenarios (from 2015–2100) and one historical scenario (from 1850–2014) (Hausfather, 2019). These CMIP scenarios, as listed in Appendix E, have several new features relevant to policymakers and others, and are used by scientists to improve and enhance climate change projections information. Considering the model's maturity, coupled with the nature of physical risk measurement and the comparability of results, most vendors still follow the RCP approach when running physical climate hazard assessment services. However, the integration could be improved and some providers are taking steps to do this. For example, MSCI seeks to provide consistent physical risk analysis by mapping the physical risk costs of an input RCP scenario onto the aligned output scenarios, such as the RCP-SSPs (e.g. SSP1–2.6) and NGFS scenarios.

Physical risk scenarios continue to be underpinned by assumptions of the IPCC RCPs, primarily through a moderate emissions pathway (RCP 4.5) and a high emissions scenario (RCP 8.5). RCP 8.5 is a helpful assessment scenario for modelling purposes, as the IPCC working groups use the RCP 8.5 scenario to contrast a world with extreme climate change with a world in which emissions remain low (Climate Matters, 2022). Climate scientists argue that the very high-end scenario is essential to study the potential physical risks of extreme climate change (Schwalm et al., 2020). Critics argue that labelling it as "business-as-usual" miscommunicates the likelihood of such a drastic increase in CO_2 emissions, and therefore should not be considered business-as-usual

(Hausfather & Peters, 2020). In the context of climate change, however, a "business-as-usual" scenario is often used to refer to a scenario in which GHG emissions continue to rise rapidly, with no significant changes or interventions to reduce them. With that, the term "business-as-usual" may not accurately convey the likelihood of a drastic increase in GHG emissions under an RCP 8.5 scenario. While GHG emissions could continue to rise under a business-as-usual scenario, it is important to note that many countries worldwide are taking steps to reduce their emissions, such as implementing carbon pricing schemes and investing in renewable energy. The actual outcome will depend on the actions taken by individuals, organisations, and governments to mitigate and adapt to climate change. In summary, a "business-as-usual" scenario may not accurately reflect the current or future reality of GHG emissions, and it is important to note that many actions are being taken to reduce emissions and mitigate the effects of climate change.

Building off the IPCC RCPs and SSPs, the NGFS has developed a series of physical risk scenarios. These provide another mainstream source of risk assessments for scenario analysis in the financial sector. These modelling efforts by FIs are a partnership with the NGFS to evaluate the financially relevant impacts associated with different physical risk scenarios. The NGFS scenarios include orderly and disorderly 1.5°C and 2°C scenarios (both of which are in the range of the low-temperature scenario RCP 2.6), a scenario based on NDCs associated with 2.5°C warming and a Current Policies scenario associated with 3°C+ of warming, which is closely related to the high temperature scenario of RCP 6.0. The transition pathways all share the same underlying socioeconomic assumptions that are derived from SSP2, which outlines a "middle-of-the-road" future (NGFS, 2022). According to the NGFS, the general criteria for physical risk scenarios include requirements to be: (i) plausible, representing a possible and realistic future; (ii) distinctive, exploring a range of different options; (iii) enable climate-related macroeconomic and financial risks to be identified and assessed with geographic considerations; and (iv) enable key sensitivities and nonlinearities to be captured (NGFS and World Bank, 2022).

The NGFS has updated its physical risk scenario results to reflect changes alongside its transition risk assessments in its 2022 Technical Documentation Report:

1. Temperatures rise in all pathways and exceed 3°C in the Current Policies pathway.
2. Temperature increases are unevenly felt worldwide, with areas of higher latitudes and land areas experiencing higher temperatures.
3. Estimates of chronic physical risk GDP losses were calculated at the country level. (Kalkuhl and Wenz, 2020). The results suggest that GDP losses could be up to 18% by the end of this century in the Current Policies Scenario, with losses highest in tropical geographies. However, the analysis does not account for extreme weather impacts, sea-level rise, migration, conflict, or adaptation measures.
4. GDP losses from acute physical risks were included for the first time in NGFS scenarios, using historic damages from extreme weather events taken from the international disaster database, EM-DAT.
5. This information was used as input to the NiGEM model to estimate the impacts of acute risks on global GDP in three NGFS scenarios. Several key factors were measured: (i) the hazard associated with each regional peril; (ii) the influence of climate change on the hazard; and (iii) the exposure, dependent on geography and including dynamics such as population, economic growth, and migration.

4.3 Physical hazards

The table below provides an overview of the latest available hazards among the tool providers, including frequently used indicator variables for them, and the secondary effects. As there are more hazards presented by the IPCC and other scientists, vendors continue to work on their hazard coverage and extend their indicators to capture secondary effects such as planned flood defences, and other metrics which relate to damage and loss, such as peak wind gusts, flood depths and wet-bulb temperatures.

Table 3: Physical risk hazards and a selection of commonly used indicators

Climate Hazards		Risk indicators	Secondary effects
Acute	**Hurricanes and typhoons**	▪ Cumulative wind speed	Coastal regions and islands are the most vulnerable as they are affected not only by the direct impact of a storm but also by secondary hazards, such as storm surges and pounding waves.
	Floods	▪ Flood frequency ▪ Flood severity ▪ Rainfall intensity ▪ Very wet days (>95th p) ▪ Wet days (>10mm)	Disruption of services, health impacts such as famine and disease, and tertiary effects could change the position of river channels, leading to landslides.
	Wildfire risk	▪ Change in days with high wildfire potential ▪ Change in maximum wildfire potential ▪ Days with high wildfire potential ▪ Maximum wildfire potential	Secondary effects, including erosion, landslides, impaired water quality, and smoke damage, often accompany fire events.
Chronic	**Sea level rise**	▪ Absolute coastal flood frequency ▪ Relative coastal flood exposure	Rising sea levels lead to multiple adverse effects like coastal erosion, inundations, storm floods, tidal waters encroachment into estuaries and river systems, and contamination of freshwater reserves.
	Heat Stress	▪ Energy demand ▪ Extreme heat days ▪ Extreme temperature	The health impacts of rising air temperature are compounded by increased atmospheric water vapor, which reduces humans' ability to dissipate heat.
	Drought Stress	▪ Meteorological drought: i.e. days per annum with precipitation below 1mm	Increasing temperature, in addition to changes in precipitation patterns, can cause drier weather conditions and hence more intense and frequent drought events, which can have severe economic, environmental, and social impacts.
	Precipitation Stress	▪ Current baseline water stress ▪ Current inter-annual variability ▪ Future water demand ▪ Future water supply ▪ Water demand change ▪ Water supply change	The effects of adverse rain include flooding. Heavy rainfall effects in urban areas can be especially catastrophic, endangering lives and damaging infrastructure.

4.4 Assessment methodology

Physical risks can be assessed across multiple dimensions: hazards, exposure, and vulnerability. Hazards refer to the probability of dangerous climate change events, which may be acute or chronic. Physical climate risk assessment requires information on these factors for each company or security issuer. Based on the literature, the term "physical risk" can be conceptualised with the following equation: **Risk = Hazard x Vulnerability x Exposure.** As mentioned previously, hazards are potentially damaging physical events, phenomena, or human activities that may cause environmental degradation, harm human health, cause social or economic disruption, or precipitate property damage or loss of land. As the second attribute, 'exposure' refers to each asset's risk in these climate events. The IPCC defines it as "the nature and degree to which a system is exposed to significant climate variations" (IPCC, 2020), such as the presence of people, species, economic or social activities (including public services), and physical assets, (e.g. buildings, infrastructure), or any other defined variation exposed to hazards in a specific area. Finally, vulnerability is the susceptibility to the hazard regarding physical, societal, and economic factors, which include actions taken to reduce or adapt to the hazard.

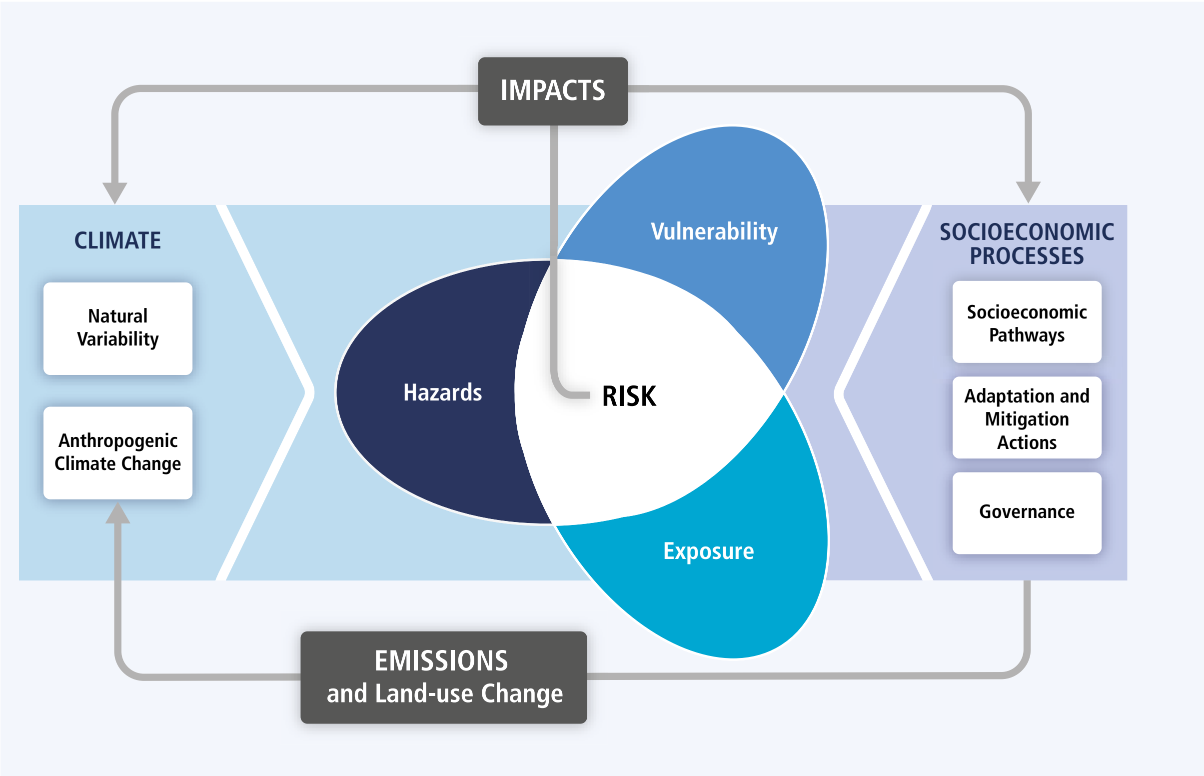


Figure 7: The IPCC AR5 conceptual framework with risk at the centre (IPCC, 2014).

The equation mentioned above is not only conceptual; each parameter can also be quantified using spatial data. For example, exposure can be illustrated by the number of buildings, the economic value, or the number of people impacted. Those numbers define how the risk is displayed. With this, Figure 7 demonstrates the coherence and shows the IPCC AR5 conceptual framework for assessing the multiple interacting risks of climate change. An updated version of this 'risk propeller' from the WGII contribution to the AR6 can be found in Appendix F. The AR6 report has a stronger focus on the interdependencies of climate, ecosystems, and biodiversity with human societies, and this figure is designed to reflect this. For the scope of this report and for this section on physical risk, we are referencing the AR5 conceptual framework in Figure 7.

Physical risks have direct financial consequences for organisations where those risks are realised, as well as for up-front insurance and investment-related costs. How physical risks change over time through the dynamic relationship of the three core components of risk (hazard, exposure, vulnerability) need to be better understood and it has yet to be dealt with in a coherent, consistent, and widespread manner. However, if one dimension of the physical risk framework increases, and if the other two are constant, then the overall risk has increased.

A physical risk assessment methodology typically has multiple steps that begin with an iterative process of defining scope, setting objectives, and collecting data. Following this, the relevant scenario must be chosen along with the impacts to be measured. Lastly, interpreting results to incorporate into decision-making is the last crucial step and defining significant assessment limitations (NGFS, 2022). Figure 8 below depicts this six-step process:

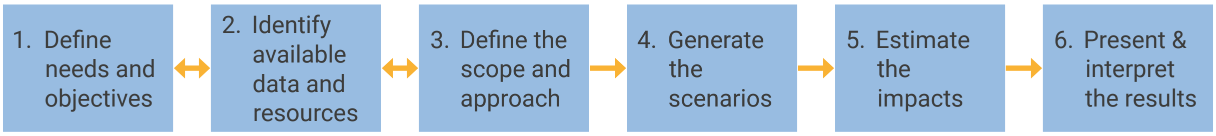


Figure 8: Physical Climate Risk Assessment Process (World Bank, 2019).

An elaboration of the step-by-step process for physical climate risk assessment can be found in the NGFS Physical Risk Assessment Report. Further, each data set models several different metrics, but the most useful for the financial sector are those metrics that cover balance sheet impacts and macroeconomic data focused on the most relevant impacts of these hazards, such as financial losses and changes in macroeconomic factors (see Appendix B). Through a forward-looking assessment of acute climate shocks and their socioeconomic impacts, the proposed framework can support better-informed decision-making for a broad range of potential applications, including managing climate-related public contingent liabilities, central banks' climate stress-testing, and climate-resilient financial product development.

In summary a physical climate risk assessment requires different types of data, for example:

1. Macroeconomic data

a. National accounts
b. Physical capital
c. Household consumptions
d. Informal sector
e. Regional GDP/GVA
f. Labour and productivity
g. Trade flow
h. Government spending and revenue

At this moment, the macroeconomic data is taken from places such as the NGFS, market reports, and government databases, but these sources may also be expanded and interpolated by tool providers.

2. Asset-specific financial information

a. Capital adequacy
b. Assets and liabilities
c. Management
d. Earnings
e. Liquidity
f. Vulnerability to risk

Generally, asset-level data is becoming more frequent, and more companies are disclosing publicly detailed data, such as their geolocation of fields, capacity, productivity, and ownership information. In addition, frameworks such as the TCFD are voluntary recommendations that support the progress toward disclosure of climate-related risks and opportunities.

3. Climate-related data

a. Geospatial data
b. Hazard information
c. Weather details

Climate-related information is getting more accurate and reliable in the predictions of global temperature increases as they are based on well-founded physical principles. Further, observations are coming from more radars, the latest technology, and satellites that continue to enrich the climate models. Historical and forward-looking data, such as the IPCC Atlas and the Word Bank Climate Change Knowledge portal, are available as public hazard data sets. However, end-users should be aware of the limitations and uncertainties that still remain, particularly in how acute weather events may change in the future.

Going forward, physical risk models will be able to aggregate greater sources of data, with the use of geospatial and remote sensing data, climate model projections, artificial intelligence (AI), and data mining. AI will be of increasing importance in accessing data from various sources. For physical risks, this could include 'vision learning' from geospatial data, which will also help to expand the range of physical hazards covered.

One area for improvement in physical risk models is assessing the impacts from secondary effects driven by climate change, whether socio-economic (e.g., migration and conflict) or environmental (e.g. public health shocks). These secondary impacts are difficult to model given the human behaviour element of socio-economic shocks and the unpredictable nature of public health impacts. However, public research funding is being directed towards modelling limited climate change-induced impact scenarios, such as the CASCADES project. This EU-financed initiative will model trade and supply chains, analysing the impact of acute and physical climate change-related hazards on agricultural production, energy, and commodity markets. Combined with "macro-economic modelling, qualitative political analysis, and strategic policy simulations", this will enable an assessment of areas of critical concern and potential solutions for Europe and beyond (CASCADES, 2022).

SECTION 5:

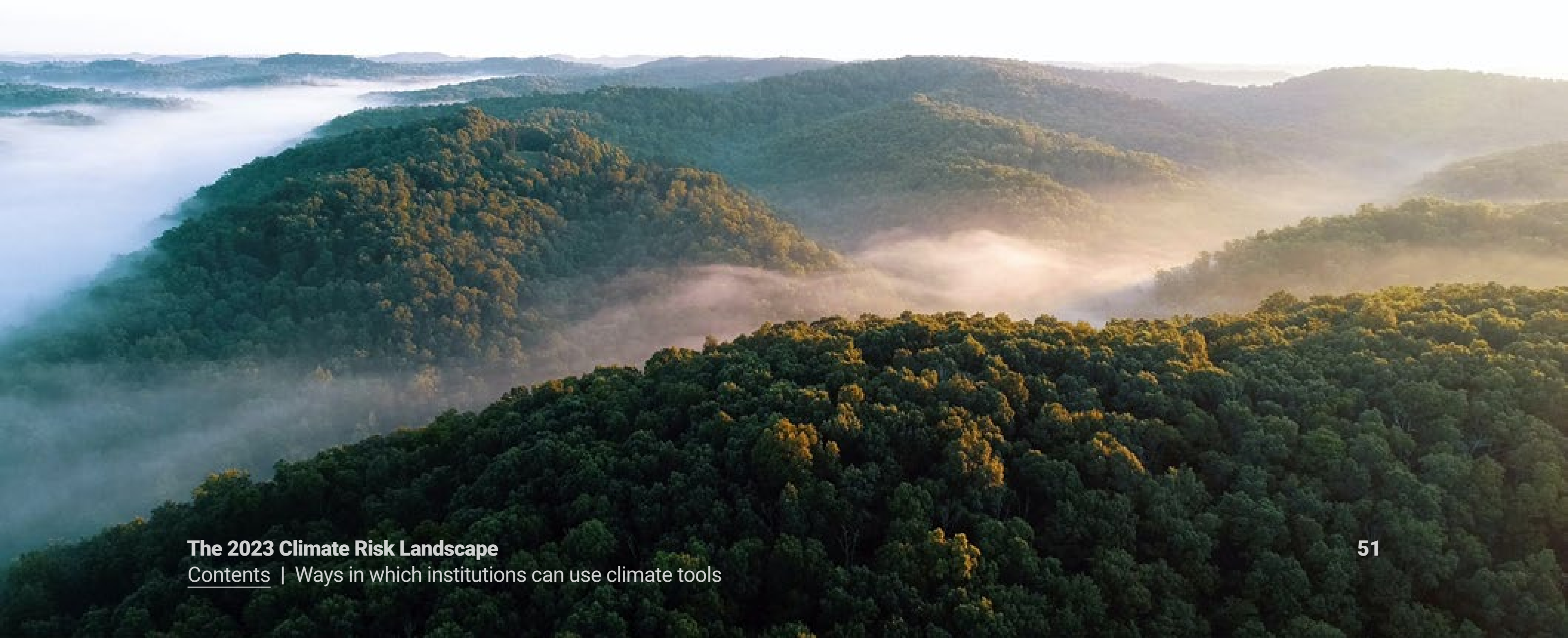
Ways in which institutions can use climate tools

5.1 Navigating climate risk: use cases

This section highlights use cases for the external employment of climate tools by FIs to prepare and confront climate change. Firms gradually recognise the importance of understanding and managing climate risks in their portfolios and operations in current and future investments, along with capital allocation. Conducting in-house assessments of climate risk currently requires considerable time, knowledge, and capital. As a consequence, FIs are outsourcing climate analytic services to external companies that help them measure climate risk and provide data, models, analysis, and methodologies. These services are designed to help investors and other FIs to understand, report, and act on the financial risks and opportunities associated with climate risk in their portfolios. In addition, they offer solutions that empower the integration of ESG across investment workflows and help users report against regulatory and stakeholder requirements and policies.

By assessing climate risks, institutions can address drivers of vulnerability in their portfolios to build adaptative capacity. As these evaluations are highly complex and lack causality compared to conventional risk assessments, using climate risk tools can be helpful. The goal is then to interpret these analyses and use the results in their business activities and management to confront ongoing and future climate changes that affect humanity on a global scale (European Commission, 2022). Below are the five most common use case areas for businesses and industries:

- Assessing climate risks: identifying, measuring, and monitoring these risks
- Setting strategy: developing effective transition, resilience, and business operation plans, and assessing alignment with those plans. If regularly applied, it also helps to implement learning and/or updating of priors and beliefs, and to give support for tracking the progress of implementing a strategy and targets over time
- Engaging with clients: supporting client transition plans to a Paris-aligned economy
- Assessing climate opportunities: identifying growth potential and new businesses
- Meeting regulatory and stakeholder requirements: releasing disclosures and conducting stress tests



5.2 Exploring identified use cases

5.2.1 Assessing Climate Risks

Through continuous portfolio monitoring and modelling, tools for assessing climate risk can be deployed to achieve risk identification, measurement, and monitoring. FIs will understand the exposure and portfolio value changes under different assumptions or scenarios and integrate the results into their risk management systems. Climate risk tools can provide tailored analytics to understand where and to what extent their investments, operations, and downstream supply chains are likely to be exposed to climate impacts (Carbon Plan, 2022).

a. Identifying climate-related exposure:

When identifying physical risks at the portfolio level, for example, the most commonly adopted approach at present is site-specific analytics of real assets displayed through geospatial mapping against hazards. Using geolocation to identify physical and sovereign assets, tool providers can show the precise locations of exposure risks anywhere across the globe. This is a straightforward identification task as it typically requires only a postal address or the latitude and longitude coordinates of the assets in the portfolio. Other input categories can provide further granular detail of potential financial impacts. These categories include current market value, square footage, facility type (office, residential, power plant, etc.), and date of a facility's construction. Such data are typically provided by the clients, rather than by the providers themselves.

Providers that leverage geospatial identification include Munich Re, XDI, S&P Global's TCS, ISS ESG, Moody's Climate Solutions, Planetrics, Aladdin Climate's physical risk calculations, and PwC's Climate Excellence Tool. Clear identification of hazard exposure is made possible typically through colour-coded mapping, with darker shades of red and orange being the common identifier of extreme hazard risks across different temperature scenarios. Beyond easily identifiable assets, such as office or residential buildings, XDI and Munich Re also include hazard breakdown for critical infrastructure assets that are not easily mapped. Examples of such assets include bridges, railroads, and highways. Mapping difficulties represent an essential consideration when measuring supply chain risks.

Although such approaches are currently widespread, recent research shows the problems inherent in applying global 'top-down' climate scenarios to explore financial risks at geographical scales of relevance to FIs (e.g. city-scale) (Pitman et al., 2022). Their findings suggest that bottom-up approaches that model acute risks (e.g. catastrophe modelling and storylines) produce a more robust assessment of material risks relevant to the financial sector. A small number of vendors are now providing climate risk models that quantify the costs of damage and business interruption from climate change. To do so, they use the hazard, exposure and vulnerability framework described in the previous section. Moody's RMS integrates the detailed, bottom-up catastrophe modelling approach used in the re/insurance industry for the past 30 years, together with climate model output and research. This approach is designed to produce forward-looking climate risk models. An updated version of Moddy's Climate on Demand tool will be released later in 2023.

Identifying exposures to transition risks requires different criteria and is primarily done through assessment of an asset's sector, sub-sector, and geography. Tool providers can identify at-risk assets within a portfolio with some information about the underlying assets, usually by public securities classification coding like ISIN and NAICS (North America only), along with the asset's value, such as assets under management or market value. Not all providers measure private equity, but some can establish proxies with relatively little information. McKinsey's Planetrics, for instance, can estimate climate impacts for private entities with information on the country name or code (ISO), sector classification, and the value of holdings; as well as carrying out more specific analysis where financial and/or emissions data is available for the entities. Tool providers display transition risks in quantitative and qualitative portfolios, such as through negative or positive financial impact contribution (in %) of the sector and sometimes the underlying assets. For example, PwC's Climate Excellence Tool uses heatmaps to identify financial impacts from transition risks with breakdown by sector, region, and a sector-region combination. It also offers a world map view that displays geographic-specific transition risks and opportunities. Depending on the level of analysis, these identifications can be broken down by individual asset contribution to the portfolio. Assets and portfolios can also be compared side-by-side and overlay benchmarks provided by the vendor or the user, respectively.

b. Measuring climate-related risks

A good starting point for FIs looking to measure climate-related risks and opportunities is evaluating carbon-related activities in their portfolios and operations. Valuable metrics include: carbon footprints (Scope 1, 2, and possibly Scope 3, either on an absolute or intensity basis); revenues from fossil fuels (brown shares) and green products and services (green shares); temperature alignment scores; levels of fossil fuel reserves; and stranded asset impact predictions. In addition to reporting on portfolio exposures to carbon-related assets, identifying stranded asset risk can contribute to present-day investment decisions to move capital away from fossil fuels to reduce portfolio risk and contribute to a low-carbon economy.

After performing backward-looking measurements of climate risks, tool providers incorporate forward-looking assumptions through scenario analysis to fully encapsulate future risks and opportunities. Translating potential climate scenarios into measurable and decision-useful metrics are vital components of effective climate risk tools. These financial impacts are commonly represented by cVaR (climate value-at-risk), which estimates gains or losses in a portfolio corrected for various climate change scenarios. Providers will convert climate risks and opportunities into quantifiable impacts to balance sheets, such as those to company Earnings Before Interest, Tax, Depreciation, and Amortisation (EBITDA) that reflect increases or decreases in operational costs and projected sales figures. These impacts can be either stand-alone or aggregated on multiple levels: individual assets, portfolio, and at the regional or country level. Providers measure EBITDA and cash flow impacts under different scenario assumptions that include carbon price assumptions, either through a regional or global carbon price. Tool providers will either use discounted or undiscounted cash flow models to reflect financial impacts. For example, BlackRock's Aladdin Climate uses a Capital Asset Pricing Model that discounts 30 years to reflect equity impacts. MSCI introduced the annual undiscounted cost timesteps at the issuer level, which takes into account the absolute costs or profits associated with sustainable models over a period of 20 distinct time-steps. The cost timesteps are calculated annually for the next 15 years, as well as for specific fixed years in the future, such as 2040, 2045, 2050, 2070, and 2100.

Financial impacts can be further incorporated into credit models to quantify the default risk of counterparties existing in credit, investment, and trading transactions. Potential parameters include climate-adjusted probability of default (PD), distance to default (DD), and loss given default (LGD). Planetrics provides climate-stressed financial statements that can be incorporated into existing scorecard models for FI credit risk. Other financial metrics can be estimated in potential climate catastrophes in physical risk scenarios. Examples here include revenue loss, days of operational downtime, property damages, and changes in macroeconomic factors, such as local GDP impacts, decreased trade, and increases in unemployment. For insurers, another metric could be changes to a risk premium rating.

c. Perform portfolio monitoring

Climate risk tools can continuously monitor portfolio's the exposure of an FI's portfolio to ongoing physical and transition hazards. For example, Munich Re provides live-event assessments during natural disasters or extreme weather events to help measure anticipated impacts as hazards evolve in real time. Similarly, Moody's Climate Solutions provides live-event quantification of the potential costs and damage impacts of such events through its climate risk models. MSCI's Climate Lab Enterprise enables risk management and scenario analysis portfolio monitoring, scalable from small institutions to firms with millions of positions. It incorporates organisation-wide visibility of investment strategies through dynamic dashboards.

XDI's Hub allows banks to monitor risks to mortgage portfolios whilst ensuring all customer information remains 'off system', thus speeding up internal compliance signoffs and on-boarding. A different form of monitoring by Moody's Climate Solutions measures risks to company ESG scores from daily news updates. This analysis, known as climate controversy analysis, leverages third-party news to interrogate controversies associated with individual companies, such as litigation or greenwashing claims. It measures trends over time along with individual occurrences, which informs companies' ESG scores. These scores are subsequently used as a screening mechanism. They can represent a significant consideration in the short term as they have the capacity to directly affect shareholder value and stock prices.

5.2.2 Strategy setting

Climate analytic services enable companies to adjust their operational strategies and spot new business originations to be positioned for long-term success based on regional, sectoral, or company-level risk assessment results. After identifying and evaluating the risks and opportunities, FIs are better positioned as they can embed the relevant risks and opportunities into their business strategies.

a. Developing effective transition, resilience, and operation plans

FIs utilise climate risk solutions to track carbon footprints over time and establish net-zero or emission targets from a present-day baseline. Throughout the implementation process, companies can compare across different implied temperature pathways against their targets to measure their alignment, such as creation of a Paris Agreement-aligned portfolio. Entelligent, for example, generates transition risk scores that perform a gap analysis between business-as-usual forecasts and a Paris-aligned future. Firms can use this analysis to strategise how to close the gap in intervals of two years and merge their portfolio's business-as-usual forecast to a 1.5°C Paris-alignment by 2050 and up to 2100.

Climate risk tools assist investing institutions and asset managers in building portfolios with higher adaptive capacity and more resilience against physical and transition risks, such as designing innovative sustainable finance products. Tool providers can help banks and other financial firms to create products such as sustainability-linked loans, for example. Banks studied in a recent World Resources Institute (WRI) working paper, Banking Beyond Climate Commitments, mention that establishing a solid methodology for collecting accurate GHG data represented a major barrier to creating innovative sustainable finance products. This is where climate analytics can fill a gap in knowledge and processes, allowing FIs to avoid creating costly and time-intensive internal GHG data tracking system. An important consideration is that tool providers can have different features that can be used for other use cases and strategies, depending on client goals and needs. Providers such as WTW offer a range of solutions to develop alongside clients for different levels of sophistication and objectives, from standardised and straightforward to highly sophisticated and tailored to individual client strategies. Its product offering includes data on climate transition risk metrics, an active management research platform, and a passive equity portfolio and funds. It also offers consulting services and bespoke solutions for the creation of tailored scenarios and analytical tools.

b. Assessing alignment with strategic plans

While tool providers can help firms develop strategic aims to align with a low-carbon economy, they can also assess ongoing alignment thereafter. Implied temperature rise (ITR) portfolio analysis is common to tool providers when assessing alignment. Ortec Finance's ClimateALIGN methodology uses the same net-zero scenario as that used in the ClimateMAPS risk tool. This allows users to assess their investment's climate risk and climate impact using a consistent set of scenario assumptions.

Transition strategies can be initially high-level, such as committing to net-zero pledges and broad alignment to the current and upcoming regulatory landscape. However, they are expected to increase in ambition within the decade. Properly assessing alignment to such strategies is a complex task and is both backward and forward-looking. First, companies must consider their current contributions to carbon emissions through financed emissions, in their operations, and increasingly downstream throughout their whole value chain. The total volume of GHG emissions is a raw metric quantified on an aggregate or intensity basis and is inherently backward-looking. The next step is to convert these emissions into a forward-looking metric, such as an ITR score. This is typically expressed in degrees Celsius. ClimateALIGN helps financial firms by creating a portfolio-specific temperature score and charts this against a net-zero-by-2050 path. Ortec Finance's ClimateALIGN methodology for portfolio alignment is compliant with recommendations from the TCFD's Portfolio Alignment Team (PAT) and GFANZ, originally developed with the Open-Source Climate (OS-Climate) initiative.

Similarly, ICE's tool uses forward-looking metrics as ITR scores and aligns them with PAT recommendations from TCFD. Paris Alignment analysis through S&P Global's TCS similarly tracks the portfolio's alignment of goals to limit warming to 2°C above pre-industrial levels, evaluating the adequacy of investments made over time to meet this target. It utilises historical data and forward-looking assumptions in the medium term (2012–2030), which minimises the uncertainties of using only forward-looking assumptions. In addition to emissions, the tool measures alignment with the necessary energy mix to achieve a 2°C future. However, ITR scores seem to be most appropriate for carbon-intensive sectors rather than diversified portfolios. As such, they should be assessed in conjunction with other types of analysis (FSB, 2020).

5.2.3 Engaging with clients

Given the special intermediary function of the financial sector, consideration needs to be given by lenders, insurance underwriters, and investors in the financial market to the climate alignment and climate risk management of their full value chain. As a result, FIs must engage and support their clients, especially large corporates on their decarbonisation and financial needs. Climate analytics services help improve investment and risk management by supporting the responsible monitoring of capital linked to an FI's clients. An FI can use climate risk results to perform collateral analysis and reconciliation of, for example, cash flows and credit risks associated with its clients.

By conducting robust climate analysis, an FI can spread knowledge and dedication from its workflows to its clients.

a. Supporting client transition plans to a Paris-aligned economy

CISL has developed a framework for best practices in bank-client engagement. It takes a five-step approach: (i) setting the scene in understanding the client's starting point; (ii) assessing the gaps between their starting point and their climate ambitions; (iii) designing a clear transition finance plan with appropriate metrics and targets; (iv) structuring innovative financing solutions; and (v) monitoring progress and removing barriers to long-term implementation (CISL 2021).

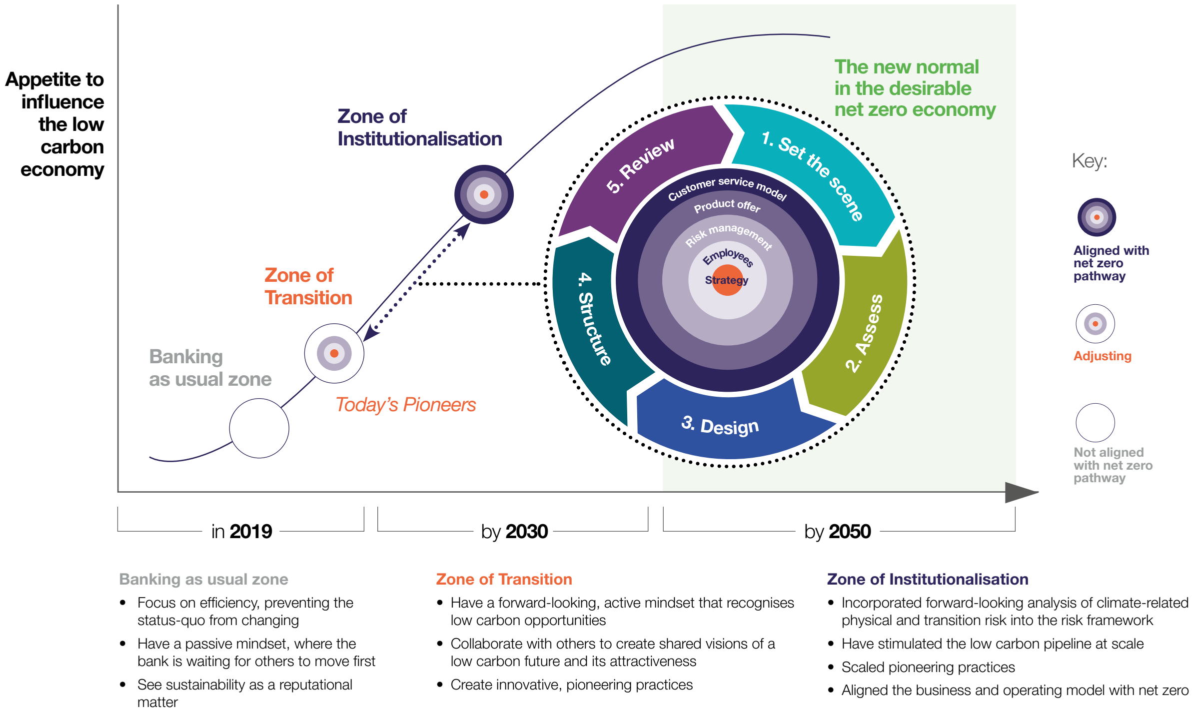


Figure 9: The roadmap to a low carbon bank of 2030, from Bank 2030 (CISL, 2020).

Similarly, WRI takes a five-step approach in its recommendations for private-sector banks to successfully engage their client's integration of Paris alignment into their business models. It highlights the necessity in a bank-client relationship to clearly understand how, and within which time frame, the client will align itself with a net-zero economy. If it appears impossible, the bank may consider screening out this particular client (WRI, 2021). As part of the bank's renewed business model, client engagement in a Paris-aligned economy will necessitate a need for enhanced capabilities and internal structures, as shown below:

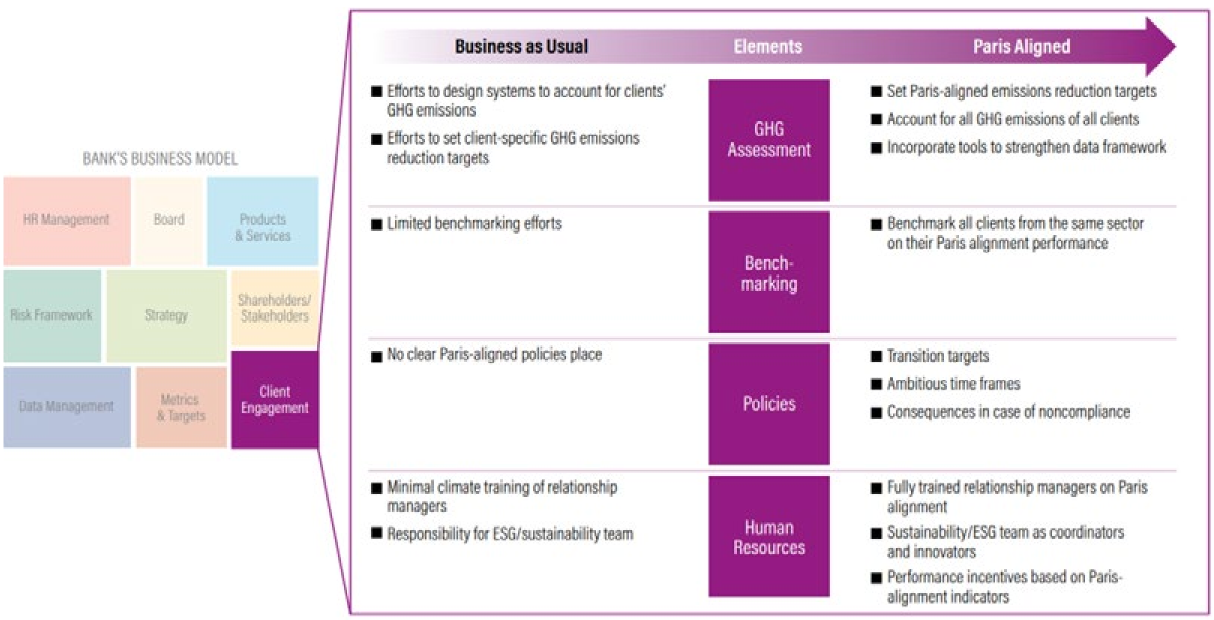


Figure 10: Elements of Paris-aligned client engagement (WRI, 2021).

b. Mitigating risks

FIs equipped with climate risk identification and management tools are better positioned to help mitigate risks in their client's businesses. Incorporating climate risks into traditional risk management frameworks is still in its initial stages. However, those FIs that have managed to do so in their frameworks can build capacity for their clients, such as enhancing scenario analysis to identify, assess, and mitigate risks. Where financial firms can help their clients is in assisting them to prioritise the most critical risks to their businesses, considering the specific nuances of each client's individual circumstances.

The TCFD explains that climate-related risks have additional criteria to consider beyond the traditional "likelihood and impact" of company risk management, which are "vulnerability" and "speed of onset" (TCFD, 2020). This is where climate analytic tools can be beneficial. A toolkit of risk identification, assessment, and response tools might typically include economic scenario generation, hazard mapping, probabilistic modelling, horizon scanning, and scenario analysis over long time horizons. Such a toolkit equips FIs well to assist their clients in adapting their existing risk management procedures so as to include climate risk. Scenario analysis allows companies to prepare strategies for shifts in policy and regulation, technology, markets, acute and chronic physical risk impacts with varying speed, consistency, and geographic dispersion levels.

Nevertheless, in addition to medium- to long-term developments of climate risks, the speed of onset of these risks can be rapid and unpredictable. This is notably the case with acute physical risks such as sudden natural disasters, for instance. Real time analysis of operational and financial impacts can help absorb and mitigate these risks. As mentioned previously, tool providers such as Munich Re can measure the financial impacts of weather events as they occur, such as an evolving hurricane across the South-eastern United States or a wildfire in Northern Australia.

5.2.4 Assessing climate opportunities

a. Identifying growth potential and new businesses

Although the bulk of analysis on climate change scenarios can focus on its associated risks, there are also opportunities to be discovered through industries and companies that will thrive in a low-carbon economy. With this transition, there will be a shift in demand for new business models, products, and services. Net zero and other low-temperature scenarios are based on assumptions of rapid decarbonisation across the major polluting sectors of today's economy. Therefore, when assessing the opportunities for new business and potential growth, it is helpful to evaluate companies in the most polluting industries, such as power generation and transportation (WRI, 2022).

When projecting a net-zero economy in 2050, some sectors and industries are more promising than others. For example, some of the winners of a low-carbon economy are destined to be businesses that operate in renewable energy and electric vehicle (EV) manufacturing. These can be identified through climate scenario analysis, quantified as increases in sales with direct contributions to the bottom-line. More specifically, MSCI measures transition opportunities through a low-carbon technology model, where patent filings and current estimated low-carbon revenues are used as proxies for firm-level innovative capacity. Using the current revenue estimates as a baseline, "future green revenues" are projected through the development and sale of low-carbon technologies under 3ºC, 2ºC, or 1.5ºC scenarios. WTW takes a similar approach. In its case, however, it considers future cashflows for each operating asset or line of business. This enables investors to identify opportunities—including both enablers and accelerators—in the net-zero transition.

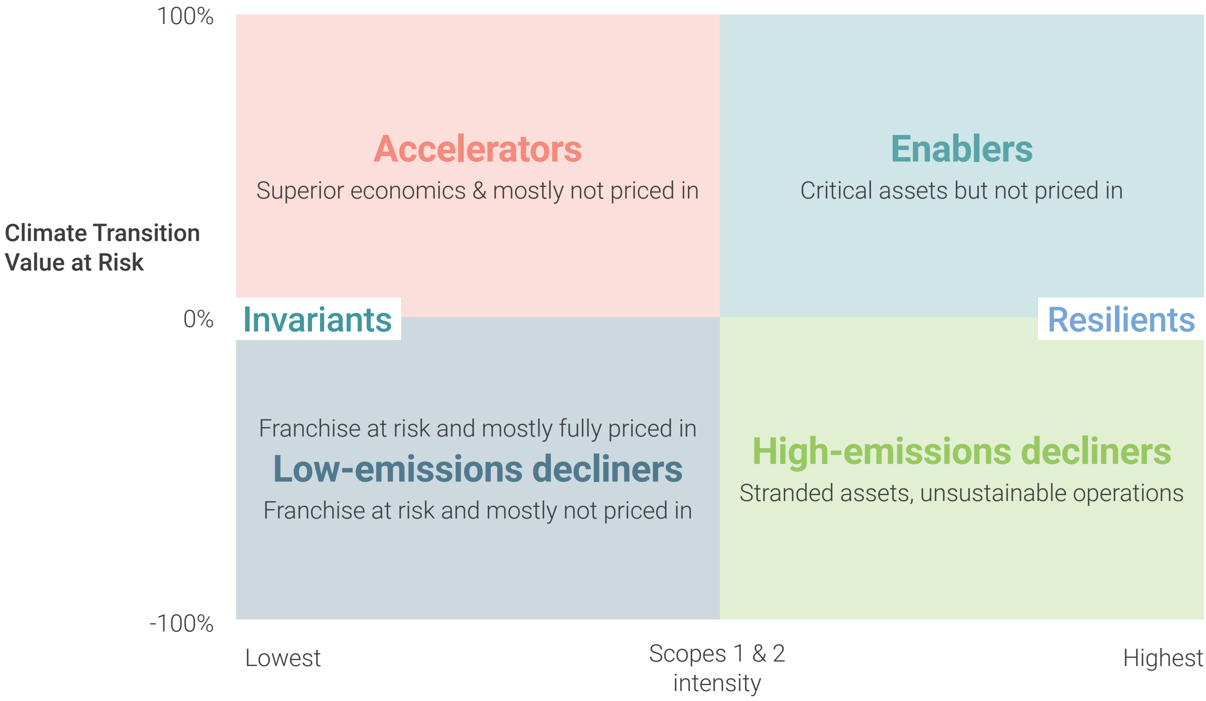


Figure 11: Identifying enablers and accelerators, inspired by WTW (UNEP FI, 2022).

As climate risk tool providers can project revenues and CAPEX as well as discounted cash flows at the company and sector level, this provides FIs with a means to assess opportunities for long-term investments. Besides social and shareholder pressures to divest from polluting industries and businesses, investments in low-carbon companies can represent good business opportunities in the long term and can avoid losses from stranded assets. For instance, automotive companies that rely heavily on sales from traditional internal combustion vehicles and do not have ambitious plans to switch to EVs will suffer in net-zero and other low-temperature scenarios. Financial firms can account for this by shifting financial flows to companies whose product lines are aligned with a net-zero economy now, but more importantly over the long term.

5.2.5 Meeting regulatory and stakeholder requirements

The integration of climate assessment tools has proven to be a valuable asset in ensuring compliance with supervisory expectations on risk management, stress testing, scenario analysis and disclosure. Supervisory expectations relating to these have been set by various regulators and policymakers throughout the world, including for example, by the ECB in the Eurozone and the Prudential Regulation Authority (PRA), in the UK. These expectations are likely to be yet further developed, whilst also increasingly backed by enforcement action by supervisors. At the same time, such expectations are likely to become more prevalent, with a growing number of supervisors throughout the world adopting similar requirements. This trend is likely to accelerate with the establishment of a global baseline for climate disclosures, via the International Sustainability Standards Board, and their expected endorsement by the International Organisation of Securities Commissions. These regulatory drivers will ultimately mean that the use of climate assessment tools will become increasingly essential to meet supervisory expectations and ensure effective climate-related risk management.

a. Releasing disclosures:

Metrics that are useful for disclosure will become vital given the ongoing developments to incorporate mandatory climate-related financial disclosures in various jurisdictions, such as the EU, the United States, Australia, and Japan. The ISSB is developing a global baseline sustainability disclosure standard, which is due to become effective starting January 2024, which will force tool providers and financial firms to act quickly and in sync. Voluntary TCFD-aligned reporting has become a popular climate transparency tool for banks, and the ISSB will be influenced partially by the TCFD framework. In the future, these required climate disclosures will become more granular and their inclusion will be expected in companies' annual reports. For example, the proposal by the SEC will require US-listed companies to disclose any targets or commitments to climate goals, impacts of climate change on financial statements, and GHG emissions data. Therefore, providers will need to adjust their tools to be aligned with the most up-to-date requirements and have disclosures presentable in a format that is easily accessible in both a public-facing and internal manner. Among those providers already active in this space are Entelligent and ISS ESG, which offer TCFD-aligned reporting with specific metrics, such as weighted average carbon intensities (WACIs) and exposure to carbon-related assets—one of the TCFD's recommendations for reporting by asset owners and managers. S&P Global's TCS also provides useful disclosure information on the level of carbon-related assets within a portfolio. In partnership S&P Global, Moody's Analytics and McKinsey provide assistance, data, and analytics to support the SEC reporting requirement. With the help of tool providers, FIs can easily report the exposures of their portfolios to business activities in extractive industries as well as their holdings in companies that have identified fossil-fuel reserves.

b. Conducting stress tests and complying with supervisory risk management expectations:

Banks will be expected to determine the main climate risk drivers on their risk profiles, and they must do so over varying time horizons and scenarios (BIS, 2021). Banks can use the generated outputs to ensure compliance with the supervisory requirements outlined in existing frameworks, including stress testing capital levels under different climate scenarios. Most recently, the Bank of International Settlements (BIS) issued guidance on bank management of climate-related financial risks, laying out supervisory expectations on banks. An increasing number of stress tests (including the recent FRB exercise) are wanting to test the possible effect on a loan portfolio of specific events such as a 100-year hurricane in the North-eastern United States in 2050 may have. This follows similar approaches adopted by the re/insurance industry in recent years. Such requirements will require event-based models that combine the principles of catastrophe models with climate modelling covering multiple future scenarios and time horizons.

Banks must therefore be prepared to conduct stress testing via scenario analysis to measure their capital and liquidity adequacy in possible future climate outcomes. These assessments should incorporate physical and transition risks relevant to their capital and liquidity under different time horizons. The extent and complexity of these scenario analyses will depend upon the bank's size, systematic importance, and business model—with larger and more complex banks expected to have more advanced capabilities. Moreover, the ISSB confirmed in November 2022 that companies must use climate-related scenario analysis to adequately disclose their resilience and identify their risks and opportunities.

As new regulatory requirements rapidly come into force in the coming years, banks must move quickly to meet expectations. Not only can developing in-house methods for these complex analyses take years, but climate scenarios are being updated all the time. As a consequence, many banks have opted to partner with tool providers to bolster their internal capabilities.

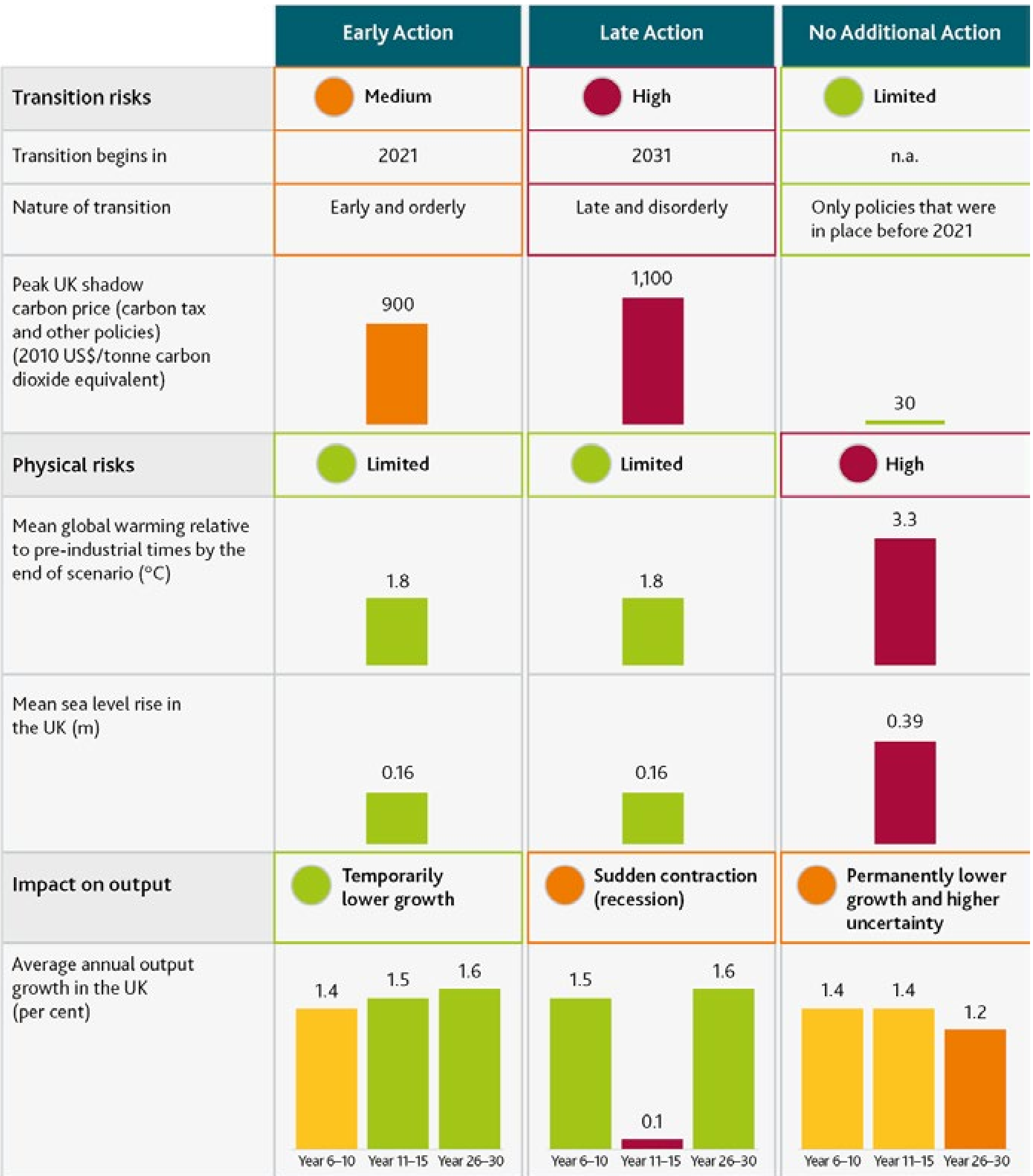


Figure 12: Climate tools as part of supervisory stress test (Bank of England, 2021).

5.3 Challenges institutions face in integrating the results into their own processes

This section summarises some main challenges FIs commonly see when utilising the results from climate tool providers, including the following:

Integrating climate risk assessment results into operations and finance-related decision-making	Ensuring data quality, reasonable assumptions, and meaningful analytics methodologies	Avoiding the 'black-box phenomenon' and potential litigation risks

For many FIs that use climate analysis from outside firms, integrating results and analysis into their operations and appropriate financial metrics for decision-making represents a significant challenge. Depending on each vendor's climate risk assessment metrics, the initial results can appear excessively technical. This is especially the case when they are not presented as financial parameters that can be directly embedded in financial reporting, existing workflows (such as credit modelling), or other streamlined decision-making processes. To avoid this confusion, FIs should be supported by the tool providers in how to interpret and translate the results into clearer and more decision-useful information. Throughout the process, FIs should upskill multiple levels of leadership to help ensure the correct interpretation and utilisation of climate risk-related analytics. Courses to facilitate this are offered by groups such as Moody's Analytics Learning Solutions. Climate tool users also need to establish governance, incentive, and internal risk management structures that define the roles of each department in utilising climate risk analytics results. These actions align with the TCFD's core recommendations, including governance, strategy, and risk management, and demonstrate how TCFD pillars can all interlink together.

Ensuring data quality with reasonable assumptions and rational approaches is another challenge that FIs face when using an external party to perform their assessments. It is vital for them to understand the vendors' processes as they must communicate the information to their customers and base key decisions on it. Imperfect data poses difficulties for vendors when conducting the analysis. Consequently, it is common to use inferred data, deploy proxy approaches, and add various assumptions to complete the exercise. These steps rely on complex forms and estimates. Responsibility for the accuracy of these inputs is not always clear. As a result, it is necessary to ensure adequate communications so that FIs are fully aware of the robustness of data and approaches before using the results derived from them.

Finally, several FIs highlighted the importance of avoiding what is known as the 'black-box phenomenon' when using third-party analyses. With increasing standardisation and mainstreaming in the climate risk tool space, off-the-shelf products and services can bring convenience and litigation risks at the same time. To avoid alignment issues, tool providers must be in touch with the latest regulatory requirements and be transparent with their methodology's limitations. At the same time, banks, insurers, investors, and asset managers with overly complex processes should build their in-house expertise to perform climate-related financial and economic decision-making rather than relying solely on external services. Moreover, a lack of internal knowledge acquisition can impede the ability to capitalise on the opportunities presented by the transition process. Without a thorough understanding of the potential business model adaptations that may be necessary or advantageous, organisations will be unable to fully harness the opportunities presented (UNEP, 2022).

SECTION 6:

A roadmap for financial institutions wishing to choose a risk assessment tool

As the landscape of climate analytics is rapidly changing, it would be of use for FIs to take a structured approach to evaluate their options for a suitable tool provider. In the attempt to provide such a framework, UNEP FI has developed a roadmap for these assessments. This roadmap is based on consultation and conversations with FIs, researchers, and climate analytical tool providers. A special thanks to Julia Bingler (University of Oxford) and Chiara Colesanti Senni (University of Zurich), who have been an important inspiration for this step-by-step approach. The hope and aim of this roadmap are to help firms to make better decisions when choosing how to conduct these assessments and when selecting which tool provider might best meet their requirements. This roadmap captures decision points between institutional needs and the tools' parameters as well as outputs. This offers an integrated procedure to evaluate individual needs and then match it with different vendors' offerings.

A practical Roadmap for financial institutions looking to select a climate tool

What do you want?
Determining the necessary specifications

1. Asset Class
Decide which asset class will be assessed:

- Make sure that your tool is well developed within your specific asset class.
- There is an increase of coverage of more asset classes (public/private) among many tools.
- Poor coverage of real estate, mortgages & agriculture.

2. Coverage
Identify what to assess:

- Coverage at the asset, sector, firm, or country levels
- Assessment of the portfolio's exposure to current and future GHG emissions
- Physical Hazards, could be both acute/chronic
- Resilience and adaptive capacity
- Transition Risks Orderly/Disorderly
- Company and portfolio exposure
- Portfolio vulnerability

3. Scenario
Provide analysis for the required scenarios:

- Most vendors use the IPCC, IEA or NGFS scenarios.
- IEA and IAMs are typically used for temperature analysis.
- Market movements towards scenarios that capture the speed of transition. Therefore, it is important that banks also look into vendors that provide NGFS scenario analysis(orderly, disorderly, Hothouse).
- Provides different time horizons

4. Output
Output metrics & format:

- Most providers express their output in quantitative or financial terms
- USD, kg GHG emissions
- VaR, Expected Return, PD, Credit Ratings
- Qualitative or report outputs
- Narrative dashboards
- Temperature alignment
- TCFD-aligned automated report features

What do you need?
Evaluation of the analytical tool

1. Validity
Transparency

- Assumptions
- Disclosure of methodology
- Interpretation

Verification & credibility

- Data sources
- Citations & reviews
- Third-party validation

Science-based approach

- Scientific resources supporting its model
- Peer-reviewed

2. Usability
User friendliness

- Clear layout and customised visualization
- Intuitive and explanatory modules for the platform and its structure
- Access to the platform
- Interactivity and possibility of incremental analysis

Flexibility

- Customizable platform according to needs

3. Analysis depth
Output interpretability

- Model structure, scenarios and assumptions reported
- Risk amplification

Uncertainty

- Baseline adaptable
- Scenario-neutral (various risk realisations)
- Probability distribution of input and output

4. Transferability
Transferable results

- The results are feasible to translate into financial measures relevant to the beneficiary

Incorporation

- Output and takeaways from the tool can be used in setting business strategies and portfolio monitoring

Figure 13: A Roadmap for FIs in choosing a climate risk assessment tool (UNEP FI, 2023).

Conclusion

Since the 2021 Landscape Report publication and the Tool Supplement, there have been a variety of new developments and updates to the climate risk assessment tool landscape that this research paper aims to summarise. Chapter 2 elaborates on the latest regulatory signs of progress since COP26 and COP27, incorporating global developments, international appreciation of adaption finance tools, and expanding regulatory requirements. Chapter 3 surveys the market, lists the available tools, and explains the general trends observed, including movement towards integration of the goal of net zero by 2050. It also comes with time horizon updates, reflections on the growing pressure to be transparent, and the increasing focus on providing outputs and metrics that are useful for decision-making and disclosure. Chapters 5 and 6 take a deeper dive into how tool providers—both individually and on an integrated risk platform—assess physical and transition risk in FIs' portfolios. Chapter 7 then guides FIs on utilising climate analytics tools, highlighting common use cases for banks and challenges faced in integrating the results into their processes. Finally, Chapter 8 concludes the report with a roadmap showing the steps that banks can take to choose a climate risk assessment tool.

While this paper captures the evolution of the risk assessment tool market, and the evolution of the needs of banks, it ultimately acts as a snapshot. It reflects the current needs and desires of FIs, what we know about climate change and our willingness to respond to it, and lastly the current market for tool and model capabilities. These tools are a support mechanism as they enable banks to identify polluting industries and overall climate risks and opportunities in their portfolios, helping them reach ambitious climate commitments. These tools and capabilities will continue to evolve in the coming weeks, months, and years. Climate change research is dynamic, just like the nature of climate change itself. Climate risk assessment tools must be updated constantly to keep up with this dynamism; continuous research on this topic—such as the *2021 Landscape Report*, the *Tool Supplement*, and this paper—reflect this reality.

Appendix

Appendix A: Overview of transition scenarios

Scenario Provider	Name	Sector	Est. implied temp. rise	Basis
IEA World Energy Outlook (WEO) [updated annually]	NZE2050 (Net-zero emissions by 2050)	Energy	1.5°C	Outlines the technology, policies, and behaviour change necessary to bring about net-zero emissions by 2050 and includes key energy related UN SDGs.
	SDS 2020 (Sustainable Development Scenario)	Energy	1.8°C (66%) 1.5°C (50%)	Considers social (SDG) and climate goals
	STEPS (Stated Policies Scenario)	Energy	Around~2.5°C	Accounts for stated policies and measures in place or under development in each sector (replaces the New Policies Scenario, NPS)
	APS (Announced Pledges Scenario)	All sectors	1.7°C	Assumes that governments will meet fully and on-time all climate-related commitments made, and includes related pledges made by the private sector and NGOs; does not achieve outcomes targeted in SDS 2020.
	Delayed Recovery Scenario (DRS)	Energy	<2.7°C	STEPS with a delayed recovery from pandemic
IEA Energy Technology Perspectives (ETP) [2020 release feeds into SDS scenario]	2DS (2 Degrees Scenario)	Energy	2°C	Rapid decarbonisation pathway in line with the Paris Agreement
	B2DS (Beyond 2 Degrees Scenario)	Energy	1.75°C	Includes the extent of clean energy technologies if pushed to their practical limits, in line with ambitious aspirations of the Paris Agreement
	RTS (Reference Technology Scenario)	Energy	2.75°C	Takes into account existing energy and climate-related pledges, including NDCs.
IPCC	RCP (Representative Concentration Pathways)	All sectors	1.0°C (RCP 2.6) 1.8°C (RCP 4.5) 2.2°C (RCP 6.0) 3.7°C (RCP 8.5)	RCPs outline pathways according to different levels of radiative forcing in the CMIP5
IPCC	SR15	All sectors	1.5°C	Set of P1–4 pathways to meet 1.5°C target, building on RCP 1.9

Scenario Provider	Name	Sector	Est. implied temp. rise	Basis
IPCC	AR6	All sectors	1.6°C (SSP1–1.9) 1.7°C (SSP1–2.6) 2.0°C (SSP2–4.5) 2.1°C (SSP3–7.0) 2.4°C (SSP5–8.5) **(mid-term estimates 2041–2060)**	Assesses results from the CMIP6 project in 5 SSP scenarios, with a broader range of GHG, land-use, air-pollutant futures than AR5, and accounts for solar activity and background forcing from volcanoes
NGFS	Orderly (NZ 2050 and Below 2°C)	All sectors	1.4°C (NZ 2050) 1.6°C (Below 2°C)	Transition Risks include policy reactions, technology change, CO_2 removal, and regional policy variation. Both orderly and disorderly have alternate scenarios with limited or full CDR
	Disorderly (Divergent NZ and Delayed Transition)	All sectors	1.4°C (Divergent NZ) 1.6°C (Delayed Transition)	Higher transition risk than for Orderly scenario
	Hot-house World (NDCs and Current Policies)	All sectors	2.6°C (NDCs) 3°C+ (Current Policies)	Only current policies implemented, not NDCs, i.e. equivalent to IEA STEPS
OECM	One Climate Earth Model (OECM 1.0) OECM 2.0 (2022)	All sectors	1.5°C	1.5°C trajectory in 10 world regions without the continued use of fossil fuels Sectoral decarbonisation pathways and targets broken into Scope 1, 2, and 3 for industry sectors defined by CIGS standard
UNPRI Inevitable Policy Response (IPR)	Forecast Policy Scenario	All sectors	1.8°C	Based on the anticipated policy response to meeting the Paris Agreement and subsequent impact on emissions reduction and temperature outcomes
	Forecast Policy Scenario + Nature	All sectors	Currently no agreed upon target for biodiversity levels analogous to 1.5°C	Focused on climate policy trends and their interaction with land use, including nature-related policy action.
	Required Policy Scenario	All sectors	1.5°C	Current assessment of future policy developments needed to deliver 1.5°C outcome

Appendix B: Financial and macroeconomic data variables for risk assessment

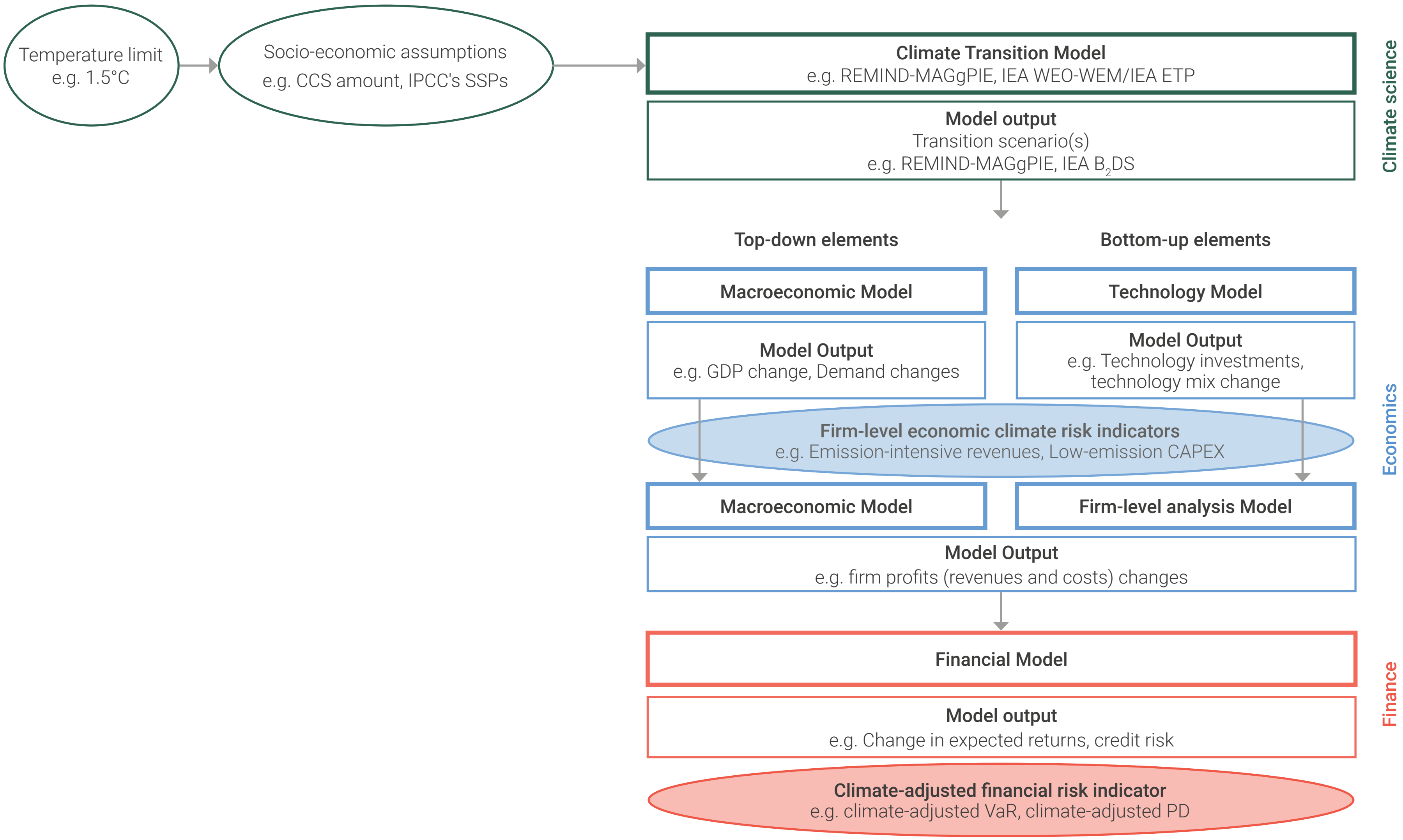
Balance sheet data

Capital adequacy	▪ Primary capital ▪ Total capital ▪ Total loans and credit growth
Assets and liabilities	▪ Adjusted assets ▪ Total assets ▪ Gross assets ▪ Nonperforming loans ▪ Non-interest-accruing assets ▪ Restructuring loans ▪ Charged-off loans ▪ International asset position by countries or by regions
Management	▪ Construction loans ▪ Agricultural loans ▪ Loans past due ▪ Loans to bank insiders ▪ Management overhead
Earnings	▪ Net interest income ▪ Returns
Liquidity	▪ Liquidity coverage ratio ▪ Net loans
Sensitivity to risk	▪ Total income from interest rates ▪ Change in interest rate income ▪ Change in total assets

Balance sheet data

National accounts	▪ Current accounts ▪ Financial accounts ▪ Capital accounts ▪ Balance sheets
Physical capital	▪ Stock of physical capital (in value and in volume, i.e., in current price and constant price ▪ Physical capital depreciation rate
Household consumption	▪ Household final consumption by sector
Informal sector	▪ Contribution of informal sector to GDP ▪ Number of households working in the informal sector
Regional GDP/GVA	▪ Regional GDP/GVA (including sector breakdown)
Labour and productivity	▪ Mean/median wage, by sector and region ▪ Mean/median hours worked, by sector and region ▪ Employment rate by actor ▪ Number of jobs by sector
Trade flow	▪ Import/export tables by sector (in value and in volume)
Government spending and revenue	▪ Aggregate public investment ▪ Total assistance and transfer to households ▪ Tax revenue by source (income, capital gains, sales/ consumption, tariffs/duties) ▪ Bond issuance (volume)

Appendix C: Example analysis structure, deterministic, from ETH Zurich



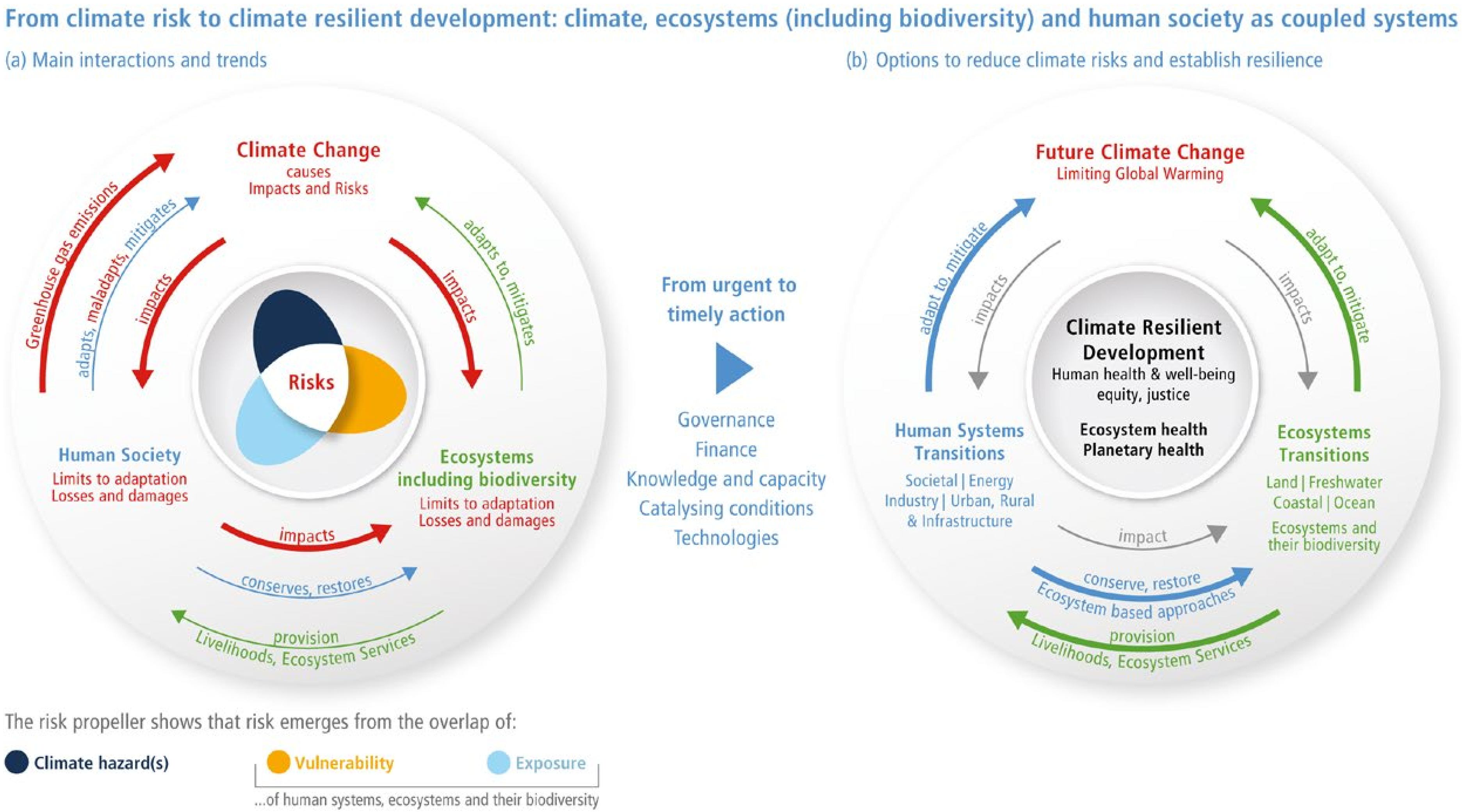
Appendix D: Shared Socioeconomic Pathways in the IPCC Sixth Assessment Report

	Near term, 2021-2040		Mid-term, 2041-2060		Long term, 2081-2100	
Scenario	**Best estimate (°C)**	**Very likely range (°C)**	**Best estimate (°C)**	**Very likely range (°C)**	**Best estimate (°C)**	**Very likely range (°C)**
SSP1−1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
SSP1−2.6	1.5	1.2 to 1.8	1.7	1.3 to 2.2	1.8	1.3 to 2.4
SSP2−4.5	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP3−7.0	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
SSP5−8.5	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

Appendix E: Scenarios included in CMIP6 (Frazier *et al.*)

IPCC scenarios	Description	Estimated warming 2041–60, °C
Historical	Simulation of climate variables from the recent past from 1850 to 2014. These predictions are from a coupled atmosphere-ocean general circulation model (AOGCM) using observed variables such as atmospheric composition, land use, and solar forcing. The historical simulation can be used to evaluate model performance against present climate and observed climate change.	N/A
SSP1–1.9	Based on SSP1 with low climate change mitigation and adaptation challenges that lead to a future pathway with a radiative forcing of 1.9 W/ m^2 in the year 2100. The SSP1–1.9 scenario fills a gap at the very low end of the range of plausible future forcing pathways, due to interest in informing a possible goal of limiting global mean warming to 1.5°C above pre-industrial levels based on the Paris COP21 agreement.	1.6
SSP1–2.6	Based on SSP1 with low climate change mitigation and adaptation challenges that lead to a radiative forcing of 2.6 W/ m^2 in the year 2100. The SSP1–2.6 scenario represents the low end of plausible future forcing pathways. SSP1–2.6 depicts a "best case" future from a sustainability perspective.	1.7
SSP4–3.4	Based on SSP4 in which climate change adaptation challenges dominate that leads to a radiative forcing of 3.4 W/ m^2 in the year 2100. The SSP4–3.4 scenario fills a gap at the low end of the range of plausible future forcing pathways. SSP4–3.4 is of interest to mitigation policy since mitigation costs differ substantially between forcing levels of 4.5 W/m^2 and 2.6 W/m^2.	N/A
SSP5–3.4OS	Based on SSP5 in which climate change mitigation challenges dominate with a peak and decline in forcing towards an eventual radiative forcing of 3.4 W/ m^2 in the year 2100. The SSP5–3.4OS scenario branches from SSP5–8.5 in the year 2040 whereupon it applies substantially negative net emissions. SSP5–3.4OS explores the climate science and policy implications of a peak and decline in forcing during the 21st century. SSP5–3.4OS fills a gap in existing climate simulations by investigating the implications of a substantial overshoot in radiative forcing relative to a longer-term target.	N/A
SSP2–4.5	Based on SSP2 with intermediate climate change mitigation and adaptation challenges that lead to a radiative forcing of 4.5 W/m^2 in the year 2100. The SSP2–4.5 scenario represents the medium part of plausible future forcing pathways. SSP2–4.5 is comparable to the CMIP5 experiment RCP4.5.	2
SSP4–6.0	SSP4–6.0 is based on SSP4 in which climate change adaptation challenges dominate and RCP6.0 that lead to a radiative forcing of 6.0 W/m^2 in the year 2100. The SSP4–6.0 scenario fills in the range of medium plausible future forcing pathways. SSP4–6.0 defines the low end of the forcing range for unmitigated SSP baseline scenarios.	N/A
SSP3–7.0	Based on SSP3 in which climate change mitigation and adaptation challenges are high, which leads to a radiative forcing of 7.0 W/m^2 in the year 2100. The SSP3–7.0 scenario represents the medium to high end of plausible future forcing pathways. SSP3–7.0 fills a gap in the CMIP5 forcing pathways that is particularly important because it represents a forcing level common to several (unmitigated) SSP baseline pathways.	2.1
SSP5–8.5	SSP5–8.5 is based on SSP5 in which climate change mitigation challenges dominate that lead to a radiative forcing of 8.5 W/ m^2 in the year 2100. The SSP5–8.5 scenario represents the high end of plausible future forcing pathways. SSP5–8.5 is comparable to the CMIP5 experiment RCP8.5.	2.4

Appendix F: Working Group II Contribution to the IPCC AR6 Report, 'Risk Propeller'



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